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Original article

Taxonomy, population status and ecology of Indian desert monitor lizard *Varanus griseus koniecznyi* Mertens 1954 in the Thar desert of Rajasthan

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ABSTRACT

Among monitor lizards of the family Varanidae, Indian desert monitor lizard *Varanus griseus koniecznyi* Mertens 1954 is one of the lesser-known species globally and due to lack of data on this species it is so far not evaluated by IUCN and excluded from the latest assessment of monitor lizards of Southeast Asia and Indo-Australian Archipelago. The present study was undertaken from January 2013 to June 2017 to fill this gap during which taxonomic evaluation along with an assessment of population and ecology of this species was carried out in the Thar desert of Rajasthan (TDR). The study brought into knowledge many morphological variations along with intraspecific variations of scale microstructure of this lizard. The population density was found to be highest in the Jaisalmer (0.102/ha) district of western Rajasthan, followed by Bikaner (0.08/ha) and Sikar (0.077/ha) districts. The overall population was quite low (0.068/ha) in the area. The study further revealed the species is habitat specialist and lives in a narrow range of habitats and microhabitats, and hence, the species may not adapt to the rapidly changing environment in the TDR. Their activity was found to be highest between 9–12 hrs followed by 12–15 hrs and foraging was found to be their predominant activity followed by resting and feeding. In the absence of any detailed study on this species, the study points towards immediate conservation efforts for the species in its current distribution. Baseline data generated through this study will no doubt help to safeguard the species in the TDR and further research on this species in the future.

1. Introduction

Monitor lizards of the family Varanidae represent an ancient group of Anguimorph lizards representing a monophyletic group and are classified under a single genus *Varanus* (King et al., 1991; Böhme, 2003; Vidal et al., 2012; Zheng and Wiens, 2016). They are widely distributed in the old world. They inhabit both the mainland and islands of all geological types, and reported from Africa, South and Southeast Asia, Central Asia, Middle East, the Arabian Peninsula, the Indo-Australian Archipelago, and several Pacific islands such as the Solomons, Admiralties and Marianas (King et al., 1991; Böhme, 2003; Koch et al., 2013; Zheng and Wiens, 2016; Utez et al., 2020). They are considered conspicuous animals and comprise the most enormous living poikilothermic predators on our planet after crocodiles and pythons (King et al., 1991; Böhme, 2003; De Lisle, 1996; Koch et al., 2013).

All Varanid monitors are highly diversified and exhibit remarkable differences in their body color, size, tail morphology, habits, and habitats (De Lisle, 1996; Pianka et al., 2004). They are represented by a total 80 species and 23 subspecies from all over the world (Uetz et al., 2020). Of these, 44 species of monitor lizards with eight subspecies are known from Indo-Australian Archipelago (Koch et al., 2013; Uetz et al., 2020). In India, five species and subspecies of monitor lizards are found. They are the common (=Bengal) monitor *Varanus bengalensis bengalensis* (Daudin, 1802), the desert monitor *Varanus griseus koniecznyi* Mertens, 1954, the yellow monitor *Varanus flavescens* (Hardwicke & Gray, 1827), the South Asian water monitor *Varanus salvator salvator* (Laurenti, 1768), and the Andaman water monitor *Varanus salvator andamanensis* Deraniyagala, 1944 (Aengals et al., 2018; Uetz et al., 2020). Among these, the Andaman water monitor is endemic to India; the common monitor is the most common, while the desert monitor is the least common (Rao, 1997; Molur and Walker, 1998; Uetz et al., 2020). Currently, all the monitor lizards found in India are facing various threats like habitat fragmen-

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tation, degradation, loss, and illegal trading that has resulted in pushing them locally extinct in many parts of this country. Hence, they are enlisted under Schedule I of Wildlife Protection Act, 1972 and Appendix II of CITES (WPA 1972; CITES, 2020). However, they are declared as LC (Least concern) by IUCN except for the Indian desert monitor lizard (IUCN, 2020).

Desert ecosystems are rich with reptilian fauna as they are characterized by habitat heterogenicity (Pianka, 1986). Globally there are two species and three subspecies of monitor lizards found in deserts viz., *V. g. griseus* (Daudin, 1803) from Africa, Saudi Arabia and Middle East, *V. g. caspicus* (Eichwald, 1831) from Middle East and Central Asia, *V. g. koniecznyi* Mertens, 1954 from India and Pakistan, and *V. nesterovi* from Iraq-Iran border (Uetz et al., 2020). Since these monitor lizards are exclusively arid-adapted, they are known as desert monitors.

The Indian desert monitor lizard lacks proper information on its ecology and population status in its current distribution. Hence, to date it is not evaluated by IUCN (IUCN 2020), and the latest assessment of monitor lizards of Southeast Asia and Indo-Australian Archipelago by Koch et al. (2013) excluded this species. In India, this species survives in the desert areas of northwestern India in Rajasthan and Gujarat (Smith, 1932, 1935; Dave, 1961; Auffenberg et al., 1990; Sharma, 1996, 2002; Daniel, 2002; Molur and Walker, 1998; Vyas, 2000; Das, 1989, 2005, 2007; Gaur et al., 2013, Uetz et al., 2020). Further, the main population of this species in India is found in the Thar desert of Rajasthan (TDR) as the TDR represents the major part of the Great Indian desert (about 62%) (Baqri and Kankane, 2002). Hence, to understand the current population status and ecology of this lesser-known species, the present study was undertaken in the TDR. The study also aims to document morphological variations and evaluate taxonomic characters to identify the species in the field.

2. Materials and methods

2.1. Study area

The study area was the TDR (22^0 30′ to 32^0 05′ N latitude and 68^0 05′to 74^0 45′ E longitude) that covers an area of about 1, 91, 650 sq. km and spreads over 13 districts of Rajasthan. It includes the entire Ganganagar, Hanumangarh, Bikaner, Barmer, Jodhpur, and Churu districts and part of Nagaur, Ajmer, Pali, Jalore, Jhunjhunun and Sikar districts (Fig. 1) (Baqri and Kankane, 2002). It comes under the Biogeographic Zone 3A (Thar Desert) (Rodgers et al., 2002) that represents a unique ecosystem supporting rich biodiversity.

Details about the general features of the area have been described by Gupta and Prakash (1975), Baqri and Kankane (2002), Goswami and Ramesh (2008), and Kar (2014). The entire area presents gently undulating plains, sand dunes separated by sandy plains, and barren hills or '*bhakars*'. Several saline beds or playas (locally known as '*dhands*') are scattered throughout the region. The soil is predominantly sandy desert soil with a small patch of alluvial soil on its north-eastern part and grey-brown soil in the semiarid tract. The area experiences a harsh climate with extremes of cold and hot. The annual rainfall is relatively low, ranging from about four inches (100 mm) or less in the west to about 20 in. (500 mm) in the east. The weather pattern is broadly classified into four distinct seasons viz., summer (March to June), monsoon (July to September), post-monsoon (October to November), and winter (December to February). About 90% of the total annual rainfall occurs during the season of the southwest monsoon, from July to September. May and June are the hottest months of the year, with temperatures rising to 122 °F (50 °C). January is the coldest month with a minimum temperature ranging between 41 and 50 °F (5–10 °C). Dust storms (locally called '*aandhi*') is common in May and June. Ecologically the vegetation of this region is sparse and falls under the category "Thorn forest". Much of the area is occupied by dry open grassland with trees and thorny bushes, the forests being almost negligible, comprising only 1.8% of the total area. All the plants of this region are well adapted to the xeric environment. Luni is the main river in western Rajasthan. Currently, India Gandhi Nahar (Canal) Project (IGNP) carrying water from Ravi-Beas comprising about 649 km. from Harikki Barrage, Punjab to Jaisalmer district, Rajasthan is the main source of water in this region.

2.2. Methodology

The present study was undertaken from January 2013 to June 2017. Data was collected through regular field survey in the TDR using both four wheelers and bike. Priority was given to survey areas where the species was recorded earlier.

2.2.1. Taxonomic study

Taxonomic identification of *Varanus* spp. was carried out in the field following manuals of Smith (1935), Minton (1966), Daniel (2002) and Sharma (2002). Dead specimens (road accident deaths) were examined in the field, and body measurements of intact specimens were taken with the help of a digital Vernier caliper. SEM of body scales of one specimen was carried out following Bucklitsch et al. (2016). For this, a piece of epidermis measuring about 1 cm X 1 cm was cut from different body parts, transferred into SEM stubs, then gold coating and imaging was carried out using GGSIPU SEM facility. For scale microstructure, descriptions by Bucklitsch et al. (2016) was followed.

2.2.2. Population assessment and distribution in the TDR

The study area being quite large, primarily the population of the species was enumerated through intensive search in different parts of the TDR following 'perambulation' (Ralph et al., 1993; Dieni and Jones, 2002) method. Later 'belt-transect' (Carpio et al., 2015) method was followed only in those areas where the species occurrence was confirmed by direct observation or road accident death sighting. In both 'perambulation' and 'belt-transect' methods, species was searched in a fixed area within a specified time limit by walking, but in 'perambulation' a larger area was searched randomly. In 'belt-transect' method, 1000 m X 50 m area was covered in 1hr, two such transects were covered in a day, rotated in different time periods of the day: 6–9 hrs, 9–12 hrs, 12–15 hrs, 15–18 hrs. Number of transects studied during this study in different districts of the TDR were; Barmer = 24; Bikaner = 45, Churu = 18; Hanumangarh = 18; Ganganagar = 18; Jaisalmer = 45; Sikar = 18. GPS points were taken using Garmin Map 62S handheld GPS device for species occurrence along with habitat and microhabitat information for each encounter of species. However, for population estimation, only data collected through belt-transect method was used, and population density (per ha.) was determined using the following formula-

Density = N/A (Henderson, 2009)
Here, N = Total number of Individuals
A = Total area

For the preparation of the distribution map, both live and dead specimen sighting points were used. Mapping of species distribution was done using ArcGIS 10.2. by importing ground control points (GCPs) for species on the base map of the study area.

2.2.3. Field ecology

The classification of reptile habitats in the TDR given by Krishna (1975) and Das (2005) was referred to document habitats of the

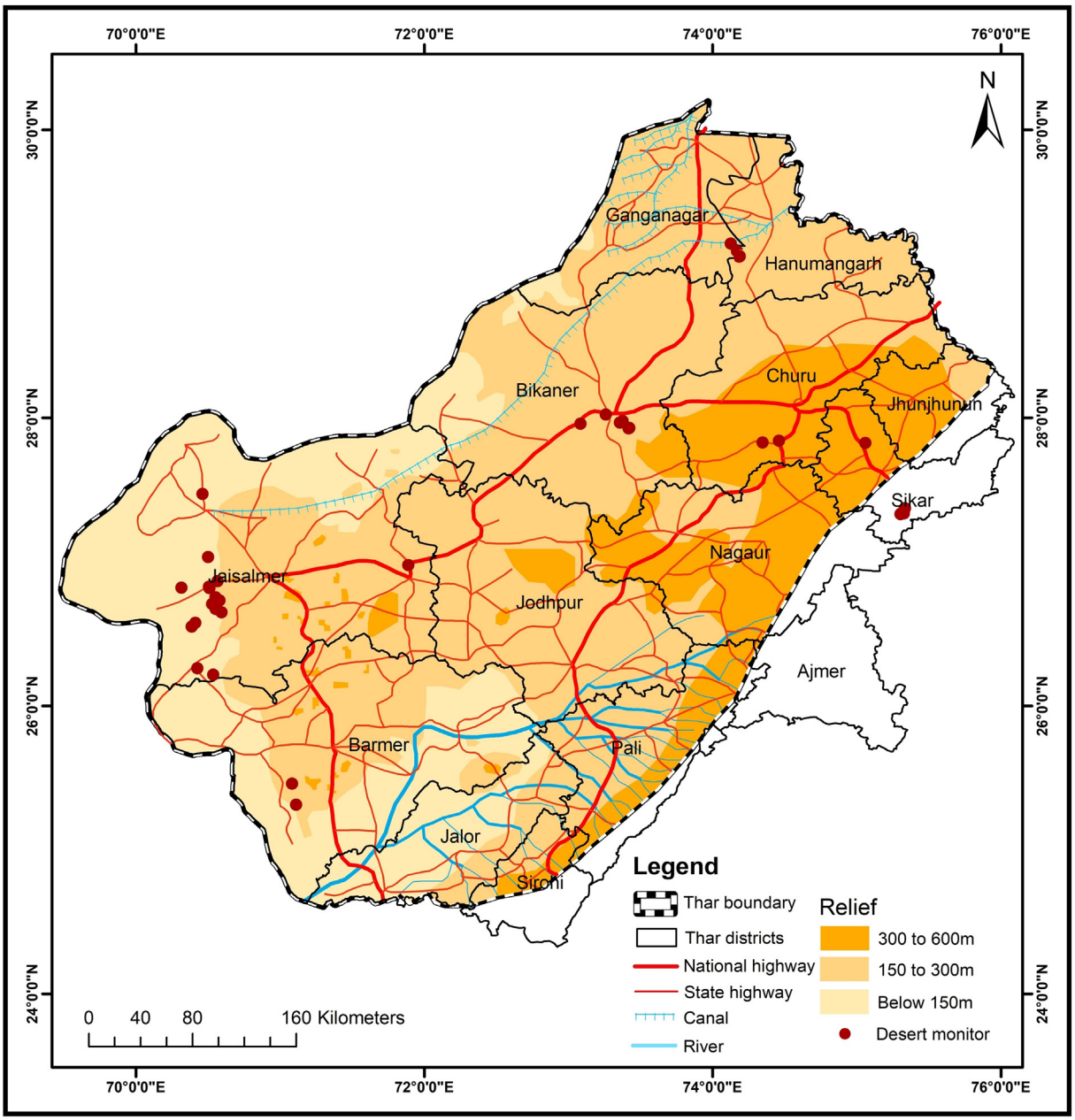

Fig. 1. Distribution of Indian desert monitor lizard in the TDR.

species. Field data on habitat, microhabitat, and activity time of the species collected through all the methods was taken into consideration for analysis. For the activity budget, 'focal animal' sampling (Altmann, 1974) was followed during which observations were repeated in every minute. At places where possible, 'ad libitum' sampling (Altmann, 1974) was also followed to document other ecological information. Associated reptile taxa and plant species were identified in the field using the manuals of Daniels (2002) and Bhandari (1990) respectively.

3. Results

3.1. Taxonomy

The study revealed the Indian desert monitor lizard is sandy or brownish-yellow in color, frequently having a grey tinge on the head, abdomen, and tail. (Fig. 2 A-E; Fig. 3 A,C; Fig. 5; Fig. 8 C,D; Fig. 13 A-E; Fig. 14). They were found to be polymorphic, and three types of body markings were noticed among members of the species viz. bands, dots, and blotches (Fig. 2 B-E, Fig. 3 C; Fig. 5; Fig. 8 C,D; Fig. 13 A,B,E; Fig. 14). Adults and subadults were found to be larger in size, dull in color, and without or with light or indistinct body markings (Fig. 2 A-C; Fig. 3 C, Fig. 5; Fig. 8 C,D; Fig. 13 A,B, E; Fig. 14), whereas juveniles were smaller in size, brighter in color and with prominent body markings (Fig. 2 D,E). They possess a pair of dark streaks in their temporal region extending between eye and nape (Fig. 2 D,E; Fig. 3 A; Fig. 5; Fig. 13 C; Fig. 14).

The study also revealed they possess the following taxonomic features important to identify them in field viz., the tip of the snout depressed, the nostril is very close to eye i.e., the distance from nostril to eye is from 28 to 40% of the distance from nostril to tip of snout, and the tail is completely round throughout its length (Fig. 3 A-C). It is worthy of mention here that by the above-mentioned characters, the species can be clearly delaminated in

Fig. 2. Morphological variations of Indian desert monitor lizard, A-C: adult and subadult; D-E: juvenile.

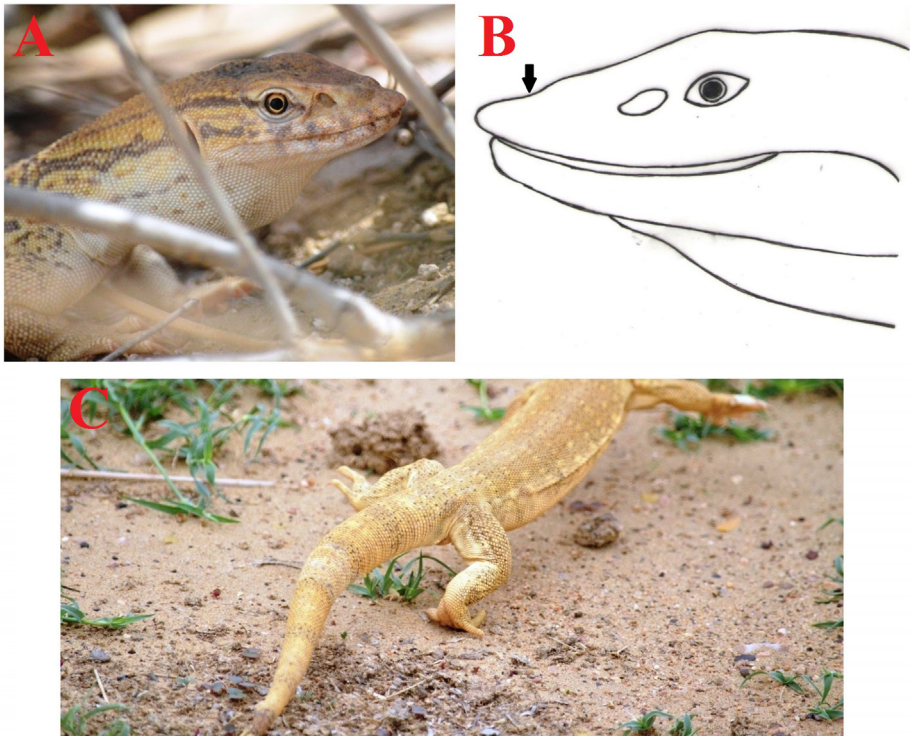

Fig. 3. Body parts of Indian desert monitor lizard, A,B. Head (snout tip is marked with arrow); C. Tail.

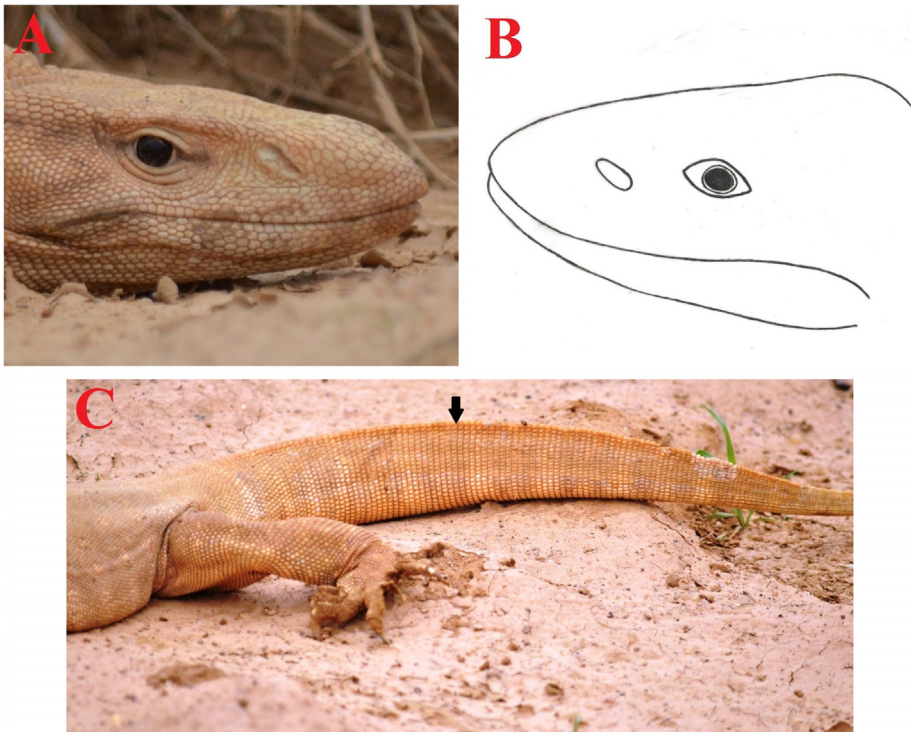

Fig. 4. Body parts of common monitor lizard, A,B. Head (snout tip is marked with arrow); C. Tail (longitudinal ridge marked with arrow).

Fig. 5. Abnormal tail tip (marked by arrow) in Indian desert monitor lizard.

the field from common monitor lizard with which it coexists in the desert. In the later species the tip of the snout is convex, the nostril not very close to eye (nearly at mid position, as the distance from nostril to eye is between 40 and 50% of the distance from nostril to tip of snout) and the tail bears double-toothed longitudinal ridge on dorsum (Fig. 4 A-C). Interestingly, in one individual of desert monitor lizard, an abnormal tail tip was observed (Fig. 5).

Further, in the Indian desert monitor lizard, scales at the mid-body were found to be in 118–128 transverse rows. Their ultra-structure through SEM imaging revealed they possess non-overlapping scales that are encircled by one or more rows of granular scales. Their nuchal scales are oval and separated by multi-layered granular scales, dorsal (abdominal) scales are elongated and separated by multi-layered granular scales, ventral (abdominal) scales are rectangular with slightly blunt caudal edges and separated by a discontinuous ring of granular scales between each longitudinal row of scales, dorsal caudal scales are rectangular with strongly blunt caudal edges and separated by multi-layered granular scales between each longitudinal row of scales, ventral caudal scales are irregular and separated by multi-layered granular scales between each longitudinal row of scales (Fig. 6 A-F).

3.2. Distribution and population status in the TDR

In this study, Indian desert monitor lizard was recorded from seven districts of the TDR viz. Barmer, Bikaner, Churu, Ganganagar, Hanumangarh, Jaisalmer, and Sikar districts, (Fig. 1). Population density of the species was found to be highest in Jaisalmer (0.102/ha) followed by Bikaner (0.080/ha), Sikar (0.077/ha), Barmer (0.058/ha), Ganganagar and Hanumangarh (0.044/ha each), and Churu (0.033/ha) districts. Overall density was found to be 0.068/ha. (Fig. 7).

3.3. Ecology

3.3.1. Habits

The species is diurnal, burrowing, and in many parts of the TDR coexist with the common monitor lizard, but their burrows were found at least 100–500 m away from burrows of common monitor lizard. Their burrow openings were nearly round (Fig. 8A), semi-circular, slightly oval or irregular (Fig. 8B) in shape, and most of the burrows were observed near vegetation. They regularly scan their surrounding from their burrow just keeping their head at the level of burrow opening (Fig. 8 A,B) and hence, not easily traced in the field. It was also noticed they at times change their burrow and sometimes use rodent burrows. They are shy, highly sensitive, and with slight disturbances, try to escape into nearby bushes or burrows. They don't maintain strict homing instinct and choose any burrow during such conditions. If failed to escape, they tend to display an inflated throat with arching of back and tail above ground and start hissing (Fig. 8 C). At extreme conditions of danger, they display self-defence by opening their mouth wide (Fig. 8D)

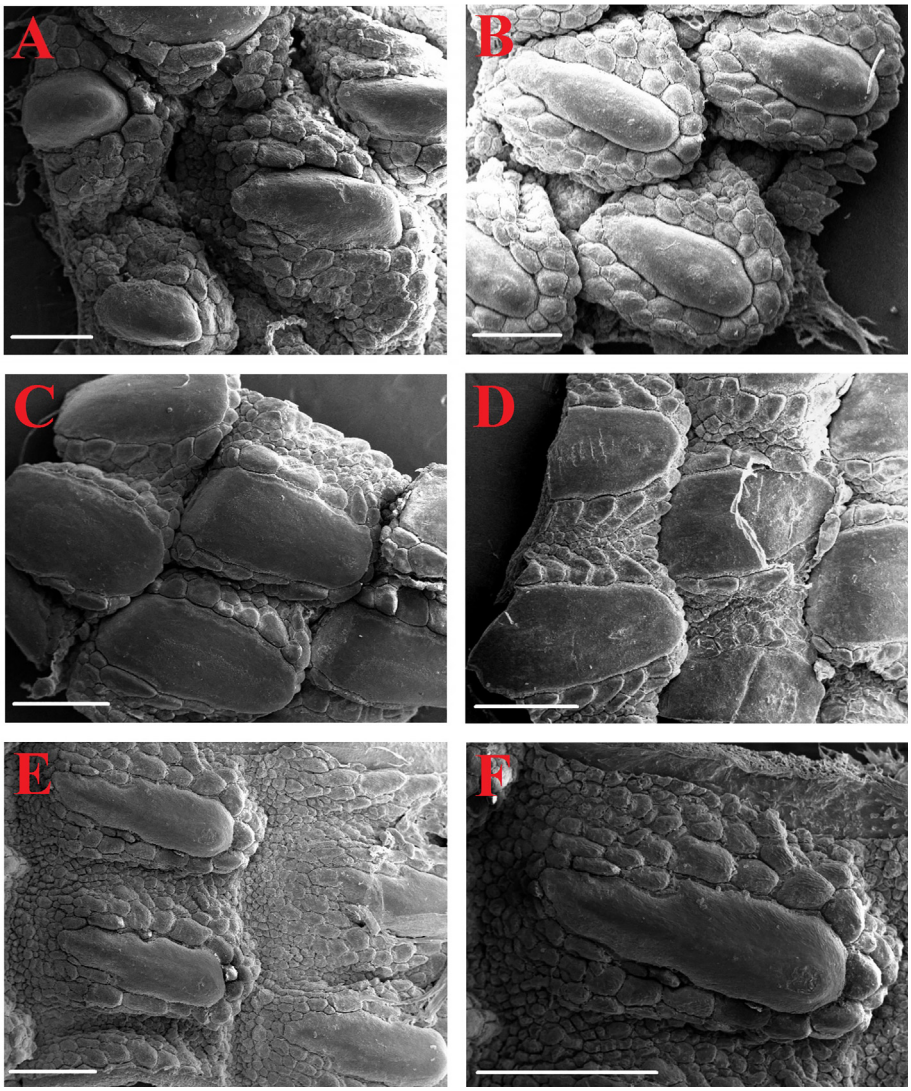

Fig. 6. Scale microstructure of Indian desert monitor lizard through SEM, A. Nuchal scales; B. Dorsal (midbody) scales; C. Ventral (midbody) scales; D. Dorsal caudal scales; E. Ventral caudal scales, F. Same, enlarged (Scale A-F = 400 μm).

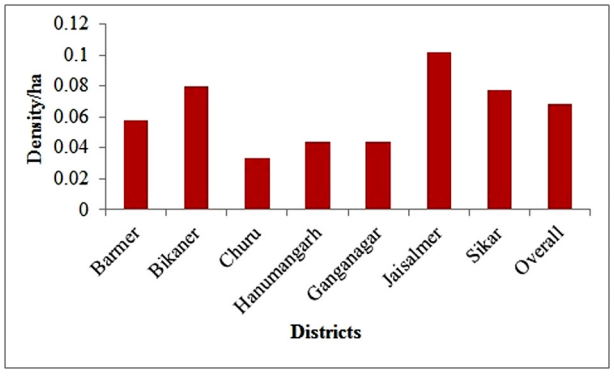

Fig. 7. Population density of desert monitor lizard in the TDR (N = 64).

3.3.2. Habitat and microhabitat

In the TDR, out of six types of reptilian habitats viz., sandy (sandy plains or sand dunes with or without vegetation), gravelly (gravelly plains with or without vegetation), wetland (habitats within 1 km radius of water body), habitat influenced by humans (habitats within 1 km radius of human settlements or agricultural fields), saline (saline depressions with or without vegetation) and rocky (rocky terrain), the species was observed in first four habitats (Fig. 9 A-F). Sandy habitat was found to be the most preferred. All their habitats were found to be associated with sand dunes, i.e., they live in the interdunal area, or their habitats are located adjacent to or nearby sand dunes (0–3 km range). Other herpetofauna that were observed in their habitat is *V. b. bengalensis, Saara hardwickii, Trapelus agilis, Calotes versicolor, Bufoniceps laungwalaensis, Ophiomerous raithmai, Acanthodactylus cantoris, Ophisops jerdoni, Hemidactylus brookii, Eryx johni, Coluber ventromaculatus* and *Bufo stomaticus.* Common vegetation observed in their habitats in Bikaner and Jaisalmer districts is given in Table 1.

Four microhabitats were recorded for Indian desert monitor lizard in the TDR viz. Bare ground (BG), Grass clump (GC), On stones (OS) and Under bushes (UB). Bare ground was found to be the most preferred followed by under bushes (Fig. 10).

3.3.3. Daily activity

They have a wide home range and can move 500 m to 1 km from their burrow during daily activity. Their activity was found to be highest between 9-12 hrs followed by 12–15 hrs as revealed from their sightings (Fig. 11).

Fig. 8. Common body postures of Indian desert monitor lizard, A.B. Scanning of surrounding from burrow; C.D. Self-defence postures.

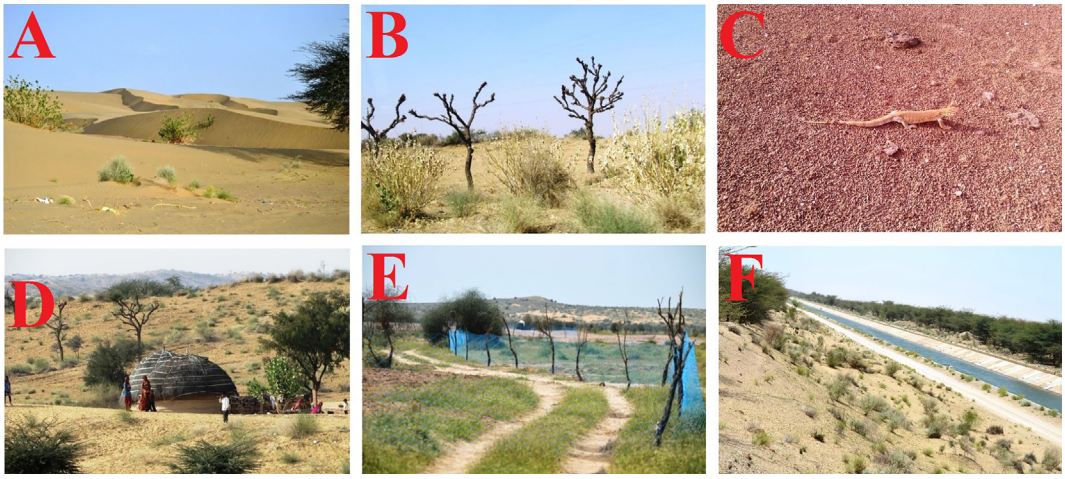

Fig. 9. Habitats of Indian desert monitor lizard in the TDR, A,B. Sandy, C, Gravely, D,E. Habitats influenced by humans, F. Wetland.

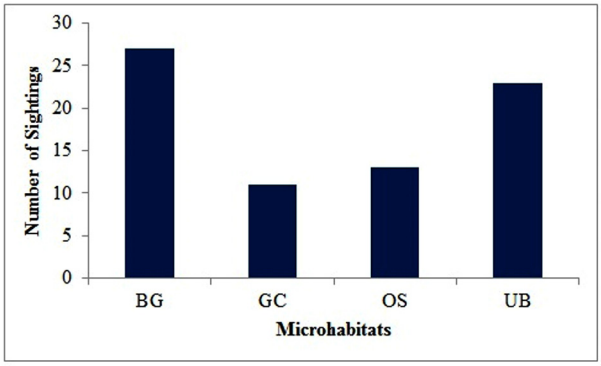

Fig. 10. Microhabitat use by desert monitor lizards in the TDR.

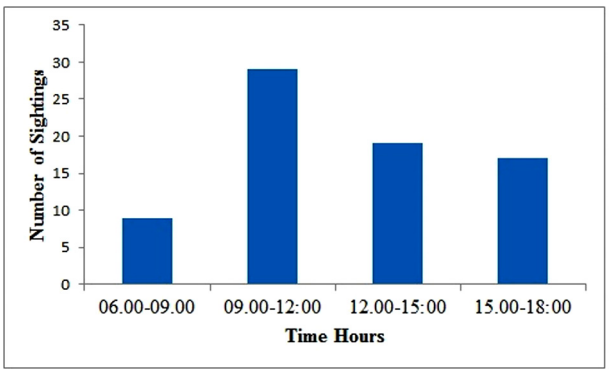

Fig. 11. Activity period of desert monitor lizards in the TDR.

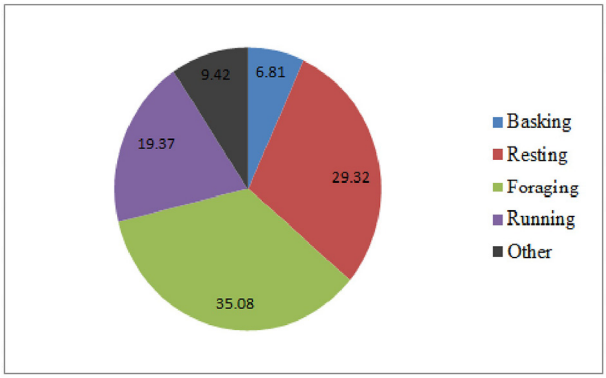

Fig. 12. Activity budget (in %) of desert monitor lizards in the TDR.

Their activities were classified into five categories i.e. basking (lying in the sun in the open area without moving any part of the body), resting (sitting in the shade to avoid direct sun), foraging (actively searching for food or feeding), running (escaping for the retreat) and others (snout beating, head puffing or hissing in still condition). Foraging was found to be predominant activity followed by resting and feeding (Fig. 12).

3.3.4. Food and feeding

They are active foragers. Outside their burrow, they actively search their food on the ground and burrows of other animals (Fig. 13 A-C). But to predate larger active prey like rodents or lizards, they keep on watching the prey by half emerging from their burrows and laying their body low on the ground behind vegetation or stones and catch it by suddenly rushing it (Fig. 13 D-E). The species found to be fed upon a variety of animal diets viz. beetles (Fig. 13 C), lizards (Fig. 13 E), mole (Fig. 13 F), rodents, grasshoppers, flies, and spiders, but beetles found to be the predominant diet for the species throughout the year as revealed from direct field observations and gut content analysis of road accident specimens. Apart from beetles, juvenile of the Indian spiny-tailed lizard was found to be one of their common diet (Fig. 13 E).

3.3.5. Predators and scavengers

At one instance, one black kite attempted to predate one juvenile of this species, but the lizard suddenly escaped into the nearby bushes. Their dead bodies were found to be scavenged by Egyptian vultures, common crows, and feral dogs. Beetles and ants were found to be associated with their dead bodies.

3.3.6. Sloughing

During the study, sloughing of body skin in pieces was observed in some individuals (Fig. 14).

4. Discussion

4.1. Taxonomy

The present study brought into knowledge many morphological variations for the Indian desert monitor lizard. The study also

Fig. 13. Foraging and food of Indian desert monitor lizard, A. Actively foraging posture; B. Searching rodent burrows; C. Feeding on beetle; D. Watching the active prey in a still condition; E. Feeding on the Indian spiny-tailed lizard *Sarra hardwickii*; F. Mole *Suncus murinus* in the gut content.

Fig. 14. Sloughing in Indian desert monitor lizard.

revealed many taxonomic features, i.e., shape of the snout tip, position of nostril, and tail shape by which this species can be clearly identified in the field through careful observation. These features are in accordance with findings by Smith (1935), Minton (1966), and Sharma (2002).

In reptiles, the scale number, their microstructure, and arrangement is used for species delamination as these traits are species-specific and stable (Landmann 1986; Pianka and Vitt 2003; Bucklitsch et al., 2016). In this study, the number of scales at the midbody of the Indian desert monitor lizard is within the range given by Smith (1935), Minton (1966), and Sharma (2002). Scales also show regional specificity that depends on the specific environment to which they adapt, and hence, intraspecific variation exists across different geographical regions (Chang et al., 2009; Bucklitsch et al., 2016). Bucklitsch et al. (2016) have studied the scale microstructure of monitor lizards and their allies, but their study lacks intraspecific variation of most of the species, including the Indian desert monitor lizard. They have studied the scale microstructure of Indian desert monitor lizard from a specimen from Karachi, Pakistan. This study, first time, brought into knowledge several intraspecific variations of scale microstructure of Indian desert monitor lizard viz., nuchal scales are widely separated by 3–6 layers of granular scales vs. 1–3 layers in the specimen from Pakistan, ventral (abdominal) scales are with slightly blunt caudal edges vs. strongly blunt caudal edges in the specimen from Pakistan, dorsal caudal scales are widely separated by 5–6 layers of granular scales vs.1–2 layers in the specimen from Pakistan (Bucklitsch et al., 2016). Interestingly, the study also revealed that ventral caudal scales are well differentiated from dorsal caudal scales in their shape and arrangement that is not observed in the study by Bucklitsch et al. (2016) and subjected to further investigation.

Abnormal tail tip as observed during the study points towards accidental healing of injured tail tip because tail regeneration is absent among large-bodied lizards like Varanids (Arnold, 1984; Bateman and Fleming, 2009). However, this assumption is subjected to further investigation.

4.2. Population status and distribution in the TDR

The study confirmed that the Indian desert monitor lizard survives in a wider part of TDR in comparison to its previous reporting in the area by Dave (1961), Sharma (1996, 2002), Das (2005, 2007), Gala and Khandal (2010), Gaur et al. (2013), and Solanki et al. (2015). Population density shows the main population of this lizard is confined to Jaisalmer district of western Rajasthan and overall population of the species is quite low in the study area. The findings are in accordance with Minton (1966), who has reported that this species is not common like the common monitor lizard in desert areas of Pakistan. It is worthy of mentioning here that currently, the species is facing various threats in the form of poaching, illegal trade, and large-scale habitat alteration and degradation due to increasing anthropogenic activities in the entire TDR (Joshi et al., 2019). Recent studies by Hashmi et al. (2013) have also revealed that the species at present faces various threats, and its population is also quite low in desert areas of Pakistan. Hence, the conservation of this species is of high concern in its current distribution.

Table 1
Associated vegetation in habitat of Indian desert monitor lizard in TDR.

S. No.	Scientific Name	Local Name	Bikaner	Jaisalmer
	Leptadenia pyrotechnica	Khimp	+	+
	Aerva persica	Bui	+	+
	Crotalaria burhia	Saniya	+	+
	Calotropis procera	Aak	+	+
	Prosopis juliflora	Vilayti Kikar	+	+
	Ziziphus nummularia	Ber	+	+
	Corchorus depressus	Bahuhali	+	–
	Heliotropium marifolium	Choti santri	+	–
	Dactyloctenium sp.	Dub	+	+
	Capparis decidua	Ker	+	+
	Salvadora persica	Khara Jaal	+	+
	Fagonia schweinfurthii	Dhamasa	+	–
	Lasiurus scindicus	Sevan	+	+
	Tribullus terrestris	Gokhru	+	+
	Citrullus colocynthis	Tumba	+	+
	Calligonum polygonoides	Fog	+	+
	Indigofera linnaei	Leel	+	–
	Cyperus sp.	Mothiya	+	+
	Corchorus tridens	Jute	+	–
	Sueda fruticosa	Jaal	+	+
	Prosopis cineraria	Khejri	+	+
	Parthenium hysterophorus	Gajar ghaas	+	–
	Solanum surattense	Ringni	+	–
	Euphorbia sp.	Thor	+	+
	Cucumis callosus	Kachar	+	–
	Lycium barbarum	Chiritta	+	+

Note: +=Present; – =Absent.

4.3. Ecology

The coexistence of the Indian desert monitor lizard with the common monitor lizard and its preference for sandy habitats over other habitats in the desert environment is in accordance with findings of Minton (1966) and Auffenberg (1990). The study revealed this species frequently change its burrows, which is supported by similar findings by Vernet (1982) and Ibrahim (1997). Self-defence postures and behavior, as revealed in this study, are in accordance with findings by Tsellarius and Tsellarius (1997).

During this study, Indian desert monitor lizard was observed in four habitats and not noticed in rocky and saline habitats in which common monitor lizard was found. Sandy habitat was found to be most preferred, which is in accordance with findings of Minton (1966) and Auffenberg (1990), who from their study have revealed that Indian desert monitor lizard prefers sandy tracts over other habitats. Though they were noticed near isolated houses and agricultural fields, they were not found inside cluster settlements, unlike common monitor lizards, which is subjected to further investigations. This study also provides an elaborated list of plant species and associated herpetofauna in the habitat of this species in the TDR that will no doubt help to understand the biotic interaction of this species. Previously, Auffenberg (1990) has provided a list of few plants associated with habitat of this species in India and Pakistan. However, the study by Ibrahim (1997, 2001) has revealed that desert monitor's activity is not confined to a particular vegetational type, especially when foraging.

The species was also observed in four microhabitats and not noticed in several other microhabitats like under rocks, under logs, crevices, on walls (of houses or water tanks) and tree-trunks in which common monitor lizard was sighted. Sharma (2002) has reported that Indian desert monitor lizard is not a good climber and swimmer, and probably this is the reason the species was not sighted on walls and tree trunks. Overall findings of this study show that Indian desert monitor lizard lives in a narrow range of habitats and microhabitats unlike common monitor lizard and hence, this species is habitat specialist, unlike common monitor lizard.

The study further revealed that this species has a wide home range, which is supported by similar reporting by Vernet (1982), Tsellarius and Men'shikov (1994), and Ibrahim (2002). Their maximum activity was found to be between 9–12 hrs, which is with accordance in Ibrahim (2002).

The mode of foraging of this species is in accordance with findings of Pianka et al. (2004), Tsellarius et al. (1997), and Tsellarius and Tsellarius (1997). The diet of this lizard, as revealed in this study, is in accordance with Corkhill (1928), Dave (1961), Auffenberg (1990), and Tsellarius et al. (1997). This lizard feeding upon Indian spiny-tailed lizard is also earlier reported by Auffenberg et al. (1990), and Ramesh and Ishwar (2008).

Sloughing was noticed in this lizard, which is common among squamates (Doneley, 2018; Chang, 2009). According to Chang (2009), reptile scales continuously interact with their harsh terrestrial environment producing wear-and-tear and episodic shedding of their skin maintain their epidermis intact, replacing worn skin.

5. Conclusion

This study brought into knowledge many morphological variations of Indian desert monitor lizard by which the species can be identified in the field through careful observation. Through this study, many intraspecific variations of scale microstructure first time came to be known that will no doubt help to understand the regional specificity of the species across different geographical regions. This study is also a pioneer attempt to bring into knowledge the population status of this species in the TDR and revealed currently the main population of this lizard is confined to the Jaisalmer district of western Rajasthan. Its overall population was found to be quite low in the study area. The study further revealed that the species is habitat specialist and lives in a narrow range of habitats and microhabitats. Hence, the species may not adapt to the rapidly changing environment in the TDR. In the absence of any detailed study on this lesser-known species, the study points towards immediate conservation efforts for the species in its current distribution. Baseline data generated through this study will no doubt help to safeguard the species in the TDR and further research on this species in the future.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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