

Occurrence and ecological aspects of the two-fingered skink *Chalcides mauritanicus* at the Chafarinas Islands in North Africa

JOSÉ MARTÍN^{1,*}, ROBERTO GARCÍA-ROA¹, JESÚS ORTEGA¹, PILAR LÓPEZ¹, ANA PÉREZ-CEMBRANOS², ALICIA LEÓN², LUIS V. GARCÍA³ & VALENTÍN PÉREZ-MELLADO²

¹*Departamento de Ecología Evolutiva, Museo Nacional de Ciencias Naturales, CSIC, José Gutiérrez Abascal 2, 28006 Madrid, Spain*

²*Departamento de Biología Animal, Edificio de Farmacia, Campus Miguel de Unamuno s/n, Universidad de Salamanca, 37071 Salamanca, Spain*

³*Departamento de Biogeoquímica, Ecología Vegetal y Microbiana, Instituto de Recursos Naturales y Agrobiología de Sevilla, CSIC, 41012 Sevilla, Spain*

*Corresponding author. E-mail, jose.martin@mncn.csic.es

ABSTRACT: The two-fingered skink, *Chalcides mauritanicus*, is a fossorial species from North Africa, where it has only been found at a few localities in sandy sea shores. Virtually nothing is known about its ecology. For the first time, we report here the occurrence of an apparently large and well-preserved population of *C. mauritanicus* at the Chafarinas Islands (NW Africa). In addition, we study some aspects of the morphology and ecology (microhabitat, soil and diet selection) of this skink. Adult females were larger than males but had heads of similar size. In this population, we found an equilibrated sex-ratio. Adults showed a very high frequency of regenerated tails, suggesting a high predation pressure. Skinks were restricted to a small area of Congreso Island where, far from sea-shore, they selected sandy microhabitats far from the shore. These microhabitats were characterized by higher cover at the substrate level of bare soil and medium rocks, lower cover of leaf litter and grass, and more sparse subarborescent vegetation than available microhabitats. Soils occupied by skinks had a higher proportion of sand, and lower proportion of gravel, silt and clay, resulting in a much lower soil compaction, than most soils of the island. The bulk of the diet of *C. mauritanicus* was made by small beetle larvae, which were consumed in higher proportion than expected by their availability.

Key words: Skinks, *Chalcides*, Morphology, Diet, Habitat selection, North Africa

Among the most characteristic reptile species of North Africa, there are around 24 skink species belonging to the genus *Chalcides* (Squamata, Scincidae), most of which occur in Morocco and surrounding areas, although the genus extends across northern Africa, Canary Islands, western Asia and southern Europe (Bons & Geniez 1996; Carranza *et al.* 2008). Some of these skink species are common and widespread, but many others have restricted distributions and even have been recorded on a few occasions, at a few localities. Therefore, the available information about these skinks is rather scarce (Bons & Geniez 1996). This lack of knowledge may be due not only to presumed low population densities but also to the semifossorial or fossorial habits of some of these species that, consequently, are difficult to observe.

The two-fingered skink *Chalcides mauritanicus* (Duméril & Bibron, 1839) is a poorly known fossorial species from North Africa. It is a small sized skink, with a very elongated body and strongly reduced limbs. It has only two fingers in the forelimbs and three toes in the hind limbs (Caputo *et al.* 1995; Mateo *et al.* 1995). Dorsal coloration is yellowish or grey-brownish, with dorsal diffuse stripes formed by small black dots. Body sides have a lateral dark band with large dots, and the vent is grey with small black dots sparsely distributed. Tail is long and typically red in juveniles. Based on mitochondrial DNA analyses, *C. mauritanicus* is placed as a basal species in the clade of grass-swimming *Chalcides*, from where it split apart 9.9 million years ago (Carranza *et al.* 2008). It is a fossorial, coastal, lowland skink, found under rocks or dead wood in dunes and sandy sea shores (Mellado *et al.* 1987; Bons & Geniez 1996). The known distribution of *C. mauritanicus* is limited to few localities in a very small coastal area of North Africa. It is found at low abundance along the sandy coast of north-west Algeria, between Oran (35°41'N, 0°37'W) and Ghazouat (35°05'N, 1°50'W). In Morocco it has only been found in Ras el Ma (35°08'N, 2°25'W), near the mouth of the Moulouya river, in Saidia (35°07'N, 2°21'W), and between Beni Enzar (35°16'N, 2°56'W) and Nador (35°10'N, 2°55'W). This species was also recorded once in Melilla (35°17'N, 2°57'W) (Doumergue 1901; Mellado *et al.* 1987; Mateo *et al.* 1995, 2009; Bons & Geniez 1996, Fahd *et al.* 2002). This species is considered “*Endangered*” by the IUCN, because its extent of occurrence is less than 5,000 km², its distribution is severely fragmented, and there is continuing decline in the extent and quality of its coastal habitat (Mateo *et al.* 2009).

This skink has been found only occasionally and always in low numbers. This fact could explain the little amount of attention it has received and why nothing is virtually known about its

ecology and life history traits. For the first time, we report here the occurrence of a population of *C. mauritanicus* at Chafarinas Islands (NW Africa). This population had been overlooked for many years, in spite of several herpetological surveys (Mateo 1991; García-Roa *et al.* 2014). In this work, we also studied some aspects of morphology and ecology of this skink. We specifically described: 1) its distribution and general aspects of the island area where we found skinks, 2) biometrical data of males, females and juveniles (which could not be sexed), and the population structure, 3) vegetation, rock cover and physical characteristics of soils occupied by skinks, comparing them with habitat availability, and 4) the diet studied from faecal pellets obtained from living individuals. The diet is compared with invertebrate availability in those microhabitats occupied by skinks.

MATERIALS AND METHODS

Study area and sampling procedures

We conducted field work during two weeks in March 2014 (spring) at the Chafarinas Islands (Spain), a small archipelago located in the southwestern area of the Mediterranean Sea (35°11'N, 2°25'W). These islands are located 4.6 km off northern Moroccan coast (Ras el Ma, Morocco) and 50 km to the east of the Spanish city of Melilla. It consists of three small islands: Congreso, Isabel II (the only inhabited by men), and Rey Francisco. Congreso (25.6 ha) is the only known island with a present day population of *C. mauritanicus* (see below). Vegetation is dominated by plants adapted to salinity and drought (i.e., the average annual precipitation is 300 mm), such as species of *Salsola*, *Lycium* and *Suaeda* genera. Soils are scarcely developed. They are mainly Entisols, having an A horizon directly on the rock or unconsolidated parent material; and Inceptisols, more developed than entisols, and having an incipient subsurface (“cambic”) horizon (Clemente *et al.* 1999; García *et al.* 2002; García 2005).

We searched for buried skinks, during the day between 07:00 and 12:00 (GMT), either lifting stones or gently excavating with hands in sandy areas. Skinks were captured by hand. After measurements, all skinks were released at their exact point of capture in less than five min. To minimize the probability that the same individuals were captured twice, we sampled once each area.

Habitat and soil characteristics

To characterize the microhabitat occupied by skinks, we made four transects of 1 m in length, to the four cardinal orientations starting from the point where each individual was first located. We used a scored stick standing vertically at 16 sampling points (four points in 25 cm intervals of each transect), and we recorded the contacts with the stick at ground level of 'bare soil', 'leaf litter', 'grass', classifying rocks according to their size as 'small rocks' (5-20 cm), 'medium rocks' (20-60 cm) or 'large rocks' (> 60 cm). We also recorded plant contacts above the surface with the stick and the type of vegetation: 'herbaceous', or woody bushes ('*Salsola*' or '*Lycium*'). We calculated the percentage of cover (i.e. % of contacts) of each habitat variable in the area surrounding each skink (for a similar sampling methodology see Martín & López 2002).

We used a hand penetrometer (Eijkelkamp Co., Em Giesbeek, The Netherlands) (Herrick & Jones 2002) to measure 'soil compaction' at ten random points close to the central point and calculated an average value for each site. Then, we took a bulked soil sample (around 300 g) between the surface and 10 cm depth. Later, in the laboratory, we determined by using sieving and the Bouyoucos hydrometer method the percentage of the different soil particles: 'gravel' (2-60 mm), 'sand' (2-0.05 mm), 'silt' (0.05-0.002 mm) and 'clay' (< 0.002 mm) (for details see Dane & Topp 2002).

Microhabitat and soil availability were estimated along a series of random transects covering the whole Congreso Island. A sample was taken every 25 m, choosing the nearest stone to a given transect point as the centre of the sampling area. Then, we followed the same procedure as when encountering skinks to measure habitat and soil variables.

Original variables expressed as percentages were subjected to angular transformation; the remainder variables, were logarithmically transformed to ensure normality. We used General Lineal Models (GLMs) to analyze whether the microhabitat and soil characteristics differed between sites available and used by skinks. We applied a FDR (False Discovery Rate) tablewise correction to control for Type I error inflation (Hochberg & Benjamini 2000; García 2003, 2004).

Biometrical measurements

Using an electronic portable balance, we measured body mass (to the nearest 0.01 g) of each individual after collecting the faecal samples (see below) to avoid confounding effects. We employed a metallic ruler, to the nearest 1 mm, to measure the 'snout-to-vent length' (SVL), from the tip of the snout to the cloacal flap, 'tail length', and the 'trunk length', between the forelimbs and the hind limbs. We used a digital camera (Canon EOS 40D) with a macro lens (Canon EF 100mm f/2.8L IS USM) and a ring flash speedlite (Canon Macro Ring Lite MR-14EX) to take digital pictures of the head in dorsal, lateral and ventral views, using a graduated scale as a reference. Later, we measured head dimensions, to the nearest 0.1 mm, from an enlarged picture in a computer screen. We measured 'head length', as the distance between the tip of the snout and the posterior side of the parietal scales, 'head width', as the greatest distance between the external sides of the parietal scales, and 'head height', as the greatest distance from the highest portion of the head to the bottom of the lower jaw. We determined the sexes of adult skinks by examining the cloaca and carefully everting the hemipenis of males. Juveniles could not be reliably sexed. We used General Linear Models (GLMs) to analyze whether morphological log-transformed variables differed between sexes and age categories. We used Statistica 8.0 (StatSoft Inc., Tulsa, OK) and StatXact 3.1 (Cytel Software Co., Cambridge, MA) to analyze data.

Diet

Diet samples were obtained by collecting faeces of live skinks. Faeces were individually stored in Eppendorf vials. Prey remains were identified up to order or family level under a binocular dissecting microscope. We carefully searched for body parts of soft-bodied prey that were less likely to be digested (e.g., head capsules in insect larvae and chelicerae in spiders). Prey numbers for each faecal pellet were conservatively estimated by counting only easily identifiable remains. In lizards, diet reconstruction based on such meticulous faecal pellet analysis is a standard method to quantify diet without compromising animal well-being. Besides, this method is highly comparable to diet reconstruction based on gastric contents removed from dissected stomachs (e.g., Angelici *et al.* 1997; Hawlena & Pérez-Mellado 2009; Pérez-Mellado *et al.* 2011).

Diet composition was described as ‘prey abundance’ (i.e., the percentage of a given prey type relative to the total prey number) and ‘prey presence’ (i.e., the percentage of individual skinks consuming a given prey type). To estimate the size of Coleoptera larvae, we measured with a micrometer eyepiece the length of intact or nearly intact head capsule of larvae, which were used to estimate total length and biomass using predictive regression equations (for details see Calver & Wooller 1982; Hódar 1997).

To estimate patterns of diet selection, we made random routes to estimate the availability of potential invertebrate prey in the microhabitats used by skinks and only during the time of maximum skink activity (pers. obs.). We randomly lifted rocks that might hold skinks (> 10 cm length), avoiding small stones. During two min for each rock, we counted and identified the invertebrates (> 2 mm long) that were observed on the undersurface of the turned rock and on the substrate exposed on turning. We included invertebrates that escaped when the rock was lifted. We also gently excavated with a small stick inside a 25 cm radius circle surrounding the rock to look for buried invertebrates (for similar procedures, see Martín & Salvador 1993; Goldsbrough *et al.* 2003; Civantos *et al.* 2013; Martín *et al.* 2013b).

To estimate prey selection, we used the selectivity index (D) of Ivlev (1961) modified by Jacobs (1974) according to the formula: $D = (r-p)/(r+p-2rp)$, where r is the proportion of a given prey type in the diet and p is its available proportion in the environment. However, given that with low sample numbers the error in D is likely to be high (Lechowicz 1982), we also calculated the relativized electivity index (E^*) of Vanderploeg & Scavia (1979). This index was calculated as: $E^*_i = [W_i - (1/n)] / [W_i + (1/n)]$, which uses the number (n) of available prey types and the selectivity coefficient $W_i = (r_i/p_i) / \sum_i(r_i/p_i)$, based on the proportions of prey i in the diet (r_i) and in the environment (p_i). These two selectivity indices range from -1 (total avoidance) through 0 (no or random selection) up to $+1$ (maximum positive selection). Electivities were tested for significance by using χ^2 tests, comparing the observed proportions of each prey type in relation to the numbers of all other prey types, with expected proportions based on similar data from available prey and restricted to actually consumed groups (Sokal & Rohlf 1995).

RESULTS

Distribution and general observations

Skinks were first encountered and studied in a herpetological survey of Congreso Island made in March 2014. This population had been overlooked in previous herpetological surveys of Chafarinas Islands. All observations of skinks ($n = 35$) were concentrated in a small area of 2250 m² in the south-east tip of Congreso Island, coinciding with the restricted area of very sandy soils (see below). However, the area was located outside sandy beaches or dunes, because observations were made at altitudes between 26 and 53 m (mean \pm SE = 34.5 \pm 1.0 m), in an elevated stepped plateau area, separated from the seashore by tall rock cliffs (at least > 20 m height). In this area *C. mauritanicus* is syntopic with *C. ocellatus*, which is widespread in the island. Later specific surveys in other areas of Congreso Island and the two remaining islands (Isabel II and Rey) of the Chafarinas archipelago did not yield any additional observation of *C. mauritanicus*.

In spring, skinks were found early in the morning; either buried in the sand under rocks (45.7% of total of observations), where they could be thermoregulating, or by digging in sand accumulations close to the rocks and bushes (54.3%), where skinks presumably might be foraging later in the day. We never observed any skink above the soil surface. Moreover, when skinks were extracted from the sand and then released, they quickly buried themselves in the sand.

The numbers of captured adult skinks of each sex (males, $n = 14$, 51.8%; females, $n = 13$, 48.2 %) implied an observed adult sex ratio of 1:0.93 (males:females), which did not significantly differ from a theoretical 1:1 sex ratio ($\chi^2 = 0.003$, $df = 1$, $P = 0.96$). On three occasions, we found a male and a female together under the same rock, and on one occasion the pair was accompanied by a juvenile. We also found 8 juveniles with their typical red tails. The proportion of juveniles in the population was 22.2% and the ratio juveniles:adults was 1:3.37.

Microhabitat selection

Microhabitats occupied by skinks were characterized by a significantly higher cover at the substrate level of bare soil and medium rocks, and significantly lower cover of leaf litter and

grass than average microhabitat availability in Congreso Island (Table 2). Regarding skinks found under rocks the average dimensions of rocks were 24 x 18 cm and 11 cm height ($n = 16$). That is, with similar dimensions to available rocks in the surroundings (25 x 23 cm and 15 cm height; GLMs, $F_{1,30} < 0.75$, $P > 0.25$ for all rock dimensions). Subarboreal vegetation was also sparser at the sites occupied by skinks, with a significantly lower cover of *Salsola* bushes than its average availability (Table 1).

Soils used by skinks were clearly different from those found in the rest of the Congreso Island. These soils had a significantly higher proportion of sand, and a lower proportion of gravel, silt and clay (i.e., they were typical sandy soils) than available soils (Table 1). This particle composition of the soil led to significantly much lower soil compaction at sites occupied by skinks.

Morphological measurements

Adults were significantly greater than juveniles for all biometrical variables (GLMs; $F_{1,33} > 12.43$, $P < 0.0013$ in all cases) (Table 2). In comparison with adult males, adult females were significantly larger ($F_{1,25} = 6.89$, $P = 0.015$) and heavier ($F_{1,25} = 4.82$, $P = 0.038$). Females also had a significantly longer trunk length ($F_{1,25} = 7.64$, $P = 0.01$), but this result was just the consequence of a larger body size (GLMs with SVL as a covariant; $F_{1,24} = 1.06$, $P = 0.31$). However, adult males and females did not significantly differ in their absolute head size (head length: $F_{1,25} = 0.01$, $P = 0.97$; head width: $F_{1,25} = 0.82$, $P = 0.37$; head depth: $F_{1,25} = 1.48$, $P = 0.23$) or in relative head size (GLMs with SVL as a covariant; head length: $F_{1,24} = 0.38$, $P = 0.54$; head width: $F_{1,24} = 1.21$, $P = 0.28$; head depth: $F_{1,24} = 2.58$, $P = 0.12$) (Table 2).

Tail loss was very common in the population of adult skinks; insofar as we found regenerated tails in 85.2 % of adult skinks but only in 12.5 % of juveniles ($\chi^2 = 15.13$, $df = 1$, $P = 0.0001$). There were not significant differences in the frequency of regenerated tails between sexes in adults (males = 92.9 %; females = 76.9 %; $\chi^2 = 1.36$, $df = 1$, $P = 0.24$).

Diet selection

We recorded the availability of invertebrates at 28 points, all of which contained some invertebrates (Table 3). Formicidae (ants) and Coleoptera (beetles) were the most abundant invertebrates in the skinks' habitat during spring, with these two groups accounting for 84.1 % of all invertebrates. Thysanura (silverfish), Araneae (spiders) and Isopoda (isopods) were also found but in lower numbers (Table 3). The invertebrates with a greater presence at sampling sites were Coleoptera, Thysanura, Araneae and Formicidae (Table 3).

The number of individual prey items that could be identified per faecal pellet of the skinks ranged between one and four (mean \pm SE = 1.6 ± 0.2 ; $n = 17$ faecal pellets). The diet of *C. mauritanicus* skinks consisted mainly of insect larvae, of which at least half could be identified as Coleoptera larvae. The rest of larvae could not be identified up to family level (Table 3). Insect larvae were found in all faecal pellets. Estimated size of Coleoptera larvae consumed by skinks ranged between 13 and 16 mm (mean \pm SE = 14.3 ± 0.7 mm) and their biomass (dry weight) ranged between 6 and 11 mg (mean \pm SE = 8.2 ± 1.2 mg). Snails and butterfly nymphs were also found in the diet, although in much lower proportions (Table 3).

In comparison with the abundance of available prey types, and according to the Jacobs' electivity index (D), skinks significantly selected all consumed prey types, while entirely avoided other available potential prey types (Table 3). A similar pattern of selection was suggested by the relativized electivity index (E^*) of Vanderploeg & Scavia. Employing this index, only insect larvae seemed to be consumed in significantly higher proportion than expected, while the consumption of other groups did not significantly differ from their availability (Table 3).

DISCUSSION

In this study, we report the occurrence and some aspects of the ecology of an apparently large and well preserved, but spatially restricted, population of the two-fingered skink, *C. mauritanicus*, at the Chafarinas Islands. Although, these islands are just less than 5 km in front of previously known localities (Bons & Geniez 1996), the occurrence of this skink in the islands had not been detected, neither expected, in spite of several herpetological surveys of the islands (García-Roa *et al.* 2014). The habitat occupied by *C. mauritanicus* at the Chafarinas Islands is

rather different than the beach dunes employed by this skink in coastal localities (Mellado *et al.* 1987; Bons & Geniez 1996). In Congreso Island this species is presented in sandy areas relatively independent from sea-shores. This may be a relict habitat in Congreso Island, the remainings of the sandy tombolo that formerly joined this island with the continent (Barrera & Pineda 2007). Skinks might have been gradually relegated to this area when the sea level rose and the action of sea erosion formed high cliffs, isolating this area from the sea shore.

Characteristics of both habitats are, however, similar, and the fossorial “sand-swimming” habits of this skink may clearly explain the observed pattern of habitat selection. As in other fossorial reptiles (Martín *et al.* 1991, 2013a; Greenville & Dickman 2009), the ability for burrowing and its energetic costs should greatly restrict habitat use to soils easy to burrow. The very low compaction of these scarce sandy soils, in comparison with the average higher values found in other more developed soils of the island (Clemente *et al.* 1999; García 2005), would reduce costs of, for example, foraging and mate searching. This possibility would explain the restricted distribution of skinks. Sites used by skinks also have lower cover of grass and bushes, which might be explained by the sandy little developed soils in those sites. Finally, selected sites also have a higher cover of medium rocks, which could be used as nocturnal refuges, for foraging or for thermoregulation, as suggested by the observed daily pattern of rock usage by this species and by thermoregulatory behavior, as in other fossorial reptiles (López *et al.* 2002).

Our data indicated a larger average adult body size in this insular population (average SVL larger than 72 mm) than values previously described by Caputo *et al.* (1995) for mainland populations (i.e., average SVL = 65.9 mm; range = 54.7–71.8, based on 10 specimens). This fact could be simply explained by a sampling bias or because skinks might attain larger body sizes, perhaps because of older ages, in this insular population. Although our sample size is limited, biometrical data also suggest the existence of a sexual dimorphism in body size, with females being larger and heavier, which might be linked to reproductive constraints. The reproductive mode of this species is, however, yet not known, although viviparity is suspected (Mateo *et al.* 2009). The relatively low proportion of juveniles in the population would suggest small litter sizes, which could be a constraint of fossoriality (Shine 1985). Alternatively, juveniles might be more secretive and difficult to be found because of higher predation pressure or different habits.

In spite of fossorial habits, and the fact that we never observed skinks above the soil surface, the high rate of regenerated tails suggest that predation on this population is frequent.

Similar tail loss rates for males and females suggest that predation rather than intrasexual aggression between males is the main cause. A potential predator of this skink in the Chafarinas Islands can be the horseshoe whip snake (*Hemorrhois hippocrepis*), a snake often observed in this part of the island (García-Roa *et al.* 2014). Juveniles of this snake could be specialized in the consumption of reptiles (Pleguezuelos & Moreno 1990). Also, scorpions might prey on these small skinks (Castilla 1995). Finally, the yellow-legged gull (*Larus michahellis*) that nests in higher numbers in this area of the island, may be responsible of the high tail loss of skinks. Even if in this case, tail loss perhaps would not be the consequence of true attacks by gulls, but the result of ground exploratory behavior of gulls in search of any edible matters (Pérez-Mellado *et al.* 2014). In this way, the movements of the loose sand when skinks move, being still buried but close to the surface, might attract the attention of gulls. The occurrence of a red bright conspicuous tail in juveniles, suggests that this may be an important antipredatory mechanism, by diverting attacks away from vital areas, increasing strikes on the tail, and thus escape probability, as it occurs with many other lizards (Watson *et al.* 2012; Ortega *et al.* 2014; Fresnillo *et al.* 2015).

The diet of *C. mauritanicus* consisted almost exclusively of insect larvae, which were mainly Coleoptera larvae. Although these larvae were found at low relative abundance in the habitat, the corresponding adult Coleoptera, particularly Tenebrionids, were one of the most abundant and frequent invertebrates found in the sandy areas occupied by skinks (except for the ants). Thus, these large numbers of beetles were expected to produce enough larvae to sustain skink requirements. Larvae provide a great energetic contribution, which would compensate the required cost for their localization in the subterranean environment. Similarly, some fossorial amphisbaenians (López *et al.* 1991; Martín *et al.* 2013b) and skinks (McCoy *et al.* 2010) select insect larvae in spite of their relatively low abundance. This apparently restricted diet probably also reflects the restricted amount of available prey in the sandy foraging sites. The diet could be more generalist in other localities with a higher diversity of prey types (McCoy *et al.* 2010). In contrast, the small size and the narrow mouth gape of *C. mauritanicus* could probably explain that this skink does not feed on adult Coleoptera as other sympatric larger skink species do (Attuma *et al.* 2004; Kalboussi & Nourira 2004; Civantos *et al.* 2013). This suggests that morphological adaptations of the head to fossoriality may restrict the consumption of suitable prey types and reduce effectiveness in feeding (Andrews *et al.* 1987). Also, the small size of *C.*

mauritanicus might suggest that they might preferentially feed on other small prey types, such as ants or termites, as other fossorial lizards do (Huey *et al.* 1974). However, termites are very rare in these islands and ants seem to be avoided, as occur in other skinks (Kalboussi & Nourira 2004; Civantos *et al.* 2013), probably because ants provide low energy and contain much undigestible chitin, and their colonial defensive behavior might effectively preclude underground attacks by small fossorial reptiles (López *et al.* 1994, 2001).

The two-fingered skink, *C. mauritanicus*, has an endangered status and its conservation suffers from many problems associated to the human-induced progressive loss of quality of its habitat in North African coast (Mateo *et al.* 2009). The confirmed presence in a well protected and managed nature reserve area of an apparently large population of this skink, in comparison with the low numbers found in other localities, are actually good news. However, the restricted microgeographical distribution (less than 1 % of the Congreso Island surface) and the strict microhabitat selection of *C. mauritanicus*, indicate that the suitable habitat is very scarce and that this population of the Chafarinas Islands may be threatened even by random accidental events. In this way, strong rains with associated overland water flow may erode and destroy the sand accumulations where skinks are found. Also, rising sea levels from global climate change are definitely a threat for this species in their coastal localities, although it could be a lesser concern in the island population where skinks are found at higher altitude. This prompts for future studies aimed to deepen the ecological requirements of this species. Finally, it could be extremely interesting to perform regular surveys controlling for potential negative effects on this population. This will permit to establish optimal management techniques that ensure the conservation of *C. mauritanicus*.

ACKNOWLEDGEMENTS

We thank three anonymous reviewers for helpful comments, the personal and facilities of the field station of the “Refugio Nacional de Caza de las Islas Chafarinas” that provided logistical support. We thank Ángel Sanz, Francisco López, Alfredo Ruiz and Javier Zapata for friendship and help in the Islands. R. García-Roa benefited from a FPI grant, J. Ortega from a CSIC JAE-pre grant, A. Pérez-Cembranos from a FPU grant of the Spanish Ministry of Science and Education and A. León from a predoctoral grant of the University of Salamanca. Legal authorization and

support for the study was provided by the Organismo Autónomo de Parques Nacionales (Spain), with additional financial support from the Ministerio de Ciencia e Innovación research projects CGL2009-12926-C02-02, CGL2011-24150/BOS and CGL2012-39850-CO2-02, from the Regional Government of Andalusia project BIOGEOBIRD (P09-RNM-4987) and from FEDER funds.

LITERATURE CITED

- ANDREWS, R.M., F.H. POUGH, A. COLLAZO & A. DE QUEIROZ. 1987. The ecological cost of morphological specialization: Feeding by a fossorial lizard. *Oecologia* 73: 139–145.
- ANGELICI, F.M., L. LUISELLI & L. RUGIERO. 1997. Food habits of the green lizard, *Lacerta bilineata*, in central Italy and a reliability test of faecal pellet analysis. *Ital. J. Zool.* 64: 267–272.
- ATTUMA, O., C. COVELL & P. EASON. 2004. The comparative diet of three Saharan sand dune skinks. *Afr. J. Herp.* 53: 91–94.
- BARRERA, J.L. & A. PINEDA. 2007. Islas Chafarinas. La geología de un archipiélago deseado por todos. *Tierra Tecnol.* 30: 13–30.
- BONS, J. & P. GENIEZ. 1996. Amphibians and Reptiles of Morocco. Asociación Herpetológica Española, Barcelona, Spain.
- CALVER, M.C. & R.D. WOOLLER. 1982. A technique for assessing the taxa, length, dry weight and energy content of the arthropod prey of birds. *Aust. Wildl. Res.* 9: 293–301.
- CAPUTO, V., B. LANZA, B. & R. PALMIERI. 1995. Body elongation and limb reduction in the genus *Chalcides* Laurenti 1768 (Squamata Scincidae): A comparative study. *Tropic. Zool.* 8: 95–152.
- CARRANZA, S., E. N. ARNOLD, P. GENIEZ, J. ROCA & J. A. MATEO. 2008. Radiation, multiple dispersal and parallelism in the skinks *Chalcides* and *Sphenops* (Squamata: Scincidae), with comments on *Scincus* and the age of the Sahara Desert. *Mol. Phyl. Evol.* 46: 1071–1094.
- CASTILLA, A.M. 1995. Interactions between lizards (*Podareis hispanica atrata*) and scorpions (*Buthus occitanus*) in the Columbretes Islands. *Boll. Soc. Hist. Nat. Balears* 38: 47–50.

- CIVANTOS, E., J. ORTEGA, P. LÓPEZ, A. PÉREZ-CEMBRANOS, V. PÉREZ-MELLADO & J. MARTÍN. 2013. Diet selection by the threatened Chafarinas' skink *Chalcides parallelus* in North Africa. *Afr. J. Herp.* 69: 78–89.
- CLEMENTE, L., L.V. GARCÍA & A. RODRÍGUEZ. 1999. Los suelos de la Isla del Congreso (Chafarinas). Pp. 201–206. In L. PALLÍ-BUXÓ & C. ROQUE-PAU (Eds.) *Avances en el Estudio del Cuaternario Español. Actas de la X Reunión Nacional de Cuaternario*. Gerona, Spain.
- DANE, J.H. & G.C. TOPP (Eds.). 2002. *Methods of Soil Analysis. Part 4. Physical Methods*. Soil Science Society of America and American Society of Agronomy. Madison, Wisconsin, USA.
- DOUMERGUE, F. 1901. Essai sur la faune erpétologique de l'Oranie. *Bull. Soc. Geogr. Archeol. Oran* 19-21: 1–404.
- DUMÉRIL, A.M.C. & G. BIBRON. 1839. *Erpétologie Générale ou Histoire Naturelle Complète des Reptiles. Tome cinquième*. Librairie Encyclopédique de Roret, Paris.
- FAHD, S., F.J. MARTÍNEZ-MEDINA, J.A. MATEO & J.M. PLEGUEZUELOS. 2002. Anfibios y Reptiles en los territorios transfretanos (Ceuta, Melilla e islotes en el Norte de Africa). Pp. 383–415. In J.M. PLEGUEZUELOS, R. MÁRQUEZ & M. LIZANA (Eds.) *Atlas y Libro Rojo de los Anfibios y Reptiles de España*. Dirección General de la Conservación de la Naturaleza-Asociación Herpetológica Española, Madrid.
- FRESNILLO, B., BELLIURE, J. & CUERVO, J.J. 2015. Red tails are effective decoys for avian predators. *Evol. Ecol.* 29: 123–135.
- GARCÍA, L.V. 2003. Controlling the false discovery rate in ecological research. *Trends Ecol. Evol.* 8: 553–554.
- GARCÍA, L.V. 2004. Escaping the Bonferroni iron claw in ecological studies. *Oikos* 105: 657–663.
- GARCÍA, L.V. 2005. Suelos de las Islas Chafarinas y sus relaciones ecológicas. *Ecosistemas* 14: 135–139.
- GARCÍA, L.V., T. MARAÑÓN, F. OJEDA, L. CLEMENTE & R. REDONDO. 2002. Seagull influence on soil properties, chenopod shrub distribution, and leaf nutrient status in semi-arid Mediterranean islands. *Oikos* 98: 75–86.
- GARCÍA-ROA, R., J. ORTEGA, P. LÓPEZ, E. CIVANTOS & J. MARTÍN. 2014. Revisión de la distribución y abundancia de la herpetofauna en las Islas Chafarinas: Datos históricos vs. tendencias poblacionales. *Bol. Asoc. Herp. Esp.* 25: 55–62.

- GOLDSBROUGH, C.L., D.F. HOCHULI & R. SHINE. 2003. Invertebrate biodiversity under hot rocks: Habitat use by the fauna of sandstone outcrops in the Sydney region. *Biol. Cons.* 109: 85–93.
- GREENVILLE, A.C. & C.R. DICKMAN. 2009. Factors affecting habitat selection in a specialist fossorial skink. *Biol. J. Linn. Soc.* 97: 531–544.
- HAWLENA, D. & V. PÉREZ-MELLADO. 2009. Change your diet or die: Predator-induced shifts in insectivorous lizard feeding ecology. *Oecologia* 161: 411–419.
- HERRICK, J.E. & T.L. JONES. 2002. A dynamic cone penetrometer for measuring soil penetration resistance. *Soil Sci. Soc. Am. J.* 66: 1320–1324.
- HOCHBERG, Y. & Y. BENJAMINI. 2000. On the adaptive control of the false discovery rate in multiple testing with independent statistics. *J. Educ. Behav. Stat.* 25: 60–83.
- HÓDAR, J.A. 1997. The use of regression equations for estimation of prey length and biomass in diet studies of insectivore vertebrates. *Misc. Zool.* 20: 1–10.
- HUEY, R.B., E.R. PIANKA, M.E. EGAN & L.W. COONS. 1974. Ecological shifts in sympatry: Kalahari fossorial lizards (*Typhlosaurus*). *Ecology* 55: 304–316.
- IVLEV, V.S. 1961. *Experimental Ecology of the Feeding of Fishes*. Yale University Press, New Haven, Connecticut.
- JACOBS, J. 1974. Quantitative measurements of food selection; a modification of the forage ratio and Ivlev's selectivity index. *Oecologia* 14: 413–417.
- KALBOUSSI, M. & S. NOUIRA. 2004. Comparative diet of northern and southern Tunisian populations of *Chalcides ocellatus* (Forsk., 1775). *Rev. Esp. Herp.* 18: 29–39.
- LECHOWICZ, M.J. 1982. The sampling characteristics of electivity indices. *Oecologia* 52: 22–30.
- LÓPEZ, P. & J. MARTÍN. 1994. Responses by the amphisbaenian *Blanus cinereus* to chemicals from prey or potentially harmful ant species. *J. Chem. Ecol.* 20: 1113–1119.
- LÓPEZ, P. & J. MARTÍN. 2001. Chemosensory predator recognition induces specific defensive behaviours in a fossorial amphisbaenian. *Anim. Behav.* 62: 259–264.
- LÓPEZ, P., J. MARTÍN & A. SALVADOR. 1991. Diet selection by the amphisbaenian *Blanus cinereus*. *Herpetologica* 47: 210–218.
- LÓPEZ, P., E. CIVANTOS & J. MARTÍN. 2002. Body temperature regulation in the amphisbaenian *Trogonophis wiegmanni*. *Can. J. Zool.* 80: 42–47.
- MARTÍN, J. & P. LÓPEZ. 2002. The effect of Mediterranean dehesa management on lizard distribution and conservation. *Biol. Cons.* 108: 213–219.

- MARTÍN, J. & A. SALVADOR. 1993. Tail loss and foraging tactics of Iberian rock-lizards, *Lacerta monticola*. *Oikos* 66: 318–324.
- MARTÍN, J., P. LÓPEZ & A. SALVADOR. 1991. Microhabitat selection of the amphisbaenian *Blanus cinereus*. *Copeia* 1991: 1142–1146.
- MARTÍN, J., P. LÓPEZ & L.V. GARCÍA. 2013a. Soil characteristics determine microhabitat selection of the fossorial amphisbaenian *Trogonophis wiegmanni*. *J. Zool.* 290: 265–272.
- MARTÍN, J., J. ORTEGA, P. LÓPEZ, A. PÉREZ-CEMBRANOS & V. PÉREZ-MELLADO. 2013b. Fossorial life does not constrain diet selection in the amphisbaenian *Trogonophis wiegmanni*. *J. Zool.* 291: 226–233.
- MATEO, J.A. 1991. Los Anfibios y Reptiles de Ceuta, Melilla, Chafarinas, Peñon de Vélez de la Gomera, Peñon de Alhucemas e islotes. *Rev. Esp. Herp.* 5: 37–41.
- MATEO, J.A., PH. GÉNIEZ & J. BONS. 1995. Saurians of the genus *Chalcides* Laurenti 1768 (Reptilia, Scincidae) in Morocco, I: Review and distribution. *Rev. Esp. Herp.* 9: 7–36.
- MATEO, J.A., U. JOGER, J.M. PLEGUEZUELOS, T. SLIMANI, E.H. EL MOUDEN, PH. GENIEZ & I. MARTÍNEZ-SOLANO. 2009. *Chalcides mauritanicus*. In IUCN 2012. IUCN Red List of Threatened Species. Version 2012.2. www.iucnredlist.org (accessed 19 October 2014).
- MCCOY, E.D., N. IHÁSZ, E.J. BRITT & H.R. MUSHINSKY. 2010. Is the Florida sand skink (*Plestiodon reynoldsi*) a dietary specialist? *Herpetologica* 66: 432–442.
- MELLADO, J., V. CAPUTO & G. NASCETTI. 1987. Sobre las poblaciones de *Chalcides* del Nordeste de Marruecos. *Rev. Esp. Herp.* 2: 183–186.
- ORTEGA, J., P. LÓPEZ & J. MARTÍN. 2014. Conspicuous blue tails, dorsal pattern morphs and escape behaviour in hatchling Iberian wall lizards (*Podarcis hispanicus*). *Biol. J. Linn. Soc.* 113: 1094–1106.
- PÉREZ-MELLADO, V., A. PÉREZ-CEMBRANOS, M. GARRIDO, L. LUISELLI & C. CORTI. 2011. Using faecal samples in lizard dietary studies. *Amphib.-Rept.* 32: 1–7.
- PÉREZ-MELLADO, V., M. GARRIDO, Z. ORTEGA, A. PÉREZ-CEMBRANOS & A. MENCIA. 2014. The yellow-legged gull as a predator of lizards in Balearic Islands. *Amphib.-Rept.* 35: 207–213.
- PLEGUEZUELOS, J.M. & M. MORENO. 1990. Alimentación de *Coluber hippocrepis* en el SE de la Península Ibérica. *Amphib.-Rept.* 11: 325–337.
- SHINE, R. 1985. The evolution of viviparity in reptiles: An ecological analysis. Pp. 605–694. In C. GANS & E. BILLET (Eds.) *Biology of the Reptilia*, Vol. 15. John Wiley and Sons, New York.

- SOKAL, R.R. & F.J. ROHLF. 1995. *Biometry*. 3rd ed. W.H. Freeman and Co., New York.
- VANDERPLOEG, H.A. & D. SCAVIA. 1979. Calculation and use of selectivity coefficients of feeding: Zooplankton grazing. *Ecol. Model.* 7: 135–149.
- WATSON, C.M., C.E. ROELKE, P.N. PASICHNYK & C.L. COX. 2012. The fitness consequences of the autotomous blue tail in lizards: an empirical test of predator response using clay models. *Zoology* 115: 339–344.

Table 1. Variables (mean \pm SE) that characterize microhabitats and soils found at the sites available and used by *C. mauritanicus* skinks at the Congreso Island (Chafarinas Islands, N. Africa). Results (F , P) of GLMs comparing sites available and used are given. Significant probabilities after applying a sharpened FDR correction (corrected threshold: $P \leq 0.018$) are marked in bold.

	Available ($n = 46$)	Used by <i>C. mauritanicus</i> ($n = 35$)	$F_{1,79}$	P
<i>Ground level:</i>				
Bare soil (%)	31.5 \pm 2.0	62.3 \pm 2.54	49.95	<0.0001
Leaf litter (%)	23.6 \pm 2.5	7.5 \pm 1.3	29.05	<0.0001
Grass (%)	16.0 \pm 2.8	4.1 \pm 1.2	14.97	<0.0001
Small rocks (%)	16.3 \pm 2.8	17.1 \pm 1.8	0.11	0.74
Medium rocks (%)	3.3 \pm 0.9	8.6 \pm 1.4	8.37	0.005
Large rocks (%)	1.4 \pm 0.9	0.4 \pm 0.1	0.49	0.48
<i>Plant cover above:</i>				
Herbaceous vegetation (%)	23.8 \pm 2.8	24.3 \pm 2.4	0.01	0.90
<i>Salsola</i> bushes (%)	23.6 \pm 2.4	8.4 \pm 1.6	23.18	<0.0001
<i>Lycium</i> bushes (%)	5.5 \pm 1.74	3.2 \pm 0.9	1.25	0.27
<i>Characteristics of soil:</i>				
Soil compaction (kg/cm ²)	2.3 \pm 0.2	0.5 \pm 0.1	82.90	<0.0001
Gravel (%)	46.9 \pm 1.7	5.7 \pm 1.5	444.46	<0.0001
Sand (%)	49.9 \pm 1.4	77.3 \pm 1.1	288.50	<0.0001
Silt (%)	19.1 \pm 0.8	10.3 \pm 1.2	91.54	<0.0001
Clay (%)	30.9 \pm 1.0	12.3 \pm 0.3	251.17	<0.0001

Table 2. Biometrical variables (mean \pm SE; range below) of adult male and female and juvenile *C. mauritanicus* skinks at the Congreso Island (Chafarinas Islands, N. Africa).

	Males (<i>n</i> = 14)	Females (<i>n</i> = 13)	Juveniles (<i>n</i> = 8)
Snout-to-vent length (mm)	70.8 \pm 1.0 (64–74)	74.8 \pm 1.5 (70–83)	49.7 \pm 1.8 (42–56)
Tail length (only animals with intact tails) (mm)	54.0 (54)	69.0 \pm 5.0 (64–74)	44.2 \pm 4.3 (30–54)
Body weight (g)	2.28 \pm 0.12 (1.59–2.66)	2.64 \pm 0.11 (2.12–3.02)	0.89 \pm 0.10 (0.43–1.14)
Head length (mm)	5.7 \pm 0.2 (4.4–6.3)	5.6 \pm 0.2 (4.7–6.5)	4.8 \pm 0.1 (4.2–4.9)
Head width (mm)	4.2 \pm 0.2 (3.0–4.9)	4.3 \pm 0.1 (3.7–4.7)	3.6 \pm 0.2 (2.9–4.2)
Head depth (mm)	3.8 \pm 0.1 (3.1–4.6)	3.6 \pm 0.1 (3.4–4.2)	3.2 \pm 0.3 (2.7–3.8)
Trunk length between limbs (mm)	56.0 \pm 0.5 (55–58)	61.3 \pm 3.5 (55–67)	39.0 \pm 5.0 (34–44)

Table 3. Total abundance of invertebrates (> 2 mm) available under rocks and buried in sand, and composition of the diet of *C. mauritanicus* at the Congreso Island (Chafarinas Islands, N. Africa) in spring. Abundance (total number, *n*, and %) of organisms or prey in each sample and proportion of samples (presence) containing a particular organism or prey item are given. The electivity index of Jacobs (*D*) and the Vanderploeg and Scavia's relativized electivity index (*E**) for each prey type, and the statistical significance (*P*, from a χ^2 test) of these indices are given.

	Available			Diet			Electivity index (<i>D</i>)	Electivity index (<i>E</i> *)	<i>P</i>
	Abundance <i>n</i>	%	Presence %	Abundance <i>n</i>	%	Presence %			
Gastropoda	2	0.5	7.1	2	8.0	12.5	+0.891	+0.086	0.0003
Soliphuga	2	0.5	7.1	-	-	-	-1	-1	
Araneae	11	2.7	28.6	-	-	-	-1	-1	
Isopoda	7	1.7	7.1	-	-	-	-1	-1	
Chilopoda	1	0.2	3.6	-	-	-	-1	-1	
Thysanura	31	7.7	39.3	-	-	-	-1	-1	
Dermaptera	1	0.2	3.6	-	-	-	-1	-1	
Lepidoptera (nymph)	1	0.2	3.6	1	4.0	6.3	+0.908	+0.195	0.009
Coleoptera Ad. (Tenebrionidae)	41	10.2	57.1	-	-	-	-1	-1	
Coleoptera Ad. (others).	6	1.5	17.9	-	-	-	-1	-1	
Formicidae	296	73.9	25.0	-	-	-	-1	-1	
Insect larvae	3	0.7	10.7	22	88.0	100	+0.998	+0.806	<0.0001
Total Invertebrates	402	100	100	25	100	100			