



ECOSYSTEMS

Population ecology of a critically endangered gecko, endemic to north-eastern of Argentina

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Abstract: *Homonota taragui* is an endemic gecko of the northeast of Argentina. We estimate demographic parameters: number of individuals by populations, sex and ontogenetic stage; sexual dimorphism; survival of this species; and describe the use of microhabitat and movement patterns. We measured 11 morphological variables, determined the sex and marked individually. We found bigger head width in males. Some factors contribute to the vulnerability of this species such as its constrained geographical distribution, use of the specific microhabitat and the isolation of their populations. We highlight demography studies as an essential data source for management and conservation of critically endangered species.

Key words: *Homonota taragui*, microendemism, demography, mark-recapture studies, Paraje Tres Cerros.

INTRODUCTION

Population ecology studies on the structure and dynamics of biological populations provide essential and valuable information about the target species (Hutchinson 1978). Effective conservation policies can be planned only after a clear understanding of the ecological processes and the assessment of the demographic parameters underlying the population dynamics of a species. The quantitative estimation of the population vital rates, such as birth, mortality, immigration and emigration, are therefore especially relevant for threatened species. Endemic species, often poorly studied, are intrinsically vulnerable because the restricted distribution area limits their capability of resilience to environmental changes (Malcolm et al. 2006).

The evolution of endemic species is favored in discrete ecosystems, with a medium

to high degree of contrast with respect to its surroundings matrix (Watson 2002). In some areas, the irregular surface of the land may act as a geographical barrier to the gene flow and promote the evolution of endemism (Porembski et al. 1998, Fredericksen et al. 2003). As an example, endemic species are often found in “inselbergs” (from the Germanic “island-mountain”), which are solitary, usually monolithic mountains or groups of mountains which rise abruptly from surrounding plains, like rocky outcrops (Porembski et al. 1998). These geological features that protrude from the surrounding land surface behave like true geographic islands. In these areas, the combination of unique environmental conditions (e.g., microclimate and soil) and biotic communities often results in habitats singularities ecologically (Porembski & Barthlott 2000, Burke 2003, Fredericksen et al. 2003). The inselbergs provide a set of

microhabitats available to many animal species, several endemics. The environmental conditions of the inselbergs are unique in terms of, such as, heat radiation from the rock surface after sunset, (high) temperature during the daytime, abundant water availability, high humidity, and several other structural characteristics (Fredericksen et al. 2003).

There are cases of endemics species on inselbergs for species of the *Homonota* genus (*H. rupicola* and the microendemism of *H. taragui*, see below). The genus *Homonota* (Phyllodactylidae, Squamata) comprises 13 species of nocturnal and terrestrial lizards (Cacciali et al. 2018) distributed in Argentina, Bolivia, Brazil, Paraguay and Uruguay (Abdala 1997, Avila et al. 2012, Cajade et al. 2013a, Morando et al. 2014, Cacciali et al. 2017, 2018). Regarding the distribution range of the species of the genus, some of them, (*H. darwini*, *H. borellii*, *H. andicola* and *H. underwoodi*), have a wide geographical distribution, whereas others (*H. uruguayensis* and *H. whitii*), have intermediate distribution (>400 km²), and *H. rupicola* and *H. williamsii*, are restricted to minimal ranges (Morando et al. 2014, Cacciali et al. 2017). *Homonota taragui* is the species with the smallest distribution known for this genus, less than 2 km². However, due to lack of scientific studies on this taxon, the geographical distribution of some species of the genus *Homonota* (*H. fasciata*, *H. horrida*, *H. septentrionalis*, *H. marthae*) is still vaguely known (Cacciali et al. 2017). All *Homonota* species are oviparous and insectivorous (Ceï 1986, 1993, Abdala 1997), mostly terrestrial and able of colonizing different environments, like sandy habitats, humid leaf litter and rocky habitats (Kluge 1964, Ceï 1986, 1993). The literature on *Homonota* species have focused on essential aspects of ecology and biology (*H. fasciata*; Kluge 1964, Aun & Martori 1994, Gómez & Acosta 2001, Nieva Cocilio et al. 2016), refuge

use (*H. borellii*, *H. darwini* and *H. rupicola*; Cruz et al. 2004, Aguilar & Cruz 2010, Cacciali et al. 2015) reproduction (*H. horrida*, *H. darwini* and *H. fasciata*; Cruz et al. 1994, Ibarzüengoytía & Casalins 2007, Nieva et al. 2013), behavior (*H. borellii*; Godoy & Pincheira-Donoso 2009), diet (*H. darwini* and *H. fasciata*; Kun et al. 2010, Nieva Cocilio et al. 2016), growth (*H. darwini*; Piantoni et al. 2006, Kubisch et al. 2012) and phylogeny (*H. uruguayensis*; Morando et al. 2014, Felappi et al. 2015, Cacciali et al. 2017, Daza et al. 2017). However, there is still a substantial lack of knowledge regarding the biology and ecology of the genus *Homonota* and in particular for recently described species and for those with restricted distributions. The taragüi gecko (*Homonota taragui*, Figure 1) is endemic to the Paraje Tres Cerros (Corrientes, Argentina). Only three populations of this species are known, and each of them inhabits one rocky outcrop. Due to being recently described (Cajade et al. 2013a) and understudied, information about this species is limited to some aspects of natural history and microhabitat use (Odriozola 2014). The taragüi gecko is a microhabitat specialist, found only in rock-rock substrates, that is, its microhabitat is characterized by being made up of large blocks of rocks, where smaller rocks are supported (Figure 2). Since its description, the populations of *H. taragui* have been listed as vulnerable. The vulnerability of this species is related to its constrained geographical distribution, so any environmental change on its habitat, might cause the irreparable decline in any of the three existing populations, or even the extinction of all known populations (Cajade et al. 2013a). Besides, the first record of an albino *Homonota* specimen in *H. taragui*, triggered alarms that the population maybe were suffering an increase in inbreeding depression by the expression of the recessive alleles of albinism (Courtis et al. 2015). Also, the particular environmental



Figure 1. Adult of *Homonota taragui*.

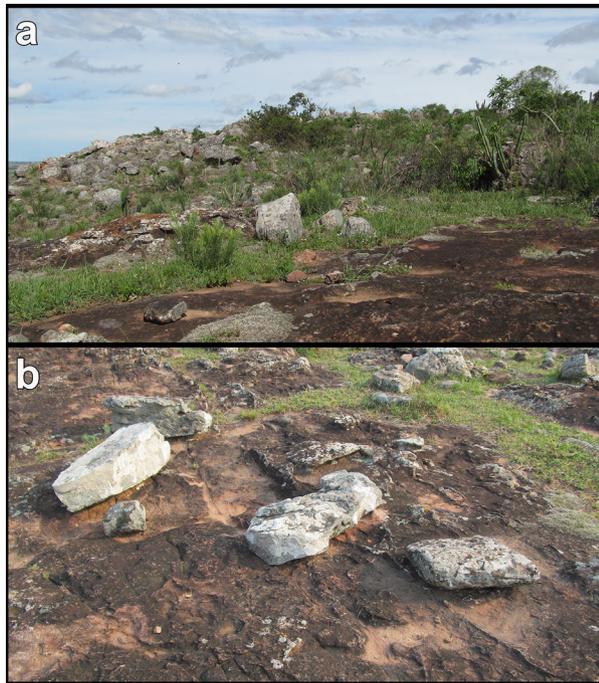


Figure 2. Rocky environments of the hills of Paraje Tres Cerros (a) where the microhabitat of *Homonota taragui* is located (b). This microhabitat is formed by large blocks of rocks where smaller rocks are supported (rock-rock substrate).

(rocky outcrops) and the fragmentation of its populations make a scenery where *H. taragui* experiments an evolution in isolation, allowing the study and detailed understanding of its biology. With scarce information available for its biology in 2016, *H. taragui* was classified as “critically endangered” according to IUCN criteria (Arzamendia et al. 2016). Fortunately, since 2014, two of the three discrete rocky outcrops are protected by the creation of a private conservation area, providing the protection of two of the three populations of *H. taragui*.

The limited knowledge of the biology and the current state of their populations, the new worrisome clues about the critical situation of *H. taragui* demonstrate the need to obtain, as soon as possible, quantitative data to designate effective protection measures and safeguard the populations of this species. The characteristics of the study site, which is small, and behaves like real islands (natural laboratories), allow a detailed study and monitoring of the individuals of this species. This study aims to (i) estimate the number of individuals per populations, sex and ontogenetic stage; (ii) evaluate the existence of sexual dimorphism and the potential causes; (iii) estimate the survival probabilities of each population to identify the most vulnerable groups; and (iv) describe the microhabitat use and movement patterns.

MATERIALS AND METHODS

Study area

The study area occurs in the Ñandubay district of the Espinal phytogeographic province (Cabrera 1976). The climate of this region is subtropical (according to the classification of Köppen 1900) and perhumid without a pronounced dry season (according to the rain regime proposed by Bagnouls & Gausson 1997). Mean annual temperature is 21.5°C, the warmest

month is January (26°C) and the coldest month is July (14°C). Mean annual precipitation reaches 1500mm, with the driest season in winter and the rainiest season in autumn (Carnevali 1994).

The topographic relief of the Paraje Tres Cerros (Figure 3) is made of three rocky outcrops, locally known as “the hills”: Nazareno (29°0.6′26.51″S 56°55′56.90″W, 179 m a.s.l., 83 ha), Capará (29°0.9′14.00″S 56°51′44.5″W, 158 m a.s.l., 79 ha) and Chico (20°0.6′45.74″S 56°55′7.78″W, 148 m a.s.l., 34 ha). These rocky outcrops consist of quartz sandstone rocks of the late Jurassic and early Cretaceous period (Herbst & Santa Cruz 1999) of the stratigraphic formation Botucatu (Aceñolaza 2007). These rocky outcrops are the only elevations in the region, representing isolated hills that rise over a flooded plain. The environmental conditions of these hills are strictly related to their exposure. Sparse shrub vegetation with grasses characterizes the northern slope, whereas in the southern slope, there are scattered patches of hydrophilic forest (Parodi 1943, Cajade et al. 2013b).

Field data collection

Surveys were conducted for 5 days every month from April 2015 to April 2017. We sampled two populations of *Homonota taragui*: the Chico population (CP hereafter) and the Nazareno population (NP hereafter), both located within a private conservation area, the Reserva Natural Privada Paraje Tres Cerros. We searched the individuals in the following way: we surveyed along transects through the potential microhabitats (Heyer et al. 1994), that is, we walked through the slope and the top of each hill in the places where the rocks supported by large blocks of rocks are found. As each sampling trip lasted five days, each day individuals were searched at different sites, so that it was possible to cover the entirety of each of the hills (since they are small and the largest has only 83ha). We

determined this methodology from a preliminary study we conducted that showed that these geckos are not found in other areas where these microhabitats are not. For each monthly sampling, two people conducted the transects for six hours, which resulted in a sampling effort of 144 hours for each of the two study populations. Ten morphometric measurements were taken (in agreement with Cajade et al. 2013a) to the nearest 0.1 mm with digital calipers: *TL*, total length; *SVL*, snout-vent length, from the tip of snout to vent; *VW*, maximum width of the vent; *BTW*, maximum width of the base of the tail; *HW*, head width, at level of the temporal region; *HL*, head length, the distance between anterior edge of auditory meatus and snout tip; *HH*, maximum height of head, at level of parietal area; *TrL*, trunk length, the distance from axilla to groin from posterior edge of forelimb insertion to anterior edge of hindlimb insertion; *HuL*, humerus length, and *FL*, femur length. Also, we measured body mass (*BM*) using an electronic balance MH-200g/0.01g. We determined the sex of captured specimens by visually evaluating the presence (males) or absence (females) of the hemipenes. The presence of a protuberance in the cloaca of *H. taragui* was assignable to the presence of hemipenes through its eversion during the examination of collected specimens. The sex was additionally corroborated in some females, by the presence of eggs by visual and palpation inspection during the reproductive period. Individuals with *SVL* <30 mm were classified as juveniles due to lack of morphological evidence to determine sex (vent protuberance or oviductal egg). The captured specimens were individually-marked by using toe-clipping codes (Donnelly & Guyer 1994), which will allow us to perform a mark-recaptured analysis and, in the future, to estimate the individual's age using the skeletochronology method. It is the most commonly used tool for evaluating the age

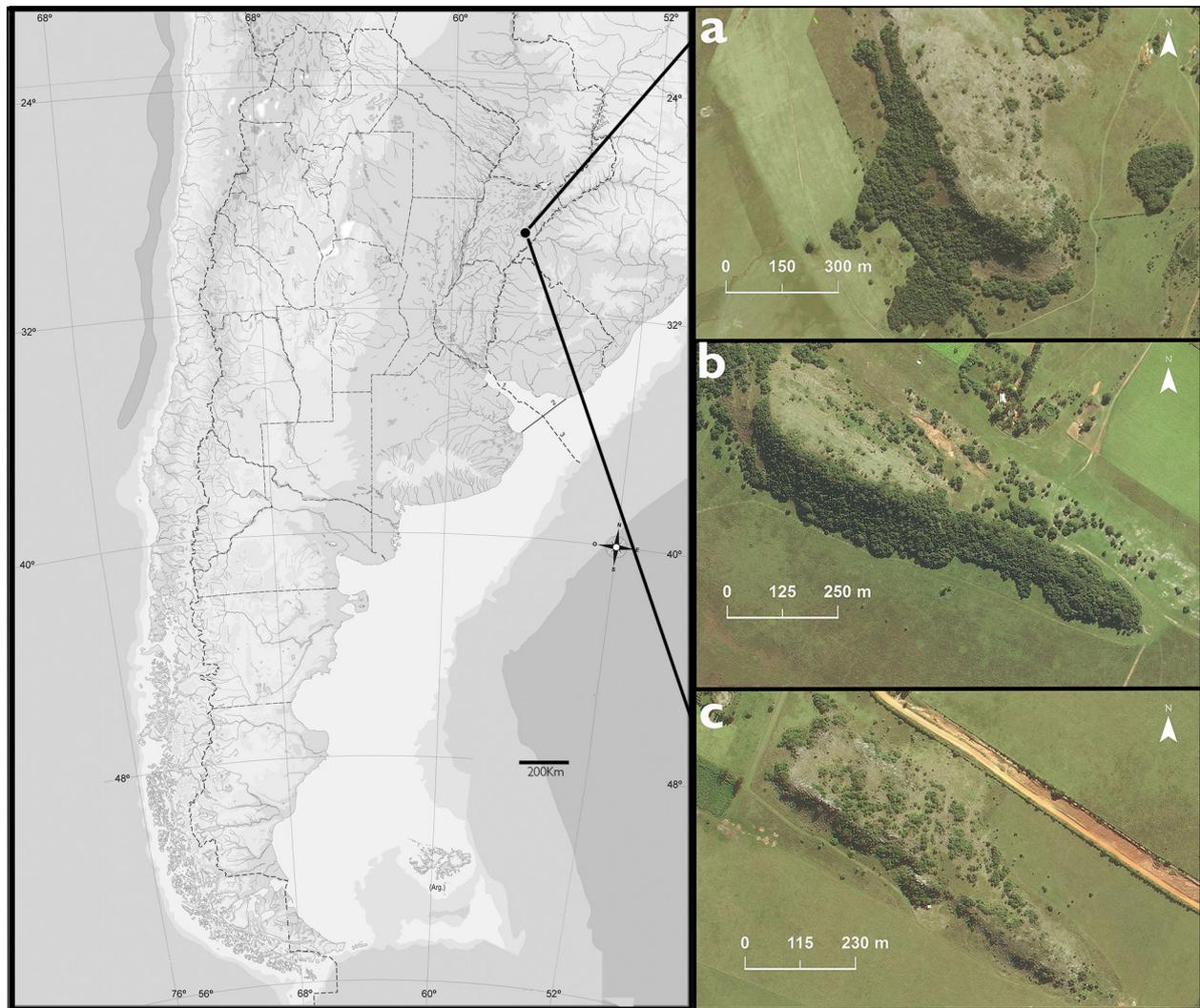


Figure 3. Distribution map of *Homonota taragui*. Location of the Paraje Tres Cerros, Corrientes province, Argentina. Details of the hills Nazareno (a), Capará (b), and Chico (c).

structure of amphibians and reptiles, providing age estimation through nonlethal means (Castanet & Smirina 1990, Marangoni 2006). The advantage of this marking technique is that it does not affect the lizards' activity and that it is a permanent mark (Borges-Landaez & Shine 2003). We recorded the exact location of the individuals captured using a Garmin GPS device (e-trex Legend H). Immediately after the morphometric measurement, we released the individuals back to their original microhabitat (under the same stone where it had been caught).

Mark-recapture data analyses

We used the Cormack–Jolly–Seber (CJS, hereafter) capture–mark–recapture model (Cormack 1964, Jolly 1965, Seber 1970) implemented in MARK (White & Burnham 1999) to estimate the apparent survival (Φ) and recapture probability (p) of females and males in the Chico and Nazareno populations. First, we ran the goodness-of-fit test (GOF) in U-CARE (Choquet et al. 2005) to test the assumptions of the CJS and to identify a global (starting) model for model selection. One of the components of GOF (Test.3SR) tests whether the

survival over the first interval after the capture is different from the survival over the subsequent intervals, a situation that may indicate age effect or presence of transient individuals. The GOF analysis revealed a slight overdispersion due to a transient effect (Test3.SR, statistic for transient = 2.319, $p = 0.020$). Deleting the first encounter for each individual solved the overdispersion issue which indicates that a CJS model with an age effect in survival would have an adequate fit to the data. After a preliminary analysis, we decided that our global model would not incorporate temporal variation in either Φ or p to guarantee parameters' estimability. Accordingly, our global model included a two-class age effect in Φ (i.e., different in the first vs. the subsequent intervals after the individual capture) and the non-additive effect of sex and population (CP and NP) on both Φ and p .

The model selection was based on Akaike's Information Criterion corrected for small sample size (AIC_c) to determine the most supported models (Burnham & Anderson 2002). First, we ranked the competing models (all the combinations nested to the global model) of p while holding Φ in their general form (like in the global model). Then, we ranked the competing models of Φ while holding p in the form of the lowest AIC_c model found in the previous step (Lebreton et al. 1992). We considered models within 2 AIC_c units of the lowest AIC_c value as nearly equivalent in explaining the data (Burnham & Anderson 2002) and, to limit model selection uncertainty, we computed model-averaged estimates of monthly apparent survival probability and recapture probability.

Statistical analyses

All variables were log-transformed in order to achieve normality. We conduct multi and univariate mixed model analysis of variance (GLM) testing for differences in ten

morphometric variables between sexes as fixed effect and, populations (NP and CP) and sex nested population, as a random effect). All analyses were carried out with type III general linear models using the STATISTICA 7.0 statistical package (StatSoft Inc. 2001). Since most of the individuals had broken tails, we excluded the total length from the analyses (Colli et al. 2003). To identify differences in the ratio of males and females within each of the populations, we used a difference between two proportions test. We determined the sex ratio (dividing males by females) in each population and used Chi-square test to evaluate sex ratio changes between CP and NP. Also, we calculated the adult ratio (dividing adults by juveniles) and to detect changes between populations in this parameter we used a Fisher's exact test. Finally, we determined the total density of CP and NP and along the seasons by dividing the number of individuals observed (total or in each season) by the area (ha) of each hill.

RESULTS

Population parameters

We captured 137 individuals over the entire study period (two years). The minimum number of individuals captured, just one, was during the warmest months (December 2016 and February 2017) and, vice versa, we captured the largest number of individuals in the coldest month (August 2015, $n = 17$). The high density of individuals was in winter (0.69 ind/ha; $n = 81$), followed by autumn (0.61 ind/ha; $n = 71$), spring (0.51 ind/ha; $n = 60$), and the lowest density was observed in summer months (0.42 ind/ha; $n = 49$).

In the two years studied, we captured 77 individuals in CP (34 males, 26 females and 16 juveniles) and 60 in NP (36 males, 19 females and 4 juveniles). The sex of only one adult in

each population was not ascertained. The total density of individuals recorded in the CP was 1.76 ind/ha, and in NP was 0.67 ind/ha.

We studied the sex ratio in each population separately: CP = 1.31 and in NP = 1.89. The proportion of males and females in CP were significantly different ($p = 0.035$, by differences between two proportions test) but we didn't find difference in NP ($p = 0.519$ by differences between two proportions test). On the other hand, there is no significant difference in the sex ratio between populations jointly analyzed ($\chi^2 = 0.04$; $df = 1$; $p = 0.839$). The adult ratio in CP its 3.81 and in NP its 14, so we found significant difference in the proportion of adults and juveniles between populations ($p = 0.013$, by Fisher's exact test).

Sexual Dimorphism

The descriptive statistics of the morphometric variables is showed in Table I. We found significant differences between sexes and populations in the set of morphological traits we had measured (MANOVA - Sex: Wilk's $\lambda = 0.81$, $F_{10,103} = 2.42$, $p = 0.013$; Population: Wilk's $\lambda = 0.79$, $F_{10,103} = 2.69$, $p = 0.006$). Also, we found significant population differences in the vent width (VW) and the base of the tail width (BTW) (ANOVA - VW: $F_{1,112} = 5.39$, $p = 0.022$; BTW: $F_{1,112} = 4.03$, $p = 0.047$). The specimens captured in NP were bigger both in VW and BTW than those captured in CP (Table I). Since, by analyzing the populations separately, we did not appreciate any sexual difference in the morphometric variables (Wilk's $\lambda = 0.96$, $F_{10,103} = 0.44$, $p = 0.922$), we pooled the two populations together and found sexual dimorphism in only one trait: the males had (HW) a bigger width head than females ($F_{1,112} = 4.89$, $p = 0.029$) (Table I).

Mark-recapture studies

The percentage of recaptured individuals increased in the successive sampled months,

and the percentage of new marked individuals decreased (Figure 4). The best model (lowest AIC_c) for the recapture probability included the non-additive effect of sex and population (Table II). The best model structure for apparent survival included differences between populations and between the first vs. subsequent intervals after the first individual capture. However, there was considerable uncertainty in the model selection as four models received similar support ($\Delta AIC_c < 2$) (Table II). The top three models, which accounted for over 71.7% of the AIC_c weight, had no sex effect in apparent survival, suggesting that there were little survival differences between females and males. Overall, we found higher survival rates in NP and during the intervals after the first (Table III). And finally, we find that the recaptured probability was exceptionally low in NP and, overall, higher for males than females (Table III).

DISCUSSION

Homonota taragui is a gecko with particular habits, taking refuge in specific microhabitats, being found more frequently in the colder months and being extremely faithful to its site. This study strongly supports that this species is a microhabitats specialist, because we have not recorded individuals on those rocks where there was some soil, only in rock-rock substrate. This loyalty to the microhabitat site were found in another species of the genus, such as *H. fasciata* (Aun & Martori 1994, Nieva et al. 2013), *H. horrida* (Fredericksen et al. 2003) and *H. darwini* (Aguilar & Cruz 2010). A remarkable observation about *H. taragui* is that the resident individuals, i.e. those captured at least twice, were always registered under the same rock and this happened even for those individuals that were captured many times (14 times the maximum record). Previous studies have shown that reptile species that

are habitat specialists have higher extinction rates (Foufopoulos & Ives 1999). Therefore, this is one of the risks faced by *H. taragui*, being vulnerable to small changes that may occur in its environment, which may cause the extinction of this entire.

The fact that we have registered individuals in all the sampled months differs with the work previously done (Odriozola 2014), in which they did not observe individuals in warmest months (January), with temperatures of 53°C were recorded under rocks. In concordance to Odriozola (2014) study, our lowest captures records also correspond to the months with higher temperatures (January), but with slight differences in the highest temperatures recorded in the microhabitats of *H. taragui* (43°C in present study). In both studies the same methodology was used to measure the temperature under the rocks, however this marked difference (10°C) could be due to different factors such as time of day, rock size, time of exposure of the rock in the sun, among others. But of course, under these conditions, individuals cannot be found under these shelters. Probably to avoid overheating, the geckos move towards other refuges like the cracks of the big rocks. Seasonal shifts in the qualitative nature of selected microhabitats by reptiles have previously been related to temperature effects (Christian et al. 1983, 1984, Paulissen 1988, Webb & Shine 1998). Our maximum frequency of occurrence was in winter, it could be suggesting that individuals would harness these refuges for thermoregulation, during the coldest months, because the smalls rocks supported on rock slabs receive solar radiation and have higher temperature and at night retain the heat, originating a suitable microclimate for the establishment of geckos. These same seasonal patterns were found in other species of geckos that live in rocky outcrops of Australia, where the records of

Table I: Descriptive statistic of morphological variables studied in adults of *Homonota taragui*. Body mass (BM) in grams. Snout-vent length (SVL). Vent Width (VW). Base of the tail width (BTW). Head width (HW). Head length (HL). Head height (HH). Trunk length (TrL). Humerus length (HuL). Femur length (FL), in millimeters. NS: P value not significant.

	Chico hill (n=61)			Nazareno hill (n=56)			Males (n=70)			Females (n=45)			
	Median ±SD	Min	Max	Median ±SD	Min	Max	Median ±SD	Min	Max	P value	Median ±SD	Min	Max
BM	1.59± 0.31	0.76	2.14	1.72± 0.22	1.17	2.20	1.60± 0.23	1.07	2.20	NS	1.73± 0.32	0.76	2.18
SVL	37.55±2.30	32.40	41.74	37.63± 2.01	32.74	41.42	37.55± 2.10	32.40	41.74	NS	37.86± 2.16	32.56	41.66
VW	3.69± 0.37	3.04	4.50	3.91± 0.41	3.08	5.09	3.70± 0.33	3.10	4.63	NS	3.88± 0.49	3.04	5.09
BTW	4.34± 0.46	3.35	5.42	4.59± 0.47	3.54	5.50	4.48± 0.41	3.55	5.44	NS	4.43± 0.54	3.35	5.50
HW	7.57± 0.46	6.63	8.77	7.78± 0.41	5.85	8.52	7.73± 0.41	6.63	8.77	0.02	7.60± 0.52	5.85	8.56
HL	9.66± 0.77	5.51	10.79	9.92± 0.45	8.62	10.95	9.85± 0.72	5.51	10.72	NS	9.85± 0.53	8.48	10.95
HH	4.70± 0.49	3.46	7.09	4.79± 0.44	3.99	5.68	4.76± 0.51	3.46	7.09	NS	4.71± 0.42	3.75	5.68
TrL	17.71± 1.16	14.81	21.09	17.54± 1.75	11.70	22.59	17.42± 1.24	13.54	21.10	NS	17.92± 1.75	11.70	22.59
HuL	4.10± 0.43	3.31	5.34	4.04± 0.40	3.06	4.81	3.98± 0.40	3.06	5.34	NS	4.22± 0.39	3.41	4.98
FL	5.88± 0.58	4.57	7.10	5.88± 0.59	4.57	7.10	5.90± 0.51	4.71	7.09	NS	5.98± 0.67	4.57	7.10

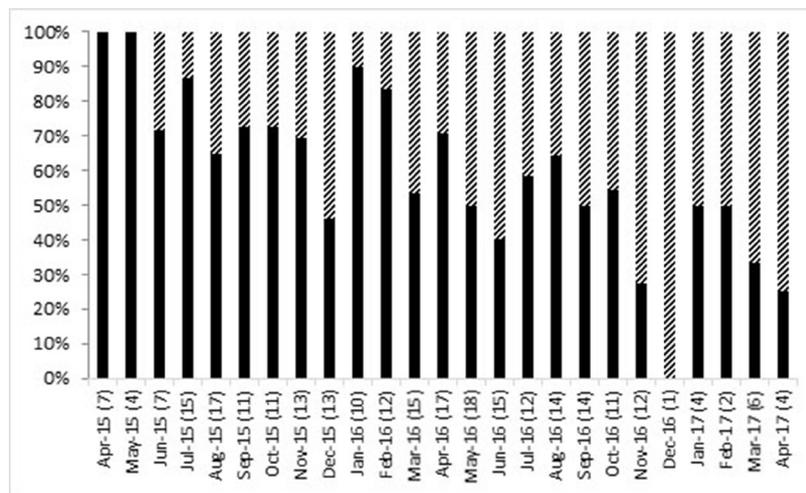


Figure 4. Monthly percentage of individuals of *Homonota taragui* marked (black bars) and recaptured (striped bars) in Paraje Tres Cerros during April 2015 and April 2017 (n).

individuals during the summer were reduced up to 74% compared to spring (Kearney 2002). Here we suggest that geckos take refuge in the crevices of large rocks when temperatures are very high, since the crevices are likely to be considerably cooler than surface rocks and, in this way, they would avoid overheating.

The density of individuals in each populations is markedly different (CP = 1.76 ind/ha; NP = 0.67 ind/ha) could suggest, on the one hand, that even if the hill is smaller, the population has a greater availability of microhabitats, since it is known that in geckos, the population size depends, among other factors, on the availability of microhabitats (Sarre 1998). On the other hand, it could also be indicating that the microhabitats have a better access allowing a greater catchability of geckos, although it would be a biased sampling. In order to determine if these differences are due to it, it is suggested that in subsequent studies the availability of microhabitats in each of the populations should be measured, since this species is a specialist in the use of microhabitats and this could be influencing the size population. In this way, the first mentioned hypothesis would be put to the test. In addition, in future studies, obtaining a thermal profile

of the cracks to test the availability of thermal shelters to avoid overheating could be essential to estimate the thermal risks of *H. taragui* (in a context of climate change).

Besides *H. taragui* present a geographic distribution extremely reduced, their populations do not have connection. Chico and Nazareno hills are separated 1 km from each other by grassland, citrus plantations and cattle, without available microhabitats that allows the flow between populations. Even, the Capará hill, where is presented the third known population of this species, is 6 km away (Figure 1, Cajade et al. 2013b, Fandiño et al. 2017). Our study confirms the absence of flow between populations since we did not find individuals with a mark from one population to another, this isolation being a factor that favors the vulnerability of the species. In lizards, the disadvantageous consequences of inbreeding and decreased genetic variability have been reported, such as malformations or decreased survival of individuals (Olsson et al. 1996), and the appearance of deleterious recessive genes (Courtis et al. 2015).

The sexual size dimorphism is a common phenomenon in lizards (Anderson 1994). One of the factors as a promoter in the evolution of sexual size dimorphism is sexual selection.

Table II. Survival models and associated biological hypotheses for *Homonota taragui* in Paraje Tres Cerros. The most supported model is in bold. Model notation: Φ , apparent survival probability; p , recapture probability, sex, sex (females and males); pop , population (Chico, Nazareno); a_2 , two-class age effect (different probability in the 1st vs the subsequent intervals after the first capture); +, additive effect; *, non-additive effect. Table notation: *Dev*, deviance of the model; *NP*, number of identifiable parameters; AIC_c , Akaike information criterion value corrected for small sample size; ΔAIC_c , difference in AIC values between the current model and that with the lowest AIC value.

Model	Dev	NP	AIC_c	ΔAIC_c	Biological hypothesis
$\Phi_{a_2+pop} p_{sex+pop}$	449.7857	6	570.0630	0.0000	Survival depended on the additive effect of age and population; additive effect of sex and population for recapture.
$\Phi_{a_2} p_{sex+pop}$	453.1552	5	571.2995	1.2365	Age effect on survival; additive effect of sex and population for recapture.
$\Phi_{a_2*pop} p_{s+pop}$	449.2684	7	571.7020	1.6390	Survival depended on interaction of age effect and population; additive effect of sex and population for recapture.
$\Phi_{a_2+sex+pop} p_{sex+pop}$	449.3548	7	571.7885	1.7255	Additive effect of age, sex and population for survival; additive effect of sex and population for recapture.
$\Phi_{a_2+sex} p_{sex+pop}$	453.0584	6	573.3357	3.2727	Survival depended on additive effect of age and sex; additive effect of sex and population for recapture.
$\Phi_{a_2*sex} p_{sex+pop}$	451.7430	7	574.1766	4.1136	Survival depended on interaction between age effect and sex; additive effect of sex and population for recapture.
$\Phi_{a_2*sex*pop} p_{sex+pop}$	446.8837	11	578.1851	8.1221	Survival depended on the interaction of age effect, sex and population; additive effect of sex and population for recapture.
$\Phi_{a_2*sex*pop} p_{pop}$	449.4837	10	578.5310	8.4680	Survival depended on the interaction of age effect, sex and population; Recapture depended of population.
$\Phi_{a_2*sex*pop} p_{sex*pop}$	446.8737	12	580.4547	10.3917	Survival depended on the interaction of age effect, sex and population; recapture varied whit the interaction of sex and population.
$\Phi_{a_2*sex*pop} p.$	463.3038	9	590.1221	20.0591	Survival depended on the interaction of age effect, sex and population; constant recapture.
$\Phi_{a_2*sex*pop} p_{sex}$	462.6400	10	591.6873	21.6243	Survival depended on the interaction of age effect, sex and population; recapture depended on sex.

According to this theory, males should be the largest sex (Shine 1978, 1994, Berry & Shine 1980) and they should exaggerate organs related to rivalry success and/or territory advertisement in lineages exhibiting male-male aggression. We found that males have wider heads than females and we suggest two possible explications for

this difference in head size in favor of males. First, within the sexual selection theory, the heads in lizard are typically used as weapons in combats. Indeed, the sexual selection would benefit to greater males because the large individuals have a greater capacity to physically displace smaller opponents or dominate them, it

Table III. Real estimates of apparent survival and recaptures probabilities of *Homonota taragui* corresponding to the most parsimonious model (Φ_{a2+p} , p_{s+p}). SE, standard error; CI, confidence intervals (95%).

	Estimate	SE	CI
Apparent survival			
Chico population	0.885	0.030	0.813-0.932
Nazareno population	0.943	0.026	0.865- 0.977
<i>Recapture probabilities</i>			
Females Chico population	0.187	0.040	0.121-0.278
Females Nazareno population	0.051	0.019	0.024-0.104
Males Chico population	0.262	0.053	0.172- 0.378
Males Nazareno population	0.076	0.024	0.041-0.138

means, this attribute affects intrasexual combat. Second, these differences in body sizes between males and females could be a consequence of differences in the use of food resource between them, as a strategy to avoid an overlap in the trophic niche, suggesting different foraging patterns and/or microhabitat use (Pianka 1976, Toft 1980, Houston & Shine 1993, Herrel et al. 2009). This is support by several studies on sexual variation in diet in other species of the genera, such as in *H. andicola* (Blanco et al. 2009), *H. darwini* (Kun et al. 2010) and *H. fasciata* (Nieva Cocilio et al. 2016), however will be necessary to conduct studies of trophic ecology in *H. taragui*, to test this hypothesis. Another possible cause of the reduction in the pronouncement of other dysmorphic characteristics (since they only differ in head size) could be due to the lack of genetic variability that *H. taragui* populations present. To determine if this statement is true, future studies on the genetic variability of populations of this species are recommended.

Likewise, Cruz (1994) found sexual dimorphism in one populations of *H. fasciata* in the head width, length and height, greater in males, in one population of Salta province (Argentina), coinciding with our results. In the same species Nieva et al. (2013) found sexual dimorphism in radio-ulna length, being higher in females than in males, and tibia-fibula length,

being this variable major in male in populations of San Juan province (Argentina). So, although differences between sexes of this species could vary between populations, in both studies they propose that this difference in favor of males, could be due to agonistic encounters, since it is known that these gekos are markedly territorial (Abdala 1986, Vitt 1986, Cruz 1994, Nieva et al. 2013).

The mark-recapture study allowed us to identify a transient effect, similar in both sexes. The presence of transient effect suggests that there are more taragüi gekos expected under CJS model were seen only once. This would indicate that there are individuals who behave as transience and who are passing through the study area, but they don't stay there. Probably the individuals are in constant movement within the study area, and this movement is due to it constant search for a partner, or they must search for new microhabitats (shelters) with favorable conditions, to settle there. This behavior was also recorded in other species of the genera, such as *H. fasciata* (Abdala 1986, Nieva et al. 2013).

The analysis of apparent survivor showed that there are no differences in this parameter between males and females. Some authors explain that the differences in mortality between sexes, may reflect differences in body size, with

higher mortality in those larger individuals (Iverson et al. 2016). This could be an explanation to our results, since there are no significant differences in body size between males and females. The apparent survival is greater in individuals from the Nazareno population. In turn, this hill is the largest, and we could assume that it offers greater availability of resources. On the contrary, Chico hill having a smaller size, may be causing greater intraspecific competition for resources, what is reflected in a lower survival. Therefore, it is the individuals in this population who are most vulnerable and we suggest that these results could be taken into account in future projects.

The particular system of isolated rocky outcrops acting as biographical island, such as, Paraje Tres Cerros offers a great potential to study issues which today are of global concern and which might affect conservation biology, as well as, to understand ecological and evolutionary processes (Porembski & Barthlott 2000).

Studies that provide basic information on the biology and ecology of little-known species are necessary to lay the foundations of knowledge from which conservation decisions can be made and define management strategies. Such knowledge is critical to propose science-based guidelines for the conservation of this unique gecko. The microhabitat specialization, the lack of population interconnection and the population demographic parameters here analyzed, increment our knowledge about the vulnerability of *H. taragui* in order to contribute efficiently in its conservation.

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REFERENCES

- ABDALA V. 1986. Commentaire sur la «position dressée» adoptée par *Homonota horrida* en captivité. Revue française d'aquariologie (Nancy) 13(3): 87-88.
- ABDALA V. 1997. Los geocos de Argentina. Universidad Nacional de Tucumán, Serie Monográfica y Didáctica de la Facultad de Ciencias Naturales 29: 44.
- ACEÑO LAZA FG. 2007. Geología y recursos geológicos de la Mesopotamia Argentina (Vol. 22). Consejo Nacional de Investigaciones Científicas y Técnicas, Instituto Superior de Correlación Geológica, Universidad Nacional de Tucumán.
- AGUILAR R & CRUZ FB. 2010. Refuge use in a Patagonian nocturnal lizard, *Homonota darwini*: the role of temperature. J Herpetol 44(2): 236-241.
- ANDERSON RA. 1994. Functional and population responses of the lizard *Cnemidophorus tigris* to environmental fluctuations. Am Zool 34(3): 409-421.
- ARZAMENDIA V, FITZGERALD L, GIRAUDO AR, KACOLIRIS FP, MONTERO R, PELEGRIN N, SCROCCHI MANFRINI GJ & WILLIAMS J. 2016. *Homonota taragui*. In The IUCN Red List of Threatened Species 2016: e.T56234213A56234216. <http://dx.doi.org/10.2305/IUCN.UK.2016-1.RLTS.T56234213A56234216.en>.
- AUN L & MARTORI R. 1994. Biología de una población de *Homonota horrida*. Cuad Herpetol 8: 90-96.
- AVILA LJ, PÉREZ CHF, MINOLI I & MORANDO M. 2012. A new species of *Homonota* (Reptilia: Squamata: Gekkota: Phyllodactylidae) from the Ventania mountain range, Southeastern Pampas, Buenos Aires Province, Argentina. Zootaxa 3431: 19-36.
- BAGNOULS F & GAUSSEN H. 1957. Les climats biologiques et leur classification. In Annales de géographie, Armand Colin. Vol. 66, No. 355, p. 193-220.
- BERRY JF & SHINE R. 1980. Sexual size dimorphism and sexual selection in turtles (Order Testudines). Oecologia 44(2): 185-191.
- BLANCO G, VILLAVICENCIO HJ & ACOSTA JC. 2009. Field body temperature, diet, and reproduction of *Homonota*

- andicola* (Gekkonidae) in Catamarca, Argentina. *Herpetol Rev* 40(2): 156.
- BORGES-LANDEZ PA & SHINE R. 2003. Influence of toe-clipping on running speed in *Eulamprus quoyii*, an Australian scincid lizard. *J Herpetol* 37(3): 592-595.
- BURKE A. 2003. Inselbergs in a changing world—global trends. *Divers Distrib* 9(5): 375-383.
- BURNHAM KP & ANDERSON DR. 2002. Model Selection and Multi-model Inference: A Practical Information-theoretic Approach, 2nd ed., Springer Verlag, New York, USA.
- CABRERA AL. 1976. Enciclopedia Argentina de agricultura y jardinería: regiones fitogeográficas Argentinas. Acme.
- CACCIALI P, AVILA I, BUONGERMINI E & CÉSPEDez J. 2015. Nuevos datos relativos a la variación morfológica de *Homonota rupicola* (Squamata: Phyllodactylidae) y comentarios sobre su hábitat. *FACENA* 31: 53-58.
- CACCIALI P, MORANDO M, AVILA LJ & KOEHLER G. 2018. Description of a new species of *Homonota* (Reptilia, Squamata, Phyllodactylidae) from the central region of northern Paraguay. *Zoosystem Evol* 94: 147.
- CACCIALI P, MORANDO M, MEDINA, CD, KÖHLER G, MOTTE M & AVILA LJ. 2017. Taxonomic analysis of Paraguayan samples of *Homonota fasciata* Duméril & Bibron (1836) with the revalidation of *Homonota horrida* Burmeister (1861) (Reptilia: Squamata: Phyllodactylidae) and the description of a new species. *PeerJ* 5: e3523.
- CAJADE R, ETCHEPARE EG, FALCIONE C, BARRASSO A & ÁLVAREZ B. 2013a. A new species of *Homonota* (Reptilia: Squamata: Gekkota: Phyllodactylidae) endemic to the hills of Paraje Tres Cerros, Corrientes Province, Argentina. *Zootaxa*, 3709(2), 162-176.
- CAJADE R ET AL. 2013b. Las islas rocosas del Paraje Tres Cerros: un refugio de biodiversidad en el litoral mesopotámico argentino. *Biológica* 16: 147-159.
- CARNEVALI R. 1994. Fitogeografía de la provincia de Corrientes: cartas, escalas 1: 500.000 y 1: 1.000. 000. Gobierno de la Provincia de Corrientes e INTA.
- CASTANET J & SMIRINA E. 1990. Introduction to the skeletochronological method in amphibians and reptiles. In *Annales des sciences naturelles. Zool Biol Anim* 11(4): 191-196.
- CEI JM. 1986. Reptiles del centro, centro-oeste y sur de la Argentina: Herpetofauna de las zonas áridas y semiáridas. Torino, Italy: Museo regionale di scienze naturali.
- CEI JM. 1993. Reptiles del noroeste, nordeste y este de la Argentina. Herpetofauna de las selvas subtropicales, Puna y Pampas. Museo Regionale di Scienze Naturali Monografie (Torino) 14: 1-949.
- CHOQUET R, REBOULET AM, LEBRETON JD, GIMENEZ O & PRADEL R. 2005. U-CARE 2.2 user's manual. CEFE, Montpellier, France, 53 p.
- CHRISTIAN K, TRACY CR & PORTER WP. 1983. Seasonal shifts in body temperature and use of microhabitats by Galapagos land iguanas (*Conolophus pallidus*). *Ecol* 64(3): 463-468.
- CHRISTIAN KA, TRACY RC & PORTER WP. 1984. Physiological and ecological consequences of sleeping-site selection by the Galapagos Land Iguana (*Conolophus pallidus*). *Ecology* 65: 752-758.
- COLLI GR, MESQUITA DO, RODRIGUES PV & KITAYAMA K. 2003. Ecology of the gecko *Gymnodactylus geckoides amarali* in a Neotropical savanna. *J Herpetol* 37(4), 694-707.
- CORMACK RM. 1964. Estimates of survival from the sighting of marked animals. *Biometrika* 51(3/4): 429-438.
- COURTIS A, CAJADE R, PIÑEIRO JM, HERNANDO A & MARANGONI F. 2015. First record of albinism in the Taragüi Gecko *Homonota taragui* (Squamata: Phyllodactylidae). *Herpetol Notes* 8: 425-427.
- CRUZ FB. 1994. Actividad reproductiva en *Homonota horrida* (Sauria: Gekkonidae) del Chaco occidental en Argentina. *Cuad Herpetol* 8: 119-125.
- CRUZ FB, KOZYKARISKI ML, PEROTTI MG, PUETA M & MORENO L. 2004. Variación diaria de la temperatura corporal en dos especies de lagartos nocturnos (Squamata: Gekkonidae: *Homonota*) con comentarios sobre el uso de refugios. *Cuad Herpetol* 8: 15-22.
- DAZA JD, GAMBLE T, ABDALA V & BAUER AM. 2017. Cool Geckos: Does Plesiomorphy Explain Morphological Similarities between Geckos from the Southern Cone? *J Herpetol* 51(3): 330-342.
- DONNELLY MA & GUYER C. 1994. Mark-recapture. Measuring and monitoring biological diversity: Standard methods for amphibians, p. 183-200.
- FANDIÑO B, FERNÁNDEZ JM, THOMANN ML, CAJADE R & HERNANDO AB. 2017. Comunidades de aves de bosques y pastizales en los afloramientos rocosos aislados del Paraje Tres Cerros, Corrientes, Argentina. *Rev Biol Trop* 65(2): 535-550.
- FELAPPI JF, VIEIRA RC, FAGUNDES NJ & VERRASTRO LV. 2015. So far away, yet so close: strong genetic structure in *Homonota uruguayensis* (Squamata, Phyllodactylidae), a species with restricted geographic distribution in the Brazilian and uruguayan pampas. *PloS One* 10(2): e0118162.

- FOUFOPOULOS J & IVES AR. 1999. Reptile extinctions on land-bridge islands: life-history attributes and vulnerability to extinction. *Amer Natur* 153(1): 1-25.
- FREDERICKSEN NJ, FREDERICKSEN TS, FLORES B, MCDONALD E & RUMIZ D. 2003. Importance of granitic rock outcrops to vertebrate species in a Bolivian tropical forest. *Trop Ecol* 44: 185-196.
- GODOY M & PINCHEIRA-DONOSO D. 2009. Multi-maternal nesting behaviour and a potential adaptive signal for its evolution in the Argentinean gekkonid lizard *Homonota borelli*. *J Biol Res-Thessaloniki* 12: 221-224.
- GÓMEZ PF & ACOSTA JC. 2001. Estructura poblacional y tasa de crecimiento individual de *Homonota Fasciata* (Squamata: Gekkonidae) en San Juan, Argentina. *Multequina*, 10.
- HEYER WR, DONNELLY MA, MCDIARMID RW, HAYEK LAC & FOSTER MS. 1994. Measuring and Monitoring Biological Diversity. Standard Methods for Amphibians. Smithsonian Institution, Washington.
- HERBST R & SANTA CRUZ JN. 1999. Mapa litoestratigráfico de la provincia de Corrientes. *D'Orbignyana* 2: 1-69.
- HERREL A, SCHAERLAEKEN V, MORAVEC J & ROSS CF. 2009. Sexual Shape dimorphism in Tuatara. *Copeia* 4: 727-731.
- HOUSTON D & SHINE R. 1993. Sexual dimorphism and niche divergence: feeding habits of the Arafura filesnake. *J An Ecol* 62: 737-748.
- HUTCHINSON GE. 1978. An introduction to population ecology. *HUT* 504: 51.
- IBARGÜENGOYTÍA NR & CASALINS LM. 2007. Reproductive biology of the southernmost gecko *Homonota darwini*: convergent life-history patterns among southern hemisphere reptiles living in harsh environments. *J Herpetol* 41(1): 72-80.
- IVERSON JB, CONVERSE SJ, SMITH GR & VALIULIS JM. 2006. Long-term trends in the demography of the Allen Cays Rock Iguana (*Cyclura cychlura inornata*): Human disturbance and density-dependent effects. *Biol Conserv* 132(3): 300-310.
- JOLLY GM. 1965. Explicit estimates from capture-recapture data with both death and immigration-stochastic model. *Biometrika* 52(1/2): 225-247.
- KEARNEY M. 2002. Hot rocks and much-too-hot rocks: seasonal patterns of retreat-site selection by a nocturnal ectotherm. *J Therm Biol* 27(3): 205-218.
- KLUGE AG. 1964. A revision of the South American gekkonid lizard genus *Homonota* Gray. *American Museum Novitates* 2193: 1-41.
- KÖPPEN W. 1900. Versuch einer Klassifikation der Klimate, vorzugsweise nach ihren Beziehungen zur Pflanzenwelt. *Geographische Zeitschrift* 6(11. H): 593-611.
- KUBISCH E, PIANTONI C, WILLIAMS J, SCOLARO A, NAVAS CA & IBARGÜENGOYTÍA NR. 2012. Do higher temperatures increase growth in the nocturnal gecko *Homonota darwini* (Gekkota: Phyllodactylidae)? A skeletochronological assessment analyzed at temporal and geographic scales. *J Herpetol* 46(4): 587-595.
- KUN ME, PIANTONI C, KRENZ JD & IBARGÜENGOYTÍA NR. 2010. Dietary analysis of *Homonota darwini* (Squamata: Gekkonidae) in Northern Patagonia. *Curr Zool* 56: 406-410.
- LEBRETON JD, BURNHAM KP, CLOBERT J & ANDERSON DR. 1992. Modeling survival and testing biological hypotheses using marked animals: a unified approach with case studies. *Ecol Monogr* 62(1): 67-118.
- MALCOLM JR, LIU C, NEILSON RP, HANSEN L & HANNAH LEE. 2006. Global warming and extinctions of endemic species from biodiversity hotspots. *Conserv Biol* 20(2): 538-548.
- MARANGONI F. 2006. Variación clinal en el tamaño del cuerpo a escala microgeográfica en dos especies de anuros (*Pelobates cultripes* y *Bufo calamita*). PhD thesis. Sevilla, España, Universidad de Sevilla.
- MORANDO M, MEDINA CD, ÁVILA LJ, PÉREZ CH, BUXTON A & SITES JW. 2014. Molecular phylogeny of the New World gecko genus *Homonota* (Squamata: Phyllodactylidae). *Zool Scripta* 43(3): 249-260.
- NIEVA RA, BLANCO GM, ACOSTA JC & OLMEDO M. 2013. Reproducción y dimorfismo sexual en una población de *Homonota fasciata* (Squamata: Phyllodactylidae) del monte de San Juan, Argentina. *Rev Mex Biodiv* 84(4): 1266-1272.
- NIEVA COCILIO RAN, BLANCO GM & ACOSTA JC. 2016. Effects of season, sex and age on the diet of *Homonota fasciata* (Squamata, Phyllodactylidae) from Monte region of Argentina. *Iheringia. Série Zoologia*, 106.
- ODRIOZOLA M. 2014. Complementariedad y solapamiento entre los nichos espacial y temporal de cuatro especies sintópicas de lagartijas del Paraje Tres Cerros, Corrientes, Argentina. Bachelor thesis, Universidad Nacional del Nordeste, Corrientes, Argentina. (Unpublished).
- OLSSON M, GULLBERG A & TEGELSTRÖM H. (1996). Malformed offspring, sibling matings, and selection against inbreeding in the sand lizard (*Lacerta agilis*). *J Evol Biol* 9(2): 229-242.
- PARODI LR. 1943. La vegetación del departamento San Martín en Corrientes, Argentina. *Darwiniana* 6: 127-178.

PAULISSEN MA. 1988. Ontogenetic and seasonal shifts in microhabitat use by the lizard *Cnemidophorus sexlineatus*. *Copeia* 1988: 1021-1029.

PIANKA ER. 1976. Natural selection of optimal reproductive tactics. *Am Zool* 16(4): 775-784.

PIANTONI C, IBARGÜENGOYTÍA NR & CUSSAC VE. 2006. Growth and age of the southernmost distributed gecko of the world (*Homonota darwini*) studied by skeletochronology. *Amphibia-Reptilia* 27(3): 393-400.

POREMBSKI S & BARTHOLOTT W. 2000. Inselbergs: Biotic Diversity of Isolated Rock Outcrops in Tropical and Temperate Regions. *Ecological Studies*, Springer-Verlag, Berlin, 146 p.

POREMBSKI S, MARTINELLI G, OHLEMÜLLER R & BARTHOLOTT W. 1998. Diversity and ecology of saxicolous vegetation mats on inselbergs in the Brazilian Atlantic rainforest. *Divers Distribut* 4(3): 107-119.

SARRE SD. 1998. Demographics and population persistence of *Gehyra variegata* (Gekkonidae) following habitat fragmentation. *J Herpetol* 32: 153-162.

SEBER GAF. 1970. Estimating time-specific survival and reporting rates for adult birds from band returns. *Biometrika* 57(2): 313-318.

SHINE R. 1978. Sexual size dimorphism and male combat in snakes. *Oecologia* 33(3): 269-277.

SHINE R. 1994. Sexual size dimorphism in snakes revisited. *Copeia*: 326-346.

STATSOFT INC. 2011. STATISTICA (data analysis software system), version 10. www.statsoft.com.

TOFT CA. 1980. Feeding ecology of thirteen syntopic species of anurans in a seasonal tropical environment. *Oecologia* 45(1): 131-141.

VITT LJ. 1986. Reproductive tactics of sympatric gekkonid lizards with a comment on the evolutionary and ecological consequences of invariant clutch size. *Copeia*: 773-786.

WATSON DM. 2002. A conceptual framework for studying species composition in fragments, islands and other patchy ecosystems. *J Biogeogr* 29: 823-834.

WEBB JK & SHINE R. 1998. Using thermal ecology to predict retreat-site selection by an endangered snake species. *Biol Conserv* 86(2) 233-242.

WHITE GC & BURNHAM KP. 1999. Program MARK: survival estimation from populations of marked animals. *Bird Study* 46(sup1): S120-S139.

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