Review of the lizard fauna of Jordan

(Reptilia: Sauria)

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Abstract. The lizard fauna of Jordan is very diverse and forms 55.5% of the terrestrial herpetofauna of the country. Lizard species of Arabian origin form the highest percentage (43%) of the lizards, followed by Saharo-Sindian (35%), Palaearctic (20%) and only 2% with Afrotropical affinities. 69.1% of the lizard species inhabit two ecozones: Badia (Eastern Desert); and Wadi Araba and Wadi Rum. The Badia may form the focal point for the evolution of certain *Acanthodactylus* species. Jordan forms the southernmost limit of the distribution of some Palaearctic species (i.e. *Lacerta media, L. laevis, Pseudopus apodus*) and they inhabit the Mediterranean ecozone. The presence of diverse habitats in Jordan allowed certain allopatric congeneric species of the genus *Ptyodactylus* to live in isolation from one another. Southern Jordan and Wadi Rum are part of the Levantine land bridge and act as a "biogeographical filter". Most of the species found in Wadi Rum are of Arabian affinities and their distribution does not extend towards the west.

Key words. Jordan, Lizard fauna, zoogeography, biodiversity and conversation.

Introduction

Jordan is a meeting point of three zoogeographical realms (Palaearctic, Oriental, Afrotropical). The biotic configuration of the region has been modified by extensive plate tectonics which split Jordan and Arabia from Palestine and Sinai and the latter from Africa. Southern Jordan is considered to be part of the Levantine land bridge (POR 1987). Jordan is divided into four ecozones characterized by a great variety of plant communities, climatic conditions and geomorphological formations (DISI 1996). Moreover, the Eastern Mediterranean region has witnessed intensive geo-biological events that have had palaeobiological effects (TCHERNOV & YOM TOV 1988).

Fifty-six species and subspecies of lizards, belonging to seven families and 26 genera, occur in Jordan. Previous studies have dealt mainly with systematics, providing limited information on lizard ecology and biodiversity (DISI et al. 2001). The aim of this paper is to summarize the biodiversity and ecology of the lizards of Jordan, to investigate resource partitioning among species inhabiting different habitats, and to report on the effect of both biotic and abiotic factors on their distribution.

Material and methods

Specimens were collected between May 1977 and September 2008. The bulk of this collection is deposited at the Department of Biological Sciences, Jordan University Museum, Amman; the Jordan Natural History Museum; Yarmouk University-Irbid; and Jordan University for Science

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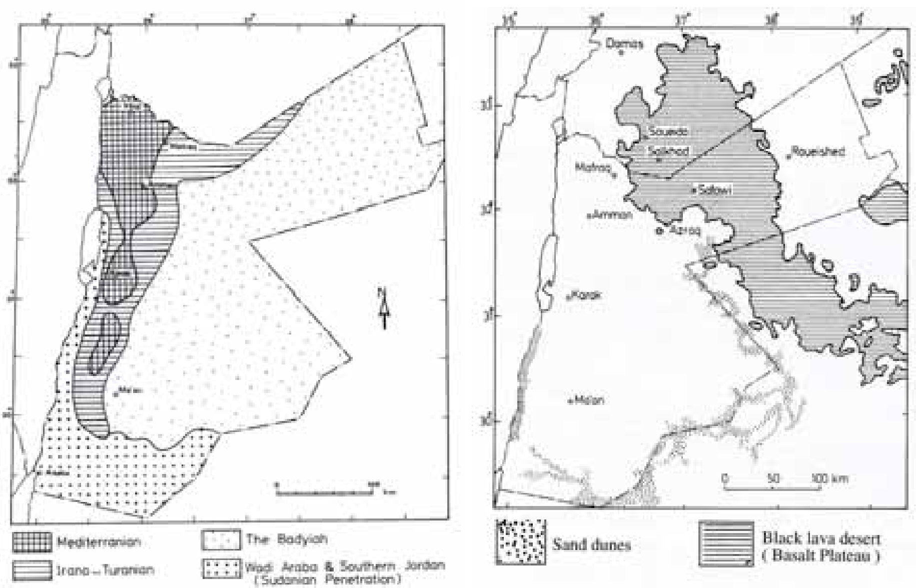

Fig. 1. Ecozones of Jordan.

and Technology-Irbid. Detailed studies covered all habitats in Jordan. Abiotic and biotic information for different localities was obtained from personal field notes and the Meteorological Department, Ministry of Transportation and the Jordan National Geographic Center (1984).

Results

Distribution of lizards by ecozones in Jordan (Fig. 1):

- Mediterranean ecozone: Lizard species limited to this ecozone are: *Cyrtopodion kotschyi orientalis, Laudakia stellio* ssp.*, Lacerta kulzeri petraea, L. laevis, L. media israelica, Chalcides guentheri, Ophiomorus latastii,* and *Pseudopus apodus* (DISI et al. 2001). This ecozone represents the southern limit of the distribution of Palaearctic species.
- The Badia or "Syrian Desert" ecozone: The Badia lies at the heart of the Saharo-Arabian-Sindian zone. Several species of lizards are endemic here: *Stenodactylus grandiceps, Trapelus pallidus agnetae, T. fieldi, Laudakia stellio picea, Acanthodactylus robustus, A. grandis, A. orientalis* and others. It may form a focal point of evolution for certain species of *Acanthodactylus* (DISI 1996, 2002).
- Irano-Turanian ecozone: This ecozone forms a transition zone between the Mediterranean and surrounding ecozones (DISI 1996).
- Wadi Araba and Southern Jordan: Species and subspecies found in Jordan and not to the west of Wadi Rum and or Wadi Araba: *Pristurus rupestris, Laudakia stellio picea, Phrynocephalus arabicus, Trapelus pallidus agnetae, T. fieldi, Acanthodacty-*

lus grandis, A. robustus, A. schmidti, A. tilburyi, A. tristrami, Stenodactylus grandiceps, Phoenicolacerta kulzeri petraea, Mesalina brevirostris microlepis and *Scincus scincus meccensis*.

Species and subspecies found in Sinai or southern Palestine but not in Jordan: *Hemidactylus flaviviridis, Stenodactylus petrii, Tarentola mauritanica fascicularis, Trapelus pallidus pallidus, T. savignii, Uromastyx ornatus, Chamaeleo chamaeleon musae, Scincus scincus scincus, Macroprotodon cucullatus cucullatus* and *Mesalina rubropunctata*. Both biotopes Wadi Araba and Wadi Rum and Eastern Badia have the highest number of species of lizards in Jordan (69.1%).

Relict Species: Relict species such as *Eumeces taeniolatus* are completely isolated in mountainous areas, separated from the main area of distribution by a considerable distance. They survive in a very fragile ecological habitat that needs immediate protection. These are relict species from postglacial periods and occupy a habitat which is ecologically similar to that of earlier (preglacial) conditions (DISI 1993, 1996).

Endemism: KOSSWIG (1955) said that there are difficulties in distinguishing natural biogeographic barriers within the Levant. TCHERNOV & YOM-TOV (1988) also indicated that the Levantine region is a transitional zone between the Palearctic and the Saharo-Arabian desert belt, with complex mosaic patterns of distribution. The subspecies *Phoenicolacerta kulzeri petraea* is endemic to Jordan. Jordan is not separated from surrounding countries by natural barriers, thus preventing the operation of isolation mechanisms and therefore endemism is limited (2% of lizards). There are, however, four areas of endemism in the Eastern Mediterranean region:

- An area where *Lacerta media israelica* and *Ablepharus rueppellii festae* are found in northern Jordan, including the Jordan Valley and northern Israel. A fourth endemic species, *Cyrtopodion amictopholis*, has been reported only from Mount Hermon (SIVAN & WERNER 1992);
- Southern Jordan bordering northwest Saudi Arabia and southern Israel including Sinai, illustrated by the presence of *Hemidactylus mindiae*;
- The Syrian Desert, which is shared by southern Syria, western Iraq, eastern Jordan and northern Saudi Arabia, is exemplified by the presence of *Stenodactylus grandiceps, Acanthodactylus robustus, A. tristrami, Trapelus fieldi* and *Laudakia stellio picea;*
- Wadi Araba harbors *Cerastes gasperetti mendelssohni.*

Abiotic factors affecting the biodiversity and ecology of the lizard fauna

Substrate type: There is a positive correlation between local distribution and substrate type (ANDERSON 1968, DISI 1987, SZCZERBAK 1994). Several species (*Stenodactylus doriae*, *Phrynocephalus arabicus*, *Acanthodactylus schmidti*, *A. tilburyi, Scincus sincus meccensis*, and *Sphenops sepsoides*) are morphologically, behaviorally and physiologically adapted to sandy habitats and are associated with the sand dunes of Wadi Araba and Wadi Rum. Sand burrowing reptiles are characterized by a flatly expanded wedge-shaped snout and the ventral position of the mouth opening protects it from ingesting sand during submerged progression. ARNOLD (1984) indicated that the vertical flanks of *Scincus* and *Sphenops* improve the lateral thrust during sand swimming. The fringed eyelids of gekkonid lizards protect their eyes. The locomotion of lizards on sand dunes is facilitated by expansion of the area of their feet through well-developed lateral fringes along the toes. Most of these psammophilic species extend their distribution more than 300 km toward the north (Al Hazim) through suitable substrate along the border between Jordan and Saudi Arabia (Fig. 2).

Ophiomorus latastii and *Chalcides guentheri* live in humid soil below the surface and their limbs have been reduced to facilitate their mainly subterranean lifestyle. *Laudakia stellio* and *Pseudotrapelus sinaitus* are associated with outcrops of rocks that they use as basking sites, observation points to control their territories, shelter from the sun, open foraging sites and places to retreat when faced with danger. However, certain species such as *Trapelus pallidus* may occupy different soil types such as alluvial fans, loam, clay and gravel soils. ANDERSON (1999) reported similar observations from Iran.

Some lacertid species such as *Mesalina guttulata*, *M. olivieri* and *M. brevirostris* prefer compact hard open clay and gravel plains. Also, the availability of cracks and holes in clay and gravel soils or burrows in plant-stabilized sandy soils may determine the local distribution of many lacertid species. These crevices provide shelter from predators and from temperature extremes (ANDERSON 1999). *Uromastyx* distribution is confined to compact gravelly soils where they are able to excavate burrows (DISI 1991).

Densities of *S. stenodactylus*, *A. boskianus* and *M. guttulata* were determined mainly by soil structure. Furthermore, both soil and annual vegetation structure determined density of *P. guttatus* and it clearly preferred microsites with very high rock content, high annual grass abundance, and high shrub cover. Moreover*, M. olivieri* favors areas with high gravel contents moderate to high herb abundance, and very low annual grass abundance.

Moisture. Mean annual values of the soil moisture index affect the distribution of lizards in Jordan. *Ophiomorus latastii, Chalcides ocellatus*, *Trachylepis vittata* and *Pseudopus apodus* are associated with damp soil and it seems clear that humidity of the soil is a limiting factor for their abundance (DISI 1993). CLARK & CLARK (1973) indicated that there are certain species of lizards (*Lacerta media, C. ocellatus* and *Ophiomorus latastii*) inhabiting the vicinity of streams banked by woody shrubs.

KHALIL & HUSSEIN (1963) found that temperature and relative humidity control the activity of *Uromastyx aegyptia* and *Agama pallidus* (= *Trapelus pallidus*). *A. boskianus* specimens collected from the arid zone of the eastern desert are larger in size and the dorsal scales become more spiny, in comparison with specimens collected from places with high altitude and higher humidity (DISI 1993). Humidity is negatively correlated with mean daily sunshine hours. As the mean daily sunshine hours increase, temperature increases and causes a drop in humidity (DISI 1987). For example *Chalcides guentheri*, *C. ocellatus*, *Trachylepis vittata*, and others favor damp soil. On the other hand, certain species avoid humid habitats, like *Sphenops sepsoides*, *Scincus scincus meccensis*, *Stenodactylus doriae*, *Acanthodactylus schmidti*, and *Varanus griseus* (Table 1).

Temperature. Variations in mean body temperature are positively correlated with corresponding mean ambient temperature in almost all species studied. Also, the time spent basking varies among seasons and with mean temperature. Moreover, the total hours of activity are much less during winter than during summer. In addition, the percentage of lizards in the sun at particular times of the day varies among seasons and with mean temperature (DISI 1993).

The mean range of temperature has a greater effect on the distribution of lizards than the mean number of days with a minimum temperature below 0ºC (DISI 1993). It is well known that prolonged exposure to cold temperature could damage reproductive cells and other heat

Fig. 2. *Laudakia stellio picea*. Photograph: Zuhair Amr.

sensitive tissues. This may explain how minimum temperature as well as vertical temperature gradient may act as a barrier for the distribution of certain herpetofauna species. The first is dependent upon latitude and the second is combined with altitude. This may allow the eastern mountains overlooking Wadi Araba to act as a barrier for certain species to block their way to the eastern plateau.

Eggs must be protected from lethal temperature and should be laid in suitable site allowing for embryogenesis to proceed. There is a correlation between color of basking lizards and time of the day. The color of *Pseudotrapelus sinaitus* becomes lighter during midday. Also, certain species, like *Trapelus fieldi*, escape the hot soil surface at midday by sitting on twigs of shrubs (Disi 1993).Temperature is negatively correlated with two attributes in distribution of lizards: altitude and mean annual solar radiation. Also, factor analysis shows that temperature plays an important role in the distribution of lizards in Jordan (Disi 1993). Pianka (1971, 1985) reported that temperature is the most important factor in understanding lizards activities.

Solar radiation. In warm months the activity of lizards is distinctly bimodal, whereas in colder months lizards are most active at noon, when the temperature is highest. Reptiles can avoid harmful solar radiation by exhibiting certain coloration (Disi 1993). Global warming and ozone depletion are associated with increases in both temperature and ultraviolet solar radiation (UV). Although UV-B radiation constitutes only about 0.5% of the total solar radiation reaching the Earth's surface, it has high potential to cause biological damage because the high-energy wavelength can be absorbed by nucleic acids and proteins of living organisms (OVASKA 1997). The absolute levels of solar UV-B increases with altitude and thus will be greater at high-elevation. Intensive UV exposure in the laboratory can result in embryonic mortality and abnormal development.

Altitude. The most effective factor in determining the distribution of lizards in Jordan is altitude. This is a complex parameter since several other abiotic parameters interact with it, such as temperature, moisture (through rainfall and/or dew), wind speed, snow, vegetation cover (DISI 1987, KREBS 1994). In Jordan there is a vegetation zonation along an altitudinal gradient from the Jordan Valley, Dead Sea basin and Wadi Araba up to the mountains where the climax vegetation consists of trees. Moreover, PEARSON & RALPH (1978) showed that reptile diversity decreases with altitude, and also density and biomass are much lower than in desert habitats on other continents as altitude increases. Certain species of lizards living in the lowlands reproduce twice, as opposed only once by those species living at high altitudes. Also, there are considerable differences in the activity of *Lacerta viridis* at 860 m a.s.l. compared to those at 500 m a.s.l., similar to that noted for *Ablepharus kitaibelli* (STRIJBOSCH et al. 1989). The chain of mountains on the eastern side of Wadi Araba may act as barrier for certain species inhabiting low areas and the sand dunes of Wadi Araba.

Biotic factors affecting the biodiversity and ecology of the lizard fauna

Vegetation. The abundance and presence of certain species of lizards are related mainly to the availability of vegetation. *Lacerta laevis, Chamaeleo chamaeleon* and *Cyrtopodion kotschyi orientalis* are present where vegetation is available. *Ablepharus ruppellii festae is* found among dead leaves of oak and pine forests of the Mediterranean biotope in Jordan.

Vegetation may provide certain physical requirements for lizards. For example, *Haloxylon* and *Nitraria retusa* stabilize sand dunes and provide suitable sites for burrow excavation among their roots. These burrows may be excavated by large arthropods or rodents, which may form a suitable source of food, especially for snakes and lizards. Vegetation may attract other faunal species that may increase the chance for presence of their prey. It also affects the available niches by modifying and increasing the microhabitats. Moreover, vegetation plays an important role in maintenance of soil and moisture conditions of the microclimates (DISI 1993).

SHENBROT & KRASNOV (1997) found that the distribution of *M. olivieri* and *O. elegans* is mainly affected by the structure of annual vegetation, while the skinks: *C. ocellatus*, *A. kitaibelli* and *E. schneiderii* are affected by the structure of shrub vegetation. KREBS (1994) indicated that the number of lizard species could be predicted by the density and structure of vegetation and not by plant species diversity. JONES (1981) stated that grazing results in changes to vegetative structure and leads to a reduction in overall lizard abundance and diversity. ARNOLD (1984) showed that vegetation affects microhabitat of lizards.

PIANKA (1986) reported that the physical structure of the vegetation profoundly influences the composition of the lizard community. *Amphibolurus isolepis* stays adjacent to plants during midday, and when approached or pursued runs into bushes or grass. Similar observations were noticed with *Acanthodactylus schmidti* which utilizes spiny bushes in Al Hazim, Jordan (DISI & AMR 1998). AL-OGILY & HUSSAIN (1983) showed that the distribution of *Uromastyx aegyptia* depends upon the suitability of the substrate coupled with preference for certain grasses and shrubs. The habitat selection of *U. aegyptia* in Wadi Araba is explained by the distribution of *Acacia* sp., *Haloxylon* sp., *Anabasis* sp. and distribution of other plants, soil type and topography of the area (DISI 1993, BOUSKILA 1984).

Fig. 4. *Chalcides guentheri*, King Talal Dam. Photograph: P. NECAS.

In the Badia, each lizard species preferred particular plant species. Moreover, *Lacerta laevis* is mainly collected from areas dominated by oak trees *Quercus* sp. (DISI & AMR 1998). While the presence of *C. chamaeleon* is dependent upon the need for structured vegetation cover.

HOUSE et al. (1980) indicated that an environment which varies in terms of topographical and vegetation structure would create a mosaic of temperature and humidity within a relatively small area throughout the day. Anthropogenic effects (unmanaged grazing, plowing of lands, infrastructural developments, and clearance of forests) resulted in the decrease in the size of lizard populations and/or their diversity (DISI & HATOUGH BOURAN 1999).

Resource Partitioning Among Lizards

The two most important resources considered as limiting factors to species biodiversity is the available number of microhabitats (sites for shelter, basking, foraging, oviposition) and food (WERNER 1987). It is difficult to identify the stomach contents to the specific level, which forms a hindrance in our understanding of true competition for prey. Partitioning of food resources could be estimated from other interspecific differences which minimize this competition: dietary behavior, morphometric measurements (especially head size), microhabitat and time of activity (seasonal and bimodal).

In the Badia, or black lava desert, the following species were recorded within a small area: *Ptyodactylus puiseuxi, Pseudotrapelus sinaitus* ssp., *Trapellus pallidus agentae, Uromastyx aegyptia microlepis* and *Masalina guttulata*. All these species are diurnal and ground-dwelling. *U. a. microlepis* is the largest among theses lizards and is herbivorous. *P. sinaitus*

Table 1. Zoogeographical and ecozone preferences of lizards in Jordan.

	Med	Badia	Araba	S Jordan	Remarks
Gekkonidae					
Bunopus tuberculatus Blanford, 1874		●	●	●	
Cyrtopodion kotschyi orientalis Stepanek, 1937	●				Jordan represent the most southern end of the distribution
Cyrtopodion scabrum (Heyden, 1827)		●	●	●	
Hemidactylus mindiae (Baha El Din, 2005)				●	
Hemidactylus turcicus turcicus (Linnaeus, 1758)	●	●	●	●	**
Pristurus rupestris Blanford, 1874			●	●	
Ptyodactylus guttatus Heyden, 1827	(●)		●		
Ptyodactylus hasselquistii (Donndroff, 1798)			●	●	
Ptyodactylus puiseuxi Boutan, 1893	●	●			
Stenodactylus doriae (Blanford,1827)		●	●	●	
Stenodactylus grandiceps Haas, 1952		●			
Stenodactylus slevini Haas, 1957		●		●	
Stenodactylus sthenodactylus (Lichtenstein, 1823)			●	●	
Tropiocolotes nattereri Steindachner, 1901			●	●	
Chamaeleonidae					
Chamaeleo chamaeleon recticrista Boettger, 1880	●	●	●	●	Jordan represent the most southern end of the distribution / CITES Annex II
Agamidae					
Laudakia stellio brachydactyla (Haas, 1951)				●	
Laudakia stellio picea (Parker, 1935)		●			Endemic to east Jordan and northwest Arabia
Laudakia stellio ssp. (Linnaeus, 1758)	●				
Phrynocephalus arabicus Anderson, 1894				●	
Pseudotrapelus sinaitus Heyden,1827		●	●	●	

	Med	Badia	Araba	S Jordan	Remarks
Trapelus pallidus agnetae (F. Werner, 1929)		●			
Trapelus pallidus pallidus (Reuss, 1833)			●		
Trapelus fieldi (Haas &Werner,1969)		●			
Trapelus ruderatus (Olivier, 1804)	●	(●)			
Uromastyx aegyptia microlepis Blanford, 1874		●	●	●	CITES Annex II
Lacertidae					
Acanthodactylus boskianus (Daudin, 1802)		●	●	●	
Acanthodactylus grandis Boulenger, 1909		●			
Acanthodactylus hardyi Haas, 1957				●	Endemic to east Jordan and northwest Arabia
Acanthodactylus opheodurus Arnold, 1980		●	●	●	
Acanthodactylus orientalis Angel,1936		●			
Acanthodactylus ahmaddisii Werner, 2004		●			
Acanthodactylus robustus F.Werner, 1929		●			
Acanthodactylus schmidti Haas, 1957		●		●	
Acanthodactylus scutellatus, Audouin, 1908		●		●	Endemic to east Jordan and northwest Arabia
Acanthodactylus tilburyi Arnold, 1809		●		(●)?	Endemic to east Jordan and northwest Arabia
Acanthodactylus tristrami (Günther, 1864)		●			
Lacerta kulzeri petraea Bischoff & Müller, 1999	●				Relict; endemic to Mediterranean biotope
Lacerta laevis Gray, 1838	●				Jordan represent the most southern end of the distribution
Lacerta media israelica (Peters, 1964)	●				Jordan represent the most southern end of the distribution

	Med	Badia	Araba	S Jordan	Remarks
Mesalina brevirostris microlepis (Angel, 1936)		●	●	●	
Mesalina guttulata guttulata (Lichtenstein, 1823)		●	●	●	
Mesalina olivieri schmidti (Haas, 1951)		●	●	●	
Ophisops elegans blanfordi Schmidt, 1939	(●)	●			
Ophisops elegans ehrenbergi Wiegmann, 1835	●	?			
Scincidae					
Ablepharus rueppellii festae Peracca, 1894	●			●?	Jordan represent the most southern end of the distribution
Chalcides guentheri Boulenger, 1823	●				Endemic to eastern Mediterranean region
Chalcides ocellatus (Forskål, 1775)	●	●	●	●	
Eumeces schneiderii pavimentatus (G.-St. Hilaire, 1827)	●				
Eumeces schneiderii ssp. (Daudin, 1802)		●	●	●	
Eumeces taeniolatus (Blyth, 1854)			●		Relict
Trachylepis vittata (Olivier, 1804)	●	●	●	●	
Ophiomorus latastii Boulenger, 1887	●				
Scincus scincus meccensis Wiegmann, 1837		●		●	Limited distribution
Sphenops sepsoides (Audouin, 1827)			●		Jordan represent the most northern end of the distribution
Anguidae					
Pseudopus apodus (Pallas, 1775)	●				Jordan represent the most southern end of the distribution
Varanidae					
Varanus griseus (Daudin, 1803)		●	●	●	CITIES Annex I

is the second largest in body and head size and is omnivorous, with a large proportion of plant material in its diet. *T. p. agnetae* inhabits different habitats; the black lava desert, the black stones are smaller and well spaced than that occupied by *T. p. sinaitus*, and occupies depressions and wadi systems covered with fine sand and scattered vegetation. It is usually found close to the habitat of *U. a. microlepis*. *P. puiseuxi* is smaller than *T. p. agnetae* and feeds on insects. The smallest species in this group is *Mesalina guttulata. Uromastyx aegyptia microlepis* occupies open areas and has its burrows in the ground, with a wide crescent-shaped opening. *P. sinaitus* is always found in association with large stony outcrops near its hiding places. *P. puisenxi* utilizes smaller rocks mostly solitary scattered rocks, while *M. guttulata* spends most of its time on the ground among scattered stones and under vegetation if present. It seems clear that the feeding habits and their habitat utilization prevent the competition among the studied species.

Eleven species of *Acanthodactylus* inhabit the Badia ecozone, six of them limited to it: *A. ahmaddisii, A. grandis, A. orientalis, A. robustus, A. tilburyi* and. *A. tristrame*, while the other five species extend their range to the southern Jordan and/or Wadi Araba: *A. boskianus, A. hardyi, A. opheodurus, A. schmidti* and *A. scutellatus*. All *Acanthodactylus* species which inhabit the Badia are diurnal, but they have different microhabitat and distributional patterns. It was found that *A. grandis* inhabits stony areas, on fairly hard substrate. *A. robustus* inhabits areas of hard substrate. *A. boskianus* inhabits fairly hard substrate and occupies a wide range of habitats. It was collected from 400 m below to 1300 m a.s.l. *A. boskianus* has especially penetrated to the Mediterranean ecozone with *A. opheodurus* (Petra).

ARNOLD (1983) stated that *A. boskianus* forages in more open areas. *A. boskianus* and *A. opheodurus* were collected from steppe grassland. They are also collected from the hills and mountains of Petra of the more typical eastern Mediterranean ecozone. Similar observations were made in Iraq (REED & MARX 1959). *A. opheodurus* inhabits a wide diversity of habitats. ARNOLD (1980) indicated that *A. boskianus* co-exists with *A. opheodurus*, and that the larger species reduce competition with the smaller one, *A. opheodurus,* by taking larger prey when adults. *A. tristrami* inhabits a fairly hard substrate; also it extends its range into steppe-type habitat on the edge of the Mediterranean ecozone but differs from the habitats of *A. boskianus* and *A. opheodurus*. *A. schmidti* utilizes areas where soft sand is partly stabilized by root systems of spiny bushes. Also, it makes use of shade thrown by the vegetation where it lives. This species is characterized by having extensive fringes on its digits, allowing it to inhabit soft sandy substrates.

In the sand dunes of southern Jordan the following species are found: *Acanthodactylus schmidti*, *A. tilburyi, Stenodactylus doriae, Scincus scincus meccensis, Phrynocephalus arabicus* and *Varanus griseus*. These species avoid competition and divide the resources of the area by utilizing different microhabitats, time activity, and the head/prey size and behavior. *A. schmidti* and *A. tilburyi* are diurnal and living in the same vicinity but the former is larger in size and prefers flat sand dune; while the latter is more confined to softer and banked dunes (MODRY ET AL. 1999). *S. s. meccensis* and *S. doriae* are limited to sand habitat and subterranean. *S. doriae* is nocturnal; while *S. s. meccensis* is diurnal; *P. arabicus* is found on sandy areas with scattered vegetation and boulders, it is diurnal and active at midday. *Varanus griseus* is the largest lizard in Jordan, diurnal and lives in both sand and gravel habitats. It is an active forager and may travel 2 km in search for food. *V. griseus* predates on all the above mentioned species; five of them evade predation by submerging rapidly beneath the sand.

Fig. 5. *Laudakia stellio* eating subadult *Ptyodactylus guttatus*. Photograph: D. MODRÝ.

Discussion and conclusions

The lizard fauna of Jordan is highly heterogeneous and diversified (DISI & AMR 1998, DISI 2002). Lizards occupy specific habitats within the different ecozones of Jordan, which suit their environmental requirements. Certain species are restricted to the Mediterranean ecozone (Table 1), while others inhabit Wadi Araba and southern Jordan or the Badia. It was found that the most effective factor in determining the distribution of the lizards in Jordan is altitude. This study shows that the second abiotic factor affecting distribution of lizards in Jordan is the mean annual values of soil moisture index (i.e. *Chalcides ocellatus* and *Trachylepis vittata*). Gekkos inhabiting the Badia and south of Jordan and Wadi Araba are mostly nocturnal or active in late afternoons in order to avoid the most desiccating period or intense solar radiation (*Ptyodactylus hassilquisti, Stenodactylus doriae* and *Bunipus tuberculatus).* Some habitats are inhabited by several species which may be an evidence for resource partitioning and niche selection. Competition among species living in the same area may be reduced among them by size differences, behavioral changes and habitat utilization. Specimens of *A. boskianus* collected from hot and arid localities in the Eastern Desert attained rough and highly keeled scales on the posterior half and tail. It is unclear if this feature is associated with drought conditions and hot environments.

The third parameter affecting the distribution of lizards is vegetation. Types of vegetation are affected by several abiotic parameters: rainfall, type of soil, temperature, solar radiation, dew, altitude, etc. Vegetation cover is an important factor that influences the habitat microclimate. Moreover, vegetation may be utilized as a refuge or foraging site. Abundance and presence of certain species of lizards are mainly related to the availability of vegetation. Also, the following parameters affecting lizard distribution in Jordan are: dew, rainfall, mean daily range of temperature, and mean annual solar radiation.

Anthropogenic effects resulted in changes in the abundance, diversity and distribution of lizard populations in Jordan (DISI & AMR 1998). Ecological changes have resulted in a rapid decline of natural habitats due to overgrazing, urban expansion, infrastructure development, mismanagement of the highlands, and fire. All these factors have led to deforestation, soil erosion and desertification, resulting in a patchy and fragile environment, and affecting the abundance of lacertid lizards (DISI 1996, 2002).

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