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Occupancy Patterns of *Acanthodactylus cantoris* and *Eutropis dissimilis* in Khyber Pakhtunkhwa, Pakistan

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Muhammad Shehzad: Conducted the field survey, collected data, and data analysis. Abdul Majid and Muhammad Rais: Supervised the research work and provided all the facilitations. Muhammad Shehzad and Muhammad Rais: Drafted and finalized the manuscript. Syed Mohsin Shah, Tauheed Ullah Khan, Waseem Ahmed, and SNK: Assisted in field visits and technical support.

Key words
Canopy, Indian fringe-fingered lizard, Striped grass skink, Sandy patches, Substrate, Southern Khyber Pakhtunkhwa, Occupancy

ABSTRACT

Reptiles, like amphibians, are considered an important indicator of the ecosystems health. They are sensitive to changes in their habitat and are used as model animals to understand ecology. Although some work has been carried out on documentation of the squamate fauna of Pakistan, very little or no attention has been given to assessing the environmental variables influencing their geographic distribution, occupancy, and habitat association. We, therefore, conducted the present study to model occupancy and detection probability of *Acanthodactylus cantoris* (Indian fringe-fingered lizard) and *Eutropis dissimilis* (striped grass skink) and examine site (substrate, canopy cover, distance to nearest wetland) and survey covariates (time of the survey and shrub cover) affecting their occupancy and detection probability in 24 sites of Southern Khyber Pakhtunkhwa, Pakistan. We carried out field surveys from March to May 2023 to collect data on the presence of the species. We ran 32 candidate occupancy models using a package unmarked in R. The top-ranked model estimated that the detection probability of *Acanthodactylus cantoris* was 0.51 ± 0.06 (95% CI 0.38- 0.64), while that of *Eutropis dissimilis* was 0.36 ± 0.08 (95% CI 0.22- 0.54). The model did not include the effect of any observation covariates (i.e. time of survey or shrub cover > or < 25%). The top-ranked model for the occupancy of *Acanthodactylus cantoris* yielded an estimate of 0.75± 0.04 (95% CI 0.006 - 0.89), while *Eutropis dissimilis* yielded an estimate of 0.68± 0.12 (95% CI 0.16- 0.88). The model included the effect (non-significant) of substrate only. The best-fit models for both studied species passed the goodness of fit tests ($P > 0.05$). We suggest carrying out more robust studies incorporating more sites and effects of other survey covariates such as season, observer, and temperature.

INTRODUCTION

With over 6000 species, lizards are a diverse group of reptiles belonging to the Order Squamata (Class: Reptilia) (Uetz *et al*., 2021) and can be found in various habitats worldwide except Antarctica (Cox *et al*., 2022). They play a crucial role in ecological systems, contribute significantly to biodiversity (Vitt, 2021), and are essential components of food webs, serving as both predators and prey, thus influencing population dynamics and energy flow within ecosystems (Zeng *et al*., 2014). In recent decades, a rapid decline in reptilian populations has been reported with at least 1829 out of 10,196 species (21.1%) declared threatened globally due to several threats such as pollution, habitat destruction, and invasive species (Cox *et al*., 2022). Being ectothermic animals, reptiles are particularly susceptible to the impacts of climate change (Biber *et al*., 2023).

Khan (2006) reported 195 reptilian species (23 families) from Pakistan, of which 38 species are endemic.

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There are 14 species of lizards in the Lacertidae and 17 species in the family Scincidae. The Indian fringe-fingered lizard (*Acanthodactylus cantoris*), family Lacertidae (Supplementary Fig. 1A) is a diurnal, ground-dwelling, medium-sized lizard (Sindaco *et al*., 2008). It is widely distributed in the southern regions of Khyber Pakhtunkhwa, Thar, Cholistan, Nara, Chagai, and Kharan deserts (Khan 2006; Shehzad *et al*., 2023). The striped grass skink (*Eutropis dissimilis*), family Scincidae (Supplementary Fig. 1B) is a diurnal, lives in wide, wet grasslands, and also reaches the tilled ground (Minton, 1966). In Pakistan, it is distributed in the Dera Ismail Khan region, along the delta of the Indus River and the salt range (Khan, 1999; Vyas, 2012). The two species have been assessed as the least concern globally (Papenfuss *et al*., 2021; Papenfuss and Litvinchuk, 2021).

Studying occupancy is essential for lizards because it can provide valuable insights into their habitat requirements, distribution patterns, and conservation needs, allowing researchers to identify critical habitat elements, evaluate the impact of habitat loss or fragmentation, and assess the effectiveness of conservation measures, thus fostering a comprehensive understanding that guides more informed and targeted lizard conservation efforts (Prugh *et al*., 2008; MacKenzie *et al*., 2017; Devarajan *et al*., 2020; Tan *et al*., 2023). Since its inception, the occupancy analysis (MacKenzie *et al*., 2003) has been widely used in conservation ecology. The analysis has been used to model the occupancy, detection probability, and habitat preference of various reptiles, especially lizards (Dibner *et al*., 2017; Michael *et al*., 2017; Oliveira *et al*., 2021; Turner *et al*., 2023). Data on the habitat and phylogeny of species *Saara hardwickii* (Indian Spiny-tailed lizard), *Eremias cholistanica* (Cholistan Desert Lacerta), *Heremites septemtaeniatus* (Golden Grass Mabuya) were provided by Ali *et al*. (2020), Masroor *et al*. (2020, 2021). Some work on the squamate fauna of Southern Khyber Pakhtunkhwa (Shehzad *et al*., 2023), Sheikh Buddin National Park (Hamid *et al*., 2021), Cholistan Desert (Ali *et al*., 2021) and Margalla Hills National Park (Masroor, 2011) is available. Balouch *et al*. (2022) examined the effect of landscape composition on the movements of the oriental garden lizard *Calotes versicolor* in agricultural landscapes of north-central Pakistan. Balouch *et al*. (2016) reported *Eutropis dissimilis* as common in the croplands of District Chakwal, Punjab, Pakistan.

However, various aspects of the natural history of several lizard species require research in Pakistan. The current study was, therefore, designed to examine factors affecting occupancy and the detection probabilities of two lizard species viz., Indian fringe-fingered lizard and striped grass skink in southern parts of Khyber Pakhtunkhwa, Pakistan. The findings are expected to expand existing knowledge about the reptilian fauna of the province, contribute new data on the occurrence of these species concerning habitat and site variables, and could be used to develop survey techniques for future population monitoring and abundance assessment for these and similar species.

MATERIALS AND METHODS

Study area

The present study was conducted in the southern part (Districts Kohat, Karak, Hangu, Bannu, Lakki Marwat, Tank, and Dera Ismail Khan) of the Province of Khyber Pakhtunkhwa (KP), Pakistan (Fig. 1). The study area lies between 840 to 174m elevation and covers an area of 24,217 km^2. The latitude and longitude are 33°35_31°51 and 71°26_70°54. The study area features the same climate throughout i.e. semi-arid hot summers and mild winters. The area experienced little monsoon rain in July and August. The minimum and maximum temperature was 5°C and 45°C, respectively. The annual rainfall ranges between 250-300 mm (Ullah *et al*., 2014; Khan *et al*., 2021).

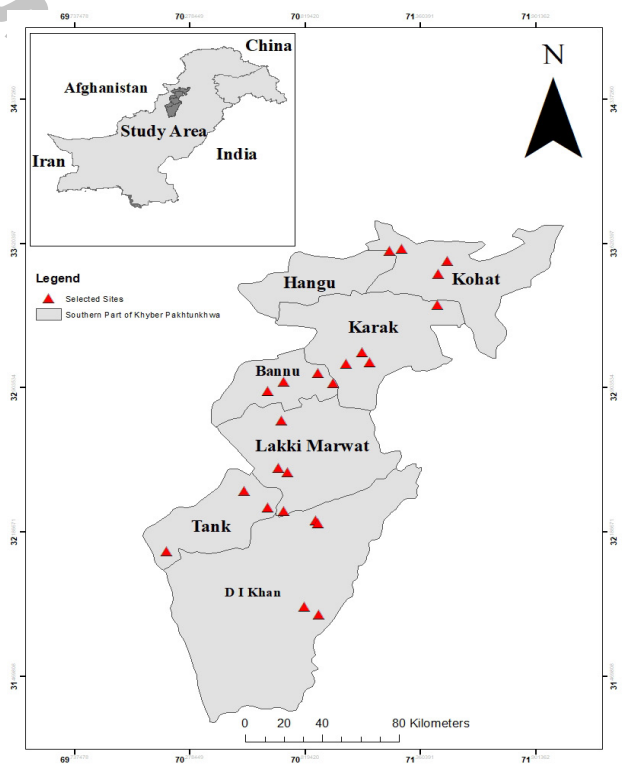

Fig. 1. Map of the study area (Kohat, Karak, Hangu, Bannu, Lakki Marwat, Tank, and Dera Ismail Khan Districts, Khyber Pakhtunkhwa, Pakistan) showing locations of the selected sampling sites.

The study area features a blend of temperate and sub-tropical vegetation. The dominant vegetation consists of *Vachellia modesta, Artemisia maritima, Monotheca buxifolia, Adhatoda vasica, Dodonaea viscosa, Lannea coromandelica, Withania coagulans*, *Eleusine compressa, Chrysopogon aucheri, Cymbopogon jwrancusa,* and *Saccharum spontaneum*. The major crops of the area include maize, rice, wheat, millet, and orchards including guava, mango, apple and peach (Khan, 1999; Ullah *et al*., 2019; Kamran *et al*., 2020).

Survey methods

We conducted field surveys from March 2023 to May 2023 at 24 sites (Fig. 1). The sites were randomly selected based on the available information about the two-lizard species' habitat and distribution (Khan, 2006; Shehzad *et al*., 2023). Each selected site was visited on three occasions with a one-month interval between each visit, to gather data on the presence/absence of the lizard species, the site covariates (substrate, canopy cover, shrub cover, distance to wetlands), and observation covariates (time). At each site, 2-3 transects (length= 500 m, width= 50 m) were laid out randomly. The transects were determined based on habitat distribution if a wetland was present then we selected three transects, if not then two, and walked at a steady slow speed to gather data on the aforementioned variables. The sighted species were identified using Khan (2006). The substrate was coded as 1 for sandy and 0 for clay, 1 if the canopy covers >25 % and 0 if < 25%, 1 if shrub covers >25 % and 0 if < 25%, 1 if a wetland was situated within 50 m and 0 if > 50 m and time was recorded as morning (7:00 am-10:00 am), noon (10:00 am-1:00 pm), and afternoon (1:00 pm-4:00 pm).

Statistical analysis

We ran a full model (~time+ shrub, ~ substrate+ canopy+ wetland) to examine the effect of these observations (time and shrub cover) on detection and site covariates (substrate, canopy cover, and presence of a wetland within 50 m) on occupancy of *Acanthodactylus cantoris* and *Eutropis dissimilis* using package "unmarked" (Fiske and Chandler, 2011; Kellner *et al*., 2023). We used the dredge function of the package "MuMIn" (Barton, 2023) and used AICc to rank the models obtained. The model with the lowest AICc was considered the best-fit model. We used three goodness of fit tests to perform model evaluation: Sum of squared errors, Pearson's Chi-squared, and Freeman-Tukey Chi-squared test ($P > 0.05$ shows good fit) (MacKenzie and Bailey, 2004; Einoder *et al*., 2018). All analyses were performed in R. 4.3.1 (R Core Team, 2020).

RESULTS AND DISCUSSION

We detected *Acanthodactylus cantoris* in 28 out of 72 (38%) sampling occasions during the study period in the selected sites of southern Khyber Pakhtunkhwa. The top-ranked model estimated that the detection probability of *Acanthodactylus cantoris* was 0.51± 0.06 (95% CI 0.38-0.64). The model did not include the effect of any observation covariates (time of survey or shrub cover > or < 25%) (Tables I, II). The naïve occupancy, assuming perfect detection, and the proportion of area occupied by *Acanthodactylus cantoris,* accounting for imperfect detection, was 0.75. The top-ranked model for the occupancy of *Acanthodactylus cantoris* yielded an estimate of 0.75± 0.04 (95% CI 0.006 – 0.89). The model included the effect (non-significant) of substrate only (Tables I, II). The occupancy was higher on the clay substrate (0.99± 0.001).

Table I. Comparison of candidate models for the occupancy model for the Indian fringe-fingered lizard (*Acanthodactylus cantoris*) and striped grass skink (*Eutropis dissimilis*). Only the top five models for each species are given.

	Model	Parameters	logLik	AICc	ΔAICc	Weight
	Acanthodactylus cantoris					
11	psi(substrate) p()	5	-27.485	68.3	0.00	4.93
12	psi(substrate) p(shrub 25%)	6	-26.718	70.4	2.07	0.175
15	psi(substrate+ canopy 25%) p()	6	-27.108	71.2	2.85	0.118
27	psi(substrate+ wetland within 50m) p()	6	-27.146	71.2	2.93	0.114
16	psi(substrate+ canopy 25%) p(shrub 25%)	7	-26.350	73.7	5.40	0.033
	Eutropis dissimilis					
9	psi(substrate) p()	3	-38.489	84.2	0.00	0.253
1	psi() p()	2	-40.248	85.1	0.89	0.162
13	psi(substrate+ canopy 25%) p()	4	-38.090	86.3	2.11	0.088
10	psi(substrate) p(shrub 25%)	4	-38.387	86.9	2.70	0.065
25	psi(substrate+ wetland within 50m) p()	4	-38.446	87.0	2.82	0.062

AICc, akaike information criterion corrected for small samples; ΔAICc, the difference in AICc values between the given model and the model that is most likely to have generated the data (i.e. the one with the lowest AICc).

Table II. Parameter estimates from the top-ranked (based on AICc) for the occupancy model for the Indian fringe-fingered lizard (*Acanthodactylus cantoris*) and striped grass skink (*Eutropis dissimilis*).

Species	Parameter	Estimate	SE	Z	P
Acanthodactylus cantoris	Intercept	-1.65	1.11	-1.49	0.136
	Substrate	11.75	37.94	0.31	0.757
Eutropis dissimilis	Intercept	7.97	30.7	0.260	0.795
	Substrate	-7.76	30.7	-0.253	0.800

SE, Standard error; P, level of significance.

We detected *Eutropis dissimilis* in 18 out of 72 (25%) sampling occasions. The top-ranked model estimated that the detection probability of *Eutropis dissimilis* was 0.36± 0.08 (95% CI 0.22- 0.54). The model did not include the effect of any observation covariates (time of survey or shrub cover 25%) (Tables I, II). The naïve occupancy, assuming perfect detection, was 0.54 while the proportion of area occupied by *Eutropis dissimilis,* accounting for imperfect detection, was 0.68. The top-ranked model for the occupancy of *Eutropis dissimilis* yielded an estimate of 0.68± 0.12 (95% CI 0.16- 0.88). The model included the effect (non-significant) of substrate only (Tables I, II). The occupancy was higher on the clay substrate (0.99±0.01). The best-fit models for both studied species passed the goodness of fit tests ($P > 0.05$).

The present study reports findings on factors affecting occupancy and detection probability of a ground-dwelling lacertid *Acanthodactylus cantoris* and a skink *Eutropis dissimilis*. Shehzad *et al*. (2023) recorded *Acanthodactylus cantoris* along the sandy patches of the river and dunes in southern Khyber Pakhtunkhwa. Balouch *et al*. (2016) reported *Eutropis dissimilis* as common from the croplands of District Chakwal, Punjab, Pakistan.

No similar work is available on these two species; however, habitat association of other reptilian species from elsewhere in the world has been studied. Previously available studies, the Eastern spiny-tailed gecko (*Strophurus intermedius)* in topographically different landscapes in south-eastern Australia (Michael *et al*., 2017), reported the null model as the best-fit model. While some previously available studies (Dibner *et al*., 2017; Michael *et al*., 2017; Oliveira *et al*., 2021; Turner *et al*., 2023). show that the best-fit model had effects of covariates. Our findings show that the two studied species are widespread in the study area. Research on population size, distribution, trends, life history, ecology, and threat assessment of *Eutropis dissimilis* is lacking (Papenfuss *et al*., 2021). Our study has filled this gap.

DECLARATIONS

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Supplementary material

There is supplementary material associated with this article. Access the material online at: http://dx.doi.org/10.17582/journal.pjz/.....

Statement of conflict of interest

The authors have declared no conflict of interest.

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Supplementary Material

Occupancy Patterns of *Acanthodactylus cantoris* and *Eutropis dissimilis* in Khyber Pakhtunkhwa, Pakistan

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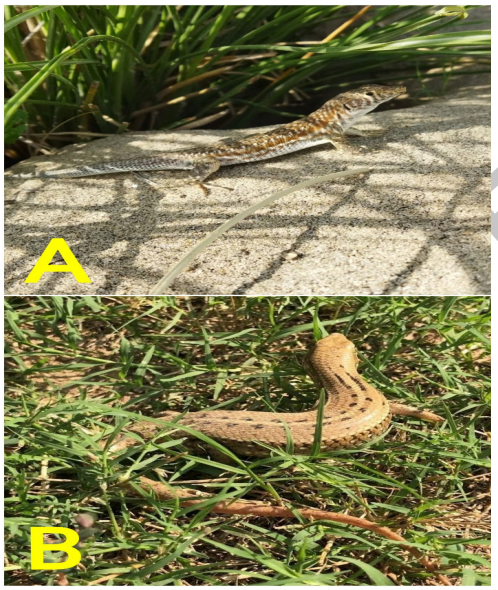

Supplementary Fig. 1. Indian fringe-fingered lizard (Acanthodactylus cantoris) (A) and Striped Grass Skink (Eutropis dissimilis) (B).

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