INNSPUB

Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 15, No. 3, p. 36-45, 2020
http://www.innspub.net

RESEARCH PAPER OPEN ACCESS

Diversity and seasonal abundance of small mammals in Bumdeling Ramsar Site, Trashiyangtse, Eastern Bhutan

Lam Norbu[*1], Phuntsho Thinley[2,3], Phurpa[4], Ugyen Dechen[1], Pema Tshering[5]

[1] *Trashigang Forest Division, Department of Forest and Park Services (DoFPS), Trashigang, Bhutan*

[2] *Ugyen Wangchuk Institute for Conservation and Environmental Research, Department of Forest and Park Services, Bumthang, Bhutan*

[3] *Ecosystem Management, University of New England, Armidale, New South Wales, Australia*

[4] *Samdrup Jongkhar Forest Division, Department of Forest and Park Services, Samdrup Jongkhar, Bhutan*

[5] *Rangjung Central School, Ministry of Education, Trashigang, Bhutan*

Article published on September 30, 2019

Key words: Fauna, Insectivores, Ramsar site, Rodents, Small mammals

Abstract

Small mammals have multiple ecological roles and are important components of the terrestrial ecosystems. They are important ecological indicators of changes in the natural surroundings. However, little is known about the small mammals in Bhutan. We conducted this study in the Bumdeling Ramsar Site in eastern region of Bhutan, aimed at enhancing our understanding of the species composition, abundance, and seasonal diversity of small mammals. We laid linear transects, each measuring 500 m in six different habitat types: agriculture land (AG), fallow land (FL), *Alnus sp*. forest (AF), open grassland (OG), riparian forest (RR), and oak forest (OF). We placed 17 collapsible Sherman live traps (23x9x8cm) in each transect to capture both ground dwelling and arboreal small mammals. We conducted the trapping exercise twice in the year 2016 (28 March to 28 April during the wet season and 1 to 30 October during the dry season), amounting to a total of 1,224 trap nights. We trapped a total of 135 individuals of small mammals, yielding seven species of rodents (90 individuals; 66.7%) and four of insectivores (45 individuals; 33.3%). We found significant difference in the number of individuals trapped among the six different habitats (X^2=66.43, *df*= 5, P<0.05) with the highest in AG (59 individuals, 43.7%) and the lowest in OG (1 individual; 0.7%) during the dry and wet season, respectively. In order to promote diversity of small mammals in the Ramsar site, we recommend reducing free-range cattle grazing and restraining domestic dogs in the vicinity of the Ramsar site.

***Corresponding Author:** Lam Norbu ✉ lam.norbu@ymail.com

Introduction

Small mammals (rodent, shrew and lagamorph ≤ 500g or 1kg) form a majority of the mammalian fauna, and they are an important component of most natural and semi-natural ecosystems (Ofori *et al*., 2015). They perform ecological roles in dispersal of seeds (Aplin *et al*., 2003; Garshong *et al*., 2013) and fungal spores (Gupta, 2011), nutrient cycling (Sieg, 1987; Klerk, 2014), and decomposition and mediation of energy flow through consumption and shedding of vegetation (Hoffmann *et al.,* 2010). They also often dubbded as environmental engineers because of their role in soil aeration through digging and burrowing, and in extreme cases, altering the whole landscape (Garshong *et al*., 2013; Gyeltshen, 2015). They also serve as essential prey for many mammals, birds and reptiles (Garshong *et al*., 2013; Chane and Yirga, 2014). They are, thus, known to play an important role in determining forest structure, composition and succession of vegetation (Ofori *et al*., 2015). Their abundance and composition in turn, are influenced by habitat structure, productivity and other important environmental factors (Demeke and Afework, 2014; Tuyisingize *et al*., 2014; Assefa and Srinivasulu, 2019).

Small mammals are considered to be good bio-indicators of habitats because of their short lifespan, rapid population dynamics, and low level of hunting pressure in comparison to larger mammals (Karuaera, 2011, Chane and Yirga, 2014). Most small mammals are prolific breeders; hence, they represent significant amount of the animal biomass in forest and other natural ecosystem (Aplin *et al*., 2003). They are also the major agricultural pests, causing substiantial damage to crops and stored farm produce (Karuaera, 2011; Ofori *et al.,* 2015). Further, they also serve as parasitic host and disease reserviors (Avenant and Cavallini, 2008; Bantihun, 2012).

On a gobal scale, there are approximately 5,416 species of mammals (Bantihun and Bekele, 2015) of which 2,706 (50%) are small mammals (Wolff and Sherman, 2007; Molur and Singh, 2009; Datiko and Bekele, 2013). South Asia alone has recorded 185 species of small mammals of which 62 are endemic to the region (Molur *et al.,* 2005). Among the South Asian countries, India has 120 species of small mammals representing 66% of Indian mammal records (Walker, 2003; Gyeltshen, 2015). Similarly, Nepal has 158 species of small mammals representing more than 60% of mammal records, and one species being endemic to Nepal (Katuwal and Koirala, 2012).

In Bhutan, there is very few documentations of small mammals, and hence, little is known about them with respect to their species diversity, distribution, conservation status, and ecology. This is largely attributed to limited explorations and studies conducted so far in the country. In fact, documentation of small mammals was initiated only in 1993, following which a few studies were conducted in the recent years. Wangmo *et al*., (2014) listed four species of small mammal from Royal Manas National Park (RMNP) in south-central region of Bhutan. Gyeltshen (2015) conducted an exploration in Jigme Dorji Nation Park (JDNP) in western Bhutan where he recorded six species of rodents. In the same year, Dorji (2015) added seven species of high-altitude rodents and shrews in the wetlands of Phobjikha, which is the third Ramsar Site in Bhutan. All of these studies are concentrated in the western region of the country, and there is no exploration from the eastern region. Therefore, we conducted this study in the eastern region of Bhutan, aimed at enhancing our understanding of the species composition, abundance, and seasonal diversity of small mammals.

Materials and methods

Study area

We conducted the study in the Bumdeling Ramsar Site (27°39'33.86" N, 91°25'47.73" E), which is situated inside the Bumdeling Wildlife Sanctuary (BWS; Fig.1), in north-eastern part of Bhutan. Our study site was designated as a Ramsar Site in 2012 in recognition of the conservation significance of the charismatic and 'Vulnerable' black-necked crane (*Grus nigricollis*) which winters annually in the area. On an average, about 90 individuals of this bird arrive

and reside in the area every year. It covers an area of 1.42 km². The elevation of the adjacent forest ranges from 1,900 to 2,050 m above sea level (a.s.l.). The wetland has 160 species of plants, 73 of birds, 38 of snakes, seven of lizards, seven of fishes and 12 of mammals (UNESCO, 2012). Among the large predators, the globally threatened and flagship species such as the Bengal tiger (*Panthera tigris*) is known to coexist with Himalayan black bear (*Ursus thibetanus*), dhole (*Cuon alpinus*), and red panda (*Ailurus fulgens*). Bhutan's national butterfly (*Bhutanitis ludlowi*) is also recorded in the study area (UNESCO, 2012; Poel, 2013). The mean annual temperature recorded is 20.2^{0}C and the mean annual rainfall is 1,065 mm (UNESCO, 2012). People residing in the vicinity of the study site follow subsistence farming which consists of crop cultivation, livestock rearing, and sale of non-timber forest produce. They also collect firewood, house construction timber, and NWFPs (such as bamboo, barks of daphne (*Daphne bholua*), fiddle heads, mushrooms, and many other wild vegetables) from the nearby forests. We selected six habitat types based on the dominant species composition: agriculture land (AG), fallow land (FL), Alnus forest (AF), open grassland (OG), riparian forest (RR), and oak forest (OF).

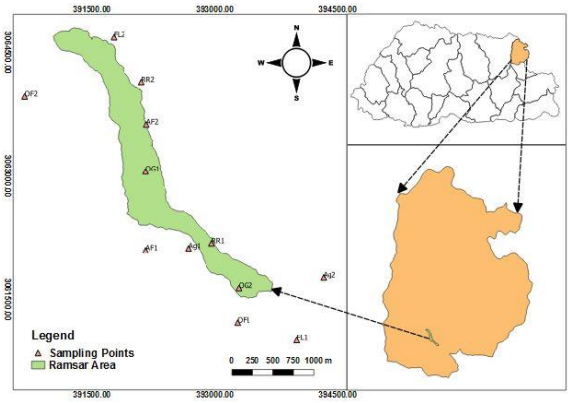

Fig. 1. Map showing study location in Bumdeling Ramsar Site (Trashiyangtse, Bhutan).

Live trapping of small mammals

At the outset, we conducted a preliminary survey in order to be able to appropriately select the trapping sites. Relevant site information such as topography, climatic conditions, and the associated flora and fauna were gathered. We conducted the trapping exercise twice in the year 2016 to compare seasonal diversity of small mammals: first round from 28 March to 28 April during the wet season and the second from 1 to 30 October during the dry season. This amounted to a total of 1,224 trap nights.

Transect lengths varying from 400 to 500 meters have been used in small mammal surveys (Klerk, 2014; Dorji, 2016). We laid linear transects, each measuring 500 m in six different habitat types of the study area. We placed a total of 17 collapsible Sherman live traps (23x9x8cm) in each transect, spaced by an interval distance of 15 m to capture both ground dwelling and arboreal small mammals. We kept the traps for three consecutive days to capture all possible small mammals. As recommended by Cunningham and Moors (1996) and Hoffmann *et al.,* (2010), we placed the traps in areas with high likelihood of small mammal visitation, such as proximity to rocks, caves, burrows, log side, bushes, fences, sheds, tree buttresses, coarse woody debris, visible droppings, food remains and runway. The traps were covered with litters, foliage and hays to camouflage and provide insulation (Barnett and Dutton, 1995; Pearson and Ruggiero, 2003). This also prevented the local people, cow herders, and stray dogs from being attracted by the shiny surfaces of the traps. We baited each trap with locally made flour dough mixed with ground nuts, apples, grapes, bananas, wheat biscuits, dry salty fish, bread, canned fish and fresh carrot following the baiting method of Barnett and Dutton (1995).

In order to be able to relocate the traps, we marked each trap location with red cloth tagged on a stick or a branch of a nearby tree or shrub. We inspected each trap twice a day: once in early morning from 7:00 hrs to 9:00 hrs and once in the late afternoon from 17:30 hrs to 19 hrs. This was to capture both diurnal and nocturnal animals (Bantihun and Bekele, 2015). During each inspection visit, we checked the baits and replenished them wherever necessary to increase trapping success and to avoid loss of animal lives

from hunger. We cautiously removed each trapped animal, placed in a polythene bag, and weighted using Pesola ® spring balance of 200g capacity.

Next, we measured each animal using the standard morphological measurement, such as head body length (HBL), hind foot length (HFL), tail length (TL), and ear length (EL), using a 30 cm metal scale. We determined the sex and reproduction status of captured individuals by observation of testis position and vagina perforations, and aged them as juvenile, sub-adult and adult. We released the live animals at the place of same ecological point after they were marked on ventral part of the body for further capture-mark-recapture studies (Hoffmann *et al*., 2010).

We identified each species following the descriptions provided in the guide books and references, particularly the field guides to mammals of Bhutan (Wangchuk *et al*., 2004), mammals of Nepal (Shrestha, 1997; Jnawali *et al*., 2011), and mammals of India (Menon, 2014). We also consulted small mammal experts in the region to identify those individuals and species which we could not identify.

2.3. Data analysis

We analysed the data using a statistical software package called SPSS™ *version 23* in combination with the Microsoft Excel™. We computed species abundance relative to the habitat types in terms of capture percentage (CP), using the formula: CP = (N_i/N_t) x 100 where, N_i = number of individuals of each species in each habitat and N_t = total number of individuals caught during the study. We calculated trapping success (TS) using the formula: TS = (TN*100)/Tn where, TN = total number of individuals captured at site and Tn = total number of trap nights at a site (Brooks *et al.,* 1990). We computed species diversity using the Shannon-Wiener o index (Shannon and Weaver, 1949) which is provided by the formula: $H' = -\sum Pi\ (lnPi)$ where, H' = Shannon-Wiener index, Pi = proportion of the total individuals belong to i^{th} species in the sample, ln = the natural logarithm, and $\sum$ = sum of the calculations. We computed species evenness (E) using the formula: $E = H'/H_{Max}$ where, $H'_{Max} = lnS$, S =total number of species in the sample, and H' = Shannon diversity index. It is also known as Pielou's Index. We determined species richness (R) using the formula: R = (S-1)/ (ln N) where, S = total number of species in the sample, N = total number of individuals of all species in a sample. It is also called the Margalef Index. We determined species dominance (D) using the formula: $D = 1/ \sum (pi)^2$ where, p = (n/N), n = number of individuals of a particular species, N = the total number of individuals of all species, and $\sum$ = the sum of the calculation. We used Chi square test to compute significant variations or differences in parameters of interests.

Results

We recorded a total of 15 species of small mammals (Table 1): *Rattus* sp., *Rattus rattus, Millardia meltada, Tatera indica, Mus musculus, Apodemus sylvaticus, Apodemus pallipes*, *Soriculus nigrescens, Soriculus caudatus*, *Sorex minutus*, *Talpa micrura*, *Suncus murinus*, *Tamiops mccllelandii,* and *Dremomys lokriah*. Among these 11 were captured live during both wet and dry seasons and the remaining four were recorded as observed species but not trapped. We trapped 135 individuals of small mammals of which 90 (66.7%) were rodents and 45 (33.3%) were insectivores. We observed several quills of Indian porcupine (*Hystrix indica*) in addition to sightings of Himalayan striped squirrel (*Tamiops mccllelandii*), orange-bellied squirrel (*D. lokriah*) and house shrew (*Suncus murinus*) in our study site.

The total number of captures differed among species. *Rattus* sp. was the most abundant species constituting 37.04% of the total number of captures, followed by *T. micrura* (17.04%). Proportions of *A. sylvaticus, S. nigrescens, and M. musculus* were 9.63%, 8.89%, and 6.67%, respectively. Rest of the species constituted below 5% of the total number of captures. The least abundant species were *M. meltada*, *R. rattus,* and *T. indica* with 3.70%, 2.22%, and 2.22%, respectively (Table 1).

There was a significant difference in the number of individuals recorded between habitat types: *Rattus sp.* (X^2=52.96, *df*=5, *P*<0.05), *M. meltada* (X^2=15.4, *df*=5, *P*<0.05), *T. indica* (X^2=15, *df*=5, *P*<0.05), *M.*

musculus (X^2=18.33, *df*=5, *P*<0.05), *A. sylvaticus* (X^2=65.02, *df*=5, *P*<0.05), *A. pallipes* (X^2=35.02, *df*=5, *P*<0.05), *S. negrescens* (X^2=16, *df*=5, *P*<0.05), *S. caudatus* (X^2=16.15, *df*=5, *P*<0.05), and *T. micrura* (X^2=115.1, *df*=5, *P*<0.05). Sixty-seven individuals of seven species were recorded in agriculture land, nine individuals of three species in fallow land, four individuals of one species in Alnus Forest, six individuals of three species in open grassland, 13 individuals of four species in Riparian, and 36 individuals of six species in oak forest (Table 2). *Rattus* sp. was the only species recorded in all habitat types: the highest (52%) in (Agriculture land) and the lowest (2%) in fallow land and open grassland. Alnus forest supported only *Rattus* sp. Except, for *R. rattus, A. pallipes*, *S. caudatus* and *S. minutus*, all species were captured during both wet and dry seasons (Table 3). The proportions of small mammals in the wet and dry seasons were 19.3% (n=26) and 80.7% (n=109), respectively. The total number of captures was significantly higher in the dry season than the wet season (80.7%, X^2=51.02, *df*=1, *P*<0.05). *R. rattus, A. pallipes*, *S. caudatus* and *S. minutus* were only captured during the dry season. Further, the distribution of species varied between wet and dry seasons in all habitats. The difference between habitat use of small mammals during the wet and the dry seasons (Table 4) was statistically significant (X^2=9.46, *df*=5, *P*<0.05 and X^2=110.60, *df*=5, *P*<0.05, respectively), with variation in species diversity between habitat types. Species diversity index of small mammals was high in Oak forest and low in Alnus forest (Table 5). The result of Shannon-Weiner Index (H') for the species diversity, arranged in descending order were 1.555, 1.493, 0.965, 0.868, 0.794, and 0 for OF, AL, FL, OG, RR and AF respectively (Table 5). The overall diversity index, evenness and species richness of the study area was H' =1.35, E= 0.56, and R= 0.074 respectively.

Table 1. Species composition, relative abundance (Ra) and conservation status of small mammals in Bumdeling Ramsar Site, Trashiyangtse, Bhutan.

Species/ Scientific name	Common name	Total number of captures	Ra (%)	Status IUCN
Rattus species	Rat	50	37.04	LC
Rattus rattus Linnaeus, 1758	Common house rat	3	2.22	LC
Millardia meltada Gray, 1837	Soft-furred metad	5	3.70	LC
Tatera indica Hardwicke, 1807	Indian gerbil	3	2.22	LC
Mus musculus Linnaeus, 1758	House mouse	9	6.67	LC
Apodemus sylvaticus Linnaeus, 1758	Wood mouse	13	9.63	LC
Apodemus pallipes Barrett-Hamilton, 1900	Himalayan field mouse	7	5.19	LC
Soriculus nigrescens Gray, 1842	Himalayan large claw shrew	12	8.89	LC
Episoriculus caudatus Horsfield, 1851	Hodgson's brown toothed shrew	7	5.19	LC
Sorex minutus Linnaeus, 1766	Pygmy shrew	3	2.22	LC
Talpa (Euroscaptor) micrura Hodgson, 1841	Himalayan mole	23	17.04	LC
Suncus murinus Linnaeus, 1766	House shrew	*	*	LC
Tamiops mccllelandii Horsfield, 1840	Himalayan striped squirrel	*	*	LC
Dremomys lokriah Hodgson, 1836	Orange-bellied Himalayan squirrel	*	*	LC
Hystrix cristata Linnaeus, 1758	Crested porcupine	*	*	LC
Total		135	100	

(*indicates sighted species, LC= Least Concern).

Of the 135 captured individuals in all trapping occasions, males comprised 40% (n = 54 individuals) and females 60% (n =81 individuals; Table 3). As the number of individuals (abundance) increased, the number of females also increased. Males accounted for a trap success of 4.41% and females of 6.62%.

Trap success differed significantly among habitats (X^2=66.43, *df*= 5, *P*<0.05; Table 4). The highest number trapped was in AG (59 individuals; 43.7%) and the lowest was in OG (1 individual; 0.7%) during the dry and wet season, respectively. The maximum trap success was yielded from AG (57.8%) and the minimum was from OG (1%) during the dry and wet

seasons, respectively. The overall trap success of the study was 11.03%. Morphometric measurements of small mammals are shown in Table 6.

Table 2. Number and abundance (%) of small mammal species among habitat types of agriculture land (AG), fallow land (FA), Alnus forest (AF), open grassland (OG), riparian forest (RR), and oak forest (OF) in Bumdeling Ramsar Site, Trashiyangtse, Bhutan.

Species	Abundance of species in each habitat types					
	AG (%)	FL (%)	AF (%)	OG (%)	RR (%)	OF (%)
Rodentia						
R. species	26 (52)	1 (2)	4 (8)	1 (2)	10 (20)	8 (16)
R. rattus	2 (66.7)	-	-	-	-	1 (33.3)
M. meltada	-	4 (80)	-	-	1 (20)	-
T. indica	3 (100)	-	-	-	-	-
M. musculus	-	4 (44.4)	-	-	-	5 (55.6)
A. sylvaticus	-	-	-	-	-	13(100)
A. pallipes	-	-	-	-	-	7 (100)
Insectivora						
S. nigrescens	6 (50)	-	-	4 (33.3)	-	2 (16.7)
S. caudatus	5 (71.4)	-	-	1 (14.3)	1 (14.3)	-
S. minutus	2 (66.7)	-	-	-	1 (33.3)	-
T. micrura	23(100)	-	-	-	-	-
Number of individuals	67	9	4	6	13	36
Number of Species	7	3	1	3	4	6
Number of trap-nights	204	204	204	204	204	204
Trap success	32.84	4.41	1.96	2.94	6.37	17.65
Species composition	50%	7%	3%	4%	10%	27%

Values in brackets indicate capture percentage (%) of that species relative to total number of captures from that site; (-) indicates no capture.

Table 3. Seasonal variation and sex distribution of small mammals trapped during wet and dry seasons in Bumdeling Ramsar Site, Trashiyangtse, Bhutan.

Species	Seasons					
	Spring season (wet)			Autumn season (dry)		
	Sex		Total number of captures	Sex		Total number of captures
	M	F		M	F	
R. species	7	7	14	11	25	36
R. rattus	-	-	-	1	2	3
M. meltada	-	2	2	1	2	3
T. indica	-	1	1	1	1	2
M. musculus	2	-	2	4	3	7
A. sylvaticus	2	2	4	3	6	9
A. pallipes	-	-	-	2	5	7
S. nigrescens	1	1	2	5	5	10
S. caudatus	-	-	-	4	3	7
S. minutus	-	-	-	2	1	3
T. micrura	-	1	1	8	14	22
Total	12	14	26	42	67	109

(M= male, F=female, - indicates absence)

Table 4. Trap success (Ts) and relative abundance (Ra) of small mammals in different habitats of agriculture land (AG), fallow land (FL), Alnus forest (AF), open grassland (OG), riparian forest (RR), and oak forest (OF) in Bumdeling Ramsar Site, Trashiyangtse, Bhutan.

Habitat types	No. of transects	Month/ Year	Season	Total number of captures	Ra	Trap night	Ts
AG	2	Mar-Aug/2016	Spring	8	5.9	102	7.8
	2	October/2016	Autumn	59	43.7	102	57.8
FL	2	Mar-Aug/2016	Spring	4	3.0	102	3.9
	2	October/2016	Autumn	5	3.7	102	4.9
AF	2	Mar-Aug/2016	Spring	2	1.5	102	2.0
	2	October/2016	Autumn	2	1.5	102	2.0
OG	2	Mar-Aug/2016	Spring	1	0.7	102	1.0
	2	October/2016	Autumn	5	3.7	102	4.9

RR	2	Mar-Aug/2016	Spring	5	3.7	102	4.9
	2	October/2016	Autumn	8	5.9	102	7.8
OF	2	Mar-Aug/2016	Spring	6	4.4	102	5.9
	2	October/2016	Autumn	30	22.2	102	29.4

Table 5. Diversity indices of small mammals among habitat types in Bumdeling Ramsar Site, Trashiyangtse, Bhutan.

Habitat	Shannon Index (H')	H'_{Max}	Pielou's Index (E)	Margalef Index (R)	Simpson Index (D)
Ag	1.493	1.95	0.767	1.43	0.02
FL	0.965	1.10	0.878	0.91	0.163
AF	0.00	0.00	0.00	0.00	0.00
OG	0.868	1.10	0.790	1.12	0.15
RR	0.794	1.39	0.573	1.17	0.05
OF	1.555	1.79	0.868	1.40	0.032

Table 6. Standard morphometric measurement of eleven small mammal species trapped live from Bumdeling Ramsar site, Trashiyangtse, Bhutan ((*BW= Weight, TL=Tail Length, HFL= Hind Foot Length, HBL= Head Body Length, EL= Ear Length).

Species	BWt[1] (g) Mean ± SD (n)	TL[2] (cm) Mean ±SD(n)	HFL[3] (cm) Mean ± SD(n)	HBL[4] (cm) Mean ±SD(n)	EL[5] (cm) Mean ±SD (n)
R. species	66.1±28.7 (50)	16.8±0.5 (50)	3.1±0.14 (50)	14.8±0.6 (50)	1.8±0.19 (50)
R. rattus	93.3 ± 10.4 (3)	16.13±1.31 (3)	3.43 ± 0.79(3)	14.0 ±3.39(3)	1.48±0.34 (3)
M. meltada	115 ±10.6 (5)	17.3±0.21 (5)	3.15±0.07 (5)	16.7±0.21 (5)	2 ±0.10 (5)
T. indica	100.2± 5.29 (3)	6.63±0.77 (3)	3.1±0.15 (3)	14.2± 0.40 (3)	1.9±0.1 (3)
M. musculus	17.45±0.1 (9)	8.1±0,14 (9)	1.75±0.07 (9)	6.65±0.07 (9)	1.5±0.07 (9)
A. sylvaticus	29.9±6.1 (13)	14.5±1.12 (13)	2.6±0.08 (13)	8.75±9.3 (13)	1.7±0.13 (13)
A. pallipes	36.42 ± 8.3 (7)	15.57±0.93 (7)	2.37± 0.34 (7)	13.18±0.74 (7)	1.65± 0.21 (7)
S.nigrescens	12±4.24 (12)	4.5±0.495 (12)	1.55±0.07 (12)	8±1.271 (12)	0.6±0.14 (12)
S.caudatus	6.72± 0.67 (7)	4.9±0.32 (7)	1.36± 0.08 (7)	6.75± 0.34 (7)	0.87±0.06 (7)
S. minutus	8.9 ± 2.9 (3)	4.3± 0.7 (3)	1.4±0.2 (3)	7.9± 0.4 (3)	0.4± 0.09 (3)
T. micrura	13.6±4.41 (23)	2.1±0.25 (23)	1.84±0.23(23)	8.7±0.45 (23)	0.7±0.2 (23)

[1]Actual weight of the animal.

[2]Tail length is measured from base of tail to bony tip.

[3]Hind foot length is measured from heel to tip of longest finger.

[4]Head body length is measured from tip of nose to the inflection point of tail.

[5]Ear length is measured from the tip to the base of ear.

Discussion

In this study, we have recorded fifteen species of small mammals in a Ramsar site in eastern Bhutan. Ten of them were rodents and five were insectivores. Four of them are new records for Bhutan, namely *Apodemus sylvaticus*, *Apodemus pallipes*, *Millardia meltada* and *Tatera indica*. Although our species list is not exhaustive, we are confident that our species list is comprehensive in light of the intensity and rigor of our study methods.

The species composition and abundance of small mammals were low in AF and OG. This is because of the homogenous vegetation dominated by tall trees (*Alnus* sp.,) in the AF and the understory is disturbed due to intensive cattle grazing, which makes it uninhabitable for small mammals due to loss of cover and less diversity of microhabitats (Baker *et al.*, 2003; Demeke *et al.*, 2007; Datiko and Bekele, 2012). Conversely, high diversity of small mammals in the OF can be attributed to the presence of relatively undisturbed ground cover which provides them enough food, nesting and hiding places (Oferi *et al.*, 2013). Besides, densely covered habitats with high diversity of plant species are preferred by most small mammal species (Dakito and Bekele, 2013).

According to Yirga and Chane (2014), distribution of small mammals over an area is not uniform and there will be more species in some habitats and few in others. Our findings and data corroborate this observation. Similar observations were made in Jigme Dorji National Park (Gyeltshen, 2015) and Wetland of Phobjikha (Dorji, 2016) in Bhutan.

We observed that the total number of captures significantly varied between the dry and wet seasons. We trapped more individuals from the AG during dry season than in the wet season. This is because of the crop residuals left in agriculture field after the harvest period which provides supplemental food to the small mammals. Seasonality causes changes in the habitat conditions in terms of food availability, foliage and cover (Dakito and Bekele, 2013). Seasonal variation and food availability thus affects trapping success (Bantihun and Bekele, 2015). Indeed, habitat complexity, food and cover availability are prime features influencing the overall distribution of small mammals (Avenant and Cavallini, 2008; Dakito and Bekele, 2013).

The average total trap success was 11.03% in our study. This is comparatively lower than 53% for Wetland of Phobjikha (Dorji, 2016) and somewhat closer to 14% for Jigme Dorji National Park (Gyeltshen, 2015). The lower trap success our study is because of many anthropogenic disturbances such as intensive cattle grazing, high degree of forestry resource collection, and presence of a few stray dogs in most of our study plots. In order to promote diversity of small mammals in the Ramsar site, we would recommend reducing the number of free-range cattle grazing and restraining the number of domestic dogs in the vicinity of the Ramsar site. We also recommend similar studies to be conducted in diverse habitat types and ecological zones to generate more information about small mammals in Bhutan and in the region. We believe that our study will aid in understanding more about the diversity and abundance of small mammals in the South Asian region.

Acknowledgements

We thank the Rufford Small Grant Foundation in the UK for funding, and Bhutan's Department of Forest and Park Services and the management of Bumdeling Wildlife Sanctuary for kindly permitting us to undertake the study. We express our gratitude to Dr. Syed Ainul Hussain, Scientist G/Senior Professor at the Wildlife Institute of India, and Mr Kunzang Dorji, Researcher at Ugyen Wangchuck Institute for Conservation and Environmental Research of Bhutan, for their guidance and support. We acknowledge Mr. Sanjan Thapa, Researcher at the Small Mammals Conservation and Research Foundation in Nepal for helps with species identification. We appreciate Dawa Gyalpo, Forester at Dungzam Park Range of Bumdeling Wildlife Sanctuary, and Ugyen Thinley, Vice Principal of Bumdeling Lower Secondary School, for their helps with fieldworks and moral supports.

Conflict of interests

The authors declare no conflict of interests.

References

Aplin KP, Brown PR, Jacob J, Krebs CJ, Singleton GR. 2003. Field methods for rodent studies in Asia and the Indo-Pacific. Austalian Centre for International Agriculture Research. Canberra, Austrialia.

Assefa A, Srinivasulu C. 2019. Species composition and abundance of rodents in Kafta-Sheraro National Park, Ethiopia: preliminary results. Journal of Threatened Taxa **11(6),** 13680-13689.

Avenant NL, Cavallini P. 2008. Correlating rodent community structure with ecological integrity, Tussen-die-riviere nature reserve, Free State Province, South Africa. Integrated Zoology **(2),** 212-219.

Baker PJ, Ansell RJ, Dodds PA, Webber CE, Harris S. 2003. Factors affecting the distribution of small mammals in an urban area. Mammal review **33(1),** 95-100.

Bantihun G, Bekele A. 2015. Diversity and habitat association of small mammals in Aridtsy forest, Awi Zone, Ethiopia. Zoological Research **38(2),** 88-94.

Bantihun G. 2012. Diversity and habitat association of small mammals in Aridtsy forest, Awi Zone, Ethopia. M.Sc. Thesis, Addis Ababa University, Addis Ababa.

Barnett A, Dutton J. 1995. Expedition field techniques: small mammals (excluding bats). London: Royal Geographical Society with IBG, London pp. 1-120.

Chane M, Yirga S. 2014. Distribution and diversity of small mammals in Borenasayint National Park, South Wollo, Ethiopia. International Journal of Biodiversity and Conservation **6(5),** pp.415-421.

Cunningham DM, Moors PJ. 1996. Guide to the identification and collection of New Zealand Rodents. Wellington. Department of Conservation, New Zealand.

Datiko D, Bekele A. 2013. Species composition and abundace of small mammals in Chebera-Churchura National Park, Ethiopia. Journal of Ecology and Natural Environment **5(6),** 95-102.

Demeke D, Afework B, Gurja B. 2007. Species composition, distribution and habitat association of

rodents from Arbaminch forest and farmland, Ethiopia. African Journal of Ecology **45,** 651-657.

Demeke D, Afework B. 2014. Habitat association and distribution of rodents and insectivores in Chebera-Churchura National Park, Ethiopia. Tropical Ecology **55(2),** 221-229.

Dorji K. 2015. Small mammals in the small country: conservation and species diversity of small mammals in high altitude wetland of Phobjikha, Wangdi Phodrang. B.Sc. Thesis, Royal University of Bhutan, Bhutan.

Dorji K. 2016. Small mammals of Phobjikha Wetland: Sampling protocols to study small mammals. Rufford Foundation, United Kingdom.

Garshong RA, Attuquayefio DK, Holbech LH, Adomako JK. 2013. Distribution and abundance of small mammals in different habitat types in the Owabi Wildlife Sanctuary, Ghana. Journal of Ecology and the Natural Environment **5(5),** pp.83-87.

Gupta S. 2011. Ecology of medium and small sized carnivores in Sariska Tiger Reserve, Rajasthan. PhD Thesis. Saurashtra University, Gujurat, India.

Gyeltshen J. 2015. Species diversity and distribution of rodents along the elevation gradients in Jigme Dorji National Park, Bhutan. Small mammal mail **7(1),** 28-35.

Hoffmann A, Decher J, Rovero F, Schaer J, Voigt C, Wibbelt G. 2010. Field methods and techniques for monitoring mammals 482-529.

Jnawali RS, Baral HS, Lee S, Archarya KP, Upadhyay G, Pandey M. 2011. The Status of Nepal Mammals: The National Red List series. Department of National Parks and Wildlife Conservation, Kathmandu, Nepal.

Karuaera NAG. 2011. Assessing the effect of bush encroachment on species abundance, composition and diversity of small mammals at the Neudamm agriculture farms Khomas Region. M.Sc. Thesis, University of Namibia, Berlin.

Katuwal HB, Koirala S. 2012. Proceedings of third seminar on small mammal issues. Small Mammals Conservation and Research Foundation, Kathmandu, Nepal.

Klerk JJ. 2014. Investigating small mammal community structure as a possible indicator of improved habitat integrity in an area cleared of alien vegetation. Natural and Agricultural Sciences, Universty of Free State, Bloemfontein.

Menon V. 2014. Indian Mammals: A field Guide. Hachette Book Publishing India Pvt. Ltd, Delhi, India.

Molur S, Singh M. 2009. Non-volant small mammals of the Western Ghats of Coorg district, Southern India. Journal of Threatened Taxa **1(12),** 589-608.

Molur S, Srinivasulu CB, Walker S, Nameer Ravikumar L. 2005. Status of south Asian non-volant small mammals. Conservation and Management Plan Workshop Report. Zoo Outreach Organization/CBSG-South Asia, Coimbatore, India, 618.

Ofori BY, Attuquayefio DK, Gbogbo F. 2013. Terrestrial small mammal community structure in an anthropogenically-altered moist semi-deciduous forest zone of Ghana. International Journal of Development and Sustainability **2(2),** 1156-1168.

Ofori BY, Attuquayefio DK, Gbogbo F. 2015. Status and challenges for conservation of small mammal assemblages of Ghana. Journal of Biodiversity and Environmental Science **6(4),** pp. 374-384.

Ofori BY, Attuquayefio DK, Owusu EH, Musah RKY, Quartey JK, Baidu YN. 2015. Seasonal changes in small mammals assemblage in Kogyae Strict Nature Reserve, Ghana. International Journal of Biodiversity and Conservation **7(4),** pp. 238-244.

Pearson DE, Ruggiero LF. 2003. Transect versus grid trapping arrangements for sampling small-mammal communities. Wildlife Society Bulletin **31(2),** 454-459.

Poel PVD. 2013. Results of 2012 rapid biodiversity survey in Bumdeling Wildlife Sanctuary. Department of Forest and Park Services, Thimphu, Bhutan.

Shrestha TK. 1997. Mammals of Nepal: with Reference to those of India, Bangladesh, Bhutan and Pakistan. Steven Simpson Natural History Book, Hingham, United Kingdom.

Sieg CH. 1987. Small mammals: Pests or vital components of the ecosystem. Lincoln, South Dakota, USA **4,** 88-91.

Tuyisingize D, Peterhans JC, Bronner GN. 2014. Terrestrial small mammal community composition in the Volcanoes National Park, Rwanda. Boon Zoological Bulletin **2(62),** 177-185.

UNESCO. 2012. Bumdeling Wildlife Sanctuary. Bhutan National Commisson, Royal Government of Bhutan.Thimphu, Bhutan.

Walker TS. 2003. Think Rat! Report on training in field techniques and taxonomy for conservation of rodents and servations. RISCINSA and Zoo Outreach Organization. Coimbatore, India.

Wangchuk T, Thinley P, Tshering K, Tshering C, Yonten D, Pema B. 2004. A field guide to the ammals of Bhutan. Department of Forest and Park Services, Thimphu, Bhutan 141-156.

Wangmo S, Wangdi Y, Wangchuk D. 2014. Report on estimating small mammal abundance in Royal Manas National Park. Research Information and Management Planning Section, Royal Manas National Park, Bhutan.

Wolff JO, Sherman PW. 2007. Rodent Societies: An Ecological evolutionary perspective. The University of Chicago Press, Chicago, 610.