Turkish Journal of Zoology

http://journals.tubitak.gov.tr/zoology/

Research Article

Turk J Zool
(2017) 41: 1045-1058

doi:10.3906/zoo-1606-34

Human activity mediates reciprocal distribution and niche separation of two sympatric mongoose species on the Pothwar Plateau, Pakistan

Riaz HUSSAIN[1], **Tariq MAHMOOD**[1,*], **Faraz AKRIM**[1], **Hira FATIMA**[1], **Muhammad Sajid NADEEM**[2]
[1]Department of Wildlife Management, PMAS-Arid Agriculture University Rawalpindi, Pakistan
[2]Department of Zoology, PMAS-Arid Agriculture University Rawalpindi, Pakistan

Received: 20.06.2016 • **Accepted/Published Online:** 01.06.2017 • **Final Version:** 21.11.2017

Abstract: Ecologically and morphologically similar species living in sympatry are predicted to partition their resources, although the resources themselves may vary in time and space and in relation to extrinsic factors. We studied two sympatric species of carnivores that vary in their distribution along a gradient of human activity, and one species exploits a wider range of food sources. We recorded the distribution of the small Indian mongoose (*Herpestes javanicus*) and the gray mongoose (*Herpestes edwardsii*) through reconnaissance surveys within high, medium, and low human activity areas of the Pothwar Plateau from November 2011 to June 2013. We found that the distribution of the two mongoose species interacted significantly with human activity levels; the small Indian mongoose was highly distributed where human activity level was high and vice versa for the gray mongoose. The gray mongoose showed a wider food niche breadth compared to the small Indian mongoose, while the food niche measured by Pianka's index overlapped between the two species at 0.95. Thus it is concluded that human-induced changes in the landscape impact on the habitat selection of mongooses on the Pothwar Plateau.

Key words: Carnivore, sympatric, population, human activity, food niche

1. Introduction

Species having similar ecological niches often shift their uses of resources in habitats where they are sympatric (Schoener, 1986) and such a phenomenon is known as resource partitioning (Walter, 1991). Many factors, like interspecific competition (Schoener, 1974), change in tolerance towards physical–chemical variables, environmental change, spatial and temporal change in availability of resources, predation (Ross, 1986), and intraguild predation (Fedriani, 2000; MacDonald, 2002), play an important role in this phenomenon. Dietary overlap between carnivores may indicate the level of interspecific competition. Although manipulative studies are required to demonstrate competition conclusively (Wiens, 1989), measuring niche overlap can be a useful first step (Carrera et al., 2008; Glen and Dickman, 2008); a high overlap in diets indicates the level of competition among predators for limited resources.

The two species of mongooses that occur sympatrically in some areas of Pakistan are useful for consideration of such issues related to sympatry. Generally, mongooses are distributed throughout the tropics and subtropics (Corbet and Hill, 1992), and on a number of introduced islands (Thulin et al., 2006). At least six species occur in Africa and seven in Asia (Hinton and Dunn, 1967; Dhakal and Diwakar, 2001; Wozencraft, 2005). Two of these species occur in Pakistan: the small Indian mongoose (*Herpestes javanicus*) and the gray mongoose (*H. edwardsii*) (Corbet and Hill, 1992; Wilson and Reeder, 1993; Roberts, 1997). Both these species are ferret-like animals having cylindrical bodies (Wozencraft, 2005) and may be sympatric in their native range (Corbet and Hill, 1992). Both are terrestrial, burrowing (Wozencraft, 1989), diurnal carnivores that occupy a wide variety of habitats (Roberts, 1997; Santiapillai et al., 2000); the small Indian mongoose prefers naturally open deciduous forests, scrublands, and grasslands and is well adapted to the outskirts of villages and towns (Robert, 1997; Shekhar, 2003), while the gray mongoose prefers open areas, grasslands, and scrublands, avoiding human dwellings (Bridges, 1948; Robert, 1997; Santiapillai et al., 2000).

Carnivores living in human activity areas face variation in prey species and are also at risk of contact with humans (Ramesh et al., 2012). They may also exhibit changes in habitat use patterns (Beckmann et al., 2003). The small Indian mongoose is an important carnivore

* Correspondence: tariqjanjua75@uaar.edu.pk

in biological niches that behaves like an omnivore and consumes a variety of food ranging from small mammals, birds, herpetofauna, and invertebrates to plant material. Some populations of small Indian mongoose are largely insectivorous, others may largely consume fruits for part of the year (Seaman and Randall, 1962), while the gray mongoose is an opportunistic hunter; its common food items are mice, rats, lizards, snakes, beetles, ground birds and their eggs, and parts of plants, i.e. fruits, berries, and roots. In India, it is reported to feed on the eggs and chicks of the red jungle fowl, peafowl, partridges, snakes, and small mammals and it is also found searching for food under stones on the beach side in Hawaii (Santiapillai, et al., 2000; Postanowicz, 2002). The gray mongoose has an elongated skull and special teeth for hunting grasshoppers, scorpions, centipedes, frogs, crabs, and fish. Their protruded and pointed canines help them to clamp onto a snake's head. Moreover, their molars with pointed cusps help in crushing insects (Whitfield, 1978).

In the current study we investigated the relative distribution of two sympatric mongoose species inhabiting the Pothwar Plateau relative to three different human activity areas (low, medium, and high activity), quantifying the niche breadth of each mongoose species and the level of niche overlap between the two species. The study tested the hypothesis that human activity level shapes reciprocal distribution and niche separation of the two sympatric mongoose species on the Pothwar Plateau.

2. Materials and methods

2.1. Study area

The Pothwar Plateau is located between lat 32.5°N and 34.0°N and long 72°E and 74°E (Figure 1). Geographically, it is bounded to the east by the Jhelum River, to the west by the Indus River, to the north by the Kala Chitta Range and Margalla Hills, and to the south by the Salt Range. The Pothwar Plateau is located in the agroecological zone-V (PARC, 1980). It comprises four districts: Rawalpindi, Attock, Chakwal, and Jhelum, including some areas of Islamabad (Ahmed, 1991; Chaudhry and Rasul, 2004) with a total area of 2.2 million hectares (Bhutta, 1999). The chief crops cultivated in the study area include wheat, groundnut, barley, sorghum, legumes, onion, melons, and tobacco. The climate is semiarid to humid. Mean maximum temperature in summer is around 45 °C and below freezing point during winter. According to 1998 District Census report, 74,64,763 people were residing in the area and there is still a tremendous increase in population. The urbanity level is about 40%. Although a great deal of inhabitants are still agrarian, many people are moving into industry and mining. Agricultural practices are dependent on rainfall and annual rainfall ranges between 250 mm and 500 mm (Govt. Punjab, 2000).

2.2. Distribution surveys

To investigate the effect of human activity levels on the distribution of two mongoose species (the small Indian mongoose and the gray mongoose), reconnaissance surveys were conducted from October 2011 to June 2013 throughout the human inhabited areas (high human activity), cultivated areas (medium human activity), and natural areas (low human activity) of the four districts on the Pothwar Plateau. The major crops being cultivated in the study area included wheat and groundnuts, favorite for rodents' pests, which, in turn, may act as prey species for mongooses. The natural or wild area had a subtropical scrub ecosystem.

The accessible roads were travelled on a motor vehicle at low speed (10–25 km/h) as described by Kochart (1986) and Milsap and LeFranc (1988). On these transects random stopovers were made at 5-, 10-, and 15-km intervals or on direct sighting of any of the mongoose species. At the stopover sites, an area of about 500 m^2 was searched for active burrows of mongoose species by locating their footprints and presence of their fecal pellets near or around the burrows as described by Richardson et al. (1987).

The populations of the two mongoose species were estimated by using the 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 mongoose.

2.3. Diet composition: fecal pellet analysis

Fecal samples of the two mongoose species were collected periodically from the twelve selected sampling sites on the Pothwar Plateau. These samples were identified in the field on the basis of their shape, size, and smell. The fecal samples were collected in self-sealing plastic bags and labelled with species name, location, season, date, and month. All samples were stored at room temperature after drying in oven or in the sunlight until the final analysis. Insects were collected and rodent species were trapped (for obtaining their hair samples) from sampling sites for reference. Prey remains were also collected from the active burrows sites of the two mongoose species to be used as reference material. Physical parameters of the fecal samples, i.e. length, diameter, and weight, were recorded in the laboratory before further analysis. The collected samples were analyzed following slightly modified procedures described by Schemnitz (1980), Siddiqui et al. (2004), and Dawson et al. (2007).

2.3.1. Preparation of whole mount and hair cast

Hair recovered from the analysis of fecal samples was washed in carbon tetrachloride for 15–20 min. A drop of Distrene Plasticizer Xylene (DPX) was poured on a clean glass slide; a single hair was placed on it and it was covered by a cover slip. The medullary patterns of the hair were observed under the microscope.

The scale patterns of the recovered hair were studied by making casts of them in glycerin jelly. The hair was cleaned in carbon tetrachloride (CCl_4) and dried. Two to three drops of glycerin jelly solution were spread over a clean slide. Before the medium became gel a cleaned hair was placed in vertical position with respect to the long axis of the slide by keeping one end of the hair projecting over the edge of the slide for easy grasping and pulling it out. The slide was allowed to set for 1.5 h. When the medium became fairly solid, the hair was pulled up using forceps with a fast jerk to prevent the hair from sticking to the solution. The cast that appeared under the microscope was almost an exact duplicate of the scales of the hair (Lavoie, 1971). Photomicrographs of the prepared hair slides of rodent species were taken to study their medulla and scale patterns using a microscopic camera having maximum resolution of 640 × 480 pixels (DEC-2 Gentaur).

2.4. Seasonal variation in diet

Seasonal variation in the diet composition of the two mongoose species was investigated by pooling the fecal samples collected into four different seasons: fall, winter, spring, and summer. The prey species richness (S), diversity index (H'), and evenness index (E) were calculated from the results of the seasonal variation using the following formulae:

Prey Species Richness (S) = total number of animal prey and plant species consumed by a mongoose species in a specific season

Diversity Index (H') = $-[p_i \times \log p_i]$ (where p_i = prey index)

Evenness Index (E) = H'/log S

A comparative account of overall food, seasonal food, and food overlap of the two species was made. Niche breadth was estimated by measuring Levin's index (B) and Levin's standardized niche breadth (B_A) as described by Krebs (1999):

$B = 1/\Sigma j^2$, where *pi* is the proportion of record in each food item *i*

$B_{A\,=}\, B - 1\ /\ n - 1$, where *n* is the number of total food categories.

Feeding niche overlap between the two mongoose species for each season was measured by using Pianka's index (1973):

$$O_{jk} = \frac{\sum_{i}^{n} p_{ij} p_{ik}}{\sqrt{\sum_{i}^{n} p_{ij}^2 \sum_{i}^{n} p_{ik}^2}}$$

O_{jk} stands for Pianka's measure of niche overlap between species *j* (SIM) and *k* (GM), p_{ij} and p_{ik} are the proportion of food category (*i* recorded in the fecal samples of species *j* and *k* respectively), and *n* is the total number of food categories.

2.5. Statistical analysis

Data on distribution of the two mongoose species in the study area were analyzed using analysis of variance (ANOVA) table of the linear model fitted in R-software. The data regarding population estimates of the two mongoose species were analyzed using the linear mixed effect model in R-software, putting minimum numbers alive (MNA) and animal burrow (AB) counts as response variables while explanatory variables having fixed effect included species, district, months, years, human, species-district, species-year, species-human, and species-month. Similarly, random effect was studied in relation to sites.

3. Results

3.1. Distribution of the two mongoose species with respect to human activity

During our survey of the Pothwar Plateau, 250 out of the total 321 sites were positive for mongoose occurrence, where the small Indian mongoose and the gray mongoose were recorded at different as well as common sites. The occurrence of the small Indian mongoose was high in areas having high human activity level, while the gray mongoose was more distributed in low human activity areas. In medium human activity areas, 95% of sites surveyed showed occurrence of both species (Table 1; Figure 1B).

ANOVA showed a highly significant difference in the distribution of mongoose species at 0.001 level of significance ($F = 284.6363$, $df = 2$, $P < 2.2e\text{-}16$ ***) in relation to human activity (Table 2). Similarly, distribution of the two mongoose species also differed significantly in different districts of the Pothwar Plateau (Table 2).

3.1.1. Mongoose populations and human activity

A higher population density of the small Indian mongoose was recorded at four sites having high human activity than the gray mongoose (Table 3). At four other sites of low human activity level, density of the gray mongoose was high. At medium human activity sites, both mongoose species showed intermediate population density (Table 2). ANOVA showed a significant difference at <0.001 level relative to different human activity levels ($F = 124.604$, $df = 2$, $P < 2.2e\text{-}16$ ***) in the populations of the two mongoose species at different levels of human activity by active burrows count (Table 2).

3.2. Diet composition

3.2.1. Physical characteristics of fecal samples

Physical characteristics, i.e. length, diameter, and mass, of the scat samples of both mongoose species (SIM = 246 and GM = 235) were measured in the laboratory before the final analysis. Average length, mass, and diameter of fecal samples of the gray mongoose were greater than those of the small Indian mongoose (Figure 2). ANOVA showed a significant difference in scat length between the

Table 1. Distribution of two mongoose species (small Indian mongoose and gray mongoose) on the Pothwar Plateau, relative to human activity.

Human activity level	Total numbers of sampling sites	Numbers of sites positive for SIM	Number of sites positive for GM	Number of sites positive for both mongoose species
High	83	78 (94%)	0 (0.0%)	5 (6%)
Medium	80	2 (2.5%)	2 (2.5%)	76 (95%)
Low	87	1 (1.1%)	84 (96.6%)	2 (2.3%)
Total	250	81	86	83

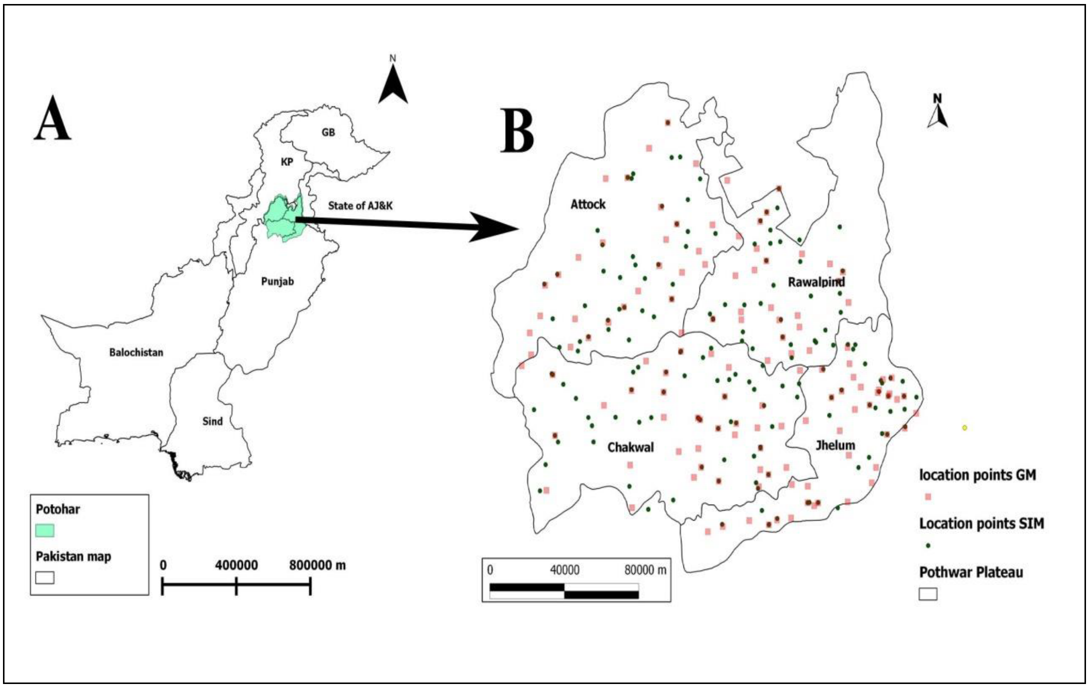

Figure 1. GIS-based map showing distribution of the two mongoose species (*Herpestes javanicus* and *H. edwardsii*) on the Pothwar Plateau (blue dots = *H. javanicus*, red dots = *H. edwardsii*).

Table 2. Statistical analysis of different parameters of the two mongoose species (*Herpestes javanicus* and *H. edwardsii*) using linear mixed effect model and analysis of variance (ANOVA) table in R-software.

Ecological parameter	Variable	df	F-value	P-value
Distribution	district	3	5.6665	0.0009104 ***
	human	2	284.6363	<2.2e-16 ***
	altitude	1	1.4748	0.2257664
Species population	district	3	21.494	2.08e-12 ***
	year	2	1.827	0.16310
	human	2	124.604	<2.2e-16 ***
	month	9	0.648	0.75489
Diet composition	species -bones	1	18.233	2.36e-05 ***
	species-insects	1	27.618	2.24e-07 ***

Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05

Table 3. Average population (per km^2) of small Indian mongoose (SIM) and gray mongoose (GM) at different human activity levels at different sampling sites of the Pothwar Plateau.

Human activity	Sampling sites		Districts	SIM population (active burrows)	GM population (active burrows)
High	A-II	Dhok Fateh	Attock	13.25 ± 0.37	4.83 ± 0.99
	C-I	Jabair pur	Chakwal	12.50 ± 0.37	9.83 ± 0.34
	J-II	Kot Basera	Jhelum	8.33 ± 0.67	9.92 ± 0.19
	R-III	Siham road	Rawalpindi	11.92 ± 0.38	4.17 ± 0.94
Mean				11.50 ± 0.44	7.19 ± 0.61
Medium	A-I	Shehbaz pura	Attock	12.67 ± 0.28	12.67 ± 0.22
	C-III	Kot Sarang	Chakwal	9.67 ± 0.26	11.92 ± 0.65
	J-III	Khengar	Jhelum	10.83 ± 0.41	12.58 ± 0.19
	R-II	Darkala	Rawalpindi	11.37 ± 0.26	10.25 ± 0.39
Mean				11.13 ± 0.30	11.85 ± 0.36
Low	A-III	Dhok Chana	Attock	8.42 ± 0.51	10.92 ± 0.56
	C-II	Kallar Kahar	Chakwal	9.83 ± 0.27	11.50 ± 0.57
	J-I	Dera Gondal	Jhelum	8.42 ± 0.23	12.67 ± 0.36
	R-I	Dheri	Rawalpindi	8.42 ± 0.26	11.50 ± 0.36
Mean				8.77 ± 0.32	11.65 ± 0.46

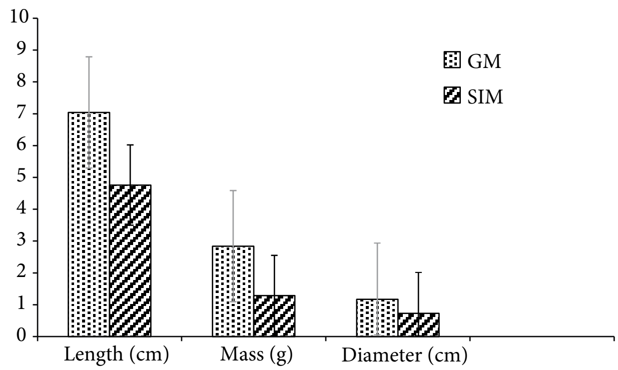

Figure 2. Average length (cm), mass (g), and diameter (cm) of SIM and GM fecal samples collected from study sites on the Pothwar Plateau.

two species ($f = 3168.39$, $df = 1$, $P < 2e-16$) at 0.001 level of significance. Fecal diameter of the two species also showed a significant difference ($f = 6586$, $df = 1$, $P < 2e-16$) at 0.001 level of significance, and also the average mass of fecal samples of the two species was significantly different ($f = 4237.53$, $df = 1$, $P < 2e-16$) at 0.001 level of significance.

3.2.2. Diet of the two mongoose species

Analysis of fecal samples of the small Indian mongoose showed insect body remains at the highest frequency, followed by mammalian hair, plant matter (including seeds), bird feathers, and vertebrate bones (Table 4). Average percent volume (%V) composition of scats showed insects being consumed at the highest proportion, followed by plant matter and seeds, and vertebrate bones, while birds were consumed in less proportion and mammalian hair was recovered at the lowest percentage (Table 4).

Fecal analysis of the gray mongoose also showed the highest percent frequency (% F) of insect body remains, followed by mammalian hair, vertebrate bones, bird feathers, and plant matter including seeds (Table 4). Percent volume consumption (%V) of recovered food items revealed the highest percentage of vertebrate bones, followed by insects, plant matter including seeds, and mammalian hair, while bird feathers were recovered in the least proportion (Table 4).

Results of diet composition of the two mongoose species compared using ANOVA showed a significant difference in %V of occurrence of mammalian hair ($f = 17.596$, $df = 1$, $P = 2.26e-05$), bones ($f = 18.233$, $df = 1$, $P = 2.36$ e-05), and insects ($f = 27.618$, $df = 1$, $p = 2.24$ e-07) at 0.001 level of significance, whereas no significance difference was found in the %V of occurrence of feathers and plant matter of the two mongoose species.

3.2.3. Rodent prey species in mongoose diet

Approximately, 67% of the fecal samples of the small Indian mongoose analyzed showed the presence of mammalian hair (Table 5). Light microscopic sections of whole mounts of recovered hair were found matched with reference hair slides of three different rodent species

Table 4. Diet composition and seasonal variation in percent frequency (%F) and percent volume (%V) of occurrence of different food items recovered from fecal samples of small Indian mongoose and gray mongoose. *SIM = small Indian mongoose; *GM = gray mongoose.

	Food items	Spring		Summer		Fall		Winter		Overall food	
		SIM (n = 60)	GM (n = 57)	SIM (n = 64)	GM (n = 60)	SIM (n = 68)	GM (n = 56)	SIM (n = 54)	GM (n= 62)	SIM (n = 246)	GM (n = 235)
% F	Hairs	68.33 (41)	80.70 (46)	60.93 (39)	82.81 (53)	79.41 (54)	87.50 (49)	57.41 (31)	75.81 (47)	67.07 (165)	82.97 (195)
	Bones	48.33 (29)	77.19 (44)	51.56 (33)	89.93 (50)	54.41 (37)	75.00 (48)	40.74 (22)	69.35 (43)	49.19 (121)	78.72 (185)
	Feather	31.67 (19)	47.37 (27)	43.75 (28)	65.00 (39)	60.29 (41)	73.21 (41)	70.37 (38)	75.81 (47)	51.22 (126)	65.53 (154)
	Insects	88.33 (53)	91.23 (52)	90.06 (58)	93.33 (56)	86.76 (59)	87.50 (49)	79.62 (43)	77.78 (42)	86.58 (213)	84.68 (199)
	Plant matter	71.67 (43)	63.16 (36)	60.94 (39)	68.75 (44)	66.17 (45)	64.29 (36)	62.96 (34)	75.93 (41)	65.44 (161)	66.80 (157)
	Unidentified & soil	81.87 (49)	84.21 (48)	79.68 (51)	86.67 (52)	82.35 (56)	78.57 (44)	88.89 (48)	85.48 (53)	82.93 (204)	83.83 (197)
% V	Hairs	8.68 ± 1.20	10.22 ± 1.30	9.56 ± 1.24	14.11 ± 1.40	6.79 ± 0.83	13.25 ± 1.58	6.11 ± 1.02	9.14 ± 1.57	7.86 ± 0.54	11.65 ± 0.74
	Bones	14.79 ± 2.27	24.21 ± 2.40	14.02 ± 1.98	23.25 ± 1.88	16.38 ± 2.36	22.98 ± 2.34	13.54 ± 2.79	16.50 ± 1.81	14.91 ± 1.16	21.63 ± 1.07
	Feather	6.38 ± 1.38	8.64 ± 1.50	8.12 ± 1.39	11.25 ± 1.61	8.36 ± 1.09	7.13 ± 0.93	10.50 ± 1.17	8.47 ± 1.23	8.17 ± 0.64	8.96 ± 0.68
	Insects	31.90 ± 2.42	22.88 ± 1.94	29.65 ± 2.25	20.86 ± 1.62	27.59 ± 2.46	20.22 ± 2.12	27.20 ± 2.81	19.13 ± 2.17	29.11 ± 1.24	20.74 ± 0.99
	Plant matter	19.91 ± 2.03	17.45 ± 2.36	23.11 ± 2.72	19.45 ± 2.26	24.31 ± 2.73	17.70 ± 2.33	22.07 ± 2.94	20.61 ± 2.79	22.55 ± 1.31	20.04 ± 1.24
	Unidentified & Soil	18.34±1.80	16.61 ± 2.11	15.55 ± 1.86	11.09 ±1.01	16.58 ± 1.65	18.72 ± 1.92	20.58 ± 2.17	21.42 ± 1.54	17.41 ± 0.92	16.97 ± 0.87

Table 5. Percent frequency (%F) of occurrence of mammalian species and insect orders (prey species) identified from the hair samples recovered from fecal samples of the small Indian mongoose (SIM) and the gray mongoose (GM) on the Pothwar Plateau.

Food items	Spring		Summer		Fall		Winter		Overall	
Mammal species	SIM (n = 41)	GM (n = 46)	SIM (n = 39)	GM (n = 53)	SIM (n = 54)	GM (n = 49)	SIM (n = 31)	GM (n = 47)	SIM (n = 165)	GM (n = 195)
Rattus rattus	43.90 (18)	13.04 (6)	38.46 (15)	9.43 (5)	42.59 (24)	14.28 (7)	38.71 (12)	6.38 (3)	41.82 (69)	10.76 (21)
Mus musculus	36.58 (15)	2.17 (1)	38.46 (15)	7.54 (4)	40.74 (20)	4.08 (2)	45.16 (14)	4.25 (2)	38.79 (64)	4.61 (9)
Nesokia indica	19.51 (8)	23.91 (11)	23.08 (9)	24.52 (13)	14.81 (10)	32.65 (16)	16.13 (5)	27.66 (13)	19.39 (32)	27.17 (53)
Tetera indica	-	32.61 (15)	-	32.07 (17)	-	26.53 (13)	-	34.04 (16)	-	31.28 (61)
Golenda ellioti	-	30.43 (14)	-	26.41 (14)	-	22.45 (11)	-	27.66 (13)	-	26.15 (51)
Insect order	(n = 53)	(n = 52)	(n = 58)	(n = 56)	(n = 59)	(n = 49)	(n = 43)	(n = 42)	(n = 213)	(n = 199)
Blattodea (cockroaches)	24.52 (13)	-	27.58 (16)	7.14 (4)	13.56 (8)	-	2.33 (1)	-	17.84 (38)	2.01 (4)
Orthoptera (grasshoppers)	16.98 (9)	30.76 (16)	22.43 (13)	26.78 (15)	25.42 (15)	28.57 (14)	41.86 (18)	45.23 (19)	25.82 (55)	32.16 (64)
Coleoptera (beetles)	16.98 (9)	21.15 (11)	13.79 (8)	25.0 (14)	22.03 (13)	24.49 (12)	32.56 (14)	28.57 (12)	20.65 (44)	24.62 (49)
Hymanoptera (ants, wasps, bees)	41.50 (22)	30.76 (16)	32.75 (19)	32.14 (18)	33.82 (23)	42.85 (21)	20.93 (9)	19.05 (8)	34.27 (73)	31.66 (63)
Odonata (dragonflies)	-	17.31 (9)	3.45 (2)	8.93 (5)	-	4.08 (2)	2.33 (1)	7.14 (3)	1.41 (3)	9.55 (19)

*SIM = small Indian mongoose; *GM = gray mongoose

(Figures 3 and 4) occurring in the study area: *Rattus rattus*, *Nesokia indica*, and *Mus musculus*. Percent frequency (% F) of occurrence of hair in the scats of the small Indian mongoose included *Rattus rattus* = 42%, *Mus musculus* = 39%, and *Nesokia indica* = 19% (Table 5). On the other hand, approximately 83% of fecal samples of the gray mongoose (Table 5) showed the presence of hair; the five prey species identified from the light microscopic slides of the whole mounts of the recovered hair were *Rattus rattus* (11%), *Mus musculus* (5%), *Nesokia indica* (27%), *Tetera indica* (31%), and *Golenda ellioti* (26%).

3.2.4. Seasonal variation in consumption of rodent species

Three different rodent species were consumed by the small Indian mongoose in the study area. During spring, the most frequently consumed rodent species was *Rattus rattus*, while the least consumed was *Nesokia indica* (Table 5). A similar pattern persisted for summer and fall with

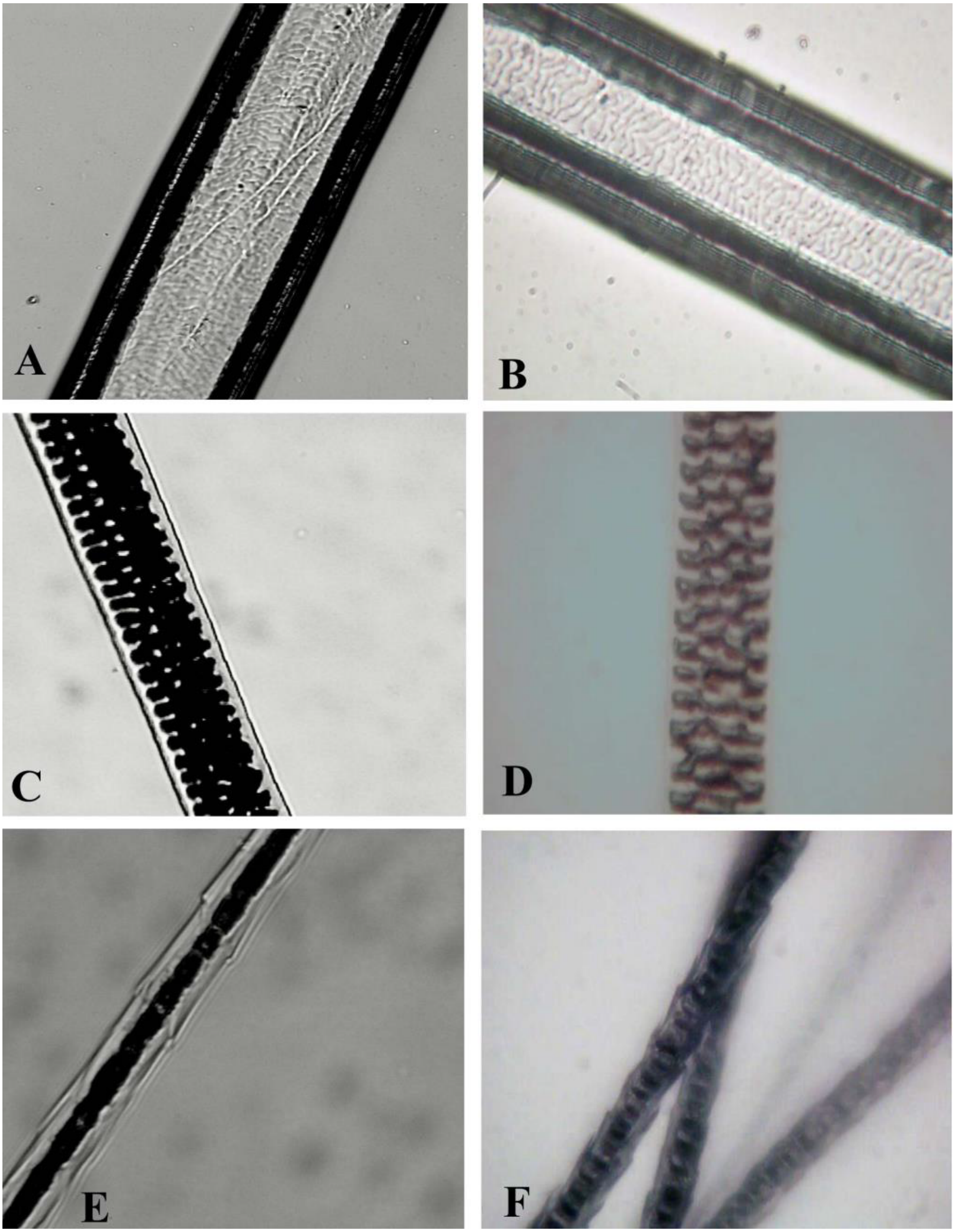

Figure 3. Photomicrographs of whole mounts of hair structure of three rodent species (recovered from fecal samples and reference hairs) consumed by the small Indian mongoose on the Pothwar Plateau. A) Whole mount of recovered hair of *Rattus rattus*, B) Whole mount of reference hair of *Rattus rattus*, C) Whole mount of recovered hair of *Nesokia indica*, D) Whole mount of reference hair of *Nesokia indica*, E) Whole mount of recovered hair of *Mus musculus*, F) Whole mount of reference hair of *Mus musculus*.

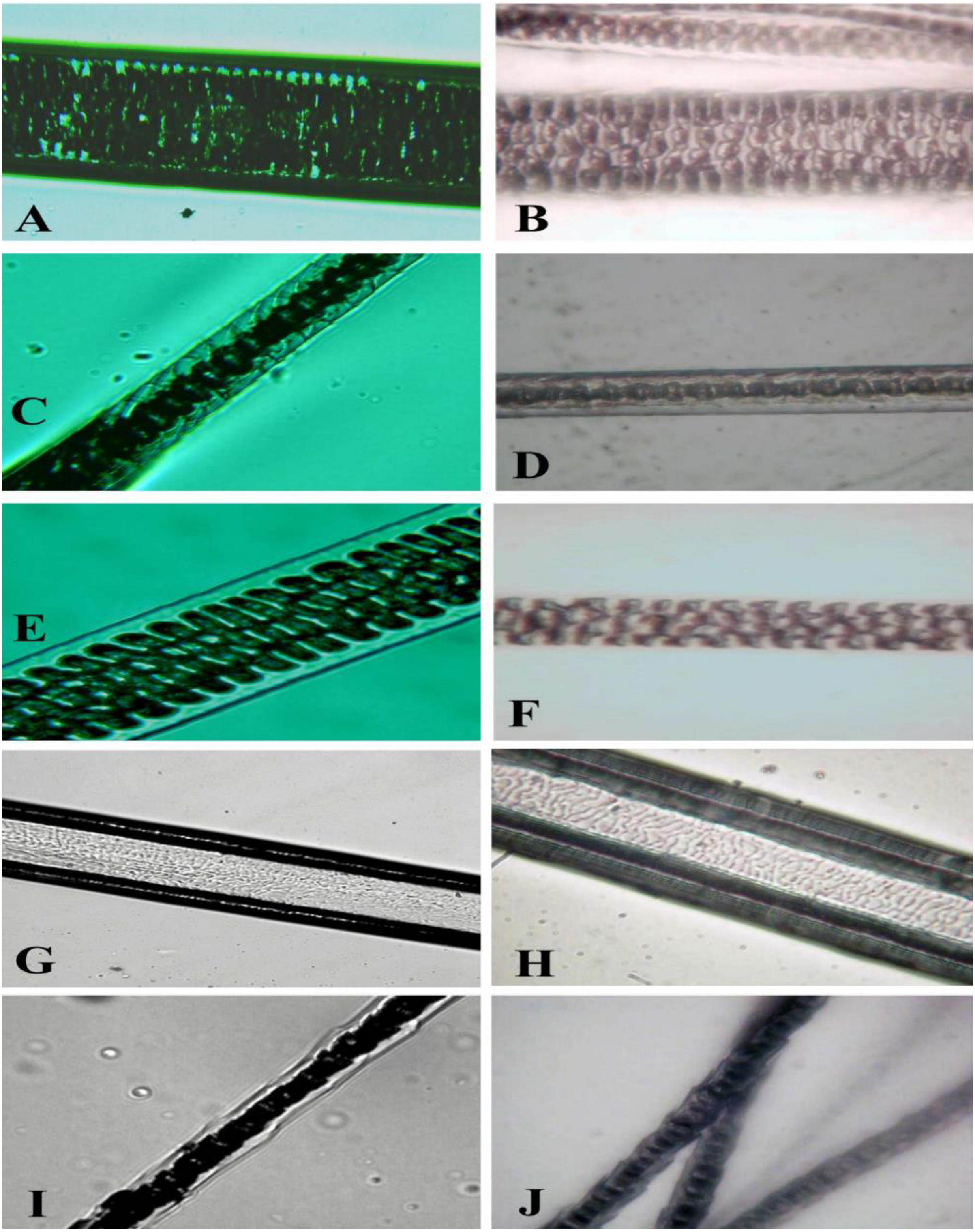

Figure 4. Photomicrographs of whole mount of hair structure of five different rodent species (recovered from fecal samples of gray mongoose and reference hair of rodents) consumed by the gray mongoose; A) Whole mount of recovered hair of *Golunda ellioti*, B) Whole mount of reference hair of *Golunda ellioti*, C) Whole mount of recovered hair of *Tetera indica*, D) Whole mount of reference hair of *Tetera indica*, E) Whole mount of recovered hair of *Nesokia indica*, F) Whole mount of reference hair of *Nesokia indica*, G) Whole mount of recovered hair of *Rattus rattus*, H) Whole mount of reference hair of *Rattus rattus*, I) Whole mount of recovered hair of *Mus musculus*, J) Whole mount of reference hair of *Mus musculus.*

little variation. However, during winter, *Mus musculus* was predominantly consumed (45%).

The gray mongoose consumed five different rodent species in the study area. *Tetra indica* was consumed most heavily during all four seasons, followed by *Golenda ellioti* in spring and summer. However, during fall and winter *Nesokia indica* was the second most frequently consumed rodent species while *Mus musculus* was the least consumed rodent species in all seasons (Table 5).

Statistical analysis showed a significant difference in the occurrence of vertebrate bones (P = 2.36e-05 ***) in the fecal samples of the two mongoose species in the study area (Table 2).

3.2.5. Insects in mongoose diet

Insects were consumed more heavily in the diet by the small Indian mongoose compared to the gray mongoose. The percent frequency of occurrence of insect orders identified from fecal analysis of the small Indian mongoose, in their consumption order, included Hymenoptera (ants, wasp, and bees), Orthoptera (grasshoppers), Coleoptera (beetles), Blattoda (cockroaches), and Odonata (dragonflies). On the other hand, for the gray mongoose, the percent frequency of occurrence of insects in preference order (Table 5) included Orthoptera (grasshoppers), Hymenoptera (ants, wasp, and bees), Coleoptera (beetles), Odonata (dragonflies), and Blattoda (cockroaches) (Table 5). Statistical analysis showed a significant difference in the occurrence of insects (P = 2.24e-07 ***) in the fecal samples of the two mongoose species in the study area (Table 2).

3.2.6. Seasonal variation in consumption of insects

Both mongoose species consumed five different insect orders in varying percentages during different seasons. The small Indian mongoose most frequently consumed Hymenoptera (ants, wasps, and bees) during spring (41%), followed by summer and fall (33% each) but least (21%) during winter.

On the other hand, the gray mongoose most frequently preyed upon Orthoptera (grasshoppers) and Hymenoptera (ants, wasps, and bees) during spring, summer, and fall but also included Coleoptera (beetles) during winter (Table 5).

3.2.7. Prey species richness (S), diversity (H'), and evenness (E) indices

For the small Indian mongoose, the prey species richness was highest in summer and lowest in fall (Figure 5), the diversity index was highest in summer and lowest in winter, and the evenness index was maximum during fall and lowest during winter. Similarly, for the gray mongoose, prey species richness was highest in summer and lowest in fall, the diversity index was highest in spring and lowest in winter, and the evenness index was highest in fall and lowest in winter (Figure 6).

On the whole, the prey species richness, diversity, and evenness indices were higher for the small Indian mongoose in comparison with the gray mongoose in the study area. Student's paired t-test showed significant differences in prey species richness (df = 3, t = 3.18, P = 0.03) and diversity index (df = 3, t = 3.18, P = 0.003) between SIM and GM. However, the evenness index between SIM and GM showed a nonsignificant difference (df = 3, t = 0.384, P = 0.76).

3.2.8. Food niche breadth and food niche overlap

The gray mongoose had a broader (7.4) niche breadth (B_A) as compared to the sympatric small Indian mongoose (6.9) in the study area (Figure 7). Student's paired t-test revealed a significant difference in niche breadth between the

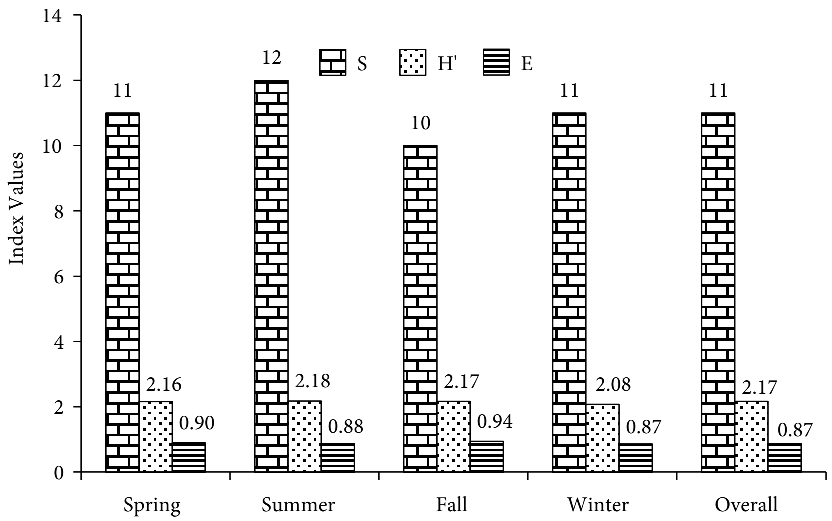

Figure 5. Prey species richness (S), diversity index (H'), and evenness index (E) of the prey species of the small Indian mongoose (*Herpestes javanicus*) on the Pothwar Plateau during the current study period.

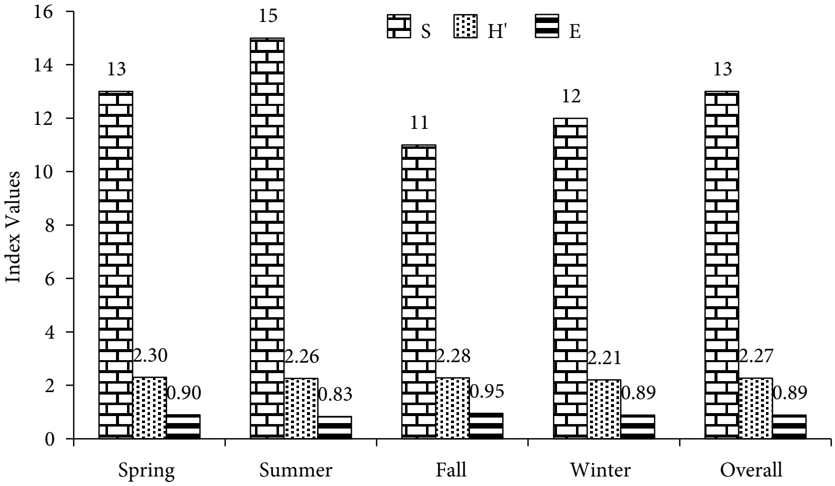

Figure 6. Prey species richness (S), diversity index (H'), and evenness index (E) of the prey species of the gray mongoose (*Herpestes edwardsii*) on the Pothwar Plateau.

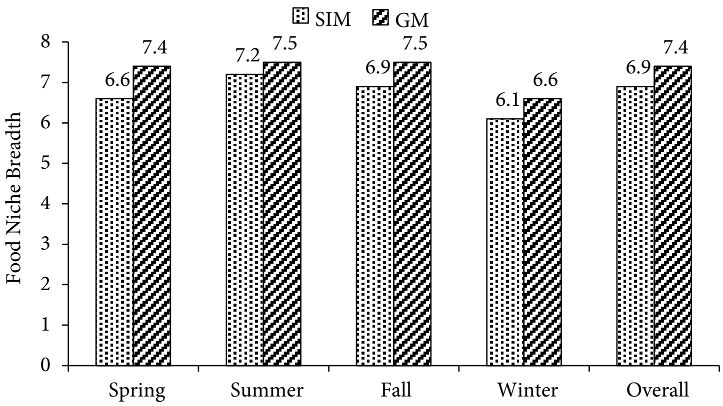

Figure 7. Food niche breadth (B_A) of SIM and GM during different seasons of the year on the Pothwar Plateau. * SIM: small Indian mongoose, *GM: gray mongoose

sympatric small Indian mongoose and the gray mongoose (df = 3, t = 3.18, P = 0.01) on the Pothwar Plateau. A high niche overlap (0.95) was found between the two mongoose species estimated by Pianka's index. The highest niche overlap between the two mongoose species occurred in winter and the lowest in spring (Figure 8).

4. Discussion

Coexistence of sympatric carnivore species is possible through niche differentiation (Pianka, 1974). Food utilization is a crucial aspect in the study of carnivore ecology, and therefore knowledge about food selection is critical to understand strategies of life history and in formulating sound conservation recommendations (Miquelle et al., 1996). The coexistence is thought to be the result of size variations between predators and their hunting strategies involve selecting different sets of prey species (Rosenberg, 1966) and the competition can be reduced when predators occupy different habitats or use the same area at different times (Schaller, 1972). Distribution of a species in an area depends upon a number of biotic and abiotic factors: vegetation, power of animal dispersions, climate and weather, resources, competition, and habitat quality. These factors affect the distribution pattern and also limit the distribution of animals in a region or country. Distribution of species on land has also been limited by a number of other barriers: deserts, mountains, and rivers (Sclater and Philips, 1899). The results of the current study show that the two mongoose species (the small Indian mongoose and the gray mongoose) are widely distributed on the Pothwar Plateau. The results of the current study support the hypothesis that the habitat used by the two mongoose species was influenced by the level of human activity. These findings expand our understanding of the

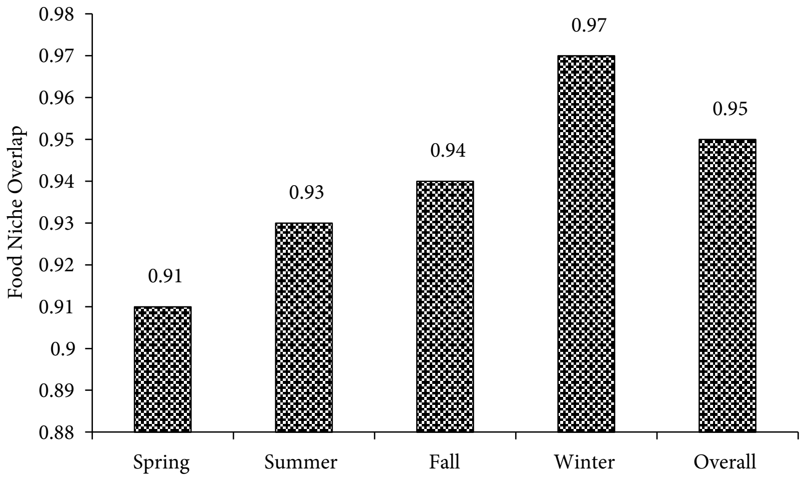

Figure 8. Food niche overlap of between SIM and GM during different seasons of the year on the Pothwar Plateau. * SIM: small Indian mongoose, *GM: gray mongoose

dynamics of flexible habitat used by the two carnivores species in human high activity areas (human dwellings), medium activity areas (cultivated fields), and low activity areas (natural areas). However, no effect of elevation (above sea level) on distribution of the two mongoose species has been indicated, although Roberts (1997) reported about the gray mongoose that it does not penetrate into the Murree foothills. The minimum and maximum elevation where the two species have been found distributed range from 203 and 874 m on the Pothwar Plateau.

We found the two mongoose species distributed throughout four districts of the Pothwar Plateau. The small Indian mongoose was more widely distributed in three districts (Chakwal, Rawalpindi, and Attock) while in Jhelum district the gray mongoose showed wider distribution. This distribution of the two mongoose species was found to be influenced by human activity levels. The small Indian mongoose was more widely distributed near or within human habitation (high human activity areas) and less in the natural areas (low human activity areas). On the other hand, the gray mongoose was more distributed in natural areas and less in human inhabited areas. Both species were almost equally distributed within medium human activity areas, indicating that both mongoose species overlap in their distribution in the areas where there is medium level human activity. Such areas contained agricultural fields, and some poultry farms near human settlements. Obviously both mongoose species should be experiencing more interspecific competition for prey species for coexistence in such habitat. Roberts (1997) and Mahmood et al. (2011) reported occurrence of the small Indian mongoose near human habitation, around poultry farms and in cultivated lands.

The population density of the small Indian mongoose was high in high human activity areas but low for the gray mongoose. In low human activity areas, the gray mongoose was found at high density. These findings indicate that the small Indian mongoose is more adapted to human dwellings while the gray mongoose avoids such areas and prefers natural areas. Such findings are also consistent with previous published literature such as by Roberts (1997), Santiapillai et al. (2000), and Francis (2008). Quinn and Whisson (2005) estimated higher population density of the small Indian mongoose (0.57 mongoose per ha) in the high human activity area of Palo Colorado and low population density (0.19 mongoose per ha) in the low human activity area of Tradewinds. In the current study, it has also been indicated that the two sympatric mongoose species may occupy the same habitat where sufficient resources are available to meet the livelihood requirements of both. The small Indian mongoose's adaptation to human vicinity is probably due to more occurrence of their prey: small rodents (*Rattus rattus* and *Mus musculus*). Elevation does not seem to affect the distribution of the two mongoose species, as the distribution range of both species was 200 m to 850 m throughout the Pothwar Plateau.

Food is the essential resource for animals and its categorization among species is important for analyzing interactions between coexisting species (Taper and Marquet, 1996). Food partitioning can change with alteration in prey abundance in different geographic sites (Clode and Macdonald, 1995). In addition to having similar diets, animal species may occupy niches that overlap in terms of spatial resources (Johnson et al., 1996). In the current study, physical characteristics (length, breadth, and mass) of the fecal samples of the small Indian mongoose and the gray mongoose were different; the gray mongoose's feces were greater in size and diameter and heavier than those of the small Indian mongoose. Fecal analysis revealed that the main food components of both mongoose species were insects and small mammals (rodents). A few earlier published studies on the diet of the small Indian mongoose by Roberts (1997), Siddiqui et al. (2004), and Mahmood et al. (2011) confirm these dietary components; similar food components were reported by Roberts (1997) in the diet of the gray mongoose.

The recovery of more frequent mammalian hair in fecal samples indicates that both mongoose species consume more small mammals (rodents) during fall but less in winter. The small Indian mongoose consumed three rodent species while the gray mongoose utilized five species, with three rodent species being common. Recovery of feathers from feces showed higher consumption of birds during winter and less during spring for both mongoose species. The consumption of insects by the small Indian mongoose was high during summer for the orders Hymenoptera, Orthoptera, Coleoptera, and Blattoda. For the gray mongoose, consumption of the orders Hymenoptera, Orthoptera, and Coleoptera was higher in summer. A couple of previous studies from other parts of the country had reported similar findings; for example, Rana et al. (2005) reported that in Faisalabad (Pakistan) region the small Indian mongoose consumed at least 9 rodent species. Siddiqui et al. (2004) reported higher consumption of birds during winter by the small Indian mongoose, while it was low in spring. These results are obvious and quite logical since insects could be more available during summer in the study area.

Consumption of plant matter including seeds by the small Indian mongoose was also high during spring and by the gray mongoose during winter, which is supported by an earlier study by Siddiqui et al. (2004).

The results of the current study establish the fact here that the small Indian mongoose consumes more insects and less small mammals while the gray mongoose species feeds less on insects but more on small mammals and birds. Siddiqui et al. (2004) reported that mongooses feed upon two major groups of crop pests, i.e. rodents and insects, and so both mongoose species in this regard play an essential ecological role in the biological control of rodents and insects. Hence the two mongoose species are the farmer's friend.

Prey species richness for both mongoose species showed variation within the seasons and was high during summer but low during fall. Similarly, the diversity index was high during summer for the small Indian mongoose but for the gray mongoose it was high during fall. A low value of diversity index for both mongoose species was recorded during winter. The evenness index of prey species also varied and was high during fall for both mongoose species, showing that prey species were not evenly distributed in the study area during different seasons. It was also noted that overall prey species richness, diversity index, and evenness index values were high for the gray mongoose as compared to the small Indian mongoose. These higher values of different indices indicated that the gray mongoose on the Pothwar Plateau has more choice of food during different seasons as compared to the small Indian mongoose.

Food niche breadth (Levin's index and standardized Levin's index) for both mongoose species was high during summer but low during winter, indicating that greater numbers of prey species are available during summer. Food niche was significantly broader for the gray mongoose compared to the small Indian mongoose, indicating a greater variety of prey in the dietary menu of the gray mongoose. Food niche overlap was high during winter and low during spring; this fact indicates more competition for prey species during winter. Overall food niche overlap between the two mongoose species was high (0.95) and such a high food niche overlap shows that the small Indian mongoose in its native range lives in sympatric relation to the gray mongoose by partitioning the resources of occupied habitats.

In conclusion, the distributions and populations of the two mongoose species on the Pothwar Plateau, part of their native range in Asia, was influenced by human activity level; the small Indian mongoose was more adapted to human inhabited areas (high human activity) while the gray mongoose was well adapted to natural areas (low human activity). The diet of both mongoose species includes insects, rodents, birds, and some plant material. However, the gray mongoose has a wider food niche breadth as compared to the small Indian mongoose, while a high food niche overlap occurs between the two mongoose species in the study area.

References

Ahmad M (1990). Groundnut in the Dry land Agriculture of Potohar, BARD Project, Pakistan Agriculture Research Council, Islamabad, Pakistan.

Beckmann JP, Berger J (2003). Rapid ecological and behavioural changes in carnivores: the responses of black bears (*Ursus americanus*) to altered food. J Zool 261: 207-212.

Begon M (1979). Investigating Animal Abundance. Baltimore, MD, USA: University Park Press.

Bhutta IA (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, NY, USA: Garden City Books. Carrera R, Ballard W, Gipson P (2008). Comparison of Mexican wolf and coyote diets in Arizona and New Mexico. J Wildl Manage 72: 376-381.

Chaudhry QZ, Rasul G (2004). Agro-climatic classification of Pakistan. Sci Vision 9: 59.

Clode D, Macdonald DW (1995). Evidence for food competition between mink (*Mustela vison*) and otter (*Lutra lutra*) on Scottish islands. J Zool (London) 237: 435-444.

Corbet GB, Hill JE (1992). The Mammals of the Indo-Malayan Region. Oxford, UK: Oxford University Press.

Dawson JP, Claridge AW, Triggs B, Paull DJ (2007). Diet of a native carnivore, the spotted-tailed quoll (*Dasyurus maculatus*) before and after an intense fire. Wildl Res 34: 342-351.

Dhakal J, Diwakar C (2001). An Introduction to CITES. Kathmandu, Nepal: DNPWC.

Donadio E, Buskirk SW (2006). Diet, morphology, and interspecific killing in Carnivora. Am Nat 167: 524-536.

Fedriani JM, Fuller TK, Sauvajot RM, York EC (2000). Competition and intraguild predation among three sympatric carnivores. Oecologia 125: 258-270.

Francis CM (2008). A Field Guide to the Mammals of South-East Asia. Princeton, NJ, USA: Princeton University Press.

Glen AS, Dickman CR (2008). Niche overlap between marsupial and eutherian carnivores: does competition threaten the endangered spotted-tailed quoll? J Appl Ecol 45: 700-707.

Government of Punjab (2000). Punjab Development Statistics, Bureau of Statistics, Govt. of the Punjab, Lahore, Pakistan.

Hinton HE, Dunn AMS (1967). Mongooses. London, UK: Oliver and Boyd.

Johnson WE, Fuller TK, Franklin WL (1996). Sympatry in canids: a review and assessment. In: Gittleman JL, editor. Carnivore Behaviour, Ecology and Evolution, Vol 2. New York, NY, USA: Cornell University Press, pp. 189-218.

Kochert MN (1986). Raptors. In: Cooperidder AY, editor. Inventory and Monitoring of Wildlife Habitat. Denver, CO, USA: US Department of the Interior Bureau of Land Management, pp. 313-334.

Krebs CJ (1998). Ecological Methodology. Menlo Park, CA, USA: Benjamin/Cummings.

Lavoie GK (1971). Food habits: A technique for slide preparation. Range Science Department, US International Biological Program. Technical Report No. 69: 1-5.

McDonald RA (2002). Resource partitioning among British and Irish mustelids. J Anim Ecol 71: 185-200.

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

Millsap BA, LeFranc Jr MN (1988). Road transect counts for raptors: how reliable are they? J Rapt Res 22: 8-16.

Miquelle DG, Smirnov EN, Quigley HG, Hornocker MG, Nikolaev IN, Matyushkin EN (1996). Food habits of Amur tigers in Sikhote-Alin Zapovednik and the Russian Far East, and implications for conservation. J Wildl Res 1: 138–147.

PARC (1980). Agro-Ecological Regions of Pakistan, Pakistan Agricultural Research Council, Islamabad.

Pianka ER (1973). The structure of lizard communities. Ann Rev Ecol Syst 4: 53-74.

Pianka ER (1974). Niche overlap and diffuse competition. Proceeding of Natural Academic Science USA 71: 2141-2145.

Polis G, Myers C, Holt R (1989). The ecology and evolution of intraguild predation: potential competitors that eat each other. Annu Rev Ecol Syst 20: 297-330.

Postanowicz R (2002). "Indian Grey Moongoose" (On-line). Lioncrusher's Domain. Accessed December 05, 2013 at http://www.lioncrusher.com/animal.

Quinn JH, Whisson WA (2005). The effects of anthropogenic food on the spatial behaviour of small Indian mongooses (*Herpestes javanicus*) in a subtropical rainforest. J Zool Lond 267: 339-350.

Ramesh T, Kalle R, Sankar K, Qureshi Q (2012). Spatio-temporal partitioning among large carnivores in relation to major prey species in Western Ghats. J Zool 287: 269-275.

Rana AS, Smith SM, Siddiqui MJI (2005). Scat analysis of small Indian mongoose feeding on fauna of some high and relatively low input crop fields. Int J Agri Biol 7: 777-780.

Richardson L, Clark TW, Forrest SC, Campbell TM (1987). Winter ecology of black-footed ferrets (*Mustela nigripes*) at Meeteetse, Wyoming. Am Midland Natural 117: 225-2397.

Roberts TJ (1997). The Mammals of Pakistan. London, UK: Oxford University Press, pp. 187-188.

Ross ST (1986). Resource partitioning in fish assemblages: a review of field studies. Copeia, 2: 352-388.

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

Schemnitz SD (1980). Wildlife Management Techniques Manual. Fourth ed. Revised. Washington DC, USA: The Wildlife Society Inc, pp. 113-126.

Schoener TW (1974). Resource partitioning in ecological communities. Science 185: 27-39.

Schoener TW (1986). Resource partitioning. In: Kikkawa J, Anderson DJ, editors. Community Ecology: Pattern and Process. Blackwell: Melbourne, Australia, pp. 91-126.

Sclater WL, Sclater PL (1899). The geography of mammals. London, UK: K. Paul, Trench, Trübner & Co.

Seaman G, Randall J (1962). The mongoose as a predator in the Virgin Islands. J Mammal 43: 544-546.

Shekhar NU (2003). Local people's attitudes towards conservation and wildlife tourism around Sariska Tiger Reserve, India. J Environ Manag 69: 339-347.

Siddiqui MJ, Rana IN, Rana SA (2004). Analysis of the scats of small Indian mongoose (*Herpestes auropunctatus*) with special reference to the insect fauna in croplands of Faisalabad, Pakistan. Entomology 26: 95-99.

Southwood TRE (1966). Ecological Methods, with Particular Reference to the Study of Insect Populations. London, UK: Methuen.

Taper ML, Marquet PA (1996). How do species really divide resources? Am Nat 147: 1072-1082.

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

Walter GH (1991). What is resource partitioning? J Theor Biol 150: 137-143.

Wiens JA (1989). The Ecology of Bird Communities. Cambridge, UK: Cambridge University Press.

Whitfield P (1978). The Hunters. New York, NY, USA: Simon and Schuster. United States Department of Agriculture Circular 118: 1-4.

Wilson DE, Reeder DM (1993). Mammal Species of the World: A Taxonomic and Geographic Reference. Second edition. Washington DC, USA: Smithsonian Institution Press.

Wozencraft WC (1989). Classification of the recent carnivora. In: Gittleman JL, editor. Carnivore Behavior, Ecology and Evolution. Ithaca, NY, USA: Cornell University Press, pp. 569-593.

Wozencraft WC (2005). Order Carnivora. In: Wilson DE, Reeder DM, editors. Mammal Species of the World. Washington DC, USA: Smithsonian Institution Press. pp. 279-348.