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Bat Fauna of Genus *Pipistrellus* from Wheat-Rice based Agro-Ecosystem of Punjab, Pakistan

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Authors' Contribution
MS and MAI did field survey and collected the data. AJ supervised the study. AHF prepared the bacula skulls for taxonomic studies. Irfan did morphometric measurements. MIA and MS wrote the article.

Key words
Bat fauna, Baculum, Chiroptera, Gujranwala.

ABSTRACT

Three rice producing districts *viz*. Gujranwala, Hafizabad and Mandi Bhauddinin, Pakistan were surveyed to explore bat fauna of genus *Pipistrellus* in central Punjab from January 2015 to December 2016. A total of 172 specimens of genus *Pipistrellus* belonging to six species *i.e. P. pipistrellus* (n = 43), *P. paterculus* (n = 12), *P. javanicus* (n = 39), *P. tenuis* (n = 18), *P. cylonicus* (n = 40) and *P. dormeri* (n = 20) were captured. Out of these six species, four are reported for the first time from the study area, whereas, *P. pipistrellus* and *P. paterculus* has already been reported from other districts of Punjab province. The shape and length of baculum were the characters that help in clear cut identification of various *Pipistrellus* species. The external body, cranial and bacular features of the species were compared with available literature.

INTRODUCTION

Genus *Pipistrellus* is represented by 51 species (Koopman, 1993) with distribution ranges extending from central southern Africa, throughout Eurasia to Japan, Indonesia, New Guinea, Solomon Islands and northern Australia with occurrence in Canada, USA and Mexico. In Indian Subcontinent the genus is represented by 12 species (Bates and Harrison, 1997) while eight species have been reported from territorial limits of Pakistan (Roberts, 1997). Members of genus *Pipistrellus* are small and their external features resemble *Eptesicus*. The nostrils in these bats are directed antero-laterally with a distinct internarial groove. The ears are small and roundly pointed with short and bluntly shaped tragus (Roberts, 1997). It is difficult to identify the species from one another on the basis of external morphology however the cranial and bacular features aid significantly to discriminate various species (Hill and Harrison, 1987).

Pipistrellus pipistrellus ranges from Britain and southern Scandinavia through Europe, China and India to Japan and Taiwan it also present in Morocco, Tunisia and Algeria (Ahmim, 2017). In Pakistan, *P. pipistrellus* has also been recorded from Gilgit (Blanford, 1888-91) in Northern areas; Kulali and Dir, Chitral in KPK (Walton, 1974).

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Pipistrellus javanicus ranges from Afghanistan, Pakistan and India to Myanmar, Indonesia, Philippines, Korea, Japan, New Guinea and perhaps Australia. In Asia, *P. javanicus* has wide spread distribution ranging from Afghanistan, Pakistan, and India to Mayanmar, Indonesia, Philippines, Korea, Japan, New Guinea and perhaps in Australia. In Pakistan the species has been reported from Karakar pass (KPK) and pine forest of Gharial, Muree Hills (Punjab) (Roberts, 1977).

Pipistrellus tenuis ranges from Afghanistan, Pakistan, India and Sri Lanka to Vietnam and Thailand. In Pakistan, the species has been reported from Malakand (Roberts, 1977) and Chitral (Sinha, 1980) in KPK; Multan, Bhatu Hisar, Chaklala (Hinton and Thomas, 1926), Chakri (Siddiqi, 1961), Khanewal, Sheikhpura (Districts) in Punjab (BMNH) and Gambat; Sukur (Siddiqi, 1961), Karachi and Malir (Walton, 1974) in Sindh and Islamabad (Javid *et al*., 2012).

Pipistrellus paterculus is geographically distributed in northern India, Burma, Thailand, Vietnam and south-west China. In Pakistan the species has been reported from Kululai (KPK) and very little is known about this bat in the country (Roberts, 1997). The species in Pakistan has been reported from Landhi (Wroughton, 1916), Malir (Walton, 1974), Karachi and Thatta in Sindh and Lyallpur and Khanewal (Roberts, 1977) in Punjab.

Pipistrellus dormerii is confined to India and Pakistan only (Roberts, 1997; Bates and Harrison, 1997). In Pakistan, the species has also been reported from Sialkot in Punjab

and Shikarpur (Sinha, 1980) in Sindh (Roberts, 1997).

Literature regarding bat fauna of Pakistan is scarce and there is dire need to explore these environment friendly creatures in various parts of country (Javid *et al*., 2014a, b). During present survey, the agro-ecosystems of Punjab province were searched to find out the chiropteran diversity belonging to the genus *Pipistrellus*.

MATERIALS AND METHODS

Three districts of the Punjab province Gujranwala, Hafizabad and Mandi-Bhaudin (Fig. 1) were explored to find out species of bats belonging to the genus *Pipistrellus*. Punjab is the most populated province of the country and the districts comprising study area constitute the core rice producing belt, hence the natural ecosystems have been replaced by the agro-ecosystems to fulfill the food and shelter requirements of increasing human population. These districts lie about 200 m above sea, average annual rainfall is about 950 mm but the rains are more frequent during monsoon. The temperature varies from 4°C during winter to above 40°C during summer (Qadir *et al*., 2008; Ullah *et al*., 2009).

Fig. 1. Map of the study area.

This two year study extending from January 2015 to December 2016 was conducted in areas of wheat-rice based agro-ecosystem of Punjab province. These areas are comprised of three districts namely Gujranwala, Hafizabad and Mandi Bhaudin. All these three districts were explored for collection of bats and location of their roosts. Three nights in each month, one night in each district was spent throughout the study period at different sampling station (Table I) and bats were captured with the help of mist and hand nets. For locating potential bat roosts in the study area, old and undisturbed buildings, ruins, abandoned wells, farm houses, tree groves and forest plantations were searched. People of the study area were also interviewed for getting maximum information about exact location of bat roosts.

Table I.- Netting stations in three districts of wheat-rice based agro-ecosystem of Punjab.

District/ sampling sites	Latitude / Longitude	Date of capture
Gujranwala		
Civil hospital	32°10.203 N 74°11.583 E	08/02/2011
Qadirabad colony	32°17.490 N 73°41.563 E	07/03/2011
Kelaske village	32 °10.803 N 73 °58.668 E	08/06/2011
Gakharmandi town	32°18.340 N 74°08.791 E	11/09/2011
Rasulnagar village	32°19.680 N 73°46.720 E	01/04/2012
Ali Pur Chattha town	32°11.272 N 74°09.361 E	18/05/2012
Verpalchattha village	32° 10.803 N 73°58.803 E	11/06/2012
Hafizabad		
District katchery	31 °58.018 N 73°34.918 E	13/05/2011
Kotsarwar village	31 °55.148 N 73 °30.189 E	02/06/2011
Nothain village	31 °56.241 N 73 °32.770 E	04/07/2011
Kalekimandi village	32°04.150 N 73°42.697 E	03/08/2011
Sukhekimandi village	31°61.116 N 73°34.108 E	02/06/2012
Pindibhattian town	31 °55.148 N 73 °16.895 E	08/07/2012
Jalal purbhatian village	32°02.390 N 73°22.510 E	03/09/2012
Mandi Bhaudin		
Farid town	32°35.123 N 73°30.460 E	08/05/2011
Phalia town	32°43.601 N 73°58.130 E	05/06/2011
Malikwal town	32°35.102 N 73°45.080 E	08/02/2012
Head Rasul rest house	32°40.096 N 73°31.150 E	05/06/2012
Mano Chak	32°25.308 N 73°45.290 E	22/07/2012

Once the bat specimens were captured, they were euthanized, placed in cotton bat bags and each specimen was weighed up to 0.1 g (Pesola balance 10050, Swiss made). Each bat was preserved in a plastic jar in absolute alcohol, its number, sex, age, exact locality and district of capture was noted on the jar. These specimens were brought to the laboratory for further observations and analysis. The external body measurements were taken using a digital vernier caliper (0-150 mm) following Bates and Harrison (1997). For cranial and bacular measurements, the skulls and bacula were prepared and measured following Bates *et al*. (2005) and Javid (2011).

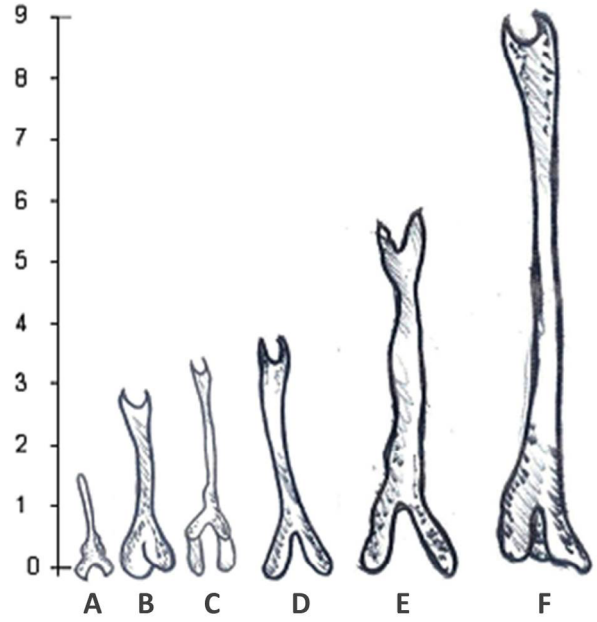

Fig. 2. Bacula of *P. pipistrellus* (A), *P. dormer* (B), *P. tenuis* (C), *P. ceylonicus* (D), *P. javanicus* (E) and *P. paterculus* (F).

RESULTS AND DISCUSSION

During present survey, a total of 172 specimens belonging to six species of genus *Pipistrellus* were captured. These include *Pipistrellus pipistrellus* (n = 43), *P. paterculus* (n = 12), *P. javanicus* (n = 39), *P. tenuis* (n = 18), *P. cylonicus* (n = 40) and *P. dormeri* (n = 20). All these six species are the first reports from the study area as the bat fauna of the study area was never documented prior to present investigation. However, *P. pipistrellus* and *P. paterculus* are the new provincial records and never recorded from Punjab province before present survey. The external body, cranial and bacular measurements of captured specimens of belonging to genus *Pipistrellus* were compared with available literature (Tables II, III).

Bacula of different species have unique shape and length (Fig. 2). *Pipistrellus pipistrellus* is a small sized narrow winged bat with forearm length 27-31 mm. The ears are broad but short in length, tragus is 4.2 mm long about half of the ear's length. The hairs are reddish brown on dorsal and slightly paler on ventral side. Average condyle-canine length is 10.9 mm. Baculum is very small, with narrow extended shaft and distal end is bifid but proximal basal lobes are well developed (Bates and Harrison, 1997). A total of 43 *P. pipistrellus* specimens were captured from study area during present survey. Average body mass of all these captured specimens was 3.3 g and the average forearm length was 28.9 cm. Average condyle-canine length (n = 3) was 10.3 mm while the average bacular length (n = 2) was 1.6 mm.

Pipistrellus javanicus is a medium size bat with forearm length 33-35 mm. Ears are short and rounded with long tragus, pelage color of dorsal side is brown, wing membranes and ears are blackish-brown (Chan *et al*., 2009). Average condyle-canine length is 12.4 mm. Baculum has long narrow shaft with distal bifid tips with well- developed proximal lobes. The average body mass of all the twelve *P. javanicus* captured during present study was 7.6 g and the average forearm length was 34.2 mm. Average condyle-canine length (n = 3) was 11.3 mm while the average bacular length was 6.0 mm.

Pipistrellus tenuis is a very small sized bat having average body weight of 3-4 g (Ingle and Heaney, 1992; Javid *et al*., 2012) and forearm length 27-29 mm. This is the smallest bat of the Indian subcontinent and is known as least *pipistrelle* or Indian pygmy bat. Morphologically *P. tenuis and P. coromandra* are very similar but can be differentiated on the basis of cranial characters (Bates and Harrison, 1997; Javid *et al*., 2012). The baculum of *P. tenuis* has thin long shaft with distinct distal bifid tip and well developed proximal lobes (Hill and Harrison, 1987; Javid *et al*., 2012). Average body mass of all the 18 *P. tenuis* specimens captured during present survey was 3.6 g. Average forearm length 29.2 mm, the condyle-canine length (n = 3) was 8.7 mm and average bacuar length (n = 2) was 3.8 mm.

Pipistrellus paterculus is a small sized bat with average forearm length 30 mm. The hairs are long and pelage color is dark brown on the head and back while ventral surface, belly hair tips are pale ginger brown. Average condyle-canine length is 11.2 mm. *P. paterculus* has large baculum with long narrow shaft and distal end has bifid tip (Bates and Harrison, 1997). Total of twelve specimens of *P. paterculus* was captured during present study have an average body mass 3 g, average forearm length was 30.5 mm, the condyle-canine length was 11.0 mm and average baculum length (n = 2) was 9.4 mm.

Table II.- Mean body mass (g) and external body measurements (mm) of six species of genus *Pipistrellus* captured from wheat rice based agro-ecosystems of Punjab, Pakistan (1, = Present study; 2 = Bates and Harrison 1997).

External	*P. pipistrellus*		*P. paterculus*		*P. javanicus*		*P. tenuis*		*P. ceylonicus*		*P. dormeri*	
measurements	1 (n = 43)	2	1 (n = 12)	2	1 (n = 39)	2	1 (n = 18)	2	1 (n = 40)	2	1 (n = 20)	2
Body mass	3.3 (2.5-4.3)	-	3.5 (2.9-4.7)	-	7.6 (4.5-10.7)	-	3.6 (1.8-5.4)	-	3.7 (2.9-4.3)	-	5(3.7-6.8)	-
Head and body length	38.2 (34.9-43.2)	40-48	41.4 (38.8-44.2)	42-48	48.2 (39.5-52)	40-55	36.8 (30-40)	33-45	53.5 (48-61.2)	45-64	46.7 (41.3-52.3)	39-55
Ear length	9.0 (6.8-12.7)	10.5-12	9.8 (8.7-11)	10-13	9.8 (7-12.2)	5-15	9.1 (7-11)	5-11	10.2 (8.3-11.3)	9.5-14	10.19 (8.7-12.4)	10-18
Tragus length	4.1 (3.2-5.1)	-	4.2 (3.4-4.8)	-	5.1 (4-7.5)	-	4.4 (3.4-6)	-	4.9 (4.1-6.1)	-	5.5 (4.7-6.2)	-
Thumb length	4.3 (3.1-5.6)	-	4.04 (3.1-5.2)	-	5.9 (4.6-7)	-	4.7 (4-6)	-	3.4 (2.5- 4.7)	-	5.3 (4.3-7.2)	-
Claw length	1.6 (1.2-2.1)	-	1.63 (1.1-2.5)	-	2.0 (12.5)	-	1.4 (0.7-2)	-	1.98 (1-3)	-	1.5 (4.3-7.2)	-
Forearm length	28.9 (26.5-3.14)	30.-31.6	30.5 (29-32.3)	29.2-34	34.2 (30.5-37.5)	30-36	29.2 (27-31)	25-30	35.3 (31.3-38)	33-42	34.5 (31.5-36.8)	32.7-36.3
3rd Metacarpal length	27.9 (24.3-31.9)	29.5-31	30.03 (28-31.8)	27.6-32.4	33.7 (29-36.5)	25.9-34.8	28.4 (26-30)	23.9-29.7	34.0 (30.2-36.8)	33-39.5	33.6 (31-36)	31.7-36.5
3rd Metacarpal: 1st phalanx	10 (9.2-11.2)	-	11.3 (9.5-12)	-	11.6 (9-13)	-	11.3 (10-12)	-	11.6 (9.8-13.2)	-	10.4 (8.3-12.5)	-
3rd Metacarpal: 2nd phalanx	8.3 (7.2-9.6)	-	8.8 (7.3-10.5)	-	9.6 (8-11)	-	9.02 (7-10.4)	-	9.6 (8.5-11)	-	9.0 (7.2-11)	-
4th Metacarpal length	27.0 (24.3-31.5)	28.7-30.8	29.6 (28-31)	27.4-32.4	32.9 (28-35)	29.9-34.7	27.8 (25.5-30)	23.7-29.2	33.1 (28.5-36)	32.6-38.5	33.3 (31-35.2)	31.6-36.4
4th Mtacarpal: 1st phalanx	9.9 (8.7-10.7)	-	10.7 (8.5-12)	-	10.4 (8.5-12)	-	10.8 (10-12)	-	101 (8.3-12)	-	9.4 (8-11.3)	-
4th Metacarpal: 2nd phalanx	6.4 (5.3-8.1)	-	7.8 (6.5-10)	-	9.2 (7.3-11)	-	8.02 (6.7-10)	-	8.5 (7.2-10.5)	-	8.5 (7.2-9.8)	-
5th Metacarpal length	26.5 (23.5-29.3)	28.4-29.8	28.4 (27.2-30)	27.1-31.2	31.5 (27.5-34.7)	29-33.4	27.2 (25-29)	23.5-28.5	31.9 (27-35.7)	30.7-36.7	33.0 (31-35)	31.2-35
5th Metacarpal: 1st phalanx	10.8 (5.3-76.4)	-	7.7 (6.5-8)	-	9.8 (7.1-10)	-	7.9 (7-10.4)	-	9.8 (8.9-11.6)	-	8.3 (7-9.5)	-
Wingspan	187 (175-207)	-	182 (142-213)	-	194 (167-221)	-	175 (137-203)	-	183 (148-198)	227-262	234 (218-225)	238-257
Tibia length	11.1 (9.7-12.8)	-	11.7 (11.2-12.3)	-	12.4 (10-14.5)	-	12.0 (11-13)	-	12.6 (10.7-14.5)	-	11.6 (10.2-13.7)	-
Calcar length	4.9 (4.5-5.7)	-	4.8 (4-6)	-	4.2 (3-5)	-	4.5 (3-6.4)	-	4.7 (3.3-6)	-	4.6 (3.7-5.6)	-
Hind foot length	6.2 (5.2-7.4)	6.0-7.0	6.6 (5.2-7.5)	6-7	8.1 (6-10)	3.0-8.0	6.3 (6-8)	3-7	9.3 (7.8-10.7)	6-11	6.9 (6.2-8.1)	5-8
Tail length	27 (24.6-28.8)	-	32.0 (28.5-35.2)	31-38	28.6 (24-33)	26-40	28.0 (22-33)	20-35	3.0 (26.3-34.6)	30-45	30.5 (27.5-34.5)	27-41
Penis length	6.3(6.1-7); n=17	-	6.8(6-8); n=5	-	8(7-9); n=5	-	6.2(4.2-8); n=6	-	8.3(8-9); n=14	-	6.3(6.1-7); n=12	-

Table III.- Mean cranial measurements (mm) of six species of genus *Pipistrellus* captured from wheat rice based agro-ecosystems of Punjab, Pakistan (1, present study; 2, Bates and Harrison 1997).

Cranial measurements	*P. pipistrellus*		*P. paterculus*		*P. javanicus*		*P. tenuis*		*P. ceylonicus*		*P. dormeri*	
	1 (n = 43)	2	1 (n =12)	2	1 (n = 39)	2	1 (n = 18)	2	1 (n = 40)	2	1 (n = 20)	2
Breadth of braincase	6.3 (5.96-6.64)	6.3-7.1	6.0	6.0-6.4	6.4 (4.3-8.5)	6.3-7.1	6.5 (4.6-8.4)	3-7	7.12 (5.15-9.09)	6.8-7.8	7.6 (7.7-7.5)	6.8-7.5
Zygomatic breadth	8.8 (7-10.6)	8.2-9	7.1	-	9.8 (7.2-12.4)	8.2-9	8.3 (6-10.6)	20-35	11.46 (7.23-15.69)	9.2 -11	11.2 (11.1-11.3)	-
Postorbital construction	3.51 (3.25-3.77)	3.3-4.3	3.3	3.2-3.9	3.9 (3.12-4.68)	3.3-4.3	4.1 (2.4-5.8)	-	4.26 (3.26-5.26)	3.7-4.3	4.2 (4.6-3.8)	3.6-4.2
Condylo-carine length	10.3 (9.9-10.67)	11.9	11.0	10.6-11.6	11.3 (7.5-15.1)	11.9-13.1	8.7 (6.6-10.8)	9.3-10.7	12.7 (7.7-17.7)	13.1-14.3	13.5 (13-14)	12.8-13.6
Condylo basal length	11.1 (10.6-11.5)		11 .5	-	12.1 (8.4-15.8)	-	9.8 (6.7-12.9)	-	10.76 (7.7-13.76)		14.3 (14-14.7)	-
Greatest length of skull	11.5 (11.13-11.87)	13-14.6	11.6	11.7-12.6	13.1 (9.5-16.7)	13-14.6	10.4 (7.7-13.1)	10.7-12.1	13.6 (8.07-19.2)	14.4-15.8	14.4 (14.2-14.6)	13.7-15
Maxillary tooth row (C-M^3)	3.51 (3.28-3.74)	4.6-5.2	4.1	4.1-4.8	3.8 (2.8-4.7)	4.6-5.2	4.2 (1.5-6.9)	3.5-4.1	6.01 (3.08-8.9)	5.2-5.9	5.3 (5.1-5.5)	5.2-5.6
Anterior palatal width	3.61 (3.1-4.1)	-	3.7	-	3.9 (2.8-5)	-	3.6 (1.9-5.3)	-	4.79 (2.7-6.7)		4.8 (4.7-5)	-
Posterior palatal width	5.3 (4.99-5.61)	-	5 .0	-	3.8 (2.9-4.7)	-	4.8 (2.5-7.1)	-	6.6 (4.29-9.09)	6.2-7.2	6.9 (6.8-7)	6.3-7
Mandibular tooth row (C-M_3)	3.58 (3.1-3.9)	4.8-5.5	4.5	4.4-5.0	3.9 (3.1-4.6)	4.8-5.5	4.7 (3.5-5.9)	3.8-4.4	5.3 (2.7-7.9)	5.7-6.5	6.1 (6-6.3)	5.5-6.1
Mandible length	7.8 (7.03-8.5)	9.3-10.7	8 .0	8.4-9.1	9.2 (9-9.4)	9.3-10.7	8.1 (7.3-8.8)	7.2-8.3	5.3 (4.88-15.4)	10.6-12	10.2 (10-10.5)	10.4-11.2

Pipistrellus ceylonicus are relatively large sized *pipistrellus* species with an average forearm length of 37.2 mm (Bates and Harrison, 1997) and weight 8 g (Roberts, 1997). Ears, face and inter-femoral membranes are dark brown in color. Some part of inter-femoral membrane near main body, tail and femora is hairy (Bates and Harrison, 1997). Dorsal pelage color of the species is greyish, red or golden brown while the ventral hairs are pale grey. The baculum has short upwardly curved shaft, bifid tip and well developed proximal lobes (Bates and Harrison, 1997). Average body mass of 40 *P. ceylonicus* specimens captured during present survey was 3.7 g. Average forearm length was 35.3 mm, the condyle-canine length (n = 3) was 12.7 mm while average length of baculum (n = 2) was 9.4 mm long.

Pipistrellus dormeri is a medium sized pipistrelle with an average forearm length of 34.4 mm and body mass 6.0-7.0 g (Madhavan, 1978), tail is short than head and body length. Hairs are dark brown on dorsal surface with grey brown tips, and paler with whitish tips on ventral surface. Average condyle-canine length 13.3 mm. Baculum has long narrow, slightly sinuous shaft and broadened, weakly bifid tip, the base is slightly broadened and bifid (Bates and Harrison, 1997). Average body mass of 12 *P. dormeir* specimens captured during present study was 5 g, average forearm length was 34.5 mm, condyle-canine length (n = 2) 13.5 mm and total bacular length (n = 2) was 3.2 mm.

CONCLUSION

With various identified species of bat fauna in different districts of Punjab and all other provinces of Pakistan, bat represents the important group of mammals that may have a vital role in ecology. Only a limited number of studies have been conducted on bat fauna of Pakistan, especially in Punjab province, that is considered to be a rich agricultural area and makes it difficult to mention on population trends and conservation status of the bats. Keeping in view the results of present study regarding the distribution of the bat species in a rich agricultural area, it is clear that efforts of the bat survey may also be focused in the nearby districts of the study area, as these are still not well explored. Therefore, further studies may be compulsory for mapping favorite bat habitats for the establishment of conservation priorities.

Statement of conflict of interest

Authors have declared no conflict of interest.

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