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ORIGINAL ARTICLE

Squamate diversity in different croplands of district Chakwal, Punjab, Pakistan

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Abstract We studied squamate diversity in 5 different croplands (wheat, sorghum, millet, maize and groundnut) of district Chakwal, North Punjab, Pakistan, in February and September, 2013, using area-constrained searches for squamates and line intercept method for vegetation. We recorded 11 squamate species (6 lizards; 5 snakes). Based on diversity index value (H) the highest squamate diversity was recorded from maize (1.91), followed by wheat (1.54), groundnut (1.51), sorghum (1.34) and millet (1.21). We recorded *Calotes versicolor versicolor*, *Ophisops jerdonii* and *Eutropis dissimilis* as most frequently sighted species in all croplands. The multivariate generalized model revealed that sightings of species differed significantly ($F_{(5,40)} = 2.89$, $P < 0.05$; Wilk's $\Lambda = 0.30$, Partial $\eta^2 = 0.94$) among cropland types and their boundary vegetation. The cluster analysis of boundary vegetation produced two main clusters: (1) groundnut and wheat, and (2) sorghum, millet and maize. We concluded that herbs (*Parthenium hysterophorus Chenopodium album*), shrubs (*Calotropis procera*, *Ziziphus jujube*, *Gymnosporia royleana*), and grasses (*Cynodon dactylon*, *Setaria pumila*) along the cropland boundary provided abode for lacertids (*O. jerdonii*) and skinks (*E. dissimilis*), while tress (*Acacia nilotica*, *Prosopis juliflora*, *Ziziphus mauritiana*) for agamids (*Calotes versicolor*). We suggest the inclusion of maintaining cropland boundary vegetation particularly grasses and shrubs in agricultural practices to ensure the conservation of squamate and their habitat.

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1. Introduction

The contribution of squamate diversity of croplands, even on global scale, remains largely meager and inappreciable. A rapid increase in global human population has resulted in the expansion of agriculture and intensification of agricultural practices affecting about 80% of terrestrial ecosystems causing loss of biodiversity (Foley et al., 2005; Green et al., 2005). It is estimated that around 28% (470 out of 1678) of the assessed reptile species diversity of the world is threatened (Gibbons et al., 2000; IUCN, 2009). Among the notable known causes of decline in the populations of reptiles are habitat destruction and modification, and use of agricultural chemicals, such as, pesticides and fertilizers (Gibbons et al., 2000).

The recent studies from North Punjab and Federal Capital Territory, of Pakistan, concentrate on herpetofauna inventories and abundance. Masroor (2011) gave an annotated checklist of 9 amphibians and 32 reptiles of Margalla Hills National Park, Islamabad. Rais et al. (2012) recorded 35 species of amphibians and reptiles (29 genera, 16 families, four orders) from Rawalpindi, Islamabad and Chakwal (North Punjab, Pakistan). However, the data on reptile diversity in agro-ecosystem are lacking in Pakistan. We hypothesized that squamate diversity (species richness and number of individuals) varied in areas with different cropland type.

2. Methods

2.1. Study area

We conducted the present study in five croplands i.e. wheat, sorghum, millet, maize and groundnut, at randomly selected sampling sites (Fig. 1) of district Chakwal (35.55° N; 72.51° E), North Punjab, Pakistan. The district has an area of 652,400 hectares. The south and south-east is mountainous and rocky, covered with scrub forest, interspaced with flat plains; the north and the north-east consist of mild undulating plain area with patches of rocky area, ravines, gorges and some desert areas. The summer temperatures range between 15 °C and 40 °C while winter temperatures average between 4 °C and 25 °C. The average annual rainfall of the district is 620 mm. Soils are generally low in organic matter, homogenized with weak structure, moderately calcareous, and with a pH of about 8. The vegetation of the district is characterized as dry subtropical broadleaved scrub type. The dominant vegetation includes: *Olea ferruginea*, *Acacia modesta*, *Dodonaea viscosa*, *Reptonia buxifolia*, *Gymnosporia royleana*, *Heteropogon contortus*, *Cymbopogon jwarancusa*, *Prosopis juliflora* and *Capparis decidua*. Only 8% of the cultivated land is irrigated (canals, wells and tube wells) while the rest relies on rain. The main crop cultivated in the district is wheat, though groundnut, maize, sorghum, chickpea, canola, millet and guar are also cultivated in patches (Akmal et al., 2014; Aslam et al., 2000; Hanif and Ali, 2014; Government of Punjab, 2013; Khan et al., 2002).

2.2. Methods

We surveyed each cropland twice, i.e. February and September, 2013. Each survey consisted of one field day (6 h) in 3 sessions; morning (0800–1000) after-noon (1400–1600) and evening (2000–2200). We used area-constrained searches (Heyer et al., 1994) to document squamate species richness and abundance. We randomly selected three sampling units, each with an area of 10 ha., within each cropland. Two observers made a thorough search of the sampling unit by random linear walk at steady pace searching all the potential habitats such as ground, tussocks, underneath stone and boundary vegetation.

We followed Khan (2006) for species identification and Pyron et al. (2013) for squamate taxonomy. We estimated percentage cover of cropland boundary vegetation using line intercept method. We laid three lines each with a length of 50–90 m along the cropland boundary, and recorded intercept length of each plant on the transect line. We grouped the recorded species as herbs (non-woody, short, lacking multiple stems), shrubs (multiple stem, medium height usually under 6 m), grasses (non-woody) and trees (woody and above 6 m) for data analysis.

2.3. Data analysis

We expressed our results as total number of sightings of squamate species per field visit per crop and of vegetation as percentage cover. We made following calculations: Relative number of sightings (RS) = number of sightings of a species/total number of sightings of all species * 100; frequency of occurrence (FO) = number of transect with a species/total number of transects * 100; Shannon–Weiner diversity index (H) = $-\sum \mathrm{pi} \ln \mathrm{pi}$, where pi is the number of sightings of a species as a proportion of total sightings of all species, and ln is the natural log of pi; and evenness index (E) = $H/\ln(S)$ where H is the Shannon–Weiner Diversity Index and S is the number of species. We calculated the percentage cover of plant species as the intercept length of species/total length of transect line * 100 (Cummings and Smith, 2000). We performed Euclidian clustering to group croplands based on similarity in boundary vegetation. We run multivariate generalized linear model (one-way MANOVA) to examine if squamate sightings (dependent variables) differed ($\alpha = 0.05$) among cropland types (fixed factor) in SPSS 22.0.

3. Results

We recorded 11 squamate species from five croplands, of these, 6 were lizards belonging to six families, viz., Agamidae (common tree lizard, *Calotes versicolor versicolor*), Eublepharidae (fat-tail gecko, *Eublepharis macularius*), Lacertidae (rugose spectacled lacerta, *Ophisops jerdonii*), Scincidae (striped grass skink, *Eutropis dissimilis*), Uromastycidae (Indus valley spiny tailed ground lizard, *Saara hardwickii*) and Varanidae (Bengal monitor lizard, *Varanus bengalensis*), and 5 snakes from 4 families, viz., Leptotyphlopidae (Brahminy blind snake, *Ramphotyphlops braminus*); Colubridae (plain racer, *Platyceps ventromaculatus*, and Oriental rat snake or Dhaman, *Ptyas mucosus mucous*); Elapidae (common krait, *Bungarus caeruleus caerulus*), and Viperidae (saw scale viper, *Echis carinatus*). Based on diversity index value (H), we recorded the highest squamate diversity from maize (1.91), followed by wheat (1.54), groundnut (.51), sorghum (1.34) and millet (1.21). We recorded the highest squamate species evenness (E) from sorghum (2.23) and the lowest (1.67) from groundnut (Table 1).

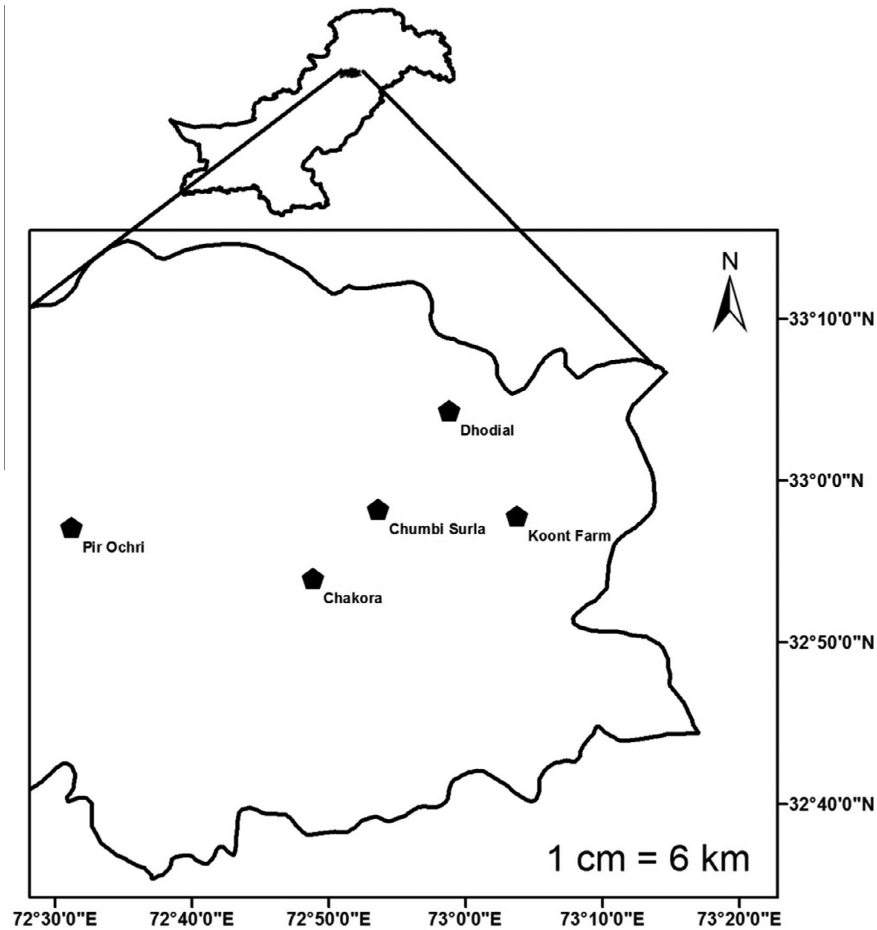

Figure 1 Map showing location of sampling sites in district Chakwal, North Punjab, Pakistan.

We recorded *C.v. versicolor*, *O. jerdonii* and *E. dissimilis* as the most frequently sighted squamate species of croplands (Table 1).

The multivariate generalized model revealed that the sightings of the recorded squamate species differed significantly ($F_{(5,40)} = 2.89$, $P < 0.05$; Wilk's $\Lambda = 0.30$, Partial $\eta^2 = 0.94$) between the studied cropland types. The number of *S. hardwickii* recorded from maize crop fields differed significantly from those recorded from groundnut ($P = 0.005$), wheat ($P = 0.003$), sorghum ($P = 0.02$) and millet ($P = 0.003$) crop fields. Likewise, the number of *E. carinatus* recorded from maize crop fields differed significantly from those appearing in groundnut ($P = 0.04$), wheat ($P = 0.04$), sorghum ($P = 0.02$) and millet ($P = 0.02$) crop fields. However, we did not find significant difference ($P > 0.05$) in sightings of other squamate species among different croplands.

We have given mean number, percent cover (±standard error) and dominant species of cropland boundary vegetation in Table 2. The cluster analysis of boundary vegetation recorded from five croplands produced two main clusters. The cluster I included groundnut and wheat while cluster II included sorghum, millet and maize (Fig. 2). Groundnut had the highest tree percent cover. The dominant herb in groundnut and wheat was *Parthenium hysterophorus*; dominant shrub species were *Calotropis procera* and *Ziziphus jujube* and dominant grasses were *Cynodon dactylon* and *Setaria pumila* (Table 2). The most frequently sighted squamate species from the boundary vegetation of these croplands were *O. jerdonii* and *E. dissimilis*. The boundary vegetation of these two croplands together constituted 47% of the recorded sightings of *Calotes versicolor*. The dominant herb species in sorghum and millet were *Chenopodium album*, *P. hysterophorus*; dominant shrubs were *G. royleana* and dominant trees were *Acacia nilotica*, *Prosopis juliflora* and *Ziziphus mauritiana*. Sorghum and millet had the highest percent coverage of herbs and shrubs and grasses, respectively (Table 2). The most frequently sighted squamate species from the boundary vegetation of these croplands was *E. dissimilis*.

4. Discussion

Our records of squamate diversity in district Chakwal are consistent with those of previous studies. We recorded all the species during our studies on general tract of the district (Rais et al., 2012). We recorded *C.v. versicolor* as the third most common in our study area. Khan and Mahmood (2004) reported the species as the most abundant species in southern parts of Pakistan (Karachi, Sindh). Our results also showed *C. versicolor* as frequently sighted species from North Punjab,

Table 1 Number of sightings (per twelve hours) (*N*), relative number of sightings (RS, %) and frequency of occurrence (FO, %) in different croplands; and Shannon–Weiner diversity index (*H*) and evenness index (*E*) of squamates recorded from croplands of district Chakwal, Pakistan.

Squamate species	Groundnut			Wheat			Sorghum			Millet			Maize			Total		
	N	RS	FO	N	RS	FO	N	RS	FO	N	RS	FO	N	RS	FO	N	RS	FO
1. *Calotes versicolor*	2	5.71	33	6	17.14	100	2	18.18	67	1	12.5	33	6	11.32	100	17	11.97	100
2. *Eublepharis macularius*	1	2.86	33	0	0.00	0	0	0	0	0	0	0	0	0	0	1	0.704	20
3. *Ophisops jerdonii*	11	31.43	67	13	37.14	100	2	18.18	33	2	25	33	13	24.53	100	41	28.87	100
4. *Eutropis dissimilis*	15	42.86	100	11	31.43	100	4	36.36	67	4	50	67	6	11.32	66	40	28.17	100
5. *Saara hardwickii*	1	2.86	33	0	0.00	0	3	27.27	67	0	0	0	11	20.75	100	15	10.56	60
6. *Varanus bengalensis*	3	8.57	67	1	2.86	33	0	0	0	0	0	0	1	1.887	33	5	3.521	60
7. *Ramphotyphlops barminus*	0	0.00	0	1	2.86	33	0	0	0	0	0	0	2	3.774	33	3	2.113	40
8. *Ptyas mucosus*	0	0.00	0	1	2.86	33	0	0	0	0	0	0	3	5.66	66	4	2.817	40
9. *Platyceps ventromaculatus*	0	0.00	0	0	0.00	100	0	0	0	1	12.5	33	0	0	0	1	0.704	20
10. *Bungarus caerulus*	1	2.86	33	1	2.86	33	0	0	0	0	0	0	2	3.774	66	4	2.817	60
11. *Echis carinatus*	1	2.86	33	1	2.86	33	0	0	0	0	0	0	9	16.98	100	11	7.746	60
Total species	8			8			4			4			9			11		
Total sightings	35			35			11			8			53			142		
Diversity index	1.51			1.54			1.34			1.21			1.95					
Evenness index	1.67			1.70			2.23			2.01			2.04					

Table 2 Mean number, percent cover (±standard error) and dominant species of cropland boundary vegetation recorded from croplands of district Chakwal, Pakistan.

Cropland	Herbs		Shrubs		Grasses		Trees	
	% cover (number)	Dominant species	% cover (number)	Dominant species	% cover (number)	Dominant species	% cover (number)	Dominant species
Groundnut	3.87 ± 0.66	*Parthenium hysterophorus*	3.17 ± 1.35	*Capparis aphylla*	4.87 ± 2.11	*Cynodon dactylon*	15.90 ± 0.61	*Ficus religiosa*
	(4.33 ± 0.33)	*Heliotropium strigosum*	(1.33 ± 0.33)	*Ziziphus jujuba*	(2.33 ± 0.33)	*Setaria pumila*	(2.33 ± 0.33)	*Morus alba*
		Aerva javanica		*Calotropis procera*		*Saccharum bengalensis*		*Ziziphus mauritiana*
Wheat	2.30 ± 0.45	*Parthenium hysterophorus*	2.33 ± 0.84	*Ziziphus jujube*	3.30 ± 1.65	*Cynodon dactylon*	7.53 ± 3.81	*Acacia nilotica*
	(2.33 ± 0.33)	*Carthamus oxycantha*	(1.33 ± 0.33)	*Calotropis procera*	(1.67 ± 0.33)	*Setaria pumila*	(1.00 ± 0.57)	*Olea cuspidate*
		Tribulus terrestris		*Olea ferruginea*		*Heteropogon contortus*		
Sorghum	5.63 ± 1.07	*Fumaria indica*	8.60 ± 0.45	*Capparis aphylla*	7.43 ± 1.70	*Desmostachya bipinnata*	9.57 ± 1.83	*Acacia nilotica*
	(4.33 ± 0.33)	*Parthenium hysterophorus*	(3.33 ± 0.33)	*Calotropis procera*	(1.67 ± 0.33)	*Cynodon dactylon*	(1.67 ± 0.33)	*Prosopis juliflora*
		Chenopodium album		*Dodonaea viscosa*		*Setaria pumila*		*Melia azedarach*
Maize	5.27 ± 1.14	*Datura stramonium*	8.10 ± 1.34	*Gymnosporia*	7.40 ± 1.17	*Cynodon dactylon*	10.50 ± 2.15	*Acacia nilotica*
	(4.00 ± 0.57)	*Astragalus spinosus*	(3.00 ± 0.00)	*Royleana*	(1.67 ± 0.33)	*Saccharum bengalensis*	(2.00 ± 0.00)	*Prosopis juliflora*
		Heliotropium strigosum		*Dodonaea viscosa*		*Desmostachya bipinnata*		*Ziziphus mauritiana*
				Capparis aphylla				
Millet	4.33 ± 0.61	*Chenopodium album*	12.47 ± 0.82	*Gymnosporia*	9.10 ± 0.56	*Cynodon dactylon*	7.17 ± 0.72	*Acacia modesta*
	(3.67 ± 0.33)	*Parthenium hysterophorus*	(3.67 ± 0.33)	*Royleana*	(1.67 ± 0.33)	*Heteropogon contortus*	(2.67 ± 0.33)	*Acacia nilotica*
		Astragalus spinosus		*Justicia adhatoda*		*Setaria pumila*		*Ziziphus mauritiana*
				Lantana camara				

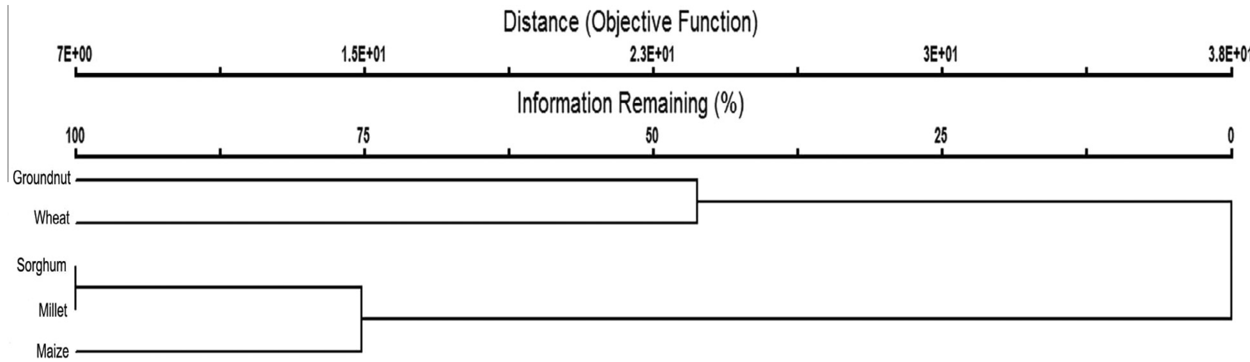

Figure 2 Single-linkage clustering of cropland boundary vegetation based on Euclidian distance.

Pakistan, which showed that the agamid species is quite common in most parts of the country. The dearth of published literature and paucity of data in Pakistan on squamate diversity of cropland habitat require a comprehensive comparison. We therefore relied on similar studies from other parts of the world. We found that herbs, shrubs and grasses along the croplands were significant for lacertids (*O. jerdonii*) and skinks (*E. dissimilis*) while trees were important for agamids (*C. versicolor*). We recorded maximum sightings of *E. carinatus* and *Bungarus caeruleus* from maize crop (Table 1). Smart et al. (2005) reported an increase in the abundance of terrestrial lizards (particularly lacertids) in areas having dense vegetation cover in communal rangelands of South Africa. Wisler et al. (2008) reported that crops, such as cereals and maize, provide cover and protection to both foraging and basking female grass snakes (*Natrix natrix*). Our findings are in accordance with aforementioned studies. Gibbons et al. (2000) reported pesticides as one of the major contributing factor in the decline of reptiles of the world. It is estimated that cotton crop accounts for about 80% of Pakistan's pesticide use (NFDC, 2002). Since cotton crop is not grown in district Chakwal, and other crops of the district receives very low pesticide application (Hussain et al., 2006), we did not report pesticides as a threat to squamates of the district.

We concluded that squamate diversity varied among the studied croplands of the district. We believe that the district has a few squamate species, with *C. versicolor*, *O. jerdonii* and *E. dissimilis* as common species. Herbs such as *P. hysterophorus* and *C. album*; shrubs: *C. procera*, *Z. jujube* and *G. royleana* and grasses: *C. dactylon* and *S. pumila* along the cropland boundary provided abode for lacertids (*O. jerdonii*), skinks (*E. dissimilis*) and vipers (*E. carinatus*) while trees *A. nilotica*, *P. juliflora* and *Z. mauritiana* for agamids (*C. versicolor*). We strongly suggest the inclusion of maintaining cropland boundary vegetation particularly grasses and shrubs in agricultural practices of the district to ensure the conservation of squamate and their habitat.

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