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Diversity and Distribution of Lizards (Reptilia: Sauria) in District Muzaffarabad, Azad Jammu and Kashmir (Pakistan)

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ABSTRACT

Lizards belong to a highly important group of vertebrates as predators of insects, parasitic/harmful to the humans, livestock and plants. They are prey of many other vertebrates and are considered as indicators of habitat quality and perturbation due to their high sensitivity to even small changes in the temperature, precipitation and light. However, they have been given least importance and are least studied, especially in the state of Azad Jammu and Kashmir (AJ K). Keeping this in view, we assessed the abundance, diversity and distribution of lizards in different localities of district Muzaffarabad, AJK during July 2018 to July 2019. We carried out field surveys in 44 selected study sites during summer (April – October) and winter (November–March). Standard visual encounter surveys and opportunistic spotting techniques were applied for data collection during transect walks in different microhabitats of lizards. Twelve species of lizards were recorded belonging to eight genera and five families. Oriental garden lizard *Calotes versicolor* was the most abundant species, while leopard gecko *Eublepharis macularius w*as the least abundant species in the study area. The species abundance of lizards was significantly different among different localities (χ^2=97.406, df=9, p<0.001), habitats (χ^2=1173.01, df=8, p<0.001) and elevation ranges (χ^2=1018.902, df=8, p<0.001). Yellow-belly gecko *Hemidactylus flaviviridis,* Brooke's or spotted house gecko *H. brookii,* Kashmir rock agama *Laudakia tuberculata* and *Calotes versicolor* were found to be distributed in all localities of the study area, while no species was recorded to be distributed in all habitats of the study area. Species richness also varied significantly among localities and habitats. The highest species richness (n=9) was recorded each in Gojra, Bheri, Machiara, Kaimanja and Danna near the human settlements (n=6). Similarly, the species diversity was the highest in Danna (H' = 1.76) near the human settlements (H' = 0.69). The findings of this study uncovered the first ever important baseline about the diversity and spatial distribution of lizard fauna of the study area. This baseline study could be used for in depth explorations in herpetology and may help in formulating lizard conservation strategy in the area.

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GA conducted fieldwork, data collection, and analysis. RAM supervised the study and revised the manuscript. UA assisted in data interpretation. SR and SK contributed to literature review and manuscript preparation.

Key words
Diversity, spatial distribution, lizard habitat

INTRODUCTION

Lizards belong to a diverse group of squamate reptiles in suborder Sauria, having more than 6000 species, that are distributed in all continents of the world except Antarctica, as well as most of oceanic islands (Pough *et al*., 2004). Lizards show enormous variation in their morphology for adaptations in a great variety of terrestrial and arboreal habitats (Khan, 2003; Hickman *et al*., 2007; McDiarmid *et al*., 2012). Major groups of lizards include monitor lizards, skinks, chameleons, iguanas, agamas, geckoes, etc. (Miller and Harley, 2010). Most of the lizards are non-venomous, except the beaded lizard (*Heloderma horridum*) and the gila monster (*Heloderma suspectum*) of North America (O'Shea and Halliday, 2001). Pakistan has a diverse and widely distributed non-venomous lizard fauna that is significantly characterized in various herpetological collections (Khan, 1999, 2000).

The number of lizard species reported from different areas of Pakistan has gradually arisen from Minton's (1966) description of 65 species to Merterns (1969) 82 species; a bit later Khan (1980) recorded 88 species, while the latest study revealed 109 species and subspecies from all over the country (Khan, 2003). Lizards from Pakistan belong to 37 genera and eight families, inhabiting all biotopes of the country (Khan, 2003).

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Lizards are indicators of both habitat quality and perturbation as they are sensitive to even small changes in the temperature, precipitation and light (Heyer *et al*., 1994; Ferguson and Pilgrim, 2009; IUCN, 2009; Relox *et al*., 2010). They are important predators of most of the insects, parasitic/harmful to the livestock. They control different seed eating insects and other arthropod predators found in their habitats (Msindai, 2014). Studies highlighted that fossorial lizards are important in ventilating the soil and nutrient cycling in the ecosystem (Channing and Howell, 2006; Ferguson and Pilgrim, 2009). They are also an important part of the rural economy (Kabigumila, 1998), not only as a source of medicine and raw material but also in terms of ecological equilibrium. For instance, geckos provide greater ecological importance and role in preventing mosquito plagues. Some lizards are also significant for drug (Schnurr, 2006) and leather industries due to use in medicine and as a source of skin, respectively. Both, legal and illegal trades exist among countries and may cause extirpation of various species. In recent years, lizards have become popular as family pets in some areas of Europe and America (West, 2009). Additionally, lizards and some other reptiles and amphibians also contribute to the economy of the country through tourism attractions and various kinds of products are sold as tourist curios.

Although, 109 species and subspecies of lizards from different areas of Pakistan, his most of the work was carried out beyond the State of Azad Jammu and Kashmir (AJK), which has a credible altitudinal and habitat range. A misconception about the poisonous nature of lizards leads to unnecessary killing of different lizards in rural communities (Pres. Observ.). Leopard gecko considered as the most venomous among lizard species, however its bite is incurable. Present study aimed to document the diversity and distribution of lizard fauna of district Muzaffarabad, AJK. Objectives of this study included enlisting of lizard species, estimating their abundance and exploring the spatial patterns of their distribution in different localities of district Muzaffarabad.

MATERIALS AND METHODS

Study area

Muzaffarabad, capital of the state of AJK, lies in the western Himalayan range between latitude 34º 03'–34º 35'N and longitude 73º 23'–73º 45' E, with a land area of 1642 km^2. The elevation ranges from 582 m in the southern part (Kohala) to 4733 m in the north (Gunja Mountain). Muzaffarabad district is bordered by District Jhelum Valley on the east, District Neelum on the northeast, Hazara division of Khyber Pakhtunkhwa on the north and northwest, and District Bagh on the south, and Murree hills (Punjab) in the southwest (Fig. 1). Topographically, the area comprises mountains with steep slopes, the area stretches from subtropical valleys to the typical Himalayan mountains in the north. The area is bestowed with thick Himalayan mixed coniferous forests, rivers (the Jhelum and the Neelum) and their tributary streams. The climate of the study area is subtropical to temperate. The mean minimum and maximum temperatures are recorded as 3.1 to 37.4°C in the months of January and June respectively. The mean annual rainfall varies between 1000–1300 mm, of which approximately 680 mm falls during the four months (i.e., May to August). The snow line in winter months remains around 1200 m, while in summer months, it ascends to 3300 m above sea level (Minhas *et al*., 2010; Qasim *et al*., 2010a, b; Anonymous, 2015; Khan *et al*., 2018).

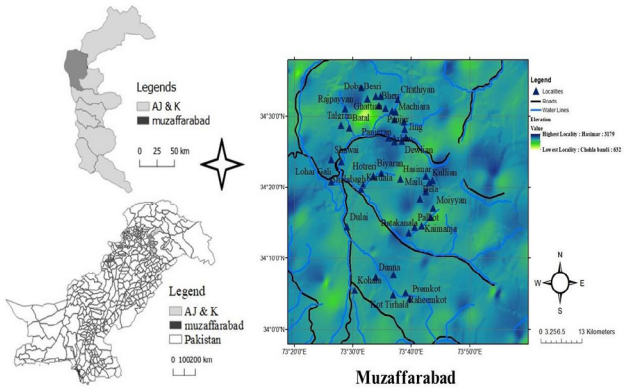

Fig. 1. Location map of Muzaffarabad district (Azad Jammu and Kashmir, Pakistan).

The important vegetation includes, *Pinus wallichiana, Taxus wallichiana, Cedrus deodara, Picea smithiana, Abies pindrow, Pinus roxburgii,* etc. while, important wildlife species include *Panthera uncia*, *Panthera pardus*, *Ursus thibetanus*, *Capra ibex, Semnopithecus ajex*, *Tragopan melanocephalus*, *Lophura leucomelanos*, *Tetraogallus himalayensis, Lerwa lerwa* and *Gyps himalayensis* (Minhas *et al*., 2010).

Site selection

We assessed the species richness, abundance, and distribution of lizards across 44 sampling sites within 10 major localities in the Muzaffarabad district: Panjkot (altitude 1670–2967 m), Panjgran (altitude 1011–1109 m), Bheri (altitude 1740–2970 m), Machiara (altitude 1609–1987 m), Sarlisacha (altitude 1421–2415 m), Talgran (altitude 971–1831 m), Gojra (altitude 632–1121 m), Langerpura (altitude 852–3179 m), Kaimanja (altitude 1391–2571 m), and Danna (altitude 639–1971 m) (Fig. 1). These sites represent nine different habitat types: human

settlements, agricultural fields, parks, stream sides, grass fields, cliffs, forests, sub-alpine scrub and alpine meadows. The localities were selected based on their potential habitats and the geographical features of the region, with input from local villagers. Each locality represents a distinct combination of ecological zones and altitudinal gradients within the study area, providing a diverse set of environments for studying lizard diversity.

We conducted surveys at each sampling site twice during summer (April–October) and once during winter (November–March) from July 2018 to July 2019. The field visit durations varied from three to five days per site, with each survey session consisting of nine field hours (morning: 0800–1100, afternoon: 1300–1600, and night: 1900–2200). To assess lizard diversity, we used the standard visual encounter survey (VES) technique during transect walks to record the presence/absence and abundance of lizards, following Crump and Scott (1994). All suitable habitats and elevation ranges, at the sampling sites were surveyed through random walks for a predefined duration (3 h per session), excluding time spent collecting habitat information or taking photographs.

Transect design

Transects of varying length and width were employed to account for the heterogeneous landscape of the Muzaffarabad district. Transects were designed with lengths ranging from 800 m to 3000 m, depending on the habitat type and the specific features of the landscape (e.g., rugged terrain or open areas). The width of the transects was set to 10 m, with a belt transect method (5 m on each side of the central line) used for consistency in sampling. Transects were spaced approximately 1000 m apart to minimize overlap and ensure independent sampling. These dimensions were chosen to ensure adequate coverage of both open areas and more complex habitats, such as rocky outcrops and forest edges.

During the daytime, two transect walks were carried out by three to five persons in each habitat at each sampling site. The team actively searched for lizards along streams, under rocks, within leaf litter, debris, holes and cracks in boulders, between rocks, and in grass (Dar *et al*., 2008; Pal *et al*., 2012; Pradhan *et al*., 2014). Additionally, we searched walls, ceilings of buildings, tree canopies, and bushes near water bodies for wall-dwelling and tree-dwelling species (Naniwadekar and Vasudevan, 2007). One nocturnal transect was searched by three to five people using torchlight while walking at a slow pace to locate nocturnal species (Khatiwada, 2011). Surveys during the winter season were conducted on sunny days to ensure optimal visibility and search conditions.

Opportunistic observations

In addition to transect surveys, some species were recorded through opportunistic sightings, and photographs were taken when possible. A DSLR camera (Nikon D5300 with a Nikkor 70–200 mm lens) was used to photograph species in their natural habitats.

Species identification

Lizards were identified using field guides and reference books by O'Shea and Halliday (2001) and Khan (2014). For further verification, photographs of each specimen were cross-referenced with existing literature, identification guides, and reputable websites.

Local status of species

The local population status of each species was determined based on abundance observed during the field surveys. The following classification criteria were applied: ER is extremely rare (n ≤ 5 individuals); R is rare (n = 6–10 individuals); UC is uncommon (n = 11–20 individuals); C is common (n = 21–50 individuals); A is abundant (n ≥ 50 individuals)

The local status was assigned based on the relative abundance recorded across all sampling sites, providing a contextual understanding of species distribution within the study area.

Use of local knowledge

Information on species occurrence and behavior was supplemented by indigenous knowledge through informal discussions with local inhabitants and experienced villagers. These insights provided valuable context for understanding the lizard populations in the region.

Data analysis

We calculated the lizard fauna diversity, evenness, uniqueness, and similarity across 202 the sampling sites and habitats using the following indices (Rais *et al*., 2015):

Shannon-Weiner Diversity Index $(H') = -\sum p_i (lnp_i)$

Where p_i = relative abundance of the *ith* species;

Evenness Index $(E) = \frac{H'}{\ln(S)}$

Where H' is the Shannon-Weiner Diversity Index and S is the number of species;

Uniqueness index $(U) = \frac{Ur}{R_{tot}}$

Where Ur is the number of species that are unique to a locality and R_{tot} is the total number of species recorded from all localities;

Sorensen's Similarity Index (Sorensen 1948) $CC = \frac{2s}{a+b}$

Where s is the number of species that are shared by the

two sites, *a* is the number of species at sites a, and *b* the number of species at site b. The significant differences in species distribution pattern among different localities, habitat types, and elevation ranges, was evaluated by Chi Square (χ^2) Test, using MS Excel 2016.

RESULTS

We recorded a total of 1010 lizard specimens belonging to 12 species and five families from different study sites in district Muzaffarabad (Table I).

Table I. List of Lizard species recorded from district Muzaffarabad, with their families, common names, zoological names, local and IUCN Status.

Families/ Common names (Zoological names)	Local status	IUCN status
Geckonidae		
Yellow-belly wall gecko (*Hemidactylus flaviviridis*)	A	NE
Spotted barn gecko (*Hemidactylus brookii*)	A	NE
Tree bark gecko (*Hemidactylus leschenaultii*)	ER	NE
Batura glacier gecko (*Altigekko baturensis*)	ER	NE
Eublepharidae		
Leopard gecko (*Eublepharis macularius*)	ER	NE
Agamidae		
Himalayan agama (*Paralaudakia himalayana*)	ER	NE
Small-scale rock agama (*Paralaudakia microlepis*)		NE
Kashmir rock agama (*Laudakia tuberculata*)	A	NE
Spiny-head rock agama (*Laudakia nupta*)	C	NE
Oriental garden lizard (*Calotes versicolor*)	A	NE
Varanidae		
Bengal monitor (*Varanus bengalensis*)	ER	NE
Scincidae		
Himalayan ground skink (*Scincella himalayana*)	C	NE

ER, extremely rare; R, rare; UC, uncommon; C, common; A, abundant.

Distribution among different habitats

The lizards were recorded to exist in nine different habitats of Muzaffarabad district. Human settlements were recorded as enriched habitat comprising 40.4% (*n*=408) of total lizards, followed by cliffs (*n*=185; 18.4%), grass fields (*n*=153; 15.2%), while the lowest number (*n*=7; 0.7%) was recorded both from sub-alpine scrub and alpine meadows (Table II). Human settlements were recorded as the most species rich habitat having 50% (*n*=6) of the total species recorded, followed by grass fields and stream sides (*n*=5; 41.6%), whereas alpine meadows were the least diverse habitat inhabited by a single (8.3%) species (Table II). Abundance of lizards varied highly significantly (χ^2=1173.01, df=8, p<0.001) across different habitats of the study area (Table II). Species diversity among the different habitats varied from 1.134 (stream sides) to 0 (forests and alpine meadows), evenness fluctuated between 0.98 (sub-alpine scrub) to 0.10 (park). The two habitats with the highest similarity (1.00) were forests and alpine meadows, while parks and grass fields had the lowest similarity (0.20). It was found that none of the habitats had any species uniqueness except human settlements with 0.25 uniqueness index (Table II).

Distribution among different localities

We recorded 12 species of lizards from 10 major localities of Muzaffarabad district. The highest number of individuals (*n*=154; 15.25%) was recorded from Danna, followed by Bheri (*n*=144; 14.26%), while the lowest number (*n*=55; 5.44%) was recorded from Gojra (Table III). Gojra, Bheri, Machiara, Kaimanja and Danna were recorded as the most species rich localities with (9; 75%) species, followed by Sarlisacha and Langerpura (8; 66.67%), while Panjgran (4; 33.33%) was recorded as the least diverse locality (Table III). Abundance of lizards varied highly significantly (χ^2=97.406, df=9, p<0.001) across different localities of the study area (Table III). Species diversity among different localities speckled from 1.764 (Danna) to 1.05 (Panjgran), evenness oscillated between 0.85 (Talgran) to 0.57 (Langerpura). The localities with the highest similarity (1.00) were Machiara and Bheri, Kaimanja and Bheri and Kaimanja and Machiara, while Gojra and Talgran had the lowest similarity (0.57). It was found that none of the localities had any uniqueness (Table III).

Distribution along elevation gradient

Lizards were recorded to exist along an altitudinal gradient from 632 m ASL to 3179 m ASL in Muzaffarabad. This gradient was divided into nine elevation ranges to check the variation along different elevations. The highest number of individuals (*n*=339; 33.56%) were recorded

Table II. Lizard diversity attributes recorded for different habitats in district Muzaffarabad during 2018-2019.

Habitats	R	A	RA	H'	E	U	Similarity index							
							AF	PAR	SS	GF	CLF	FOR	SAS	AM
HS	6	408	0.403	0.69	0.38	0.25	--	0.44	--	--	--	--	--	--
AF	2	56	0.055	0.54	0.77	--		0.33	--	0.50	0.33	0.66	0.50	0.66
PAR	4	120	0.118	0.14	0.10	--			0.22	0.20	0.50	--	--	--
SS	5	53	0.052	1.13	0.70	--				0.73	0.66	--	0.28	--
GF	5	153	0.151	0.86	0.53	--					0.60	0.28	0.50	0.28
CLF	4	185	0.183	0.77	0.55	--						--	--	--
FOR	1	21	0.020	--	0	--							0.66	1.00
SAS	2	7	0.006	0.68	0.98	--								0.66
AM	1	7	0.006	--	0	--								
Total	12	1010												

HS, human settlements; AF, agricultural fields; PAR, parks; SS, stream sides; GF, grass fields; CLF, cliffs; FOR, forests; SAS, sub-alpine scrubs; AM, alpine meadows; R, richness; A, abundance; RA, relative abundance; H', shannon-weiner index; E, evenness index; U, uniqueness index.

Table III. Lizard diversity attributes recorded for different localities in district Muzaffarabad during 2018-2019.

Localities	R	A	RA	H'	E	U	Similarity index								
							TLG	BHR	MCH	SS	PJK	PJG	KAI	LNG	DAN
GOJ	9	55	0.05	1.63	0.74	--	0.57	0.66	0.66	0.70	0.75	0.62	0.66	0.94	0.78
TLG	5	74	0.07	1.37	0.85	--		0.71	0.71	0.77	0.83	0.88	0.71	0.61	0.71
BHR	9	144	0.14	1.76	0.80	--			1.00	0.94	0.87	0.61	1.00	0.58	0.88
MCH	9	127	0.12	1.64	0.74	--				0.94	0.87	0.61	1.00	0.58	0.88
SS	8	98	0.09	1.61	0.77	--					0.93	0.66	0.94	0.62	0.82
PJK	7	97	0.09	1.41	0.72	--						0.72	0.87	0.66	0.87
PJG	4	70	0.06	1.05	0.75	--							0.61	0.66	0.61
KAI	9	113	0.11	1.67	0.76	--								0.58	0.88
LNG	8	78	0.07	1.20	0.57	--									0.70
DAN	9	154	0.15	1.76	0.80	--									
Total	12	1010													

GOJ, Gojra; TLG, Talgran; BHR, Bheri; MCH, Machiara; SS, Sarlisacha; Pjk, Panjkot; PJG, Panjgran; KAI, Kaimanja; LNG, Langerpura; DAN, Danna. For other abbreviation see Table II.

Table IV. Lizard diversity attributes recorded for different elevations in district Muzaffarabad during 2018-2019.

Elevation ranges (m)	R	A	RA	H'	E	U	Similarity index							
							900-1200	1200-1500	1500-1800	1800-2100	2100-2400	2400-2700	2700-3000	3000-3300
600 – 900	9	138	0.27	0.27	0.12	0.08	0.88	0.66	0.66	0.66	0.71	0.57	0.18	0.20
900 – 1200	9	153	0.28	0.28	0.13	--		0.80	0.77	0.77	0.71	0.71	0.36	0.20
1200 – 1500	6	87	0.21	0.21	0.11	--			0.80	0.80	0.73	0.73	0.50	0.28
1500 – 1800	9	339	0.36	0.36	0.16	--				1.00	0.71	0.71	0.36	0.20
1800 – 2100	9	249	0.34	0.34	0.15	--					0.71	0.71	0.36	0.20
2100 – 2400	5	24	0.08	0.08	0.05	--						0.60	0.28	0.33
2400 – 2700	6	10	0.04	0.04	0.02	--							0.57	0.33
2700 – 3000	2	8	0.03	0.03	0.05	--								--
3000 – 3300	1	2	0.01	0.01	--	--								
Total	12	1010												

For abbreviation see Table II.

from the 1500-1800 m elevation range, followed by 1800-2100 m elevation range (n=249; 24.65%), while the lowest number (n=2; 0.19%) was recorded from 3000-3300 m elevation range (Table IV). The elevation ranges of 600-900 m, 900-1200 m and 1800-2100 m were recorded as the most species rich with nine (75%) species, followed by 1200-1500 m and 2400-2700 m elevation ranges (n=6; 50%), while 3000-3300 m elevation range with only single (8.33%) species recorded as the least diverse elevation range (Table IV). Abundance of lizards varied highly significantly (χ^2=1018.902, df=8, p<0.001) across different elevation ranges of the study area (Table IV). Species diversity among different elevation ranges varied from 0.36 (1500-1800 m) to 0.012 (3000-3300 m), evenness wavered between 0.16 (1500-1800 m) to 0 (3000-3300 m). The two elevation ranges with the highest similarity (1.00) were 1800-2100 m and 1500-1800 m, while 2700-3000 m and 3000-3300 m had the lowest similarity (0.00). It was found that none of the elevation ranges had any species uniqueness except 600-900 m with 0.88 uniqueness index (Table IV).

DISCUSSION

Twelve species belonging to eight genera and five families were recorded during the study. Agamidae was the most diverse family represented by five species followed by Geckonidae (four species), while Eublepharidae, Varanidae and Scincidae families were represented by one species only. These results are supported by earlier studies on herpetofauna from different parts of Pakistan conducted by Khan (2003), Rais *et al*. (2015), Mohammad (2016), Haider *et al*. (2019), and Faiz *et al*. (2018). They also recorded Agamidae as the most abundant lizard family. Oriental garden lizard was found to be the most distributed lizard species as it inhabited a variety of habitats from low arid climates to high temperate regions of the study area. These findings are also in line with Khan (2014) and Jamal *et al*. (2018) who described this species as the most widely distributed lizard in Pakistan.

Lizards were recorded from nine different habitats of the study area. According to Khan (2003), every habitat anchorages its own uncharacteristic lizard fauna. Human settlements were recorded as the most enriched habitat while the sub-alpine scrub and alpine meadows as the lowest. The highly significant difference (χ^2=1173.01, df=8, p<0.001) among distribution of lizard species across different habitats is indicative of preference of some habitats over the others by lizards. The human settlements were found to be the most diverse habitat in the study area. These habitats harbor a variety of foods for lizards in the form of flying and creeping insects and provide easy living places. Similar findings were also recorded by Pradhan *et al*. (2014), who described that human settlements were the most species-rich and abundant habitats with respect to lizards in Orissa, India. The lowest species richness in sub-alpine scrub and alpine meadows was probably due to harsh environmental conditions and less availability of leaf litter because of comparatively low vegetation cover. Lima and Dill (1990) also recorded a positive correlation of lizards with the leaf litter. Lizards prefer specific habitats which fulfill their demands of food, predator avoidance, thermoregulation and participation in other life activities.

Danna locality was recorded as the most diverse locality of Muzaffarabad, it harbors a great variety of habitats, ranging from lower subtropical sub-humid river sides to high altitudinal moist and mixed temperate forest habitats, providing lizards excellent basking and breeding grounds. Moreover, the human settlements provided suitable hiding places for wall dweller geckos.

Lizards were found to be distributed between 632 and 3179 m ASL in Muzaffarabad. These findings revealed the maximum diversity of lizards at an altitude range of 1500-1800 m ASL.

Species richness decreased from nine species at 600-900 m to one species at 3000-3300 m ASL. Among 12 recorded species of lizards, nine were observed below 1000 m ASL, while only three species (*Altigekko baturensis*, *Paralaudakia microlepis* and *Scincella himalayana*) were observed above this altitude. This is because with increasing elevation, the climatic conditions become harsher, and the availability of food for the lizards decreases sharply. Hence, only a few species of lizards were found at higher altitudes. Similar findings were recorded by Khatiwada (2011) and Jamal *et al*. (2018) from Nepal and Pakistan, respectively.

The study collected first ever baseline data about lizard diversity in the study area. It highlighted the local and international conservation status of different lizard species. These finding will provide an important baseline information for future studies in this unexplored field of biodiversity. This recommends further expansion of research studies on lizards as for most of the areas of AJK, even baseline data on lizard diversity are not available.

DECLARATIONS

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Ethical statement

All field-work and sampling procedures were conducted in accordance with inter-national ethical guidelines for wildlife research. No lizards were harmed dur-ing the study.

Generative AI and AI-assisted technology statement

No generative AI or AI-assisted technologies were used in the design, data collection, analysis, or writing of this study. All work was performed manually by the authors.

Statement of conflict of interest

The authors have declared no conflict of interest.

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