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Small mammal community composition and abundance in rural human habitations of Pothwar, Pakistan

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Abstract: To determine small mammal species composition, abundance and distribution in rural human habitations, a study was conducted in four village sites of Pothwar, Pakistan between 2012 and 2014. At each site, snap trapping was conducted on seasonal basis in three types of structures (village houses, shops, and farm houses) for four consecutive nights. Over 7,680 trap nights, a total of 746 small mammals, representing eight rodent species: house mouse (*Mus musculus*), black rat (*Rattus rattus*), Indian gerbil (*Tatera indica*), soft-furred field rat (*Millardia meltada*), Indian bush rat (*Golunda ellioti*), lesser bandicoot rat (*Bandicota bengalensis*), short-tailed bandicoot rat (*Nesokia indica*), and little Indian field mouse (*Mus booduga*) and one insectivore species house shrew (*Suncus murinus*) were captured. House mouse was the most abundant and widely distributed species in the area, and showed seasonal variation in its abundance with the higher rate of capture in the winter. Black rat was the second most abundant species, but was captured from three of the four village sites. House shrew was the third most abundant and widely distributed species. Field rodents such as, Indian gerbil, soft-furred field rat, Indian bush rat, lesser bandicoot, short-tailed bandicoot rat, and little Indian field mouse were captured in the village structures, but in small numbers. Feild rodents were most commonly captured in the winter season. The results of this study indicate that rural village structures were mainly infested with two commensal species, house mouse and black rat, and field rodents were visiting human dwellings only occasionally. Therefore, it is recommended that management practices should focus on the major commensal pest species.

Keywords: Abundance, commensal small mammals, rodents, shrews, species composition.

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Introduction

Small mammals are generally defined as the mammals whose adult body weight does not exceed 5 kg, and are considered the most adaptable group of vertebrates worldwide (Merritt 2010). Among small mammals, rodents are the most abundant, comprising about 2700 species. Of these species, only 5–10% are acting as pests at different levels (Aplin *et al*. 2003; Stenseth *et al*. 2003). However, the effects of these pests can be large, and rodents are known to cause different pre-harvest and post-harvest losses in developing countries (Brown *et al.* 2013; Stuart *et al*. 2011). In Asia, what rodents eat annually is enough to feed 220 million people for the whole year (Meerburg *et al.* 2009). Recently, Belmain *et al.* (2015) reported a loss of more than 70 kg and 130 kg of rice per year in rural communities of Bangladesh and Myanmar, respectively. In Pakistan, economic losses due to indoor rodent species have not been well documented. A single study in the grain markets of

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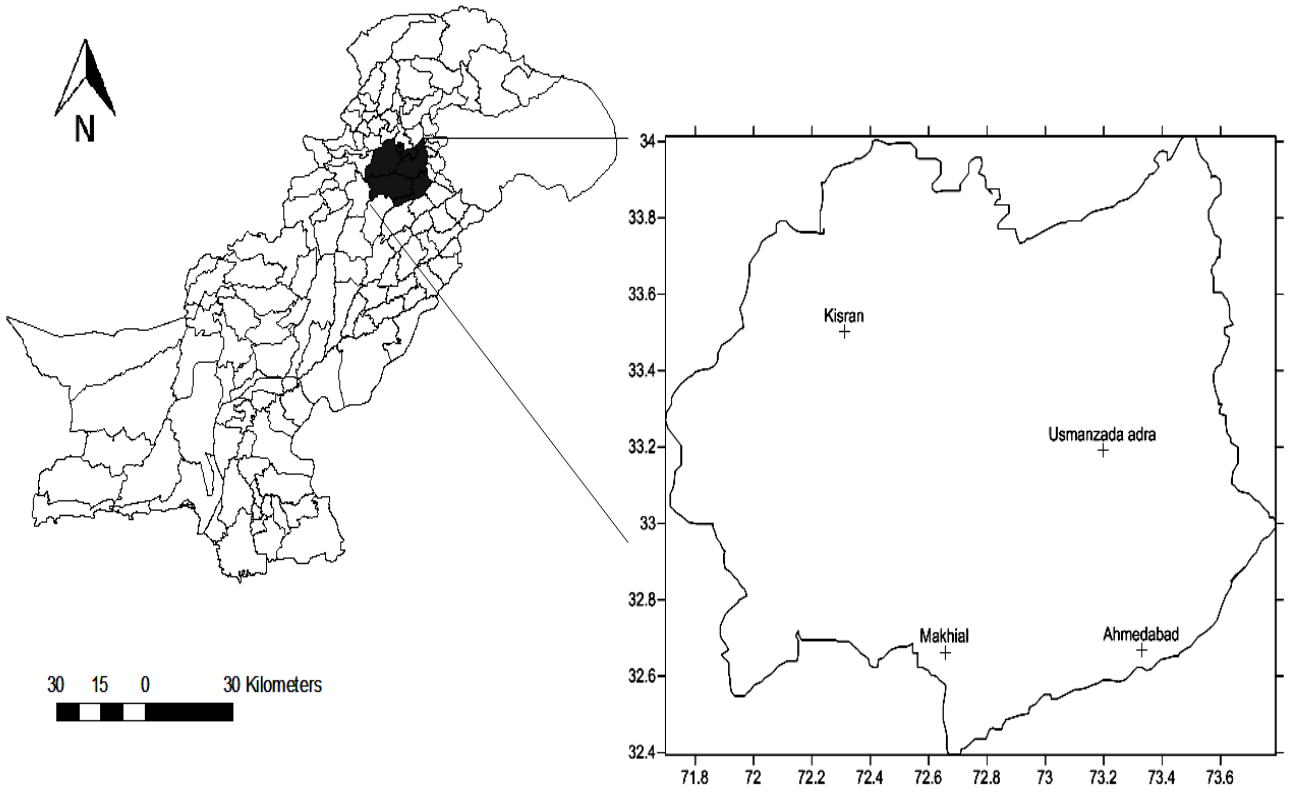

Fig. 1. Map of the study area, indicating the trapping sites (villages) in Pothwar, Pakistan.

Pakistan reported an annual grain loss of 740 kg/shop due to various rodent activities (Ahmad *et al.* 1995). In addition to crop losses, rodents may damage buildings, gnaw on electric cables, and consume and contaminate foodstuffs (Pimentel *et al.* 2000). Also, rodents as well as shrews are recognized as vectors and reservoirs of various types of pathogen (Himsworth *et al.* 2013; Liu *et al.* 2014).

Worldwide, studies on the small mammal pest species present in the indoor environments are few. In most of the cases, rodent related studies are restricted to natural habitats and crop fields. In indoor habitats, especially in the rural environments, poor living conditions of the people, and close association between wild rodents, human and domestic animals create an increased chance of disease transmission between them (Ng-Hublin *et al.* 2013; Panti-May *et al.* 2012). For rodent control activities, application of rodenticides is common. However, this poses risks to the non targeted species, and also their improper use have a negative impact on human health (Belmain *et al.* 2002; Brakes & Smith 2005; Buckle 1990). In the past decade, ecologically-based rodent management (EBRM) has been applied effectively to the field rodents (rodents present in wild), as well as for the commensal rodents (rodents associated with humans) (Belmain *et al.* 2003; Brown *et al.* 2006; Singleton *et al.* 2005). EBRM plans are based on the strong background knowledge of species composition, ecology and biology of the species present in the area, and are usually species specific and area specific (Singleton 2003).

In order to improve agriculture production and minimize economic losses due to the rodent pest species, ecologically-based rodent management is needed for Pakistan. This demands prior knowledge of the rodent species and other small mammal communities present in both indoor or outdoor habitats. Presently, we have very limited knowledge about the small mammal populations living in rural commensal habitats of Pakistan. A single study by Mushtaq-ul-Hassan (1993) has recorded the species present in the villages of Faisalabad, Punjab along with the detailed ecological studies on the *R. rattus* species present in this rural commensal habitat. No such study is available on the status of small mammal species in rural dwellings of the proposed study site, Pothwar. The Pothwar region contributes about 10% to the total agricultural production of the

country, and farmers in the area consider rodents as the major constraint in increasing yield from agriculture fields. In the cropping system of Pothwar region, five species of field rodents; Indian bush rat (*Golunda ellioti*), short-tailed bandicoot rat (*Nesokia indica*), Indian gerbil (*Tatera indica*), lesser bandicoot rat (*Bandicota bengalensis*) and *Mus* spp. have been previously reported (Brooks *et al*. 1988; Hussain *et al*. 2003; Tariq 2004).

As the crop fields and human habitations are in close proximity to each other in the rural areas, this can lead to the movement of field rodents into human dwellings depending on the agricultural activities performed in the villages. These invading rodents, as well as commensally present rodent species can cause damage to the stored grains, and other food items, or household items present in the indoor conditions. Therefore, it is important to know the status of commensal rodent species, as well as field rodent species invading rural indoor habitats, in order to determine their impact on health and economy of people in rural areas. In Pothwar region, the status of rodent speices or other small mammal species present in the commensal habitats has not been investigated. However, in order to plan suitable control measures, we require prior knolwege about the major infesting species, their distribution, and abundance in the indoor conditions of Pothwar region. Hence, the present study was aimed at determining the species composition, abundance and distribution of small mammals in the rural human habitations of Pothwar. This study will provide a baseline data of small mammal species present in the indoor environment and would help in developing appropriate management strategies against the major pest species.

Materials and Methods

Study area

The present study was conducted in Pothwar (32.5°N–34.0°N and 72°E–74°E) northern Punjab, Pakistan. Pothwar is a rainfed area, comprising four districts of Punjab province (Attock, Chakwal, Jehlum and Rawalpindi) and Islamabad capital territory (ICT) (Fig. 1). The area lies at the elevation of 350 to 575 m above sea level with the undulating topography generally sloping from North East to South West. Pothwar experiences a semi arid to humid climate. The annual rainfall of the area ranges from 450 mm in the southwest to 1750 mm in northeast, with 70% of the rainfall occurring during the monsoon months of July to September. The total area of Pothwar is 22000 km^2, of which approximately 10000 km^2 is used for various agricultural activities. The major crops grown in the area include wheat, groundnuts sorghum, maize, millet, mustard, and legumes. Wheat is the major winter crop (November–May) with inter-cropping of lentils, grams and mustard, while the two important crops of summer are groundnut and millets (May–October) (Rashid & Rasul 2011; Tariq 2004). The total human population of Pothwar is about 2 million, of which 70% population lives in rural areas. In rural areas, people have limited employment opportunities and depend on agriculture for their livelihood (Taj *et al*. 2007).

Animal Trapping

The trapping was conducted from March 2012 to February 2014 in four villages of Pothwar, namely Kisran (Site I), Makhial (Site II), Ahmedabad (Site III), and Usmanzada Adra (Site IV) (Fig. 1). At each village site, animal trapping was conducted during four seasons: Spring (March–April); summer (May–September); autumn (October–Mid November) and winter (Mid November–February). In each village, three types of structures (six houses, three shops and one farm house) were selected for snap trapping. Here, village houses refers to the residence within the main village; village shops refers to the small general stores which sell different type of food items, daily used products, fruits, and vegetables. Farm houses refers to the rural residence build away from the main village, where the villagers keep their animals and perform different agriculture activities. In total, animal trapping was conducted in 192 houses, 96 shops, and 32 farm houses during the two year study. At each site, four trapping sessions (one session/season) were conducted during each year. Metallic snap traps of two different sizes (17 × 9.5 cm and 11.5 × 4.5 cm) were used in equal proportion. In each trapping session, sixty traps (6 traps/structure) were set per night for the four consecutive nights. Traps were baited with bread (roti) soaked in vegetable oil, and were set in the evening (6–7 pm) and checked in the next morning (6–8 am). Each trapped animal was identified and assigned a field number, capture date, capture location and was placed in plastic bags for transfer to the laboratory.

Table 1. Species composition and abundance of small mammals at four sites in rural Pothwar. The relative abundance (% RA) of each species is shown in parentheses.

Species	Site-wise abundance (%RA)				Total capture	Relative abundance
	Site I	Site II	Site III	Site IV		
No. of species	7	5	4	6		
Mus musculus	110 (54.5)	229 (93.9)	36 (19)	61 (55)	436	58.4
Rattus rattus	50 (24.8)	-	134 (70.9)	33 (29.7)	217	29.1
Suncus murinus	20 (9.9)	12 (4.92)	8 (4.2)	14 (12.6)	54	2.68
Tatera indica	8 (4)	1 (0.41)	11 (5.8)	-	20	1.21
Millardia meltada	8 (4)	-	-	1 (0.9)	9	0.94
Golunda ellioti	5 (2.5)	1 (0.41)	-	1 (0.9)	7	0.13
Bandicota bengalensis	-	1 (0.41)	-	-	1	0.13
Nesokia indica	1 (0.5)	-	-	-	1	0.13
Mus booduga	-	-	-	1 (0.9)	1	0.13
Total trapped (N)	202	244	189	111	746	**100**

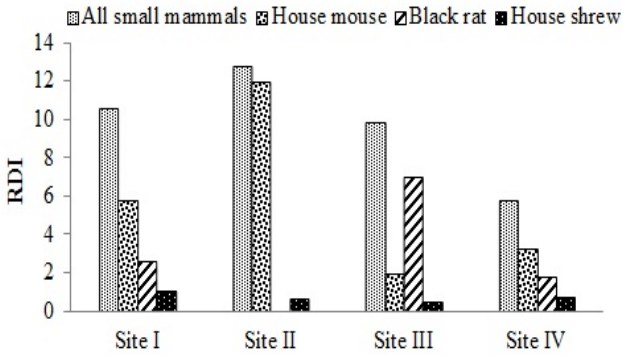

Fig. 2. Relative density index (RDI) of small mammals across four trapping sites in rural Pothwar.

Data analysis

Relative density index (RDI) was used as a measure of abudance of small mammals across different trapping sites, seasons, and strucutres. RDI was caluculated as follow: RDI = (number of captures/(number of traps) (number of nights)) × 100. Species richness (S) "the number of species captured" was compared across different trapping sites, seasons, and strucutres. Normality of the data was checked with Shapiro-Wilk's test. Non-parametric tests were applied for the analysis of results, as the data did not fulfill assumptions of parametric tests. A chi-square test was used to determine variations in the species richness across different sites, seasons, and trapping strcutures. Kruskal–Wallis test was used to compare the RDI values across different trapping sites and trapping seasons, and a Mann-Whitney test was used as a post-hoc test, if there existed a significant difference among groups. All differences with $P > 0.05$ were considered non-significant. All the analyses were performed using Statistical Package for Social Sciences (SPSS) software (version 16.0).

Results

A total of 746 individuals of small mammals were captured in 7,680 trapping nights from the commensal habitats of rural Pothwar. Among them, 692 (92.76% as 92.8%) individuals belonged to eight species of rodents, while the remaining 54 (7.23%) individuals were shrews, representing a single species of insectivore. The trapped rodent species included: house mouse (*Mus musculus*), black rat (*Rattus rattus*), Indian gerbil (*Tatera indica*), soft-furred field rat (*Millardia meltada*), Indian bush rat (*Golunda ellioti*), lesser bandicoot rat (*Bandicota bengalensis*), short-tailed bandicoot rat (*Nesokia indica*), and little Indian field mouse (*Mus booduga*). House shrew (*Suncus murinus*) was the single insectivore species trapped (Table 1).

Between the four trapping sites, no significant difference was found in the abundance of total small mammals captured (Kruskal-Wallis $H_{3,32} = 7.39$; $P = 0.06$; Fig. 2). With respect to the major pest species captured, significant difference was found in abundance of house mouse across trapping sites (Kruskal-Wallis $H_{3,32} = 9.3$; $P = 0.02$; Fig. 2). House mouse was the most abundant species at site I, II and IV and constituted 54.5%, 3.9% and 55% of the total capture, respectively. While, at Site III, house mouse was the second most abundant species contri-

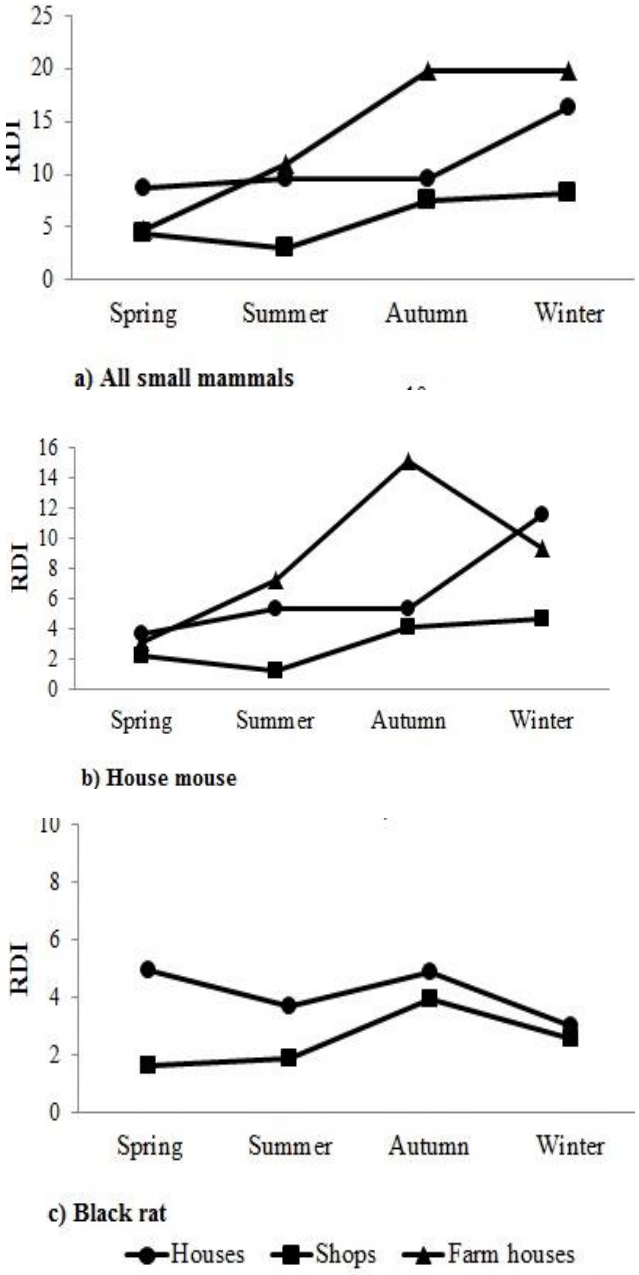

Fig. 3. Seasonal variations in the Relative density index (RDI) of **a)** all small mammals **b)** house mouse **c)** black rat in different trapping strcutures.

buting 19% of the total capture. For black rat, a significant difference was found in abundance across trapping sites (Kruskal-Wallis $H_{2,24} = 8.25$; $P = 0.01$; Fig. 2), and the highest abundance (70.9%) of black rat was found at Site III. House shrew was the third most abundant species captured from all four sites. For house shrew, no significant difference in abundance was found between sites (Kruskal-Wallis $H_{3,32} = 1.41$; $P = 0.70$; Fig. 2). Collectively, six field rodent species (Indian gerbil, soft-furred field rat, Indian bush rat, lesser bandicoot rat, short-tailed bandicoot rat, and little Indian field mouse) comprised 5.2% of the total capture. Among these field rodents, Indian gerbil was captured from three sites (I, II and III), and was relatively more common at Site III. Soft-furred field rat was captured from two sites (I, IV) and was relatively more common at Site I. Indian bush rat was mainly captured from Site I. A single individual of each of the three species, lesser bandicoot rat, short-tailed bandicoot rat, and little Indian field mouse was captured from Sites I, II and IV, respectively (Table 1). Species richness does not vary significantly across four trapping sites ($\chi^2 = 0.90$; $df = 3$; $P = 0.82$).

Across trapping seasons, three commensal species (including, house mouse, black rat, and house shrew) were captured in all the seasons with additional field rodent species: three (soft-furred field rat, Indian bush rat, and lesser bandicoot rat) in spring, four (soft-furred field rat, Indian bush rat, short-tailed bandicoot rat, and little Indian field mouse) in summer, one (Indian gerbil) in autumn, and two (Indian gerbil and soft-furred field rat) in winter. Species richness does not vary significantly across four seasons ($\chi^2 = 0.90$; $df = 3$; $P = 0.82$).

Species composition was also determined in three different types of village structures, including: houses, shops, and farm houses. Overall, across all the sites, eight species of small mammals (7 rodent species and one insectivore species) including house mouse (n = 298), black rat (143), house shrew (42), Indian gerbil (11), soft-furred field rat (6), Indian bush rat (6), short-tailed bandicoot rat (1), and little Indian field mouse (1) were captured from village houses. In the village shops, five species of small mammals were captured, including house mouse (71), black rat (43), house shrew (11), Indian gerbil (4), soft-furred field rat (3). In village farm houses, six species of small mammals were captured including house mouse (67), black rat (31), house shrew (1), Indian gerbil (5), lesser bandicoot rat (1), and Indian bush rat. (1). Species richness does not vary significantly between three types of trapping structures ($\chi^2 = 0.9$; $df = 2$; $P = 0.6$).

Significant seasonal variations were detected in the abundance of total small mammals captured from village houses (Kruskal-Wallis $H_{3,32} = 7.9$; $P = 0.04$; Fig. 3a), villages shops (Kruskal-Wallis $H_{3,27} = 8.8$; $P = 0.03$; Fig. 3a), and farm houses (Kruskal-Wallis $H_{3,25} = 12.3$; $P = 0.00$; Fig. 3a). In both

village houses and shops, abundance was significantly low in spring and summer as compared to winter, and the remaining pairwise comparisons were insignificant. In farm houses, abundance was lowest in spring as compared to the other three seasons. With respect to the major species captured, significant seasonal variations were detected in the abundance of house mouse captured from village houses (Kruskal-Wallis $H_{3,28}$ = 8.5; P = 0.03; Fig. 3b). The species was more captured in winter as compared to spring and summer. In village shops, no significant seasonal variations were detected in the abundance of house mouse (Kruskal-Wallis $H_{3,17}$ = 3.8; P = 0.28; Fig. 3b). In farm houses, significant seasonal variations were detected in the abundance of house mouse (Kruskal-Wallis $H_{3,17}$ = 8.2; P = 0.04; Fig. 3b), and the abundance was lowest in spring and summer as compared to winter. In case of black rat, no significant seasonal variations were detected in the abundance of individuals in village houses and shops (P > 0.05 for both structures; Fig. 3c). Across farm houses, the abundance of black rats could not be compared statisitically due to low capture rate (as only single individual was captured in spring). Similarly, seasonal varations in the abundance of other small mammal species could not be compared due to their low capture rate.

Discussion

In the present study, nine species of small mammals were trapped from the indoor habitats of rural Pothwar. Roberts (1997) recorded similar species of rodents and insectivores in different parts of Pakistan. In the cropping system of Pothwar, five species of rodents have been previously reported (Brooks *et al*. 1988; Hussain *et al*. 2003). With respect to commensal environment, the species richness in the present study is equal to, or higher than reported in some previous studies. For instance, Mushtaq-ul-Hassan (1993) recorded four species of small mammals from the rural human dwellings in central Punjab, Pakistan. Advani (1982) reported nine species of small mammals in rural human dwellings of the Indian desert. Similarly, in another study, Shenoy & Madhusudan (2006) reported eight species of small mammals in Banglore, India.

While the field species were captured occasionally from the four trapping sites, three commensal species, including, house mouse, black rat and house shrew were captured frequently across all the sites. House mouse was the most abundant and widely distributed species. The species was captured from all the sites, although its abundance was higher at Site II compared to other three sites. House mouse achieved the highest abundance at Site II. Perhaps, absence of black rat from this site facilitated the mouse in achieving a larger population size. The inference is supported by the fact that at Site III, where black rat population was relatively high, house mice population was apparently smaller. This can be further supported by the concept of dominance hierarchy in sympatric rodent species, where the large sized species are dominant over the smaller ones, and removing of the dominant species can cause an increase in the abundance or activity of subordinate species (Bowers *et al*. 1987; Brown *et al*. 1996; Harper & Cabrera 2010).

Black rat was recorded as the second most abundant species present in the commensal environment. The distribution of this species varied, and interestingly, no individual of black rat was captured from the site II. The absence of this species from site II may be attributed to its location and topography. The site was located on a rocky slope and surrounded by hills. The village was not served by truck road. Taber *et al*. (1967) reported that this species is limited to the towns and villages provided by railroads or truck road, and in the villages where no such roads or railway tracks are present, the only species present is the house mouse.

House shrew, a commensal insectivore species was the third most abundant species in the study area. This species was captured from all the four sites, but its abundance was relatively low as compared to other commensal species. This may be due to the type of traps we used, as we were not using pitfall traps, which have been previously considered most suitable for trapping shrews (Fichet-Calvet *et al*. 2010). Therefore, we consider trap bias could have influenced the trapping of *S. murinus* species in our study.

Indian gerbil, the fourth most abundant species was captured occasionally at the three sites. The species was recorded from all the three types of structures, viz., houses, shops and farm houses. Inside villages, Indian gerbil was captured from those houses and shops which were present at the periphery, and had crop fields nearby. Roberts (1997) reported that Indian gerbil is establishing commensally due to its aggressive

behavior, and therefore replacing black rat in some villages. However, the present study does not confirm such trends. Similar to our study, no such replacement was observed in the villages of Faisalabad, Pakistan (Mushtaq-ul-Hassan 1993).

In the present study, a very small number of field rodent species were captured from the commensal habitats. These results are not very surprising, because field species occasionally visit the indoor habitats when there is scarcity of food in outdoor conditions. A single specimen of lesser bandicoot rat was captured during the two years of trapping, indicating that the species was not commonly present in the indoor areas. Our finding is supported by the previous study of Beg *et al.* (1977). According to them, lesser bandicoot rat occurs in the kitchen gardens, or farmlands, but it is not found in the indoor habitats of both rural and urban areas. In India, the species has been reported to establish commensally and is found in warehouses and other premises in different cities (Chakraborty 1992). In our study, low trapping data for this species confirm that lesser bandicoot rat has not yet turned commensal in Pakistan. Occurrence of soft-furred field rat species in the present study is in agreement with previous studies by Roberts (1997). According to his study, the species is present in Punjab and extending westwards across the salt range to Kallar Kahar and Soon valley. On the other hand, Hussain *et al.* (2003) did not capture this species from the cropping system of Pothwar. Trapping of soft-furred field rat individuals from the northward sites (Attock and Rawalpindi) indicates that the species is extending from salt range and Kallar Kahar areas towards the north part of the Pothwar region.

Seasonal data on the abundance of major species shows that house mouse abundance varied across different seasons and was higher in winter. However, in some previous studies, high mouse abundance was reported in the dry period (Castillo *et al.* 2003; Gomez *et al.* 2008; Panti-May *et al.* 2012). This contrast in result could be due to the difference between the climatic conditions, habitat type, and cropping patterns in the areas. House mouse is a species occurring in both commensal and field conditions and appears to migrate between indoor and outdoor habitats depending on the food availability (Carlsen 1993). Also, seasonal changes in the abundance may occur due to human activities (Gomez-Villafane & Busch 2007; Mino *et al.* 2007; Wu *et al.* 2006). In Pothwar region, late autumn to early winter is the post-harvest period, and farmers usually store their harvested crops, including, millet, sorghum, and groundnuts in their houses. This provides an abundant food supply for the rodent species, and hence can cause "habitat generalist" species like, house mouse to move from the fields into the commensal habitats.

Black rat abundance did not show significant seasonal variations in the rural Pothwar region. This constancy in the abundance of black rat could be due to its living in a stable indoor environment with access to the abundant food supply. No change in abundance means that black rat was truly commensal in the area, with no movement between indoor and outdoor environments. Similarly, black rat has been reported to be a truly commensal species and was rarely found away from human dwellings (Mohr *et al.* 2007; Monadjem *et al.* 2011). One other commensal species, *S. murinus*, does not show any seasonal pattern in its abundance, indicating that the species was strictly commensal species in the Pothwar villages.

Among the major field rodent species, Indian gerbil was captured only in the autumn and winter seasons, with a relatively higher number caught in the winter months. Similarly, soft-furred field rat was commonly captured in winter season; possibly due to shortage of food in the outdoor environment during the colder months. After harvest period, the fields are left without crops, till wheat sowing. This could result in little or almost no food for the rodent species in the fields, and hence attract field rodents towards commensal habitats in search of food. Similarly, Advani (1982) reported that rodents migrate towards houses in the drought period when there is little vegetation available in the fields, and feed on stored grains and other food products in the houses. Species composition with respect to different trapping structures shows that rodents were present in all types of structures. While, in case of insectivore species, a single specimen of house shrew was captured from the farm house throughout the trapping period. These results indicate that farm houses were not the preferred habitat for the house shrews. We conclude that stable environmental conditions in the indoor habitats, promoted round the year occurrence of small mammals in different village structures. In the Pothwar region, there existed variations in the abundance of small mammals across different sites and seasons. House mouse, the most abundant species possibly showed

seasonal migration between indoor and outdoor habitats. Although field rodents were captured during this study, their low capture rate indicated that they were not interfering in the commensal habitats of Pothwar region. Hence, it is recommended that future management plans should mainly focus on the two species: house mouse and black rat. Future studies based on the movement pattern of the species are required in order to determine the habitat preference of species in the commensal environments in different conditions. With the understanding of the distribution pattern and habitat preference of the major pest rodent species, we will be able to develop effective target specific management strategies for their control in the region, and therefore, can minimize the economic losses due to the pest rodent species.

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