

# Wintry habitat selection of the Zapallaren tree iguana (*Liolaemus zapallarensis*, Müller & Hellmich, 1933) and its abundance in Changa beach, Coquimbo, northern Chile

Selección de hábitat invernal del lagarto de Zapallar (*Liolaemus zapallarensis*, Müller & Hellmich, 1933) y su abundancia en playa Changa, Coquimbo, norte de Chile

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## ABSTRACT

Urban development modifies the habitat of reptiles where we expect, the individuals to select available sites with the quality necessary for their permanence. The aim of this study was to determine the variables that favored the habitat selection and abundance of The Zapallaren Tree Iguana *Liolaemus zapallarensis*, an endemic species of Chile, during a winter season in Changa beach, Coquimbo, in northern Chile. Between June and September 2017, we made 30 random visits to 18 plots of 900 m<sup>2</sup> each. We estimated a resource selection probability function for presence-absence and abundance data using local habitat (e.g. slope, distance from the protection wall to the sea at low tide, interior height of the wall, mean height of the vegetation, rocky surface, and vegetal surface) and climatic variables (temperature, atmospheric pressure, direction and wind speed, solar radiation, and mean cloudiness) as predictors. Vegetation cover was the most important habitat variable explaining the presence of *L. zapallarensis*. In addition, increase in cloudiness and wind speed decreased the probability of selection. Manly's selectivity measure varied according to the established home ranges and the availability ratios within them. Finally, increase in cloudiness and wind speed decreased the abundance. Overall, our results show that the characteristics related to habitat and local climate influences the resource selection that favors the survival of reptiles. This work shows that beach sectors in urban contexts under anthropic pressure have important available resources that favor the presence and abundance of reptiles.

**Keywords:** behavioral ecology; ecological niche; lizards; resource selection.

## RESUMEN

El desarrollo urbano modifica el hábitat de los reptiles donde se espera que los individuos seleccionen los sitios disponibles con la calidad necesaria para su permanencia. El objetivo de este estudio es determinar las variables que favorecen la selección de hábitat y abundancia de *Liolaemus zapallarensis*, especie endémica de Chile, durante una temporada invernal en Playa Changa, Coquimbo (norte de Chile). Entre junio y septiembre de 2017, se realizaron 30 visitas al azar a 18 parcelas de 900 m<sup>2</sup> cada una. Se estimó una función de probabilidad de selección de recursos para datos de presencia-ausencia y abundancia utilizando variables de hábitat y climáticas como predictores. La cobertura de vegetación fue la variable de hábitat más importante que explicó la presencia de

*L. zapallarensis*. Además, el aumento de la nubosidad y la velocidad del viento disminuyeron la probabilidad de selección. La medida de selectividad de Manly varió según los rangos de hogar establecidos y las proporciones de disponibilidad dentro de ellos. Finalmente, el aumento de la nubosidad y la velocidad del viento disminuyeron la abundancia. En general, los resultados muestran que la selección de recursos, que favorece la supervivencia de los reptiles, está fuertemente influenciada por características relacionadas con el hábitat y el clima local. Este trabajo muestra que los sectores de playa en contextos urbanos bajo presión antrópica tienen importantes recursos disponibles que favorecen la presencia y abundancia de reptiles.

**Palabras clave:** ecología del comportamiento; lagartijas; nicho ecológico; selección de recursos.

## INTRODUCTION

Determining the most frequently selected habitat resources provides fundamental information about the nature of animals, the way they meet their need for survival and the quantitative information of a population's long-term requirements, which are useful for defining the hypothetical carrying capacity and project the impacts of habitat change (Manly *et al.* 2002). Urban development produces habitat fragmentation and the appearance of new habitats, which requires the native fauna to adapt to the challenges imposed by the transformation, reduce their population, move to suitable places, or disappear (Davis 1976, Dicken & Doncaster 1987, Koenig *et al.* 2001; Fernández-Juricic 2004, Sierra 2012). Among the taxonomic groups that respond to these challenges are reptiles that often exhibit different behaviors and aspects of their natural history compared to their counterparts in more pristine environments (Gill & Bonnett 1973).

There is a long tradition of studies of habitat use in lizards (Losos *et al.* 1993). Since different habitats have different abiotic and biotic conditions, the habitat choice can have important consequences at individual, population and community levels (Smith & Ballinger 2001, Goodman *et al.* 2008). Within their habitat, individuals are rarely located at random, and they usually choose areas with characteristics that favor their development (Schlesinger & Shine 1994, Kerr *et al.* 2003). However, the impact of urbanization on patterns of habitat selectivity in lizards has been scantily explored (Taylor *et al.* 2016).

The Zapallaren Tree Iguana, *Liolaemus zapallarensis*, an endemic species of Chile that is regularly found within its distribution range (Lobos *et al.* 2016), is distributed from Sarco Bay in the Atacama Region to Quintay in the Valparaíso Region, between 0 and 1200 m.a.s.l (Mella 2017). This species is of medium to large size with an mean snout-vent length of 104 mm, of robust appearance, and it inhabits coastal scrub with rocks under bushes (Mella 2017). The species suffered

drastic population losses during the 80's and early 90's due to poaching, and it has still not fully recovered. Despite multiple studies have shown habitat partitioning in *Liolaemus* species (Fuentes & Jaksic 1980, Medel *et al.* 1988, Schulte *et al.* 2004, Tulli *et al.* 2009), at present no study has evaluated patterns of habitat selection in *L. zapallarensis*. This work aims to determine habitat and climatic variables, which favored the selection and abundance of *L. zapallarensis* during a winter season on a beach in northern Chile, highly modified by the need for tourism development.

## MATERIAL AND METHODS

### STUDY SITE

Changa Beach (Fig. 1) corresponds to a coastal strip of 1700 m in length located at the south of the Bay of Coquimbo, northern Chile, surrounded by the city. This strip presents minimum and maximum distances of 60 m and 190 m, respectively, between the tide line and the wall that separates the beach from the pedestrian and vehicular infrastructure (Fig. 1). A Tsunami affected this area in September 2015 that produced changes in the landscape. Between the tide line and the highway there is a sandy beach with some patches of mainly herbaceous vegetation (*Salicornia fruticosa* and *Carpobrotus chilensis*), large rocks that protect the highway with some bushes and herbaceous vegetation, a separating wall in some sections and a pedestrian road between the wall and the highway that presents high frequency of vehicular traffic. The study area is subject to occasional swells, tidal movements, walking of feral dogs, cleaning activities, and removal of soil with tractors. 1200 m east of the beginning of the beach is the mouth of the El Culebron wetland. The presence of people dedicated to the extraction of drifted seaweed characterizes the first 700 m of the beach. The entire study area is open to pedestrian visitors who walk on the beach in less quantity in winter than in the summer.

The mean temperature was 12.7 °C with a minimum mean of 12.3 °C and a maximum mean of 13.2 °C, while the accumulated rainfall during the winter season was 64.9 mm (<http://www.ceazamet.cl>).

#### DATA COLLECTION

Sampling was conducted during June and September of 2017 between 12.00 and 17.00 hours, without manipulating individuals and trying to cause as little damage as possible to the habitat. 18 random plots of 900 m<sup>2</sup> were located, considering that similar species such as *L. kuhlmanni* and *L. nitidus* present home ranges between 75 and 776 m<sup>2</sup> respectively (Simonetti & Ortiz 1980, Fox & Shipman 2003). We visited each plot 30 times in a random sequence. We recorded the time, presence or absence of the species while the climate data of temperature (°C), atmospheric pressure (hPa), direction and wind speed (m/s), solar radiation (W/m<sup>2</sup>) and mean cloudiness we obtained from local meteorological stations (<http://www.ceazamet.cl>) for the time of visit of each plot. In addition, in each plot, we measured the distance (m) from the protection wall to the sea at low tide, the interior height of the wall (m), mean height of the vegetation (m)

measuring at 5 random points in the plot, rocky surface (%) and vegetal surface (%) using a GPS and ArcGis 10.5 software. At each visit, we counted the number of individuals observed in both inside and outside the plots in order to estimate the abundance of the species. We used the spatial position of individuals, determined using a GPS, to build home ranges with the fixed Kernel method (Worton 1989) in the sectors inhabited by the species separated by the stairs and ramps that serve as pedestrian access to the beach. We modified these home ranges by eliminating the parts where the species was not present. Subsequently, we established resource units, their availability within the home range and the use of each unit by the number of points registered.

#### DATA ANALYSIS

Resource selection of the species was analyzed with two approaches. (1) Resource selection probability function (RSPF) using a logistic regression based on presence/absence (1/0) data (Manly *et al.* 2002), with the site variables taken in the 18 plots and the climatic variables taken only in the plots where the species was present. (2) The most important resource selected by the species was analyzed with Manly's

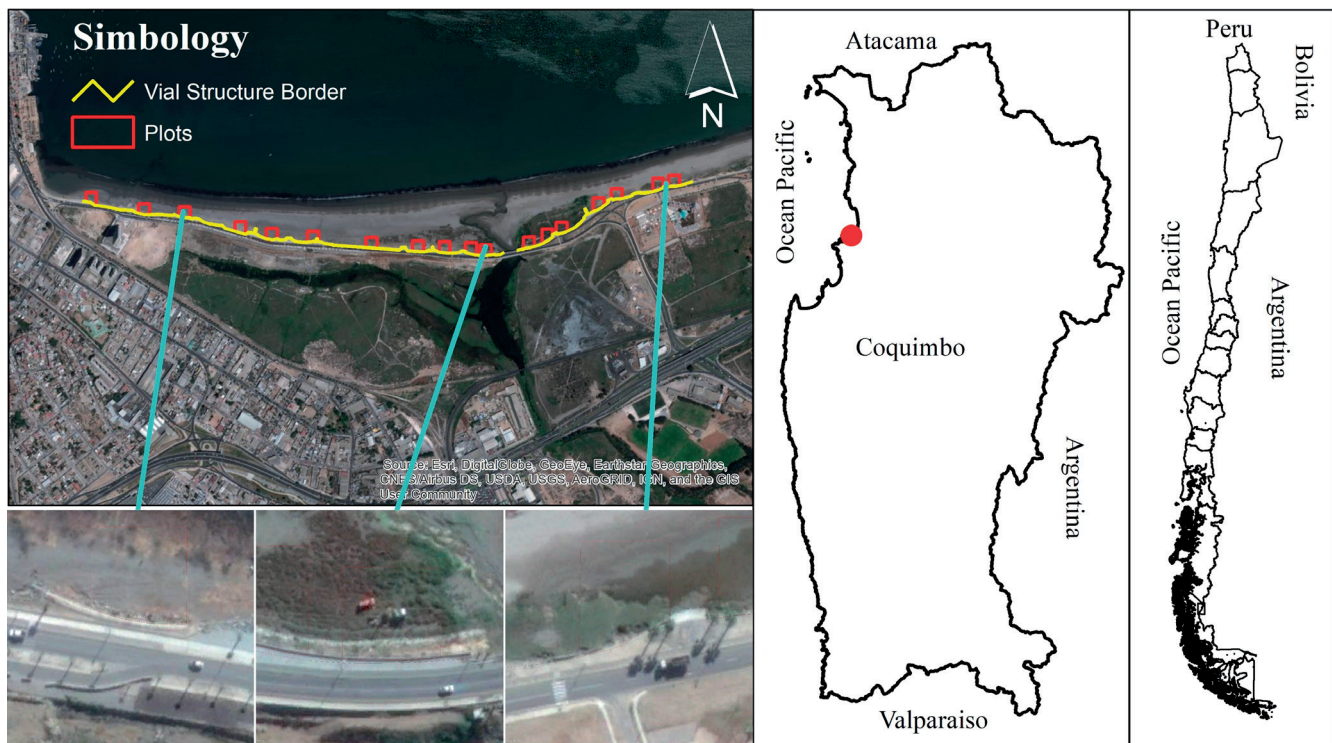


FIGURE 1. Study site location showing three sections. 1<sup>st</sup> Down left: sand and vial structure. 2<sup>nd</sup> Down middle: vegetation, wall rock and vial structure. 3<sup>rd</sup> Down right: sand, vegetation and vial structure. / Ubicación del sitio de estudio mostrando las tres secciones. 1° Abajo a la izquierda: arena y estructura vial. 2° Abajo en el medio: vegetación, pared de roca y estructura vial. 3° Abajo a la derecha: arena, vegetación y estructura vial.

selectivity measure for use and availability data, within the home range, establishing selection in favor of the resource when the value is > 1, no selection of resource when the value is = 1 and selection against the resource when the value is < 1 (Manly *et al.* 2002). We used Poisson regression to analyze the relationship between the climatic variables and the abundance of the species. All statistical analyzes were performed using the software R 3.4.0 (R Development Core Team 2017), and the best models were selected with the Akaike Information Criterion (Burnham & Anderson 2002).

## RESULTS

The Zapallaren Tree Iguana inhabited environments with slopes between 0 and 70 %, with presence of rocky surfaces in some places, scattered stones, and debris in others; herbaceous and shrub vegetation were always present. The minimum observed temperature was 12.3 °C, while the maximum temperature was 19.5 °C (mean = 14.5 °C), with cloudiness between 0 and 100 %. The variables such as distance to the tide line or rocky surface were not influential, nor were the atmospheric pressure and solar radiation.

### RSPF FOR HABITAT

The model that best explained resource selection, among all the candidate models, was the one that considered the vegetation surface variable (Table 1). The exponential value

of the vegetation surface slope (exp.b=1.01, CI 95 % 1.00-1.02) was positively related to the probability of resource selection of the species (Table 2), indicating that for each square meter of increased vegetation surface, a 1 % increase in the probability of selection was expected (Fig. 2a).

### RSPF FOR CLIMATIC VARIABLES

The model that best explained resource selection was the one that considered the cloudiness and wind speed variables (Table 1). The exponential value of the cloudiness slope (exp.b=0.03, CI 95 % 0.01-0.07) and wind speed slope (exp. b=0.74, CI 95 % 0.61-0.87), was negatively related to the probability of resource selection of the species (Table 3). This indicates that for each 1 % increase in cloudiness, we expect a 97 % decrease in the probability of selection, while for each 1m/s increase in wind speed, we expected a 26 % decrease in the probability of selection (Figs: 2b, 2c).

### MANLY'S SELECTIVITY MEASURE

After establishing the home ranges for the six groups identified, the existence of 13 resource units was determined between types of vegetation cover, ground and rock structures (Table 4). According to the use-availability criterion, the resource units selected by Zapallaren Tree Iguana varied according to the established home ranges and the availability ratios within them. There was no constant selection throughout the study area. While for the lizards from the home range 1 and 2 located immediately adjacent to the mouth of the El Culebron

**TABLE 1.** Selection of models according to the Akaike Information Criterion (AIC) to explain the resource selection (logistic regression) and abundance (Poisson regression) of Zapallaren Tree Iguana in Changa Beach (Coquimbo, Chile). / Selección de modelos según el Criterio de información de Akaike (CIA) para explicar la selección de recursos (regresión logística) y la abundancia (regresión de Poisson) del Lagarto de Zapallar en playa Changa (Coquimbo, Chile).

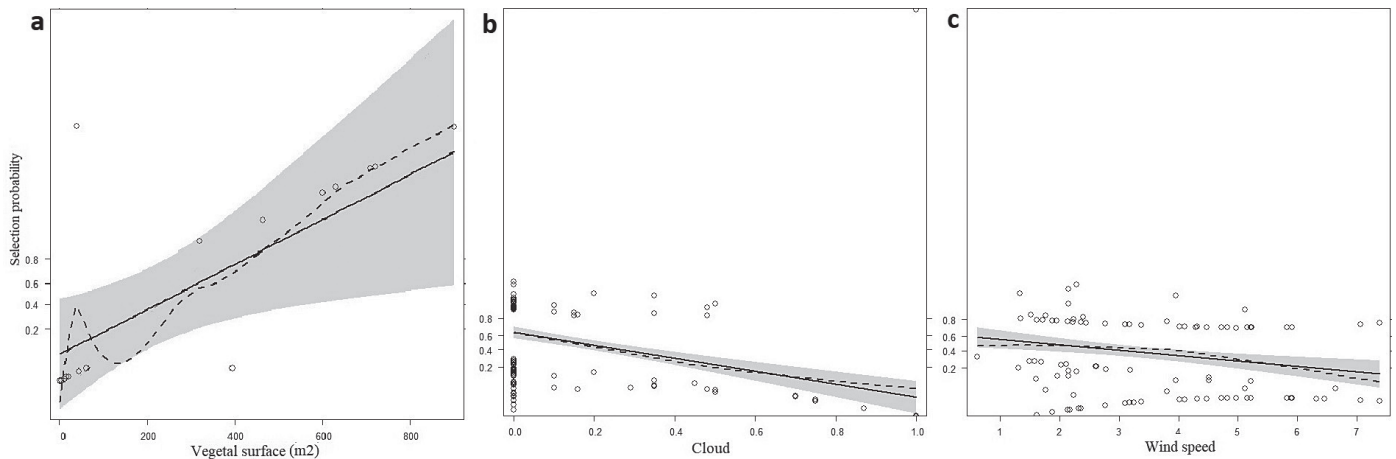
Analyses	Models	AICc	ΔAICc	Akaike Weight
Logistic	Presence ~ Vegetation surface	14.41	0.0	0.61
Regression:	Presence ~ Interior wall height + Vegetation surface	15.81	2.3	0.19
Habitat	Presence ~ Height of vegetation + Vegetation surface	16.38	2.9	0.14
Logistic	Presence ~ Cloudiness + Wind speed	299.15	0.0	0.31
Regression:	Presence ~ Cloudiness + Atmospheric pressure + Wind speed	299.65	0.5	0.24
Climate	Presence ~ Wind direction + Cloudiness + Wind speed	300.14	1	0.19
Poisson	Abundance ~ Cloudiness + Wind speed	200.57	0.0	0.30
Regression:	Abundance ~ Cloudiness + Atmospheric pressure	201.31	0.7	0.21
Climate	Abundance ~ Cloudiness + Atmospheric pressure + Wind speed	200.96	1.3	0.16
	Abundance ~ Cloudiness + Atmospheric pressure + Solar radiation	201.82	2.2	0.10

wetland the most important resource was Rock Wall, the lizards from the other home ranges selected resources related to the vegetation, with the exception of the lizards from the home range 4 that selected Sand-Ground (Table 4).

**ABUNDANCE**

A mean of 13 individuals (for the entire area) site was recorded (CI 95 % 10–16 individuals) with a difference between juveniles and adults of 3 individuals (CI 95 % 0.5–4.9 individuals,  $p=0.02$ ). The maximum count in one day was

26 individuals, while the minimum was zero (Table 5). The model that best explained the abundance was the one that considered the cloudiness and wind speed variables (Table 1). The exponential value of the cloudiness slope ( $\text{exp.b}=0.05$ , CI 95 % 0.03–0.10) and the wind speed slope ( $\text{exp.b}=0.87$ , CI 95 % 0.81–0.94) was negatively related to the probability of increase of species abundance (Table 6). This indicates that for every 1 % increase in cloudiness, the abundance of Zapallaren Tree Iguana decreased 95 %, while for each 1 m/s of increase in wind speed, the abundance decreased 13 % (Fig. 3).



**FIGURE 2.** a: Positive effect of the Vegetation Surface habitat variable on the selection probability of Zapallaren Tree Iguana. b and c: Negative effect of climatic variables, cloudiness and wind speed on the selection probability of Zapallaren Tree Iguana. / a: Efecto positivo de la variable de hábitat superficie de la vegetación en la probabilidad de selección del lagarto de zapallar. byc: Efecto negativo de las variables climáticas, nubosidad y velocidad del viento en la probabilidad de selección del lagarto de zapallar.

**TABLE 2.** Parameters of the best logistic regression model for habitat variables that explained the selection of Zapallaren Tree Iguana resources in Changa Beach (Coquimbo, Chile). / Parámetros del mejor modelo de regresión logística para variables de hábitat que explicaron la selección de recursos del Lagarto de Zapallar en playa Changa (Coquimbo, Chile).

Model	b	CI95%	P	exp.b	CI95%
Intercept	-2.39	-5.46 ; -0.60	0.03	0.09	0.00 ; 0.55
Vegetation Surface	0.01	0.00 ; 0.02	0.02	1.01	1.00 ; 1.02

**TABLE 3.** Parameters of the best logistic regression model for climatic variables that explained the selection of Zapallaren Tree Iguana resources in Changa Beach (Coquimbo, Chile). / Parámetros del mejor modelo de regresión logística para variables climáticas que explicaron la selección de recursos del Lagarto de Zapallar en playa Changa (Coquimbo, Chile).

Model	b	CI95%	p	exp.b	CI95%
Intercept	1.63	0.87 ; 2.43	<0.001	5.11	2.40 ; 11.36
Cloudiness	-3.70	-4.84 ; -2.71	<0.001	0.03	0.01 ; 0.07
Wind speed	-0.31	-0.49 ; -0.14	<0.001	0.74	0.61 ; 0.87

**TABLE 4.** Description of the resource units of each home range and estimated selection rates of Zapallaren Tree Iguana (p-values should be compared with Bonferroni level= 0.02).  $W_i$ =Selection index.  $SE.W_i$ =Standard Error.  $B_i$ =Standardized Selection index. / Descripción de las unidades de recursos de cada rango de hogar y coeficientes de selección estimados del Lagarto de Zapallar (los valores de p deben compararse con el nivel de Bonferroni = 0.02).  $W_i$  = coeficiente de selección.  $EE.W_i$  = Error estándar.  $B_i$  = coeficiente de selección estandarizado.

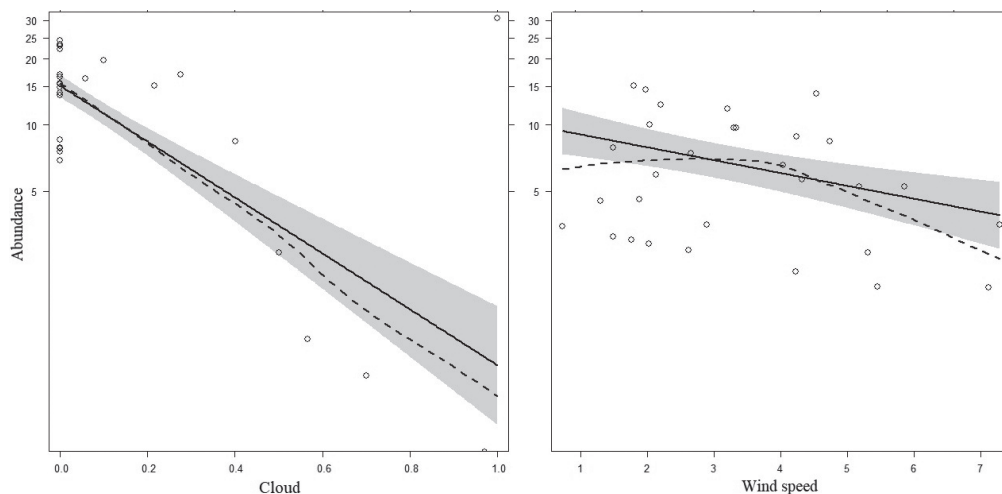
	Resource Units	Available	Use	$W_i$	$SE.W_i$	p-value	$B_i$
Home Range 1 (1019.65 m <sup>2</sup> )	Rock Wall (RW): Large rocks placed to protect the pedestrian lane and the highway	0.15	0.33	2.22	0.57	0.03	0.53
	Herbaceous Vegetation (HV): Vegetable cover dominated by <i>Nolana</i>	0.42	0.60	1.43	0.21	0.04	0.34
	Footpath (F): Pedestrian path without vegetation	0.07	0.03	0.48	0.47	0.26	0.11
	Sakixornia - Paspalum (S-P): Vegetable cover dominated by <i>Salicornia fruticosa</i> and <i>Paspalum vaginatum</i>	0.36	0.03	0.09	0.09	0.00	0.02
Home Range 2 (1482.03 m <sup>2</sup> )	Rock Wall (RW)	0.05	0.14	2.79	0.61	0.00	0.42
	Herbaceous Vegetation (HV)	0.25	0.47	1.89	0.18	0.00	0.29
	Rock Wall-Herbaceous Vegetation (RW-HB): Combination of RW and HB	0.17	0.29	1.73	0.24	0.00	0.26
	Herbaceous Vegetation- <i>Paspalum vaginatum</i> (HV-Pv): Combination of HV and Pv	0.53	0.09	0.18	0.05	0.00	0.03
Home Range 3 (530.33 m <sup>2</sup> )	Herbaceous Vegetation (HV)	0.61	0.71	1.16	0.11	0.13	0.49
	Dry Herbaceous Vegetation (DHV): Dead herbaceous vegetation dried by the effect of time	0.26	0.27	1.04	0.25	0.87	0.44
	Shrub Vegetation (SV): Shrub vegetation dominated by <i>Tessaria absinthioides</i>	0.13	0.02	0.16	0.16	0.00	0.07
Home Range 4 (921.22 m <sup>2</sup> )	Sand-Ground (S-G): Substrate formed by the mixture of sea sand and land filling	0.42	0.57	1.36	0.26	0.16	0.48
	Shrub Vegetation (SV)	0.31	0.29	0.92	0.32	0.81	0.33
	Sparce Shrub Vegetation (SSV): SV scattered on the ground	0.27	0.14	0.53	0.28	0.10	0.19
Home Range 5 (490.40 m <sup>2</sup> )	Debris Herbaceous Vegetation-Dry Herbaceous Vegetation (DHV-DHV): Combination of HV with debris and HV with sand	0.21	0.50	2.41	0.44	0.00	0.67
	Sand (S)	0.50	0.37	0.74	0.18	0.15	0.21
	Herbaceous Vegetation (HV)	0.30	0.13	0.45	0.21	0.01	0.13
Home Range 6 (731.67 m <sup>2</sup> )	Dry Plants Residues (DPR): Residues of dead and dried plants by time	0.06	0.31	5.13	1.23	0.00	0.74
	Ground-Scattered Stones (G-SS): Stones scattered on the ground	0.11	0.13	1.17	0.49	0.73	0.17
	Herbaceous Vegetation (HV)	0.83	0.56	0.68	0.10	0.00	0.10

**TABLE 5.** Mean values of abundance (number of individuals per 900 m<sup>2</sup>) of Zapallaren Tree Iguana in Changa Beach (Coquimbo, Chile). / Valores promedio de abundancia (número de individuos por 900 m<sup>2</sup>) del Lagarto de Zapallar en playa Changa (Coquimbo, Chile).

	Abundance (CI95%)	Juveniles	Adults	Difference (CI95%)	p
Mean	13 (10-16)	8	5	3 (1-5)	0.02
Maximum	26	17	11	8	
Minimum	0	0	0	0	

**TABLE 6.** Parameters of the best Poisson regression model for climatic variables that explained the abundance (number of individuals) of Zapallaren Tree Iguana in Changa Beach (Coquimbo, Chile). / Parámetros del mejor modelo de regresión de Poisson para variables climáticas que explican la abundancia (número de individuos) del Lagarto de Zapallar en playa Changa (Coquimbo, Chile).

Model	b	CI95%	p	exp.b	CI95%
Intercept	3.17	2.90 ; 3.43	<0.001	23.74	18.08 ; 30.97
Cloudiness	-2.93	-3.63 ; -2.32	<0.001	0.05	0.03 ; 0.10
Wind speed	-0.13	-0.21 ; -0.07	<0.001	0.87	0.81 ; 0.94



**FIGURE 3.** Negative effect of climatic variables cloudiness and wind speed on the abundance of Zapallaren Tree Iguana. / Efecto negativo de las variables climáticas, nubosidad y velocidad del viento en la abundancia del lagarto de zapallar.

## DISCUSSION

This study shows that Zapallaren Tree Iguana exhibits a strong habitat selection at a local scale, and climatic and landscape variables mold its distribution and abundance. Our conclusions are restricted to winter season and juvenile/adult data. However, the season, sex, age class, behavioral activity, often affect resource selection and daily activity patterns of the animal studied (Schooley 1994, McKnight & Hepp 1998, Boyce *et al.* 2002; Manly *et al.* 2002). This could be especially

important in summer, when thousands of tourists daily visit the beach. In addition, because of the limited geographical scope of this study, we cannot extrapolate the RSPF to other areas inhabited by the species (Manly *et al.* 2002).

The vegetation cover was an important variable for habitat selection, because it allows Zapallaren Tree Iguana to hide in the presence of possible predators like *Nycticorax nycticorax*, *Elanus leucurus*, *Parabuteo unicinctus*, *Athene cunicularia* and *Falco sparverius*, present in the study area (Chávez-Villavicencio *et al.* 2015). Indeed, animals seek refuge in the vegetation

every time the observer was close. Indeed, habitat structure occupation is correlated with escape behavior in different *Liolaemus* species (Schulte *et al.* 2004). The vegetation cover also allows for the protection of the accesses to their retreat sites or burrows, which are important places for survival (Kerr *et al.* 2003). Increase in cloudiness and wind speed during this study only conditioned the detection of individuals, which leads to confirm the approach of Schlesinger & Shine (1994), who mentioned that individuals within their habitat are rarely located at random, as they usually choose areas with characteristics that favor their development.

The thermoregulatory activity of the species drives the selections of the resource units found in this study, specifically behavioral thermoregulation (Bartholomew 1982). The rock wall and the spaces left by the vegetation through which sunlight passes would be the most important habitat characteristics. The selection of rock wall coincides with the selection made by other reptile species, mainly because they produce a better heat accumulation and have high thermal conductivity over the stones (Clauser & Huenges 1995), allowing to maintain optimal body temperatures to have a good performance in their physiological processes, to search for food, reproduce and escape from predators (Huey 1982). This diurnal heliothermic regulation seems to be a common for *Liolaemus* species (Schulte *et al.* 2004, Labra *et al.* 2008). Our observations, however, did not account for other types of activity (e.g. feeding or grooming). However, we know that reptiles use their home ranges to provide themselves with food and other resources, including avoiding predators (Powell & Mitchell 2012).

The cloudiness and wind speed modified the abundance of the species in the study area. When these variables were favorable, we made records of up to 26 individuals in a single evaluation day. Mella (2017), found that the species is frequent and abundant in its geographical distribution range. However, we could not find more references on its abundance. We need new studies to explore possible ontogenetic shifts in resource use and dispersal strategies to avoid intraspecific competition.

In summary, our study shows that the Zapallaren Tree Iguana has adapted its habitat selection strategy in an urbanized beach of northern Chile. Even highly urbanized areas may be able to provide a suitable habitat for the wildlife. Future studies should be aimed at understanding patterns of habitat selectivity of the Zapallaren Tree Iguana across different environmental conditions (with different regimes of anthropogenic impact), and its consequences on individual fitness, population dynamics, and biotic interactions with other sympatric species.

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