

SHORT NOTE

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**DIET OF THE MOORISH GECKO
TARENTOLA MAURITANICA IN AN
ARID ZONE OF SOUTH-EASTERN
SPAIN**

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The Moorish gecko, *Tarentola mauritanica*, is a rock-dwelling and broad-fingered gecko distributed throughout the Mediterranean region, from the Iberian Peninsula to Greece in the north, and from Morocco to Libya in the south (Martínez-Rica, 1997). The species can be found in very different natural habitats, from rock cliffs in relatively wet and woody zones, to true deserts. In addition, this reptile shows marked anthropophilous behaviour, and is common in human habitations; in fact, because it thrives in urban (towns) or developed (farms, agricultural landscapes) habitats, most studies carried out on this species focus on these non-natural environments. For instance, the diet and feeding habits of the Moorish gecko have been studied in various zones of its distribution area, but mainly in habitats developed by man (Martínez-Rica, 1974; Seva, 1988; Gil, Pérez-Mellado & Guerrero, 1993; Capula & Luiselli, 1994; Gil, Guerrero & Pérez-Mellado, 1994; Pérez-Mellado, 1994) and rarely in truly natural sites (Mellado, Amores, Parreño & Hiraldo, 1975; Salvador, 1978). The typical behaviour of the Moorish gecko, hunting close to artificial lights, has given this species a widely accepted image as a sit-and-wait predator (Seva, 1988; Gil *et al.*, 1994; Pérez-Mellado, 1994), despite the fact that this is quite different from natural situations. In the present work, we discuss the dietary composition and feeding habits of this gecko in a natural site in south-eastern Spain. Our aim is to determine the extent to which the diet of this animal in a natural landscape compares with previous studies carried out in developed landscapes.

The study area is located in the Guadix-Baza region (SE Spain), a Neogene basin at 700-1100 m asl surrounded by high mountains (1700-3000 m asl). The climate is continental Mediterranean, with warm, dry summers and cold winters (average temperature 25°C in July and 0.5°C in January), and roughly 300 mm average annual rainfall, sparsely distributed between autumn and spring, although the study site, in the lower part of the basin, is drier (Castillo-Requena, 1989).

Field work was carried out in a *rambla* (a seasonal watercourse) named Barranco del Espartal (UTM 30sWG2754, 750 m asl). The sample site is a badlands landscape, with a substrate of silt with gypsum sediments. The vegetation is sparse: 46% bare ground, 21% grassland and 33% shrub cover (see Hódar, Campos & Rosales, 1996, for details), and a mean shrub height of 80.5 cm. The main plant species include *Salsola vermiculata*, *Artemisia herba-alba* and *Gypsophila struthium*, with scattered shrubs of *Retama sphaerocarpa* and *Tamarix gallica*.

Diet analysis was based on faecal samples, collected every two weeks between April and September 1995, a period usually free of nocturnal frost (Castillo-Requena, 1989), which hampers gecko activity. Faecal analysis provides accurate information on diet (Fitch, 1987; Rosenberg & Cooper, 1990; Tucker & Fitzsimmons, 1992), and permits dietary analysis without the killing of animals, and thus is especially useful when working with protected species, as in our case. On the other hand, this type of analysis does not allow identification of the individuals from which samples are taken, thereby preventing the evaluation of direct predator-prey relationships (e.g. size relationships).

Faeces were collected by surveying two marked walls (ca. 110 m² total surface area surveyed) in silt cliffs, the result of water erosion. Geckos take refuge during the day in fissures of these walls (pers. obs.). During each visit, we collected all the faeces found, but only complete faeces were preserved. No other gecko species is present in the zone, and the only other lizard species that inhabit cliffs, *Podarcis hispanica*, is scarce at the sampling site (only three records since 1989, with more than 340 days of field work), and its faeces are clearly different from those of geckos (*Podarcis* faeces are darker in colour, and do not remain attached to the wall). Medium-sized lizards such as *Acanthodactylus erythrurus*, *Psammodromus algirus* and *P. hispanicus* are abundant, but they do not climb on cliffs in the study site. Since sampling was conducted consistently on the same area of the cliffs, and all faeces were collected, we assumed that every gecko living on the cliffs had the same probability of being sampled, thereby eliminating the risk of pseudoreplication.

Faeces were dispersed in water and examined under a 10-40x binocular microscope equipped with a micrometer (0.1 mm precision). Prey remains were identified, sorted and measured. Prey were determined to the lowest taxonomic level possible, and later assigned to OTUs (Operational Taxonomic Units, *sensu* Sneath & Sokal, 1973). Measurements of characteristic body parts provided an estimate of the body size and dry mass of each prey item by means of regression equations previously developed by using arthropods collected in the study area (Hódar, 1997). Statistical analyses of prey size and mass were made only with those prey for which body lengths or dry mass were either measured or estimated. However, for any prey with no estimated biomass, we assigned the average biomass

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TABLE 1. Taxonomic composition and biomass of the diet of *Tarentola mauritanica* in the Barranco del Espartal (SE Spain). %N, percentage of numeric frequency; %B, percentage of biomass; %P, percentage frequency of occurrence of plant remains. Prey length and biomass are expressed as mean+SE. Means followed by different letters (a,b) are significantly different according to Dunn's *a posteriori* comparisons between all pairs of months ($P < 0.01$). * excluding spiders.

Prey	April		May		June		July		August		September		Total	
	%N	%B	%N	%B	%N	%B	%N	%B	%N	%B	%N	%B	%N	%B
Arachnida*	-	-	-	-	2.44	0.03	3.95	38.99	5.05	31.66	3.53	5.73	2.39	10.30
Araneae	15.79	32.12	2.40	0.58	9.76	14.22	6.58	6.47	4.04	0.71	9.41	17.60	7.37	6.51
Onyscidae	3.95	17.07	4.00	2.64	1.22	5.38	2.63	9.56	5.05	10.87	3.53	17.43	3.50	5.13
Homoptera	2.63	0.32	-	-	3.66	0.40	7.89	0.72	15.15	2.86	22.35	2.46	8.29	1.40
Heteroptera	1.32	0.29	2.40	0.99	7.32	10.49	6.58	9.32	7.07	4.30	1.18	0.08	4.24	5.78
Lepidoptera larvae	31.58	24.26	33.60	49.00	24.39	34.06	7.89	8.08	6.06	12.83	3.53	13.57	18.60	27.90
Lepidoptera adult	3.95	2.08	1.60	0.88	3.66	1.97	-	-	-	-	2.35	1.97	1.84	0.46
Carabidae larvae	30.26	20.58	43.20	37.76	18.29	13.30	32.89	18.18	12.12	9.61	2.35	0.53	24.13	26.42
Scarabeidae	-	-	-	-	3.66	10.87	-	-	3.03	3.88	3.53	2.25	1.66	2.23
Curculionidae	-	-	2.00	1.84	1.22	1.04	5.26	2.84	14.14	15.14	12.94	17.25	6.08	5.65
Other Coleoptera	2.64	2.60	0.80	5.28	10.98	7.06	10.53	4.26	10.10	5.41	21.18	20.23	8.94	7.12
Formicidae	3.95	0.36	0.80	0.04	10.98	0.72	10.53	0.46	14.14	1.36	8.24	0.30	7.73	0.61
Other Insecta	3.95	0.29	8.80	0.98	2.44	0.44	5.26	0.41	4.04	1.36	5.88	0.60	5.34	0.49
Vegetal (%P)	7.14		0.00		8.00		8.70		12.90		3.13		5.88	
Prey length (mm)	9.79+0.62 ^a		10.62+0.44 ^a		9.06+0.65 ^a		8.58+0.82 ^b		7.27+0.53 ^b		7.24+0.81 ^b		8.88+0.27	
Prey biomass (mg)	10.03+1.70 ^a		10.88+0.80 ^a		10.81+0.99 ^a		13.08+3.37 ^a		8.55+1.43 ^b		7.92+1.37 ^b		10.22+0.79	
No. prey	76		125		82		7		99		85		543	
No. faeces	28		31		21		23		31		32		170	

for its OTU and month in order to get a better estimate of the importance of that OTU.

Dietary data were computed on a monthly basis, and summarized as percentages of both numeric frequency and estimated biomass. For vegetal remains, only occurrence was recorded. Differences in dietary composition were analysed with the *G*-test, whereas prey sizes and masses were analysed with the Kruskal-Wallis test, with the Dunn test for *a posteriori* comparisons between pairs of months (Zar, 1996). Nonparametric tests were applied because of the non-normal distribution of prey sizes and biomasses (Shapiro-Wilk test). All tests were carried out by using the JMP statistical package (SAS Institute, 1994).

A total of 170 faecal pellets was collected during the study period, containing a total of 543 identified animal prey, all arthropods (Table 1). Vegetal remains were found in 10 scats, but the nature of the records (dry leaves and debris) suggests that they were ingested accidentally. Five groups, Araneae (spiders), Homoptera (leafhoppers), Lepidoptera larvae (caterpillars), Carabidae (ground beetles) larvae, and Formicidae (ants), comprised roughly two-thirds of the diet in terms of numeric frequency; especially noteworthy was the predominance of the larvae of Lepidoptera and Carabidae, representing more than 40% of the prey identified. Two of these prey-categories – beetles and ants – also formed two of the three major prey items in other previously studied continental desert-lizard systems (Pianka, 1986), and specifically in other palearctic gecko species (Szczerbak & Golubev, 1996). Biomass

data gave a slightly different picture: although the larvae of Lepidoptera and Carabidae persisted as the dominant groups, they were followed by non-Araneae Arachnida (solpugids and scorpions), Araneae, and Onyscidae (woodlice), the three non-Hexapoda groups. These five groups constituted more than 75% of the biomass consumed by the Moorish gecko in our study area (Table 1).

However, dietary composition was not constant over time, as there were significant changes over the study period ($G = 251.17$, $df = 50$, $P < 0.0001$). Lepidoptera and Carabidae larvae were the main groups, along with Araneae, during the first half the study period. From July onwards, these decreased in numerical importance, and were surpassed by Homoptera, several types of Coleoptera, and Formicidae. A notable dietary component was non-Araneae Arachnida, comprised exclusively of *Buthus occitanus* (Scorpionida) and *Glubia dorsalis* (Soliphuga). Despite their low number, this group represented an important source of biomass in July and August, when other prey were scarce (Sánchez-Piñero 1994). In spring, the Moorish gecko preys on less sclerotised, and hence highly profitable (e.g. Karasov, 1990) groups such as larvae, but in summer, shifts to species adapted to the harsh conditions of drought and food scarcity. This change proved noteworthy also in terms of prey size and biomass: there was a significant change in prey length ($H = 58.55$, $df = 5$, $P < 0.0001$) and prey mass ($H = 28.50$, $df = 5$, $P < 0.0001$, Kruskal-Wallis test) during the active period, with geckos feeding more on longer and heavier prey

during the spring than during the summer (Table 1). Most of the prey (80.1%) were 2-12 mm body length, although some reached considerable size, e.g. a potentially dangerous scorpion measuring about 42 mm was consumed.

Like other temperate zone gekkonids (Marquet, Bozinovic, Medel, Werner & Jaksic, 1990; Valakos & Polymeni, 1990; Perry & Brandeis, 1992; Saenz, 1996; Szczerbak & Golubev, 1996), as well as those from tropical zones (Avery, 1981; Bauer & deVaney, 1987), the Moorish gecko feeds almost exclusively on arthropods. Neither the present study nor previous work in Mediterranean peninsulas (Valverde, 1967; Martínez-Rica, 1974; Gil *et al.*, 1994; Capula & Luiselli, 1994) and islands (Salvador, 1978; Seva, 1988; Gil *et al.*, 1993) indicate clear specificity for any arthropod group, but within each zone, there are usually about two dominant groups in the diet, usually Coleoptera and Araneae. In this sense, the main difference displayed by our data is the relative importance of Carabidae larvae, which were the basic elements of the diet for most of the study period. Only in the Chafarinas Islands (Gil *et al.*, 1993) did Coleoptera larvae reach relatively high values (but only 7.0% in frequency, and sample size was smaller). The greatest differences appear when our results are compared with those of Capula & Luiselli (1994) in Rome, where the two main groups are reportedly Araneae and Diptera. In fact, two flying groups, Diptera and adult Lepidoptera, represent some 36.1% of prey for the Moorish gecko diet in Rome. By contrast, in our study only 20 prey (3.7%) can be considered flying groups (adult Lepidoptera, Diptera, Formicidae winged and Neuroptera), and the most important dietary groups live mainly on low shrubs and the ground (Sánchez-Piñero, 1994; Hódar *et al.*, 1996).

The Moorish gecko has been considered a hunter almost exclusively linked to rock walls and cliffs, in contrast to the geographically proximate *H. turcicus*, which hunts mainly on bare ground (Salvador, 1978; Mellado *et al.*, 1975; Seva, 1988; but see Sáenz, 1996). However, this vision of the Moorish gecko, and in general of most Mediterranean rupicolous geckos, as primarily sit-and-wait foragers restricted to cliffs, walls and rocks, is currently under discussion (Perry & Brandeis, 1992; Gil *et al.*, 1993; Werner, Bouskila, Davies & Werner, 1997). Most of these conclusions are supported exclusively by dietary data or, sometimes, by data from only one of the microhabitats presumably used by the gecko (Gil *et al.*, 1994), despite the fact that the microhabitat seems to determine food acquisition (e.g. Sáenz, 1996). Sample sites in some of these studies are in or near human habitation (Martínez-Rica, 1974; Capula & Luiselli, 1994; Gil *et al.*, 1994), with artificial lights illuminating the walls and attracting prey for geckos (Capula & Luiselli, 1994; Gil *et al.*, 1994; Pérez-Mellado, 1994). Furthermore, other factors apart from prey availability are important in determining the diet of the gecko, and most of these factors may change between localities.

It is known that reptile species tend to forage actively when food availability is low, despite their usual sit-and-wait foraging strategy (Ananjeva & Tsellarius, 1986; Pianka, 1986). For instance, Gil *et al.* (1993) suggest that the Moorish gecko behaves as a sit-and-wait predator in the Iberian peninsula and as an active forager in Mediterranean islands, but these researchers attribute this change to reduced predation risk, rather than to reduced prey availability. We do not believe that this assumption applies to our zone, in which nocturnal and potential predators for the Moorish gecko are varied (e.g. false smooth snake *Coronella girondica*, little owl *Athene noctua*, fox *Vulpes vulpes*, hedgehog *Erinaceus europaeus*). The Moorish geckos in the study area use silt walls as diurnal retreats and at night forage on the ground far from the walls (pers. obs.), and dietary analysis indicates predation mainly upon ground-dwelling arthropods, as observed in other rupicolous geckos inhabiting arid zones in the Mediterranean region (Perry, 1981; Perry & Brandeis, 1992). Consequently, we suggest that in these arid natural habitats of south-east Spain, the species forages widely on the ground, as previously proposed for other gekkonids from arid habitats (Werner *et al.*, 1997). Although foraging widely is energetically expensive, species that engage in this mode of feeding appear to capture more prey per unit of time than do sit-and-wait species (Pianka, 1986). The narrow activity period and the low food availability of an arid zone may force Moorish geckos to forage actively on the ground instead of waiting on the silt cliffs, where food availability is relatively lower, and their main prey are rare or absent (Sánchez-Piñero, 1994). This contrasts with previously accepted ideas on the feeding habits of the Moorish gecko and Gekkonidae in general, and stresses the necessity for more detailed works on this group (Werner *et al.*, 1997).

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