Effects of natural and artificial light on the nocturnal behaviour of the wall gecko

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Abstract

Effects of natural and artificial light on the nocturnal behaviour of the wall gecko. In the present study, we evaluated the effects of nocturnal light level (i.e. lunar phase and artificial lighting) on the activity of wall geckos (*Tarentola mauritanica*) of different ages in an anthropic environment. Data on individual behaviour were collected by direct observation and later examined by means of generalized linear mixed model (GLMM) analysis. The presence of moonlight increased the number of active wall geckos. Artificial lighting reduced the effect of moonlight on the number of active geckos but not on their individual activity. A greater number of adult geckos was found around artificial light as large individuals monopolized the best foraging sites. The ability to use artificially–lit human habitats, particularly on new moon nights, can benefit the foraging activity of nocturnal lizard species such as the wall gecko.

Key words: Moon phase, Artificial lighting, Competition, Reptile, Farmhouse

Resumen

Efectos de la iluminación natural y artificial en el comportamiento nocturno de la salamanquesa común. En este trabajo evaluamos los efectos del grado de iluminación nocturna (fase lunar e iluminación artificial) en la actividad de ejemplares de salamanquesa común (*Tarentola mauritanica*) de diferentes edades en un ambiente humanizado. Los datos de comportamiento individual se recogieron mediante observación directa y posteriormente se examinaron mediante un análisis lineal generalizado mixto (GLMM, por su sigla en inglés). La presencia de luna aumentó el número de salamanquesas activas. La iluminación artificial redujo el efecto de la luna en el número de salamanquesas activas, pero no en su actividad individual. Además, se observaron más salamanquesas adultas alrededor de fuentes de luz artificial debido a que los individuos de mayor tamaño monopolizaban los mejores lugares de alimentación. La capacidad de utilizar hábitats humanizados iluminados artificialmente, especialmente durante las noches de luna nueva, puede beneficiar la actividad de alimentación en especies de reptiles nocturnos como las salamanquesas.

Palabras clave: Fase lunar, Iluminación artificial, Competición, Reptiles, Cortijo

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Introduction

Several vertebrate taxa have been shown to adjust their nocturnal activity and behaviour in terrestrial habitats in relation to the levels of moonlight (e.g. Longland, Price, 1991; Kotler et al., 1991, 2010; Clarke et al., 1996, Lillywhite and Brischoux, 2012). Since higher levels of light increase predation risks, moonlight involves a trade–off between activity and safety (Kotler et al., 2010). Therefore, night–time activity of many nocturnal prey animals is reduced during full–moon nights (Perry and Fisher, 2006). However, in contrast to prey species, the effect of light conditions at night on predators has been less studied (but see Skutelsky, 1996; Mukherjee et al., 2009). Divergent responses to moonlight among species of nocturnal reptiles such as lizards seem to arise from differential activity patterns of both prey and predators of these animals in relation to the level of illumination (Reichmann, 1998). The use of artificial outdoor lighting has increased greatly over the last century, changing illumination levels at night in most of the world's urban areas and adjacent habitats (Cinzano et al., 2001; Hölker et al., 2010). Reptile species that appear to be at highest risk of being affected by artificial lighting are generally those that occur around human dwellings and nearby roads because they are likely affected by skyglow or glare (Mazerolle et al., 2005; Rich and Longcore, 2006). However, reptile taxa occurring in or close to urban areas have rarely been studied in this context (Perry et al., 2008). Although studies on the effects of lighting on reptiles are scarce, increased prey availability around artificial night lighting has been documented in some lizard species (Perry et al., 2008).

The wall gecko (*Tarentola mauritanica*) is typically associated with vertical surfaces and is frequently observed in anthropogenic landscapes (Luiselli and Capizzi, 1999). It is mainly nocturnal, and frequently uses areas around artificial light sources for foraging. In the present study, we tested the effects of nocturnal light level (i.e. lunar phase and artificial lighting) on wall gecko activity in an anthropic environment. Since the wall gecko is a visual predator, higher natural or artificial light levels can be expected to enhance its nocturnal foraging activity. We hypothesized that larger geckos would monopolize the best sites in terms of prey availability and would therefore be more abundant in artificially lit areas.

Material and methods

Study species

The wall gecko (Fam. Gekkonidae) is a common and widespread reptile species in North Africa, where its ranges extends from Egypt west to Morocco and the northwest Western Sahara, and in the Mediterranean, where it is found from Greece to the the Iberian peninsula, usually in warm, dry coastal areas (IUCN, 2015; Arnold and Ovenden, 2002; Gasc et al., 1997). The wall gecko is mainly nocturnal but it shows significant diurnal activity in both foraging and thermoregulatory behaviour (Arnold and Ovenden, 2002). It is a medium–sized gecko (45–85 mm, snout–vent length –SVL–; Carretero, 2008) that preys on arthropods. Its diet and its hunting strategy vary with habitat (Arnold and Ovenden, 2002). In urban habitats, wall geckos can be found on walls, ruins and houses (Luiselli and Capizzi, 1999) where they follow a typical sit–and–wait foraging strategy (Hódar et al., 2006). The diet of these geckos is generally similar regarding age and sex (Gil et al., 1994), but geckos can be territorial and aggressive towards conspecifics (Carretero, 2008).

Study area

Our study was conducted at a farmhouse and its adjacent farm buildings in Tarifa (fig. 1), southern Spain (36° 02' 27.37" N, 5° 37' 04.80" W),

Sampling geckos

The survey was carried out at night three times per week between 18 July–1 August and 5–27 September 2013, by an observer wearing a headlamp. The distance between the geckos and the observer did not induce any response in the former. Walls were inspected every 30 minutes over 2 h periods after sunset. No trend was found in the number of geckos during these 2 h periods. Each individual was recorded with respect to two fixed point sources of artificial light (40 W incandescent lamps; fig. 1) defining an area of 3 m around each lamp as influenced by light (distinguishing between 'area with light' and 'dark area'). We visually estimated the size of individuals (< 6 cm; between 6 and 12 cm; between 12 and 16 cm; > 16 cm). Intra–observer variability regarding gecko size estimates was minimized through training sessions prior to sampling. Geckos smaller than 6 cm were classified as juveniles (following Atzori et al., 2007; Lisičić, 2012). We did not distinguish between sexes as it is difficult to do by direct observation (Atzori et al., 2007; Zuffi et al., 2011). We also recorded the proportion of geckos that were active at the time of the census. For each night, we assigned a 'percent moon fullness' (0 %, no moon; 100 %, full moon). There was no precipitation during the study period, nocturnal temperature was warm (20 ºC on average), and temperature variation was low (between 22 and 19 ºC). Therefore, no surveys were conducted on rainy or cool nights (< 17 ºC). However, the weather was very windy in the study area. Because insect activity is markedly affected by wind speed, surveys were not conducted on extremely windy nights (> 4, Beaufort scale). Moreover, we recorded wind speed per night on the Beaufort scale from the Windguru website to control its effects on the foraging activity of geckos (http://www.windguru.cz/es/).

Data analysis

To avoid potential biases caused by behavioral effects of capturing the individuals (i.e. observer avoidance),

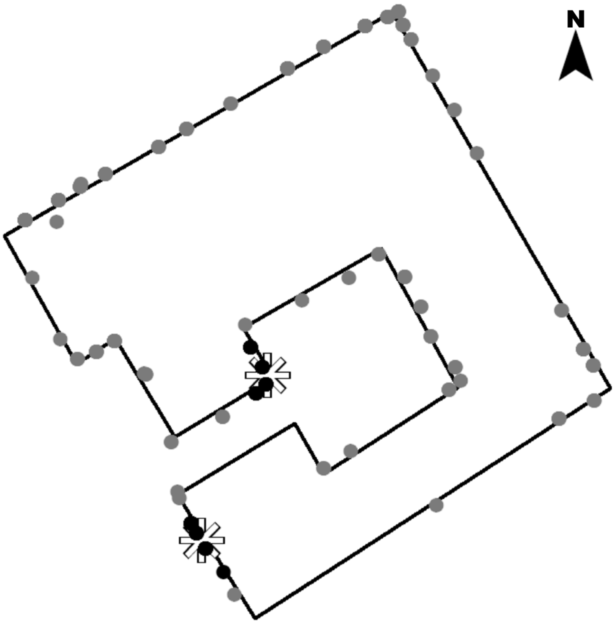

Fig. 1. Study area. Sketch of the farmhouse and its adjacent farm building. Black lines, sampled walls; asterisks, fixed point sources of artificial light (40 W incandescent lamps); grey dots, gecko locations in dark areas; black dots, gecko locations in areas with light. (Real length of the maximum rectangle: about 50 x 30 m).

Fig. 1. Zona de estudio. Esquema de la finca y su edificio agrícola adyacente. Líneas negras, paredes muestreadas; asteriscos, fuentes fijas de luz artificial (bombillas incandescentes de 40 W); puntos grises, localización de salamanquesas en zonas oscuras; puntos negros, localización de salamanquesas en zonas iluminadas. (Longitud real del rectángulo máximo: aproximadamente 50 x 30 m).

we did not mark the geckos. However, we estimated the total size of the study population by recording the particular location and size of individuals observed at each sample (every 30 minutes) per night; in this way we obtained a snapshot of the geckos every half an hour. Based on the size and location of each particular individual in each sample, we were able to individualize a minimum number of different geckos over the night. At each sample, we distinguished two types of individuals: (1) 'marked' (i.e. geckos observed in one or more prior samples on a particular night); and (2) 'unmarked' (geckos not observed before on a particular night). From this record of individual geckos, we derived a minimum population size using mark–recapture data analysis techniques. Specifically, we applied the Schumacher–Eschmeyer method (Schumacher and Eschmeyer, 1943), a refinement of the Schnabel method (Schnabel, 1938), recommended for use when departures from randomness are probable (Mares et al., 1981). These methods are extensions of the Petersen method to a series of samples and they are useful for closed populations (Krebs, 1999). According to the Schumacher and Eschmeyer method, there is a linear relationship between the proportion of marked individuals in each sample and the total number of marked animals, thus the total number of animals (*N*) could be estimated by:

$$N = \frac{\sum_{t=1}^{m} M_t^2 C_t}{\sum_{t=1}^{m} M_t R_t}$$

where, M_t is the number of individuals previously 'marked' (before time *t*); C_t is the total number of individuals caught at time *t;* R_t is the number of individuals already 'marked' when catching in time *t;* and *m* is the total number of samples. Following Schumacher and Eschmeyer (1943), for each night we plotted the number of individuals previously 'marked' (M_t) in the x–axis, and the proportion of 'marked' individuals in the *t*–th sample (R_t/C_t) in the y–axis. The plotted points should lie on a straight line of slope 1/*N* passing through the origin (fig. 2), thus allowing estimation of the population size from this regression slope (1/*N*). We measured population size estimates per night and averaged these results for the total sample of nights.

We can not rule out the possibility that the number of geckos of the same size at the same location on different nights was underestimated. However, it is unlikely that different individuals of the same size

Table 1. Estimates of the gecko population size (*N*) in the study area (Schumacher and Eschmeyer, 1943). Regression slope (1/*N*): 'marked' (M_t) in the x–axis, and the proportion of 'marked' individuals in the *t*–th sample (R_t/C_t) in the y–axis (see Material and methods and figure 2). Estimates per sample night, averaged population size and confidence intervals (CI) for the total sample of nights.

*Tabla 1. Estimaciones del tamaño de la población de salamanquesas (*N*) en la zona de estudio (Schumacher y Eschmeyer, 1943). Curva de regresión (*1/N*): ejemplares marcados (*M_t*) en el eje de abscisas y proporción de ejemplares marcados en la muestra *t* (*R_t/C_t*) en el eje de ordenadas (véase el apartado Material and methods y la figura 2). Estimaciones por muestra nocturna, promedio del tamaño de la población e intervalos de confianza (CI) para la muestra total de noches.*

Slope	*N*	Slope	*N*
0.07	14.99	0.04	26.88
0.33	3.00	0.10	10.50
0.07	14.43	0.08	12.99
0.06	17.30	0.05	18.38
0.08	12.00	0.11	9.35
0.26	3.86	0.10	9.59
0.06	16.64	0.06	17.61
0.21	4.75	0.03	32.15
0.17	5.91	0.07	14.25
0.08	11.90		

		CIs	
		–95 %	–95 %
Mean	13.50	10.18	16.82

occurred at the same location on the same night in view of territoriality and interspecific aggression (Salvador, 2002) and the gecko's sit–and–wait foraging strategy (Hódar et al., 2006). We analysed the effects of changes in nocturnal light levels on the gecko activity using generalized linear mixed models (GLMM). Regarding the fixed effects, we assessed whether the number of geckos observed per night was conditioned on moon cycle (measured as percent moon fullness), artificial lighting and wind speed using a Poisson (log link) model structure. Because the effect of the level of natural light (i.e. percent moon fullness) on gecko activity may be altered by artificial lighting, we also included the interaction term between the presence of artificial lighting and moon phase as a predictor. In order to avoid pseudoreplication among samples, we included a random intercept shared by the samples within the same date.

We further assessed whether the activity was affected by the moon light cycle using a GLMM binomial (logit link) model structure. We included the same predictors as in the model above along with age: juveniles (< 6 cm) and adults (> 6 cm). In order to avoid pseudoreplication among samples, we also included a random intercept shared by the samples that had the same value for 'individual' on the same date.

Additionally, we analyzed differences in the proportion of adults (> 6cm) and juveniles (< 6 cm) in light and dark areas by means of a χ^2–test. All analyses were performed using R 2.13.0 (R Core Development Core Team, 2011).

Results

We observed 372 geckos (34 % in areas with light and 66 % in dark areas, respectively) over 19 nights between 18th July and 27th September 2013.

According to estimates derived using the Schumacher and Eschmeyer method (1943), the total gecko population in the study ranged between 10 and 17 individuals (95 % confidence interval based on the total sample of nights; table 1).

Areas with light had a larger proportion of adult geckos whereas dark areas had a higher proportion of juveniles (χ^2 = 9.354, df = 1, *p*–value = 0.002; fig. 3). Table 2 shows backward stepwise procedure results and significant variables**.** Individual activity and the number of active geckos increased in moonlight. The larger the average size of the geckos, the fewer the individuals seen per night. Juveniles showed more frequent activity than adults. Activity decreased in relation to wind speed. Artificial lighting reduced the

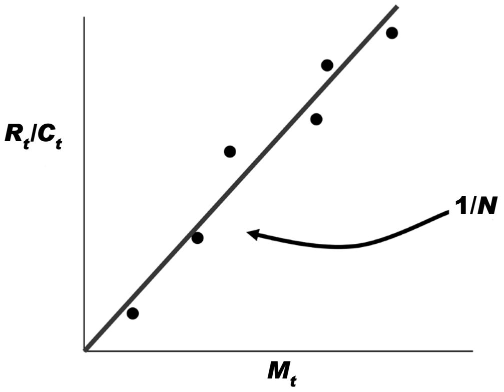

Fig. 2. Schumacher and Eschmeyer method (1943).

Fig. 2. Método de Schumacher y Eschmeyer (1943).

Table 2. GLMM model results of: A, the number of geckos observed per night (Poisson–log link); B, individual gecko foraging activity (binomial–logit link).

Tabla 2. Resultados del modelo mixto lineal generalizado de: A, número de salamanquesas observadas por noche (Poisson–logaritmo como función de enlace); B, actividad individual de alimentación de las salamanquesas (binomial–función de enlace logit).

A	Level of effect	Estimate	S.E.	z–value	Pr(>|z|)
(Intercept)		2.989	0.262	11.411	< 0.0001
% Moon		0.515	0.196	2.632	0.0085
Gecko size		–0.051	0.021	–2.425	0.0153
Artificial lighting	Light	–0.053	0.214	–0.250	0.8027
Wind speed		–0.121	0.051	–2.347	0.0190
% Moon:artificial lighting	Light	–0.800	0.317	–2.519	0.0118

B	Level of effect	Estimate	S.E.	z–value	Pr(>|z|)
(Intercept)		–1.419	0.482	–2.943	0.0033
% Moon		2.530	0.548	4.616	< 0.0001
Age		–0.817	0.284	–2.879	0.0040
Artificial lighting	Light	0.035	0.724	0.049	0.9610
Wind speed		–0.341	0.166	–2.056	0.0398
% Moon:artificial lighting	Light	–0.656	0.939	–0.698	0.4850

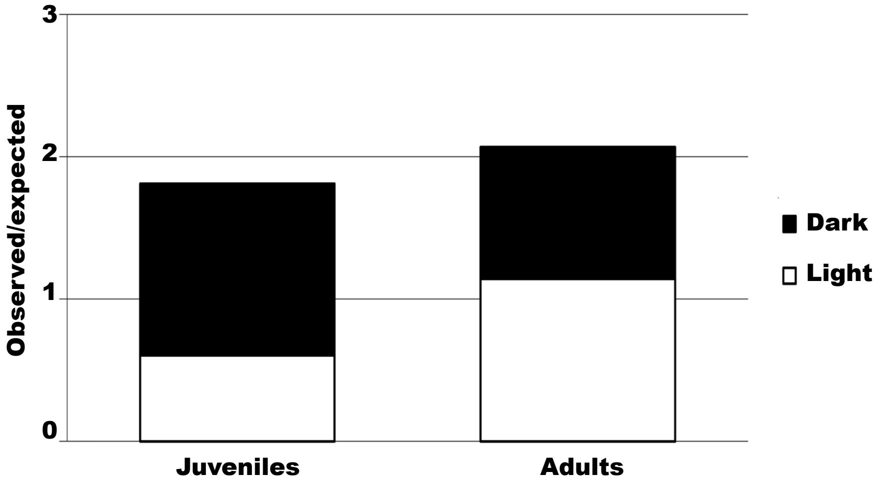

Fig. 3. Ratio between observed and expected frequencies of juvenile and adult wall geckos in areas with light and in dark areas (χ^2 = 9.354, df = 1, *P* < 0.01).

Fig. 3. Proporción entre las frecuencias observadas y esperadas de salamanquesas comunes juveniles y adultas en zonas iluminadas y zonas oscuras (χ^2 = 9,354, gl = 1, P *< 0,01).*

effect of moonlight on the number of geckos observed per night but not on individual gecko activity.

Discussion

Wall geckos in our study modified their nocturnal activity in relation to levels of light. Individual activity and the number of active geckos were higher on full moon nights. This contrasts with many nocturnal animals whose activity decreases on full–moon nights to reduce predation risks (Perry and Fisher, 2006). In anthropic environments, low levels of natural predators of reptiles allow wall gecko activity to be mainly conditioned by prey (Gil et al., 1994). Geckos take advantage of moonlightto increase their ability to detect their prey (Mills, 1986). Artificial night lighting can also enhance their visual detection. Species that are normally active during the night, including other gecko species, have frequently been documented around night lights (Perry et al*.,* 2008). Artificial lighting affects geckos directly by altering their behavior, but it also affects them indirectly by altering the behaviour of their prey. Entomologists have long known that invertebrates are attracted to artificial lighting at night, increasing the availability and predictability of food around such light sources for species like bats (Rydell, 1992), amphibians and reptiles (Garber, 1978; Rich and Longcore, 2006). Activity of many invertebrates increases around the new moon (Bowden and Church, 1973) due to less activity of visual predators (Perry and Fisher, 2006). According to our results, artificial lighting during naturally dark periods allows larger number geckos to forage under new moon nights when invertebrate attraction to artificial light is greater.

Activity levels differed between juveniles and adult wall geckos, with higher rates in juveniles than in those in adult individuals. However, adult geckos were more often encountered around artificial lighting, whereas juveniles were more frequently observed in dark areas, which may be linked to territoriality (Salvador, 2002; Carretero, 2008). Differences in spatial distribution of age classes around artificial lighting seem to be related to avoidance of aggression by small individuals (Hitchcock and McBrayer, 2006) and the monopolization of the best sites for foraging by large individuals.

The ability to use human habitats with artificial night lighting, particularly on new moon nights, can benefit the foraging activity of nocturnal lizard species such as the wall gecko.

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