Pakistan J. Zool., vol. 48(6), pp. 1931-1943, 2016.

Comparative Ecology of Two Sympatric Mongoose Species (*Herpestes javanicus* and *H. edwardsii*) in Pothwar Plateau, Pakistan

Riaz Hussain and Tariq Mahmood*
Department of Wildlife Management, PMAS - Arid Agriculture University, Rawalpindi 46300, Pakistan

ABSTRACT

Two sympatric mongoose species *viz*., small Indian mongoose (*Herpestes javanicus*) and grey mongoose (*H. edwardsii*), occur in their native range; the Pothwar Plateau. Both are terrestrial carnivores and diurnal hunters. We studied comparative ecology of the two mongoose species with reference to their distribution, habitat occupied, and populations, from November 2011 to June 2013. A distribution map of the two species was developed by extensive survey of the study area. Small Indian mongoose was found occupying human habitated areas while the grey mongoose was found occupying more natural areas, however, both species were found living together sympatrically in the cultivated areas. Average population of small Indian mongoose was found higher than the grey mongoose. In small Indian mongoose populations, male to female (M:F) sex ratio was found low but with larger family size as compared to the grey mongoose populations.

Article Information
Received 1 December 2015
Revised 19 April 2016
Accepted 27 April 2016
Available online 20 October 2016

Authors' Contributions
TM designed the study. RH collected field data. TM and RH compiled and statistically analyzed the data and wrote the article.

Key words
Mongoose, terrestrial, distribution, burrows, population, Pothwar.

INTRODUCTION

Mongoose belongs to the order Carnivora, family Herpestidae and genus *Herpestes* (Nowak and Paradiso, 1983). It is terrestrial, fossorial animal having non-retractable long claws (Wozencraft, 1989). There are 10 species in the genus *Herpestes* (Nowak, 1999; Wilson and Reeder, 2005), however, only two of these occur in Pakistan, including small Indian mongoose *Herpestes javanicus* (É. Geoffroy Saint-Hilaire, 1818) and grey mongoose or common Indian mongoose *Herpestes edwardsii* (É. Geoffroy Saint-Hilaire, 1818).

The small Indian mongoose has a native range from Pakistan and northern India to southern China and the Malay Peninsula. It is also found on Hainan Island and Java in Indonesia. In the west it extends to southern Iran (Corbet and Hill, 1992), south western Afghanistan (Hassinger, 1968), along the shore of Persian Gulf it extends up to Kuwait and Iraq (Harrison, 1968), whereas grey mongoose (*H. edwardsii*) is mainly found in south Asia, Pakistan, India, Nepal up to Ceylon. This species also occupies coastal area of Saudi Arabia and Iran (Ewer, 1973).

In Pakistan, the small Indian mongoose is widely distributed in the province of Sindh, Punjab and Balochistan, but not reported from Khyber Pakhtunkhwa (Roberts, 1997). The other species, the grey mongoose, is found commonly in the central and northern parts of Sindh, particularly inhabiting the desert tracts of Tharparkar. It also occurs in the part of Punjab; Rawalpindi and the Salt Range. In Balochistan, it sparsely occurs in southern parts. It is also found in Peshawar, Kohat and Bannu districts in the province of Khyber Pakhtunkhwa (Roberts, 1997). According to IUCN Red List of Threatened Species, both, the Small Indian mongoose and the grey mongoose, are categorized as "Least Concern" (IUCN, 2015), and included in Appendix-III of CITES.

Reportedly, head to body length of the small Indian mongoose is 30-35 cm. Tail is long, tapered and is eighty percent of the head and body length. Its fur coat is coarse without under wool. Hair are annulated with blond and golden buff, in close view it gives appearance of "pepper and salt" while from a distance it gives dark olive-brown appearance. Hair around eyes and muzzle are rusty red. Head and body length of the grey mongoose is 36-45 cm. Its tail is large, bushy and 90-100 percent of the head and body length. Fur coat is stiff and coarse, hair long, annulated with creamy-white and black appearance. This species also has rusty red hair around muzzle and eyes (Roberts, 1997).

Both species of mongoose are terrestrial and diurnal carnivores occupying a wide variety of habitats (Roberts, 1997; Corbet and Hill, 1992; Creel and Macdonald, 1995; Santiapillai *et al*., 2000). The grey mongoose occurs in areas of thickets, in cultivated fields and in bushy vegetation. It also occupies open areas, grasslands and scrub (Bridges, 1948; Santiapillai *et al.*, 2000). The most preferred habitat of the small Indian mongoose in the Pothwar Plateau is the one located in the vicinity of human habituations and also near the area of poultry

* Corresponding author: tariqjanjua75@uaar.edu.pk
0030-9923/2016/0006-1931 $ 8.00/0

farms (Mahmood *et al*., 2011) while the grey mongoose prefers open habitat and is less dependent on human habitation (Santiapillai *et al*., 2000). Firouz (2005) and Gilchrist *et al*. (2009) reported grey mongoose in India to be occurring in disturbed areas, dry secondary forest and thorn forest, and also near human settlements. They are also reported to occur in scrub and cultivated land by Francis (2008).

Very few studies have been conducted so far focusing on the populations of the two mongoose species in their entire native range. However, some estimates of populations are available from different parts of the world. Population size of small Indian mongoose estimated in Jamaica was found to be 2.6 individuals per hectare and in Puerto Rico and Trinidad islands it was 2.5 per hectare (Pimentel, 1955; Nellis and Everard, 1983). In West Indies, mean density of small Indian mongoose assessed by using capture-recapture and distance sampling methods was 1.8 per hectare (Corn and Conroy, 1998). Santiapillai *et al*. (2000) reported Indian grey mongoose density as 0.2 per km^2 in Ruhuna National Park, Sri Lanka. In another study conducted in Wilpattu National Park in northwest Sri Lanka, the grey mongoose was found the least common species. However, Shekhar (2003) reported grey mongoose to be common and abundant throughout its range; in central India, the species was common but found its abundance decreased moving from human settlements towards undisturbed areas, similarly Kumara and Singh (2007) reported grey mongoose as one of the common species of the open countryside in India. In Pakistan, only one study earlier on, reported the population density of small Indian mongoose as 0.083 and 0.085 individuals per ha, in districts Chakwal and Rawalpindi respectively (Mahmood *et al*., 2011).

Some earlier studies conducted on Hawai'i and O'ahu Islands such as by Warren (1999), established male to female ratio as 2.38 and 2.44, respectively. However, study conducted in Viti Levu, Fiji by Gorman (1979) reported male to female ratio of 1.51, while in Grenada, Nellis and Everard (1983) reported male to female ratio as 2.80 and in Trinidad as 1.18 (Nellis and Everard, 1983).

MATERIALS AND METHODS

Study area

The current study was conducted in the Pothwar Plateau (32.5°N to 34.0°N Latitude and 72°E to 74°E Longitude), that comprises of four districts; Rawalpindi, Attock, Chakwal and Jhelum, and also some areas of Islamabad (Ahmad, 1991; Chaudhry and Rasul, 2004) with a total land area of 2.2 million hectares (Bhutta, 1999), the valleys within the mountains being their catchment areas. The climate is semi-arid to humid, mean maximum temperature in summer is 45°C and below freezing point during winter. Pothwar Plateau is mountainous and rocky; the region covered with scrub forest and interspersed with flat lying plains. It provides a good habitat for different wildlife species like Punjab Urial (*Ovis orientalis punjabiensis*), Asiatic jackal (*Canis aureus*), red fox (*Vulpes vulpes*), desert hare (*Lepus nigricollis*), Indian pangolin (*Manis crassicaudata*) besides the two mongoose species (*Herpestes javanicus* and *H. edwardsii*).

Field surveys for distribution of mongoose species

To record data on distribution of the two mongoose species, field surveys were conducted from October 2011 to June 2013 throughout the human habituated, cultivated as well as natural areas of four districts of the Plateau. During these surveys all "literature defined" potential habitats of the two mongoose species (Roberts, 1997) were identified and investigated for recording the presence or absence of the particular mongoose species. Accessible roads were traveled on a motor vehicle at slow speed (10-25 km/h) following Kochart (1986); Milsap and LeFranc (1988) taking roads as transects. Before moving on a transect, pre-selected random stopovers were made while surveying the transect at a distance of 5 km, 10 km and 15 km intervals or whenever direct sighting of any of the two mongoose species was made. The presence or absence of two mongoose species was also recorded by identifying their active burrows by locating footprints and presence of faecal pellets near or around the burrows as described by Richardson *et al*. (1987) and by direct sightings in the field. A binocular (Olympus, 10 x 50mm DPSI) was used to identify the species and a digital Camera (Canon A495) was used to photograph the species and their habitats. Geographical coordinates of the sites were recorded where presence of each mongoose species was confirmed, and used to develop a distribution map of both mongoose species in the study area.

Selection of sampling sites

The potential habitats of the two mongoose species were identified and twelve (n =12) sampling sites (three sites from each district) were selected within the human habitated, cultivated and natural areas. The area of each sampling site was 100 hectares (1x1 km); each site was visited periodically after three to four weeks for data collection during the study period **(**Fig. 1). The habitats were searched for active burrows by locating footprints and presence of faecal pellets near or around the burrows.

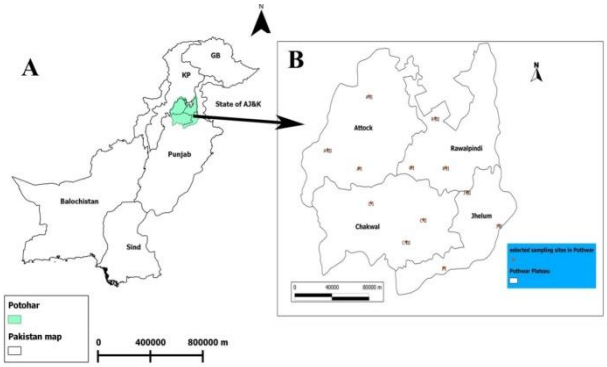

Fig. 1. Location of twelve selected sampling sites in four districts (Attock, Chakwal, Jhelum and Rawalpindi) of the Pothwar Plateau.

Vegetation analysis

For analysis of the habitat occupied by the two mongoose species in the study area, quantification of tree, shrub and herb species was carried out at the selected twelve sampling sites. Tree species were quantified by using "Point- Centered Quarter" (PCQ) method following Cottom and Cartis (1956). Three line transects were established at each sampling site, on each transect three points were marked at equal distance, which were used for recording data to calculate density, relative density, frequency, relative frequency, cover, relative cover and importance value index (IVI) of tree species in each sampling site. Shrub and herb species at each sampling site were quantified by using "Quadrat method" (Emlen, 1956). For shrubs, quadrates of 4m x 4m and for herbs quadrates of 1m x 1m sizes were used. Twenty quadrates were laid down randomly at each sampling site and shrub and herb species were identified and quantified.

Population estimation

The populations of two mongoose species were estimated by direct enumeration using "minimum numbers known to be alive" (MNA) technique (Hilborn *et al.*, 1976; Krebs, 1998) applying "capture, mark and recapture method". Sampling sites were visited regularly after an interval of three to four weeks to reduce the animals' shyness towards trapping. Forty Sherman live traps were used to capture live specimens from each site. A single Sherman trap (13x13x38 cm) was placed at each trapping station in the sampling site. Traps were placed in areas of natural vegetation and cultivated lands of less human activity at least 200 m apart to ensure independent sampling. The traps were baited using poultry meat waste and set in for trapping mongoose at each sampling site. To avoid sun, few leafy branches of vegetation were placed over the traps. Twelve trapping sessions were organized during the whole study period (from November 2011 to June 2013), each after an interval of three to four weeks to decrease the trap shyness in mongoose. Traps were set in the early morning and were visited twice; at mid-day and in the evening before sunset. Trapped specimens were immobilized and handled with care using hard cloth bag and tough leather gloves to avoid injury. After recording data like body measurements and determining sex specimens were marked using hair dye (Begin) on the bleached hair and released back into the same habitat.

Populations of two mongoose species in the study area were also estimated by using indirect enumeration method of "active burrows count" following Southwood (1966) and Begon (1979), considering the fact that one active burrow was being used by only one individual, which was confirmed with field observations. Each sampling site was searched out to locate the burrows of two mongoose species. Burrows were identified for each of the mongoose species by their opening diameter or size. Burrows activity was monitored by locating faecal matter around burrows or observing foot prints around the burrows by leveling soil in the evening and observing the foot prints on the next morning or by direct observation of animals entering and leaving the burrows.

Statistical analysis

Data were analyzed using R-Software (v3.0.2) language and environment, whereby burrow activity was analysed against plant species occurring (for both mongoose species), populations of the two mongoose species were compared within districts, seasons and the two methods used AB and MNA, and human activity levels versus mongoose population size and so on.

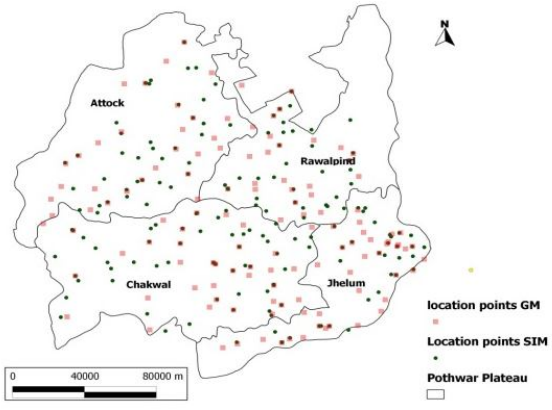

Fig. 2. A GIS-based map showing distribution of the two mongoose species in the Pothwar Plateau (green, *Herpestes. Javanicus;* red, *H. edwardsii*).

RESULTS

Distribution of mongoose species

During distribution field surveys, approximately 3410 km were travelled on motor vehicle throughout the study area using accessible roads; 250 locations out of 321 were found "positive" for mongoose presence, where any one or both (small Indian mongoose and grey mongoose) species were recorded. The small Indian mongoose was recorded at 80 (25%) sites whereas the grey mongoose was found at 89 (28%) sites. At 81(25%) sites, both mongoose species were found living together (Table I) while 71(22%) sites were negative for any of the two mongoose species.

A distribution map of the two species was developed using geographical coordinates of locations of positive sites (Fig. 2). Among four districts of the Plateau, occurrence of small Indian mongoose was high in district Attock (32%) but low in district Jhelum (13%), while grey mongoose occurrence was low (27%) in district Attock and high (36%) in district Jhelum (Table I, Fig. 2).

Altitudinal range of mongoose species

The altitudinal occurrence range of the two mongoose species was 203-874 m asl; the small Indian mongoose occurring at 207-842 m asl and the grey mongoose at 203-874 m asl. In district Chakwal, the altitudinal occurrence range was much wider for both the mongoose species; small Indian mongoose (266-842 m asl) and grey mongoose (256-874 m asl), while a narrow altitudinal occurrence range was recorded in district Jhelum; (207-481 m asl) for small Indian mongoose and (203-412 m asl) for the grey mongoose (Table I).

Vegetation in the habitat of mongoose species

The common tree species in the Pothwar Plateau in the habitat of the two mongoose species included *Ziziphus mauritiana* (IVI = 62.53) and *Dalbergia sissoo* (IVI = 56.00), which were recorded at all 12 selected sampling sites, while *Acacia modesta* (IVI = 35.38) and *A. nilotica* (IVI = 41.35) were found at eight sampling sites. Among the shrubs *Z. nummularia* (IVI = 86.29) was the only species that occurred at all sampling sites; other shrubs included *Capparis decidua* (IVI = 44.12), *Calotropis procera* (IVI = 35.87) and *Prosopis juliflora* (IVI=44.12) found at eight sampling sites. Among herbs, seven species were found at all selected sampling sites; *Carthamus oxycantha* (IVI = 18.24), *Chenopodium album* (IVI = 14.88), *Cynodon dactylon* (IVI = 20.70), *Euphorbia helioscopia* (IVI = 16.40), *Fumaria indica* (IVI = 15.34), *Peganum harmala* (IVI = 19.37) and *Urginea indica* (IVI = 14.37) (Fig. 3).

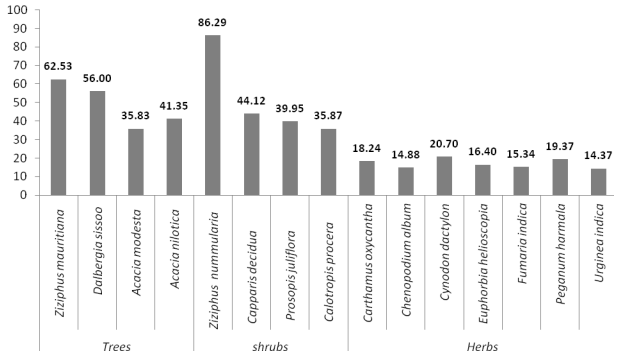

Fig. 3. Importance Value Index (IVI) 0f common plants species (trees, shrubs, and herbs) recorded in the Pothwar Plateau at twelve selected sampling sites in the habitats of the two mongoose species (*Herpestes javanicus* and *H. edwardsii*).

Phyto-association of mongoose species

Phyto-association of the two mongoose species was also investigated at the twelve selected sampling sites of the study area (Supplementary Table III). One hundred and fifty active burrows of small Indian mongoose were recorded at all sampling sites; 50% (n=75) burrows were found closely associated with *Z. nummularia*, 18% (n=27) burrows were associated with *Prosopis juliflora*, 14% burrows (n=21) were associated with *Capparis decidua*, 4.7% (n=7) were associated with *Z. mauritiana*, 4.7% (n=7) with *D. sissoo*, 2.7% (n=4) burrows with *Calotropis procera*, 2.7% (n=4) burrows with *Cannabis sativa*, 2% (n=3) burrows were associated with *Ricinus communis* and 1.2% (n=2) burrows with *Melia azedarach*.

For the grey mongoose, a total of 141 burrows were recorded at 12 different selected sites, 33% (n=46) were associated with *Z. nummularia*, 23.7% (n=32) with *P. juliflora*, 21.3% (n=30) burrows with *Capparis decidua*, 6.38% (n=9) with *Z. mauritiana*, 9.23% (n=13) with *Calotropis procera*, 2.84% (n=4) with *Ricinus communis*, 1.42% (n=2) with *M. azedarach*, 1.42% (n=2) with *Acacia modesta*, 1.42% (n=2) with *Justicia adhatoda* and 0.71% (n=1) burrow associated with *Morus alba* (Fig. 4).

Statistically, burrows activity analyzed using R-Software was found significantly different with associated plants ($f = 6.6118$, $df = 11$, $p = 0.01521$) at 0.05 level of significance (Supplementary Table III).

Population of mongoose

A high population density of small Indian mongoose was recorded in district Attock as compared to other three districts 8.67±0.49 per km^2 and 11.47±0.39 per km^2 by MNA (minimum number alive) and AB

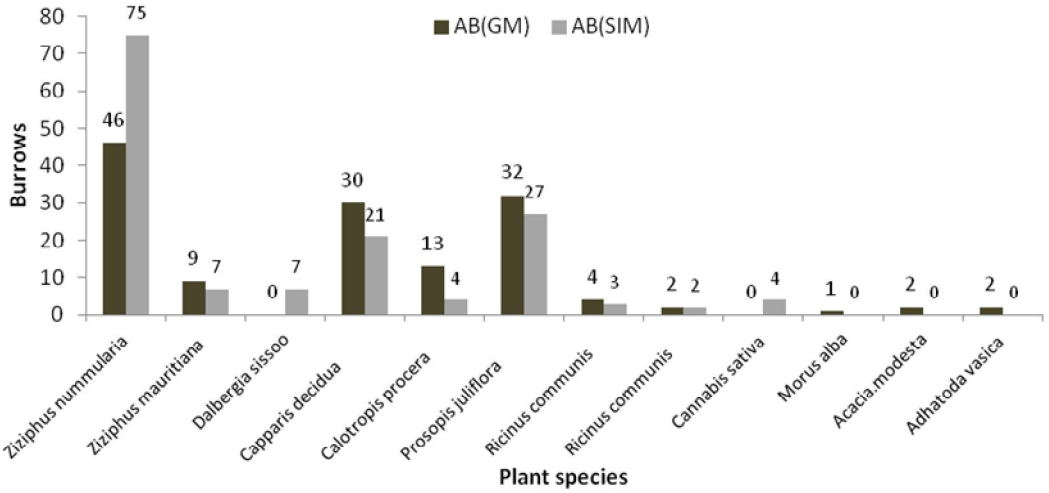

Fig. 4. Phyto-association of two mongoose species analyzed in terms of occurrence of their active burrows (AB)in the Pothwar Plateau. For SIM total number of active burrows was 150, while for the GM it was 141.

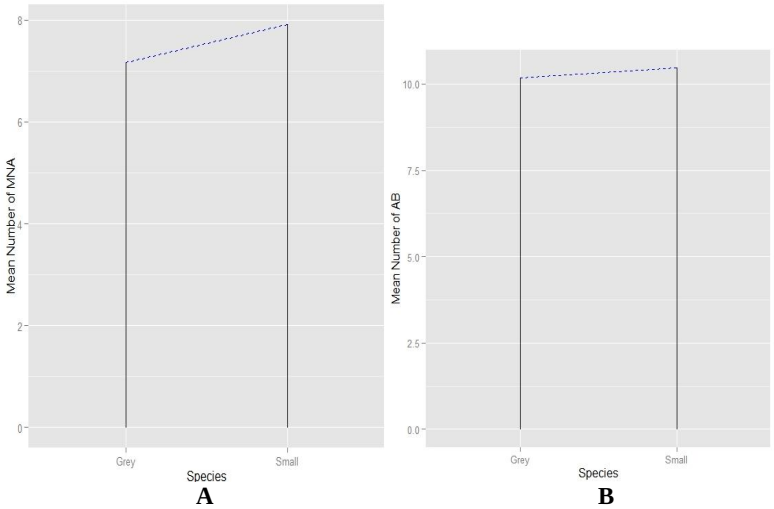

Fig. 5. Average population density of small Indian mongoose (*Herpestes javanicus*) and grey mongoose (*H. edwardsii*). **A)** minimum number alive (MNA), **B)** active burrows count (AB) methods in the Pothwar Plateau.

Table I.- Distribution and occurrence of two mongoose species (*Herpestes javanicus* and *H. edwardsii*) in four districts of Pothwar Plateau.

Districts	Total numbers of sites	Sites positive for SIM (percent)	Sites positive for GM (percent)	Sites positive for both species (percent)	Small Indian mongoose altitude range (m)	Grey mongoose altitude range (m)
Attock	75	24(32)	20(27)	13(17)	294 – 514	292 – 576
Chakwal	85	26(31)	22(26)	26(31)	266 – 842	256 – 874
Jhelum	79	13(19)	25(36)	22(17)	207 – 481	203 – 412
Rawalpindi	82	17(21)	22(27)	20(24)	354 – 613	354 – 598
Total	**321**	**80(25)**	**89(28)**	**81(25)**	**207 - 842**	**203 - 874**

SIM, small Indian mongoose; GM, grey mongoose

(active burrows) count methods, respectively. Whereas a lower population density of this species was recorded in district Jhelum; 6.53 ± 0.44 per km^2 by MNA and 9.19±0.31 per km^2 by AB count method. Statistical analysis showed a significant difference in density estimates of the species among the districts studied. The grey mongoose showed high density in district Jhelum 8.70±0.39 by MNA and 11.72±0.25 by AB counts method, while a low density in district Rawalpindi; 5.64±0.59 by MNA and 8.64±0.56 by AB counts method.

In Pothwar Plateau, average density of small Indian mongoose was 7.91±0.41 per km^2 by MNA index and10.47±0.54 per km^2 by AB count method. For grey mongoose, average density was found to be 7.17±0.52 per km^2 by MNA index method and 10.23±0.83 per km^2 (Table II, Fig. 5).

Seasonal variation in mongoose populations

The population density of small Indian mongoose was found high during winter season by MNA index method (8.63±0.52 per km^2) and AB count method (10.69±0.14 per km^2). For the grey mongoose, highest density was recorded both in summer and winter seasons *viz*., 7.61±0.17 per km^2 by MNA method and 10.71±0.27 per km^2 by AB count method during summer and 7.56±1.05 per km^2 by MNA method and 10.35±0.54 during winter by both methods (Table II).

Relative to human habitation/ activity levels

Populations of the two mongoose species were found different at different human activity levels in the study area. At four sampling sites where human activity was at a low-level, small Indian mongoose showed relatively lower density 6.33±0.36 per km^2 and 8.77±0.32 per km^2 by MNA and AB methods respectively, whereas the grey mongoose showed a higher density 8.23±0.68 per km^2 and 11.65±0.46 per km^2 by MNA and AB methods respectively (Table II). On the other hand, at the four sites having a high human activity level, higher density of the small Indian mongoose was recorded (8.61±0.47 per km^2 and 11.50±0.44 per km^2 by MNA and AB methods, respectively) in comparison with the grey mongoose which showed lower density (4.44±0.48 per km^2 and 7.19±0.61 per km^2 by MNA and AB methods respectively) at these high human activity level sites. However, at sampling sites with medium level of human activity, both mongoose species were recorded with intermediate levels of density estimates (Table II). Interactive graphs generated through R-program (Fig.6) showed change in population density of both mongoose species in relation to human activity level in the study area.

Table II.- Population density (per km^2) of the two mongoose species (*Herpestes javanicus* and *H. edwardsii*) in Pothwar Plateau. Data were analyzed using R-software, and significant differences were found at 0.001, 0.01 and 0.05 levels for Species versus District by MNA and AB=*, Species versus Seasons = non-significant difference and Species versus Human activity levels = ***).**

Parameters	Small Indian mongoose (per km^2)		Grey mongoose (per km^2)	
	MNA	**AB**	**MNA**	**AB**
District				
Attock	8.67± 0.49	11.47± 0.39	6.56± 0.53	9.47± 0.59
Chakwal	8.50± 0.38	10.66± 0.29	7.80± 0.58	11.08± 0.52
Jhelum	6.53± 0.44	9.19± 0.31	8.70± 0.39	11.72± 0.25
Rawalpindi	7.95± 0.34	10.55± 0.33	5.64± 0.59	8.64± 0.56
Mean ± SE	**7.91± 0.41**	**10.47 ± 0.54**	**7.17 ± 0.52**	**10.23 ± 0.83**
Season				
Spring	7.50± 0.09	9.95± 0.23	6.42± 0.54	9.44± 0.64
Summer	7.94± 0.09	10.7± 0.23	7.61± 0.17	10.71± 0.27
Fall	7.04± 0.74	10.46± 0.21	6.88± 0.32	10.53± 0.17
Winter	8.63± 0.52	10.69± 0.14	7.56± 1.05	10.35± 0.54
Human activity				
Low	6.33± 0.36	8.77± 0.32	8.23± 0.68	11.65± 0.46
Medium	8.79± 0.39	11.13± 0.30	8.86± 0.47	11.85± 0.36
High	8.61± 0.47	11.50± 0.44	4.44± 0.48	7.19± 0.61

Statistical analysis

Analysis of Variance (ANOVA) table of the fitted linear mixed effect model using R-program showed no significant difference in populations of the two mongoose species (by both methods) in all districts (f = 1.081, df = 3 and p= 0.4255), however, within districts, population density was significantly different at 0.001 level of significance by MNA (f = 36.146, df = 3, p< 2.2e-16) and AB (f = 26.804, df = 3, p = 4.552e-15).

The populations of the two mongoose species found were significantly different in different seasons by MNA (f=8.267, df=3, p=2.818e-05) at 0.001 level of significance and by AB count (f=3.073, df=3, p=0.02825) at 0.05 level of significance but seasonal difference in

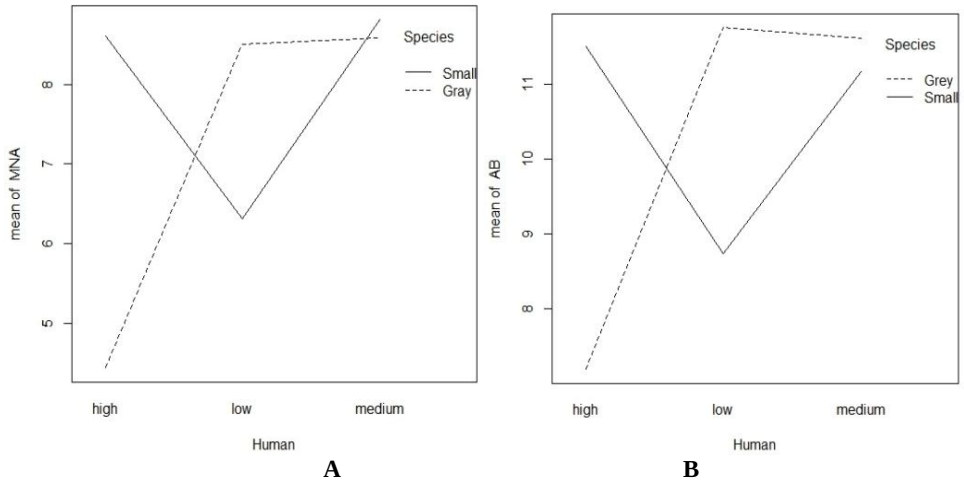

Fig. 6. Interaction of two mongoose species with human activity level assessed by using **A)** MNA, and **B)** AB methods.

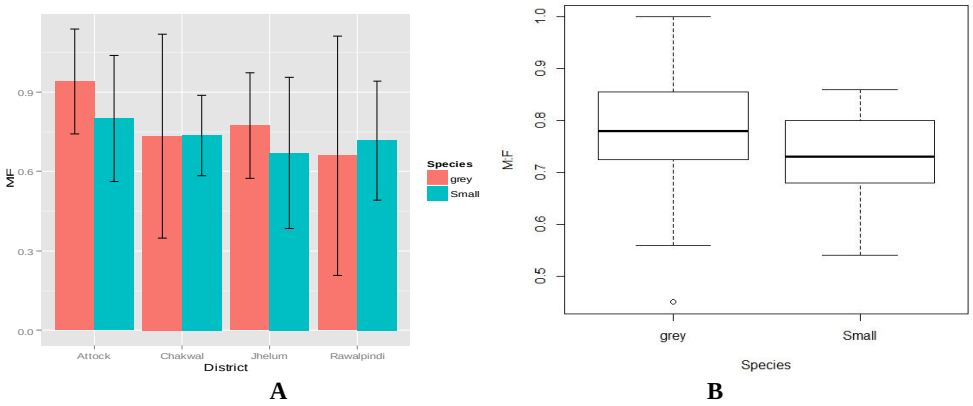

Fig. 7. A) Sex ratios (male to female) of the two mongoose species in four districts of the Pothwar Plateau, B) Average sex ratio (M:F) of the two mongoose species in Pothwar Plateau.

population of both species was non-significant both by MNA (f=1.287, df=3, p=0.27918) and AB count (f=0.771, df=3, p=0.51114) methods.

Similarly, ANOVA table of fitted mixed effect model in R-software showed that population size estimated by MNA for two mongoose species significantly differed at different human activity levels (f = 5.999, df = 2, p = 0.044) at < 0.05 level of significance; populations of the two mongoose species within an activity level were also found significantly different (f = 116.361, df = 2, p< 2.2e-16) at 0.001 level of significance. In relation to human activity level, overall population size estimated for mongooses by active burrows count (AB) was also significantly different at 0.001 level of significance at different activity levels (f = 77.461, df = 2, p = 2.723e-15) and within an activity level (f = 115.378, df = 2, p< 2.2e-16) (Supplementary Tables I, II).

Sex ratios

A higher sex ratio (M:F) of small Indian mongoose (0.77) was recorded in district Attock and lower in district Jhelum (0.67), while grey mongoose also had a higher sex ratio in district Attock (0.92) but lower in district Rawalpindi (0.71) (Table III; Fig.7A). In Pothwar Plateau average male to female ratio was 0.73±0.02 for small Indian mongoose and 0.78±0.05 for grey mongoose (Fig. 7B).

Statistical analysis was conducted by fitting linear model to find out the effects of species and district on response variable M:F ratio of the two mongoose species in Pothwar Plateau. Analysis of variance (ANOVA) table

showed non-significant difference in male to female ratios between the two mongoose species, and among the four districts in Pothwar Plateau.

Table III.- Sex ratios of small Indian mongoose and grey mongoose populations at selected sampling sites in four districts of Pothwar Plateau; data were analysed using R-software Program and significant differences were found at 0.001, 0.01 and 0.05 levels, for comparison within species and districts there was non-significant difference at these levels.

	Small Indian Mongoose			Grey Mongoose		
District	**Male**	**Female**	**M:F**	**Male**	**Female**	**M:F**
	30	35		30	31	
Attock	35	51	0.77	06	06	0.92
	17	20		23	27	
Total	**82**	**106**		**59**	**64**	
	27	34		19	22	
Chakwal	20	30	0.74	18	32	0.72
	21	28		25	32	
Total	**68**	**92**		**62**	**83**	
	14	22		20	26	
Rawal-pindi	24	34	0.72	19	25	0.71
	25	31		05	11	
Total	**63**	**87**		**44**	**62**	
	15	21		28	33	
Jhelum	13	24	0.67	18	23	0.77
	22	29		25	36	
Total	**50**	**74**		**71**	**92**	
Mean ±SE			**0.73± 0.02**			**0.78 ±.05**

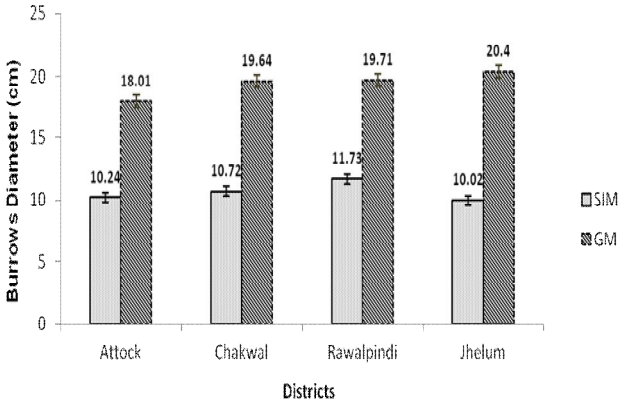

Fig. 8. Average diameters of burrows of small Indian mongoose (SIM) and grey mongoose (GM) in four districts of the Pothwar Plateau.

Burrow characteristics

Average diameter and depth of burrows of grey mongoose were found greater at all sampling sites of the four districts of the Plateau in comparison with that of the small Indian mongoose (Figs. 8, 9). Box plots also showed a difference in the mean diameters and depths of burrows of two mongoose species (Fig. 10; Supplementary Table II). Analysis of variance model using R-software showed a significant difference in diameter and depth of burrows of two species ($f = 1240.16$, $df = 1$, $p < 2e\text{-}16$) at 0.001 and ($f = 9.092$, $df = 1$, $p = 0.0028$) at 0.05 level of significance, respectively.

Body measurements

Physical body measurements of 144 adult mongooses were recorded (72 small Indian mongoose and 72 grey mongoose; 50% male specimens and 50% female specimens); average body weight, body length, tail length, total length, and ear length of the grey mongoose species were found greater as compared to those of the small Indian mongoose (Supplementary Table II). Analysis of variance models fitted in R-software showed a significant difference at 0.001 level of significance in body weight of two species ($f = 675.1$, $df = 1$, $p < 2e\text{-}16$), in body length of two species ($f = 606.5$, $df = 1$, $p < 2e\text{-}16$),in tail length of two species ($f = 1303.0$ $df = 1$, $p < 2e\text{-}16$), in total length of two species ($f = 1036.0$, $df = 1$, $p < 2e\text{-}16$) and in ear length of two species ($f = 158.4$, $df = 1$, $p < 2e\text{-}16$) (Table IV, Fig. 11A-E).

DISCUSSION

The mongoose (Herpestidae) are small-sized carnivores adapted to terrestrial habitats. They can be divided into two groups; one including small-sized social, diurnal and invertebrate eating species, and the second group including solitary, large-sized and small vertebrate eating species (Veron *et al*., 2004). They are distributed throughout the tropics, sub-tropics (Corbet and Hill, 1992) and introduced on many islands (Thulin *et al*., 2006). Two species of mongoose are reported from Pakistan; however, scanty information exists on their ecology. The current study focused on their populations inhabiting Pothwar Plateau, where the two species are sympatric.

The two mongoose species (small Indian mongoose and the grey mongoose) are widely distributed in the Pothwar Plateau; 79% sampling sites visited showed signs of occurrence of either one or both the species; 21% sites visited showing no evidence of their occurrence. Sites in three (Attock, Chakwal and Rawalpindi) out of four districts showed small Indian mongoose occurring at more number of sites than the grey mongoose, whereas in district Jhelum, grey mongoose was found more widely distributed. Earlier on, Roberts (1997) had reported small Indian mongoose as one of the commonest small carnivore in southern Sind and north-eastern Punjab, having its distribution around Jhelum and Gujranwala,

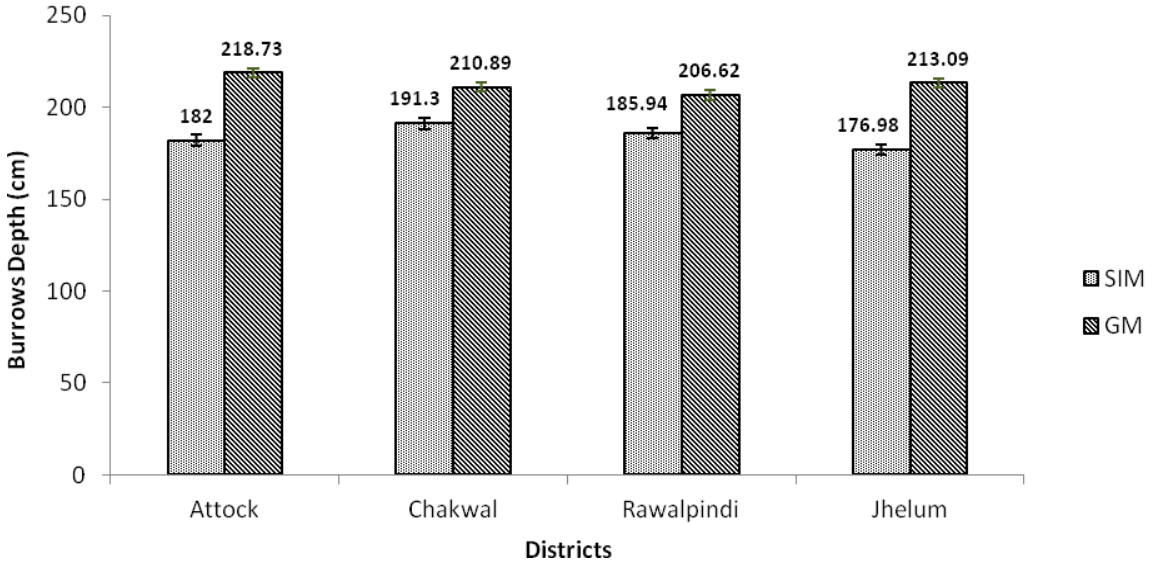

Fig. 9. Average burrow depth (cm) of SIM and GM species in four districts of the Pothwar Plateau (SIM: small Indian mongoose; GM: grey mongoose).

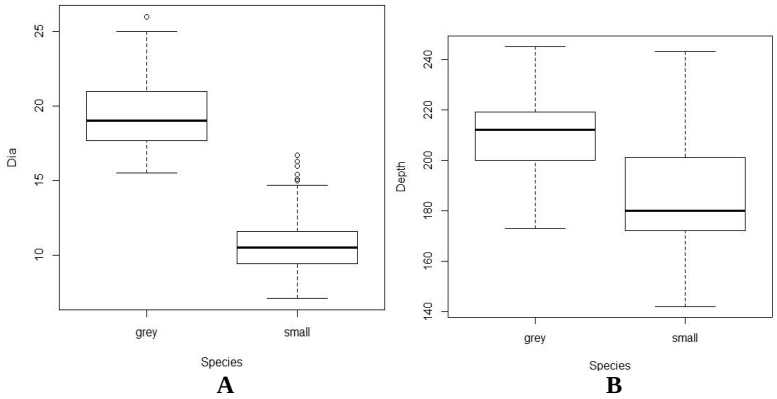

Fig. 10. Box plots showing difference in average (A) diameter (cm) (B) depth (cm), of the burrows of the two mongoose species inhabiting Pothwar Plateau.

and the Salt Range of the Punjab, and well adapted to living in more rocky areas with stunted thorn scrub typical of the Salt Range. The grey mongoose, as per Roberts (1997) was better adapted to arid conditions, occurred in the Salt Range and was plentiful around Rawalpindi.

The vegetation species of the study area are important for the two mongoose species in the context of providing them with shelter (cover) as well as food, since they prey upon small birds and insects, when they come to these plant species. The scats of two mongoose species contained seeds of *Z. nummularia* and *Z. mauritiana* indicating their importance as diet component, and also the reason of their close association with these two plant species. In addition, most of the burrows of small Indian mongoose were recorded inside the bushy clumps of *Z. nummularia* and in the hollow roots of *Z. mauritiana*, indicating that it never goes away from the bushy cover, especially when having young ones accompanying them. The two mongoose species have been found having a close association with these plant species; *Z. mauritiana* fruit is their food and they make their burrows in the roots and hollow stems of the bush in the study area. Similarly, the two mongoose species showed maximum burrow activity associated with and around *Z. nummularia.* Both mongoose species also showed a moderate level of association with *P. juliflora* and *Capparis decidua.* The small Indian mongoose showed

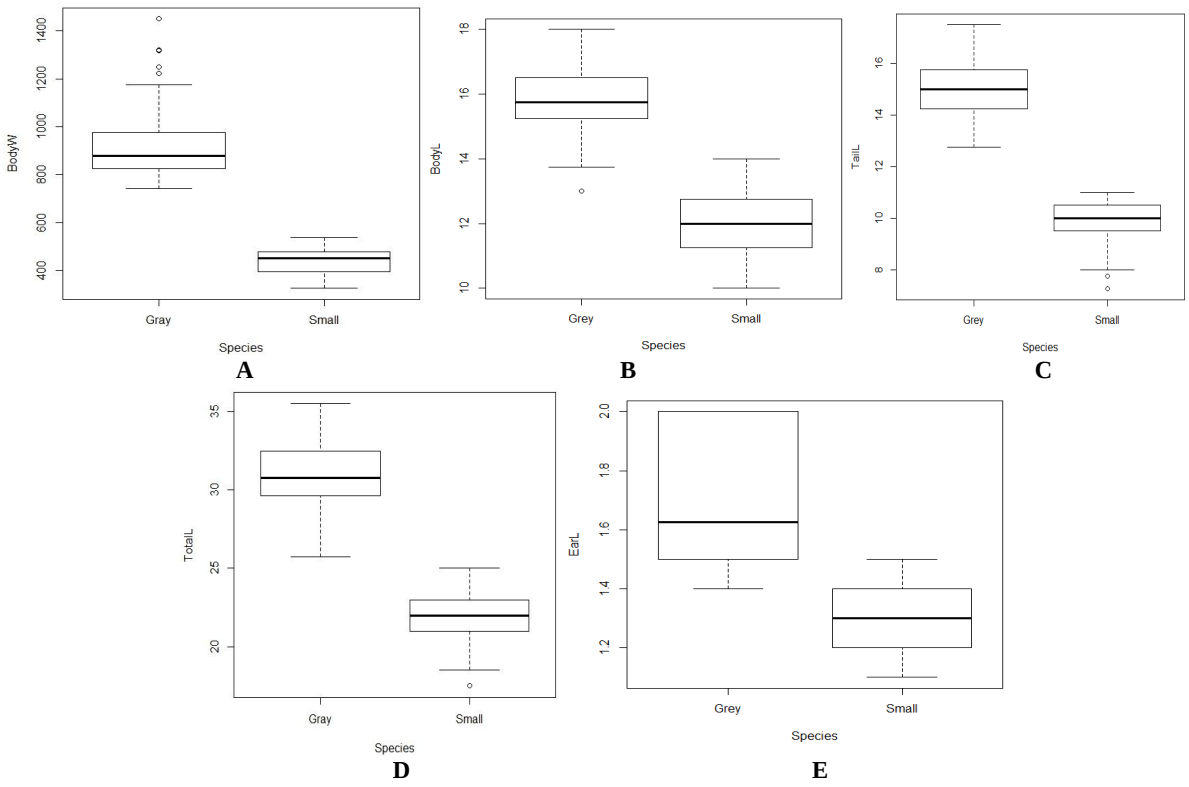

Fig. 11. Box plots showing difference in (A) body weight (g), (B) body length (cm), (C) tail length (cm), (D) total length (cm), and (E) ear length (cm) of the two mongoose species (*Herpestes javanicus* and *H. edwardsii*) in Pothwar Plateau.

Table IV.- Comparative account of different variables studied for small Indian mongoose and grey mongoose in Pothwar Plateau; data were analysed using R-software program and significant differences were found at 0.001, 0.01 and 0.05 levels; * = *p*< 0.05; **= *p* < 0.01; * = *p*< 0.0001.**

Variables		SIM	GM
Distribution		Evenly distributed throughout the plateau	Evenly distributed throughout the Plateau
Occurrence elevation		207-842m	203-874m
Habitat preference		Human settlement and cultivated areas	Natural and cultivated areas
Population density	MNA	7.91±0.41 per km^2	7.17±0.52 per km^2
	AB	10.47±0.54 per km^2	10.23±0.83 per km^2
Burrows occupancy		Share during breeding season	Share during breeding season and sever winter
Family size		4-5 including parents	3-5 including parents
Male to female ratios		0.73:1	0.78:1
Burrows diameter		10.71±0.16 cm	*19.54 ±0.19 cm
Burrows depth		184.58±1.80 cm	210.98 ±1.38 cm
Body weight		436.93±13.99 g	***931.0±23.58 g
Head and body length		30.45±0.58 cm	40.18±0.69 cm
Tail length		25.09±0.46 cm	**38.07±0.69 cm
Total length		55.47±0.99 cm	**78.23±0.1.45 cm
Ear length		3.33±0.05 cm	4.29±0.18 cm

*=p<0.05; **=p<0.01; ***=p<0.0001

no association with *Acacia modesta, M. alba* and *Justicia adhatoda* whereas the grey mongoose showed no association with *Dalbergia sissoo* and *C. sativa.*

In the current study, estimates of population of the two mongoose species revealed a lower average density of grey mongoose in districts Attock and Rawalpindi than the small Indian mongoose. However, in district Jhelum, opposite situation was found; mean density of the grey mongoose was found higher as compared to that of the small Indian mongoose. It shows that the habitat in district Attock, Chakwal and Rawalpindi is more supportive to the population of small Indian mongoose while that of district Jhelum is more supportive to the grey mongoose population. Some earlier studies show that the small Indian mongoose occurs in a variety of habitats but prefers well-watered naturally open deciduous forests, shrub lands and grasslands (Shekhar, 2003) while it tends to avoid closed evergreen forests, it utilizes secondary forests, degraded sites and areas of former evergreen forests opened by logging or similar practices (Lekagul and McNeely, 1977). The species is well adapted to living in the outskirts of villages and towns, avoids mountainous areas and therefore is absent from Himalayan region. It is generally associated with better wooded regions of the Indus plains (Roberts, 1997). The grey mongoose, on the other hand, prefers arid conditions and is less dependent on human dwellings (Robert, 1997). The species can be observed in areas of thickets, in cultivated fields and in bushy vegetation. However, it also occupies open areas, grasslands, and scrub (Bridges, 1948; Santiapillai *et al*., 2000).

The estimates of population of the two mongoose species in the study area for three consecutive years (from 2011 to 2013) have shown almost stable populations of both the species. Thus currently there are no habitat related issues in the study area that could lead to population decline of the two mongoose species. Similarly, seasonal data on population density of mongoose species showed a higher density during summer and winter seasons, compared to the other two seasons, as was earlier reported that in small Indian mongoose maximum frequency of pregnancies occurred just prior to the summer (Nellis and Everard, 1983) and in grey mongoose litters during the months of June and July (Gilchrist *et al*., 2009).

In relation to human activity level in the study area, the two mongoose species differed in their population density; for small Indian mongoose, density was high in high human activity areas, while for grey mongoose, it was high in low human activity areas. However, at medium human activity level areas, both mongoose species showed almost equal population density. These result indicate that small Indian mongoose prefers more human habitated areas as was reported by Roberts (1997). Therefore, the small Indian mongoose is well-adapted to human habitations while the grey mongoose avoids such habitats and prefer open and natural habitat.

In the populations of two mongoose species in the study area, male to female sex ratio of small Indian mongoose was found high (0.77) in district Attock but low (0.67) in district Jhelum; similarly, for grey mongoose M:F ratio was also high (0.92) in district Attock but low (0.71) in district Rawalpindi. In the Pothwar Plateau, on average, the M:F ratio was high (0.78±0.05) for grey mongoose and low (0.73±0.02) for small Indian mongoose, showing occurrence of less number of males than females for both species. Some earlier studies conducted on Hawai'i and O'ahu Islands by Warren (1999), established male to female ratio to be 2.38 and 2.44 respectively. However, the study conducted in Viti Levu, Fiji by Gorman (1979) showed the male to female ratio of 1.51, while in Grenada, Nellis and Everard (1983) reported a ratio 2.80 and 1.18 in Trinidad (Nellis and Everard, 1983). All these earlier published studies indicate higher number of males in populations of small Indian mongoose, however, in the current study in the native range of the two mongoose species, less number of males have been recorded than the number of females trapped.

Both species, the small Indian mongoose and the grey mongoose, excavate burrows for living, in addition to utilizing the natural cavities. In the current study, variable numbers of burrows of the two mongoose species were found in all selected sampling sites. The burrows were found mostly among shrubs, around the boundary margins of cultivated lands, in hollow tree trunks and roots of old trees. The mongoose species also utilized crevices in the walls and heaps of stones or bricks to dwell inside. The diameter of the grey mongoose burrows was wider and they were much deeper than those of the small Indian mongoose, most probably, because of the larger body size of the species.

General body measurements; body weight, body length, tail length, ear length and total body length of the small Indian mongoose (n=72) were found less than those of the grey mongoose (n=72). Body weight and body length of males of both mongoose species were greater than those of the females indicating a clear sexual dimorphism. Tail length of males of both mongoose species was also larger than those of the females. Moreover, grey mongoose tail was found bushier and 90-100 percent of body size while that of small Indian mongoose was less hairy, tapered and 80 percent of body length. Total body length and ear length of males of the two mongoose species were also greater than the females of either species. In general, grey mongoose total body

length was found twice than that of the small Indian mongoose.

CONCLUSION

The current study provides important ecological data about two sympatric mongoose species inhabiting Pothwar plateau. The small Indian mongoose prefers high human activity areas while the grey mongoose avoids such areas and prefers more natural areas. The populations of both species have been found stable, however, less number of males of both species were found to occur in the study area as compared to females. Average diameter and depth of burrows of the grey mongoose are greater in comparison with those of the small Indian mongoose. Males and females of both species show sexual dimorphism.

Statement of conflict of interest

Authors have declared no conflict of interest.

Supplementary material is available at
http://www.zsp.com.pk/pdf48/QPJZ-0593-F-%2023-9-16%20(SUPPLEMENTARY%20TABLES%201-3).pdf

REFERENCES

Ahmad, M., 1991. *Groundnut in the dry land agriculture of Potohar*, BARD Project, Pakistan Agriculture Research Council, Islamabad, Pakistan.

Begon, M., 1979. *Investigating animal abundance*. Baltimore, University Park Press, pp. 1024.

Bhutta, I.A., 1999. *Achievements and issues in 20th century in Small Dams (Rainwater harvesting*). Proceedings of the national workshop on "Water resource achievements and issues in 20th century and challenges for next millennium". Pakistan Council of Research in Water Resources, Islamabad Pakistan, pp. 64-69.

Bridges, W., 1948. *Wild animals of the world*. Garden City Books, Garden city, NY. pp. 273.

Chaudhry, Q.Z. and Rasul, G., 2004. Agro-climatic classification of Pakistan. *Sci. Vision*, **9**: 59-66.

Corbet, G.B. and Hill, J E., 1992. *The mammals of the Indo-Malayan Region*. Natural History Museum publications, Oxford University Press, Oxford, U.K., pp.496.

Corn, J.L and Conroy, M.J., 1998. Estimation of density of mongoose with capture-recapture and distance sampling. *J. Mammal*, **79**: 1009-1015.

Cottam, G. and Curtis, J.T., 1956. The use of distance measures in phytosociological sampling. *Ecology*, **37**: 451-460.

Creel, S. and MacDonald, D., 1995. Sociality, Group size and reproductive suppression among carnivores. *Adv. Stud. Behav.*, **24**: 203-205.

Emlen, J.T., 1956. A method for describing and comparing avian habitats. *Ibis*, **98**: 565-576.

Ewer, R.F., 1973. *The carnivores*. Cornell University Press, Ithaca, NY., pp. 500.

Firouz, E., 2005. *The complete fauna of Iran*. I.B. Tauris Publishers, London, pp. 322.

Francis, C.M., 2008. *A field guide to the mammals of South-East Asia*. Princeton University Press. Princeton, New Jersey, pp. 392.

Gilchrist, J.S., Jennings, A.P., Veron, G. and Cavallini, P., 2009. Family Herpestidae. In: *Handbook of the mammals of the world* (eds. D.E. Wilson and R.A Mittermeier), *Volume 1: Carnivores.* Lynx Edicions, Barcelona, Spain, pp. 656.

Gorman, M., 1979. Dispersion and foraging in the small Indian mongoose relative to the evolution of social viverrids. *J. Zool. Lond.*, **187**: 65-73.

Harrison, D.L., 1968. *The mammals of Arabia*, vol. II. *Carnivora, Artiodactyla, Hyracoidea*. Ernest Benn, London, pp. 193-381.

Hassinger, J., 1968. Introduction to the mammal survey of the 1965 Street expedition to Afghanistan. *Field. Zool*., **55**: 1-81.

Hilborn, R., Redfield, T.A. and Krebs, C.J., 1976. On the reliability of enumerations for mark and recapture census of voles. *Can. J. Zool*., **54**: 1019-1024.

IUCN, 2015. *The IUCN red list of threatened species*. Version 2015-4.<www.iucnredlist.org>. Downloaded on 15 November 2015.

Kochert, M.N., 1986. Raptors. In: *Inventory and monitoring of wildlife habitat* (ed. A.Y. Cooperidder). U.S. Dept. Inter. Bur. Land Manage., Denver, CO. pp. 313-334.

Krebs, C.J., 1998. *Ecological methodology*. University of British Columbia, pp. 627.

Kumara, H.K. and Mewa, S., 2007. Small carnivores of Karanatika: Distribution and sight records, *J. Bomb. nat. Hist. Soc*., **104**: 155-162.

Lekagul, L. and McNeely, D., 1977. *Herpestes javanicus*. The IUCN Red List of Threatened Species. Retrieved fromwww.iucnredlist.org.

Millsap, B.A. and Lefranc, M.N. JR., 1988. Road transect counts for raptors: how reliable are they? *J. Raptor. Res*.**, 22**:8-16.

Mahmood, T., Hussain, I. and Nadeem, M.S., 2011. Population estimates, habitat preference and the diet of small Indian mongoose (*Herpestes javanicus*) in Potohar Plateau. *Pakistan J. Zool.*, **43**: 103-111.

Nellis, D.W. and Everard, C.O.R., 1983. The biology of the mongoose in the Caribbean. *Stud. Fauna Curacao Caribb. lsI*., **195**: 1-16.

Nowak, R.L. and Paradiso, J.L., 1983. *Walker's Mammals of the World*. The Johns Hopkins Univ. Press, Baltimore Maryland, pp. 1362.

Nowak, R.M., 1999. *Walker's Mammals of the World*, Vol. I. 6th ed. The Johns Hopkins Univ. Press, Baltimore Maryland, pp. 1936.

Pimentel, D., 1955. Biology of the Indian mongoose in Puerto Rico. *J. Mammal*., **36**: 62–68.

Richardson, L., Clark, T.W., Forrest, S.C. and Campbell, T.M., 1987. Winter ecology of black-footed ferrets (*Mustelanigripes*) at Meeteetse, Wyoming. *Am. Midl. Nat*., **117**: 225-239.

Roberts, T.J., 1997. *The Mammals of Pakistan.* Oxford University Press, London, pp. 187-188.

Santiapillai, C., DeSilva, M. and Dissanayake, S., 2000. The status of mongooses (family: Herpestidae) in Ruhuna National Park, Sri Lanka. *J. Bomb. nat. Hist. Soc.*, **97**: 208-214.

Shekhar, N.U., 2003. Local peoples' attitudes towards conservation and wildlife tourismaround Sariska Tiger Reserve, India. *J. environ. Manage.*, **69**: 339-347.

Southwood, T.R.E., 1966. *Ecological methods, with particular reference to the study of insect populations*. Methuen, London, pp. 391.

Thulin, C.G., Simberloff, D., Barun, A., McCracken, G., Pascal, M. and Islam, M.A., 2006. Genetic divergence in the small Indian mongoose (*Herpestes auropunctatus*), a widely distributed invasive species. *Mol. Ecol*., **15**: 3947-3956.

Veron, G., Colyn, M., Dunham, A.E., Taylor P. and Gaubert, P., 2004. Molecular systematics and origin of sociality in mongooses (Herpestidae, Carnivora). *Mol. Phyl. Evol.*, **30**: 582-598.

Warren, H.S.T., 1999. Annual dispersal cycle of the small Indian mongoose (*Herpestes auropunctatus*) (Carnivora: Herpestidae) in Hawai'i. *Pacif. Sci.*, **53**: 252-256.

Wilson, D.E. and Reeder, M.D. (Eds.), 2005. *Mammal species of the World* (3rd ed.). Johns Hopkins University Press, 2 vols. Baltimore, pp.2142.

Wozencraft, W.C., 1989. Classification of the recent carnivora. In: *Carnivore behaviour, ecology and evolution* (ed. J.L. Gittleman), Cornell University Press, Ithaca, NY., pp. 569-593.