THE EFFECTS OF FOREST TYPE AND SEASON ON THE ABUNDANCE AND SPECIES DIVERSITY OF BATS IN NORTHEASTERN THAILAND

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Abstract

Bats are the most species-diverse group of terrestrial mammals in Thailand. However, data on the ecology of forest bats in Thailand are lacking. This study determined the influence of the vegetation and season on the abundance and species diversity of forest bats in Sakaerat Biosphere Reserve, northeastern Thailand. From June, 2013 to May, 2014, bats were captured with 16 mist nets, set up from 18.00 to 24.00 h in dry dipterocarp forest, ecotone, dry evergreen forest, and plantation for 12 nights per season (in total, 36 sample nights). Captured bats were identified to the species level and marked with permanent ink and the fur was clipped on the dorsal side of the body. A total of 81,216 net meter hours resulted in the capture of 66 individuals, representing 6 families, 7 genera, and 9 species. Of these, megabats comprised 32%, while microbats constituted 68%. The most abundant species was *Hipposideros larvatus* (34.85%). The Shannon-Wiener diversity index of bats was 1.925, while the Shannon-Wiener evenness index of bats was 0.876. Dry evergreen forest was by far the most important habitat where 91% of the captures occurred achieving a Shannon-Wiener diversity index of 1.866, compared with the ecotone where only 9% of the captures occurred (diversity 1.011). No bats were captured in the dry dipterocarp forest and the plantation. Bat abundance was also significantly different among the seasons (H= 8.91, df = 2. p = 0.011). The Shannon-Wiener diversity index of bats was highest in the rainy season (1.595), followed by the winter (1.466), and the summer (0.562), respectively.

Keywords: Bat, assemblage, vegetation, season, Sakaerat Biosphere Reserve

Introduction

Bats are the second most speciose order of mammals after rodents. Over 1,200 extant bats comprise 20% of all mammal species (Fenton, 2012). They live throughout the world, with the exception of Antarctica and a few very remote oceanic islands (Mickleburgh *et al*., 2002). Bats interact with various organisms and exhibit important roles in the ecosystem processes.

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Frugivorous bats are pollinators and seed dispersers of a broad spectrum of plant species, while carnivorous bats are predators of insects and small vertebrates (Findley, 1993; Kalka *et al*., 2008). Additionally, many bat species control pests and provide fertilizer to agricultural fields (Leelapaibul *et al*., 2005; Cleveland *et al*., 2006).

Southeast Asia is a "hotspot" for bat diversity, including about 30% of the 320 bat species currently described (Kingston, 2010). In Thailand, they comprise about 40% of the kingdom's 119 know native mammal species (Bumrungsri *et al*., 2006). However, tropical forests in Southeast Asia are among the most threatened in the world (Laurance, 2007). This may lead to the extinction of about 20% of bat species in Southeast Asia by 2100 (Lane *et al*., 2006). Thus, it is important to study bats, to prevent species extinctions, and to conserve a vital component of Thailand.

Even though tropical bats are a highly species-diverse group, vital to the proper functioning of both ecological and agricultural systems, knowledge of the diversity, distribution, and resources requirements of bats lags behind that of other mammal groups (Hutson *et al*., 2001). Moreover, data on bats in forest ecosystems are still scanty (Chung-MacCoubrey, 2005), especially forest bats in Thailand (Bumrungsri *et al*., 2006). To redress this, a bat survey was conducted in Sakaerat Biosphere Reserve, northeastern Thailand. The objectives of this study were to determine the influence of the forest types and seasons on the abundance and diversity of forest bats. Determination of bat diversity has important implications for forest management and bat conservation (Carroll *et al.,* 2002).

Materials and Methods

Study Area

Sakaerat Biosphere Reserve (SBR) is on the edge of Thailand's Korat plateau, about 300 km northeast of Bangkok (14° 30'N, 101° 55'E) (Figure 1). The approximate area is 80 km^2. The elevation ranges from 250 to 762 m above sea level. The average temperature is 35°C and the annual precipitation is 1200 mm. SBR has a tropical climate with 3 distinct seasons; the hot dry season (March-May), the rainy season (June-October), and the cool dry season (November-February). The main vegetation types in SBR are dry evergreen and dry dipterocarp forests. Dry evergreen forest covers 60% of the area. Common, typical, tree species include *Hopea ferrea, Hopea odorata,* and *Hydnocarpus ilicifolia*. Dry dipterocarp forest covers 18% of the area. Common, typical, tree species include *Shorea obtusa, Dipterocarpus intricatus, Shorea siamensis,* and *Gardenia sootepensis*. The ecotone represents the transition zone from the dry dipterocarp forest to the dry evergreen. It consists of large trees *(Dipterocarpus)* sparingly distributed amongst small shrubs and short grasses. The plantation was started with the planting of various exotic and indigenous tree species in 1982 and had been run for ten years. The main vegetation is comprised of fast growing plants such as *Acacia auriculiformis, A. mangium,* and *Gmelina arbore*. Other vegetation types in the station include bamboo forest and grassland (Sakaerat Biosphere Reserve, 2013).

Data Collection

Bats were captured from June, 2013 to May, 2014. Eight sampling sites were selected, covering 4 vegetation communities: 2 in dry evergreen forest (DEF), 2 in dry dipterocarp forest (DDF), 2 in the ecotone area (between DEF and DDF), and 2 in the plantation (Figure 1). At each sampling site, 2 mist nets (9.4 m long × 2.5 m high, 25 mm mesh size, 4 shelves) were set up at ground level (2.5 m high) and 2 mist nets were set up at a higher level (5 m high). Nets were placed across bat flyways, near ponds and across trails, and monitored every 30 minutes for 6 hours from 18.00 to 24.00 h. To avoid bias, mist nets were not erected when the moon was full or during heavy rain (Morrison, 1978; Lang *et al*., 2006).

Captured bats were kept in individual cloth bags and sent to a field laboratory at SBR. Subsequently, they were identified to species level, according to Francis (2008). After processing, the bats were marked on the wings with permanent ink and fur was clipped on the dorsal side of body before they were released back at the capture sites. This study was performed under the approval of the SUT Animal Care and Use Committee.

Data Analysis

The total species richness (S_{max}) was calculated using the Jackknife 2 estimator which makes a good correction for species richness estimation (Zahl, 1977). Completeness of the bat sampling was calculated as $(S_{obs}/S_{max})\times100$, where S_{obs} = the number of species observed in the sample. Data were analyzed with the EstimateS statistical software (Colwell, 2013).

The satisfactory level of completeness was considered at 90% (Moreno and Halffter, 2000). The relative abundance of bats was calculated as the number of individuals caught per 100 net-meter hours (length of all nets in meters × total sampling hours) (Aguirre, 2002). Species diversity was calculated using the Shannon-Wiener diversity index (H^{+}) (Tuomisto, 2010): $H' = -\log (P_1^{P1} P_2^{P2} \ldots P_s^{Ps})$, where P_1 = the proportion of individuals in the 1st species; s = the total number of species. The Shannon-Wiener evenness index (E_H) was used to quantify species evenness (Krebs, 1998): $E_H = H/H_{max}$, where H' = the Shannon-Wiener diversity index; H'_{max} = lnS. Similarity in bat assemblages among the seasons and vegetation communities were compared using Sorenson's coefficient (CC) (Krebs 1998): $CC = 2C/A+B$, where C = the number of species shared by the 2 communities; A = the number of species in community A; B = the number of species in community B.

A chi-square was used to test for differences in the abundance and species richness of bats between the ecotone and dry evergreen forest.

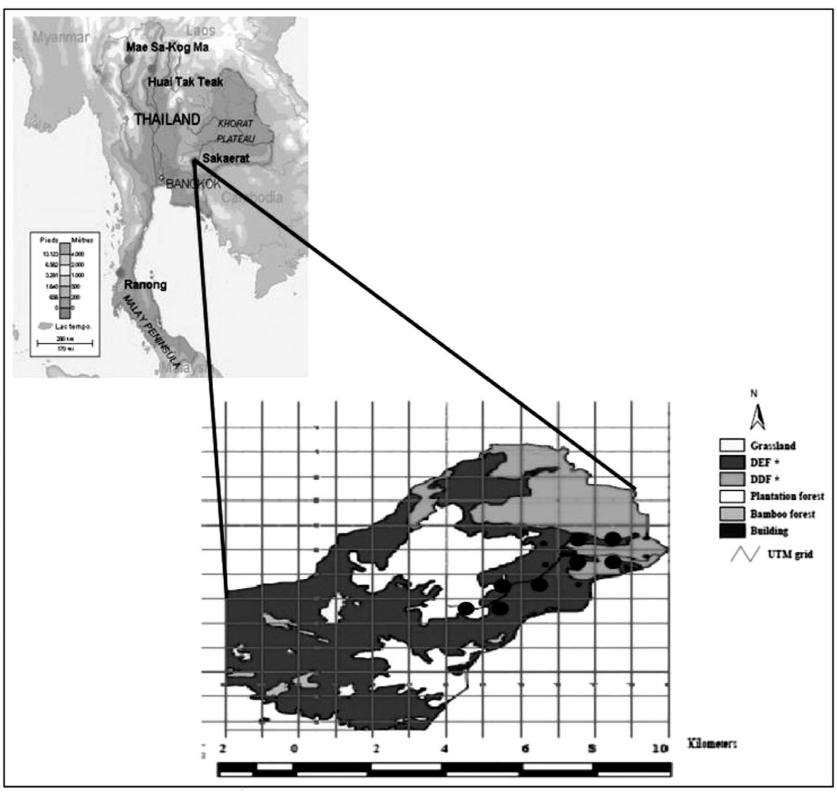

Figure 1. Study plots and location of Sakaerat Biosphere Reserve (SBR), northeastern Thailand; (•) study plots, DEF = dry evergreen forest, DDF = dry dipterocarp forest

A *T*-test was used to compare the diversity indices among the habitats and seasons. The Kruskal-Wallis test was used to test the differences in the abundance and species richness of bats among the seasons. Statistical analyses were performed using the PAST 3.02a software (Hammer *et al*. 2001).

Results and Discussion

Bat Abundance and Diversity in SBR

Sixty-six bats were caught, representing 6 families, 7 genera, and 9 species, of which 3 species were megachiroptera (*Cynopterus sphinx* (n = 10), *Megaerops niphanae* (n = 9), and *Cynopterus brachyotis* (n = 2)) and 6 species were microchiroptera (*Hipposideros larvatus* (n = 23), *Megaderma spasma* (n = 6), *Rhinolophus affinis* (n = 5), *Hipposideros diadema* (n = 4), *Myotis muricola* (n = 4), and *Chaerephon plicata* (n = 3)). No bats were recaptured. The proportion of the captured megabats was 32% while the proportion of the captured microbats was 68%. The Shannon-Wiener diversity index of bats in SBR was 1.925 whereas the Shannon-Wiener evenness index was 0.876. Estimation of bat species richness from the Jackknife 2 estimator yielded 11.12 species. The completeness of bat sampling was 80.94% of the total bat species in SBR. These data demonstrated that bat samplings in this study were nearly complete. More sampling efforts are recommended to complete the bat inventory in this area.

The total trapping effort was 81216 net meter hours (nmh). Overall trapping success was 0.08 bats/100 nmh (megachiropteran 0.026 bats/100 nmh and microchiropteran 0.055 bats/100 nmh). The most abundant species was *Hipposideros larvatus* (34.85% of total captures (0.028 bats/100 nmh)), followed by *Cynopterus sphinx* (15.15% of total captures, 0.012 bats/100 nmh), and Megaerops niphanae (13.63% of total captures, 0.011 bats/100 nmh). The remaining six species were locally rare (n ≤ 6; ≤ 0.007 bats/100 nmh).

A previous bat survey in SBR documented 11 species i.e. *Cynopterus sphinx, Megaerops ecaudatus, Taphozous saccolaimus, Megaderma spasma, Rhinolophus acuminatus, Rhinolophus pusillus, Rhinolophus affinis, Rhinolophus luctus, Hipposideros larvatus, Myotis hasseltii,* and *Murina cyclotis* (Pakarnseree *et al*., 2003). Consequently, the species richness of bats at SBR represents 15.97% (16 species) of the total bat species (119 species) of Thailand (Bumrungsri *et al*., 2006).

The number of bat species captured in this study was low, compared to other sites in Thailand. For example, 58 bat species were recorded in Thung Yai Naresuan and Huai Kha Khaeng Wildlife Sanctuaries (Robinson et al., 1996), and 24 in Loei Province (Robinson and Smith, 1997). This was probably because of the lack of large caves in the study area, as bat species which roost in caves were rarely captured (i.e. *Taphozous melanopogon* and *Hipposideros pomona*). However, comparisons of bat assemblages between this study area and other sites must be done with caution, since bat diversity is influenced by the sampling effort and sampling technique (Voss and Emmons, 1996).

Bat Assemblage Among Vegetation Communities

All bat taxa in this study were found in the dry evergreen forest (Table 1). Bat abundance in the dry evergreen forest was 0.296 bats/100 nmh. *Hipposideros larvatus* was the dominant species (n = 22; 0.108 bats/100 nmh), followed by Cynopterus sphinx (n = 10; 0.049 bats/100 nmh). Only 7 or fewer individuals were captured of the other 7 species (≤ 0.034 bats/100 nmh).

In the ecotone, only 6 individuals belonging to 2 families, 2 genera, and 3 species were captured (Table 1). The relative abundance of bats in this area was 0.03 bats/100 nmh. No bats were captured in the dry dipterocarp forest and in the plantation (Table 1).

Nearly 91% of the captures occurred in the dry evergreen forest, significantly higher than the just over 9% of the captures in the ecotone ($\chi^2 = 26.52$, df = 8, $p = 0.001$). Diversity was also significantly higher in the dry evergreen forest (Shannon-Wiener diversity index of 1.866 compared with 1.011 in the ecotone; $t = 3.36$, df = 8.74, p = 0.009). Sorenson's coefficient was 0.545 comparing the dry evergreen forest with the ecotone, which indicates that around half the bat species were shared between the 2 communities.

The absence of frugivorous bats in the dry dipterocarp forest and the plantation was probably due to the low availability of fleshy fruits. Marinho-Filho (1991) reported that the distribution and abundance of frugivorous and nectarivorous bats were related to the temporal and spatial availability of fruits and flowers. No capture of insectivorous bats in the dry dipterocarp forest and plantation may be because the wing morphology and echolocation call of insectivorous bats may not allow them to forage in the more open habitats (Phommexay *et al*., 2011).

Data from several studies showed that most bats preferred old-growth forests (Medellín *et al*., 2000; Avila-Cabadilla *et al*., 2009), so it is not surprising that most bats were captured in the dry evergreen forest at SBR, since such forest has the highest structural complexity and most plants compared with the other habitats (Humes *et al*., 1999). In addition, old-growth forests provide more roosting sites and higher food availability for bats than other forest habitats (Crampton and Barclay, 1998).

Bat Assemblage Among Seasons

Bats were most active in the rainy season, less so in the cool season, and very sparsely captured in the hot dry season (Table 2). Captures in the rainy season accounted for 65.15% of the total captured bats, the winter for 28.79% of the total captured bats, and the summer for 6.06% of the total captured bats. The total numbers of individuals were significantly different among the seasons (H = 8.91, df = 2, p = 0.011). The Shannon-Wiener diversity index was highest in the rainy season (1.595), followed by the winter (1.466), and the summer (0.562), respectively. The diversity index was not statistically different between the rainy season and the winter (t = 0.592, df = 61, p = 0.555). However, the diversity index was significantly different between the rainy season and the summer (t = 3.007, df = 7.119. p = 0.019) and between the summer and the winter (t = 2.787, df = 5.68, p = 0.0336). The evenness of bats was highest in the winter (0.911), followed by the summer (0.811), and the rainy season (0.726), respectively. The highest Sorenson's coefficient was found

Table 1. Number of individuals and relative abundance (bats/100 nmh) of captured bats in 4 vegetation communities in SBR; DDF = dry dipterocarp forest, ECO = ecotone, DEF = dry evergreen forest, PTF = plantation

Taxon	Number of individuals (Relative abundance)			
	DDF	ECO	DEF	PTF
Megachiroptera				
Cynopterus sphinx	-	-	10 (0.049)	-
Cynopterus brachyotis	-	-	2 (0.01)	-
Megaerops niphanae	-	2 (0.01)	7 (0.034)	-
Microchiroptera				
Hipposideros larvatus	-	1 (0.005)	22 (0.108)	-
Hipposideros diadema	-	3 (0.015)	1 (0.005)	-
Megaderma spasma	-	-	6 (0.03)	-
Chaerephon plicata	-	-	3 (0.015)	-
Rhinolophus affinis	-	-	5 (0.025)	-
Myotis muricola	-	-	4 (0.02)	-
Total	**-**	6 (0.03)	60 (0.296)	-

between the rainy season and the winter (0.714) but Sorenson's coefficient was lower between the rainy season and the summer (0.364), and between the winter and the summer it was the lowest (0.286). This result implies that bat species are rather similar between the rainy season and the winter.

Mello (2009) also demonstrated that Phyllostomid bats in the Neotropics reached their highest abundance in the rainy season. The variations in species richness, diversity, and abundance of bats were associated with climate conditions. The rainy season provides higher food resources for bats (both fruits and insects) (Pech-Canche *et al.*, 2011). It can be concluded that the rainy season was found to support the bat community in this study more than the other seasons.

Many bats migrate seasonally or fly long distances to reach their resources when resources are insufficient (Montiel *et al.*, 2006). In this study, the food availability of bats may be low in the winter and the summer. Moreover, the water bodies in the study area were in short supply during the winter and the summer. Bat diversity and abundance both decease when the water supply is scarce (Francl, 2008). Hence, the lower capture rates of bats in the winter and the summer in this study are probably due to the scarcity of food and water supply for the bats.

Conclusions

In conclusion, bat assemblage varied among the vegetation communities in SBR. Most bats were found in the dry evergreen forest whilst few were found in the ecotone. No bats were captured in dry dipterocarp forest and the plantation. It is clear that the dry evergreen forest is the important habitat for the bat community in SBR.

Most bats (individuals and species) were captured in the rainy season when food and water were abundant. Consequently, some bats may migrate away from the study area in winter and summer.

The bat samplings in this study are nearly complete. More samplings are recommended to complete the bat inventory in SBR. This study provides important data on the forest bat community and the relationship between bats and the vegetation communities and seasons which can be used in the conservation and management of bats in Thailand.

Table 2. Number of individuals and relative abundance (bats/100 nmh) of captured bats among the seasons in SBR

Taxon	Number of individuals (Relative abundance)		
	Rainy season	Winter	Summer
Megachiroptera			
Cynopterus sphinx	4 (0.015)	6 (0.022)	-
Cynopterus brachyotis	2 (0.007)	-	-
Megaerops niphanae	2 (0.007)	6 (0.022)	1 (0.004)
Microchiroptera			
Hipposideros larvatus	23 (0.085)	-	-
Hipposideros diadema	1 (0.004)	-	3 (0.011)
Megaderma spasma	3 (0.011)	3 (0.011)	-
Chaerephon plicata	2 (0.007)	1 (0.004)	-
Rhinolophus affinis	5 (0.018)	-	-
Myotis muricola	1 (0.004)	3 (0.011)	-
Total	43 (0.159)	19 (0.07)	4 (0.015)

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