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Wing Ecomorphology and Flight Performance of Bats in Pisan Caves, Kabacan, North Cotabato, Philippines

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Abstract - This research was conducted to study the functional morphology of the wings and flight performance of bats from Pisan caves, Kabacan, Cotabato, Philippines. This was carried out using mist netting method and measurements of mass (M) and basic wing components that include wing span (B), wing area (S). Flight parameters such as aspect ratio and wing loading were computed from the values of wing component and predictions were made using aerodynamic principles. A total of 48 individuals representing eight species were studied. Results showed that *Emballonura alecto, Myotis hors fieldii,* and *Pipistrellus javanicus* have an average wing loading and low aspect ratio that indicate an intermediate speed in flight and exceptional maneuverability that is appropriate for catching moving prey in a cluttered environment. High wing loading and low aspect ratio were noted in *Cynopterus brachyotis,Eonycteriss pelaea, Hipposideros diadema, Rhinolophu sarcuatus* and *Rousettus amplexicaudatus*.

These values indicate that these bats though fast flyers, have poor maneuverability in terms of flight performance. The study suggests that wing morphology of bats affects flight performance and habitat selection which implies that maintenance of the habitat leads to the stability of the species population.

Keywords - Bats, Pisan caves, wing morphology, flight parameters, habitat selection

INTRODUCTION

Bats are very essential in the regeneration of forest habitat and other degraded areas as they are good agent for seed dispersals and pollinations (Corlett 1998). These flying mammals are good tool in providing information about the present conditions of its community because vertebrates including bats are good indicators of ecosystem health (Hilty and Merlender 2000) and as predators of pest insects are also one of the benefits that environment can receive from bats species (Cleveland et al. 2006). Among all mammals, only bats are empowered with true flight to utilize various foraging habitat which are inaccessible to other animals. This flight capability is one of the characteristics aspects of the growth and development of bats (Suthakar and Marimuthu 1997).

The design of bat wings has a great role in its performance and behavior in flight. The ideal wing form for bats adapted to different modes of flight is predicted by means of mechanical and aerodynamic models (Norberg and Rayner 1987). Variability in morphology of bat wings is linked to differences in flight and hunting behavior. Thus, wing morphology can be used to predict flight behavior and forage efficiency (White 2005). Interspecific morhpological variation is associated with variation in behaviour and ecology and morphological variation within species might also have behavioral consequences. Wing morphology varies not only with body size but also between sexes and developmental stages into a specifically and this variation can influence wing loading, aspect ratio and mass distribution which in turn affect flight performance characteristics such as turning ability, speed and metabolic cost (Swartz, Freeman, and Stockwell 2003).

Interconnections amid morphological design and function are vital to biology. They motivate natural patterns in species distribution, phylogenetic diversification, and morphological selection. As its core, ecomorphology explores the causal relationships between organismal design and behavioral performance and investigates how these relationships influence an organism's ability to exploit its environment (Swartz, Freeman and Stockwell 2003). In addition, numerous studies have shown correlations between morphology and aspects of ecology and behaving, however, several studies have failed to discover a relationship between morphology and ecology (LOSOS 1990).

Ecomorpholgy is primarily concerned in investigating adaption of morphological features and all dependent, correlated areas such as comparisons of adaptation of morphological features and all dependent, correlated areas such as comparisons of adaptations in different organisms, modification of adaptive features due to competition and other causes, structure of ecological communities and diversity of taxa (Bock 1994). Morphological constraints have been linked to habitat portioning by different species of animals. Ecomorphology correlates to feeding behaviors and have been demonstrated to vary significantly among bats and could be an important aspect in resource partitioning strategy (Aguirre, Herrel, van Damme and Matthysen 2002). Interspecific differences have been explored, but less is known about the relationship between individuals of the same species (Kalcounis and Brigham 1995).

Pisan is a village in Kabacan, North Cotabato that has around 38 caves. It could be a sanctuary of many cave bats. Destruction of the forested areas in the Village and consumption of bats as food by locals are among the threats to bat diversity and is even exacerbated by the tourism activities in the caves (Tabora 2006).

Recent studies on the species inventory of bats in selected caves of Pisan conducted by Tabora (2006) recorded eleven species with two Philippine endemics (*Eonycteris robusta* and *Rhinolophus rufus*). *R. rufus* is also considered as near threatened by the International Union for the Conservation of Nature (IUCN) Red list of Endangered Species (2010). Another study conducted by Achondo (2009) recorded nine species in the site including two Philippine endemic species, *Haplonycteris fischeri* and *Ptenochirus jagori*.

Study on functional morphology of bats in Pisan caves has never been conducted. This study was established to provide data on the ecomorphological aspects of the bats present in the caves of Pisan and further provide ideas on their flight performance. Concepts on the relationship of morphological structure of bats and its environmental preference can be utilized as basis for conservation initiatives of the different species present in the site.

MATERIALS AND METHODS

The study was conducted in Pisan Caves (7.19958519^{o} N 124.89060285^{o} E) during the rainy season in September 2010. Collection of bats was generally made using a standard size of 12x6 meters long mist nets which were installed near the opening of the caves and other adjacent areas. Bats captured were identified up to lowest possible taxonomic classification by examining the external parts and morphometric measurements using the identification key by Ingle and Heaney (1992). The age of the bats was also determined by examining the ossification line in the joints of the wings (Anthony, 1998). Only adult individuals are used in the study. Flight performance was obtained using measurements of wing morphology; wing span (B) was measured from the distance between the wing tip of a bat with the wing extended and wing area (S) was measured from the right wing of the bat. Body mass (M) of the individual was also taken.

Using the measurements of wing morphology calculations of wing parameters were obtained. Aspect ratio (AR) was calculated as $AR=B^2/S$, where B (m) is the wing span and S (m^2) was wing area. Aspect ratio is describe as high (>8), average (6-8), and low (<6). Wing loading was calculated by $WL= Mg/S$, where M (kg) is the body mass and g is the value for acceleration due to gravity. Wing loading is described as high (>13Nm^{-2}), average (8-12Nm^{-2}) and low (<8Nm^{-2}). Aspect ratio provides an index of relative wing shape, whereas wing loading provides a measure of body weight per unit area of wing. After processing bat individuals were released on-site (Norberg and Rayner, 1987; White, 2005).

Correlation analysis was used to analyze the relationships among variables of wing morphologies.

RESULTS AND DISCUSSION

A total of 48 adult bat individuals were captured belonging to four families (Emballonuridae, Pteropodidae, Rhinolupidae and Vespertilioniade), eight genera and eight species namely *Cynopterus brachyotis* Müller (Fig. 1), *Emballonura alecto* Eydoux & Gervais (Fig. 2), *Eonycterisspelaea* Dobson, *Hipposideros diadema* Geoffroy (Fig. 4), *Myotis horsfieldii* Temminck (Fig. 5), *Pipistrellus javanicus* Gray (Fig. 6), *Rhinolophus arcuatus* Peters (Fig. 7), and *Rousettus amplexicaudatus* (Fig. 8).

Table 1. Bats captured in Pisan Caves, Philippines

Scientific name	Family	No. of individuals	Conservation Status	Distribution
Cynopterus brachyotis	Pteropodidae	5	Least concern	Non-endemic
Emballonura alecto	Emballonuridae	5	Least concern	Non-endemic
Eonycteris spelaea	Pteropodidae	10	Least concern	Non-endemic
Hipposideros diadema	Rhinolophidae	5	Least concern	Non-endemic
Myotis horsfieldii	Vespertilionidae	7	Least concern	Non-endemic
Pipistrellus javanicus	Vespertilionidae	6	Least concern	Non-endemic
Rhinolophus arcuatus	Rhinolopidae	4	Least concern	Non- endemic
Rousettus amplexicaudatus	Pteropodidae	7	Least concern	Non- endemic

*Based on the IUCN Redlist of Endangered Species (2010)

Flight Performance and Habitat Preference of Bats Captured in Pisan Caves, Kabacan, Cotabato

Interspecific comparison of flight parameters of bats captured is shown in Fig. 1. Lowest wing loading was observed in *Emballonura alecto* (10.1289 Nm^{-2}) and the highest was observed in *Rousettus amplexicaudatus* (78. 8946 nm^2). The two species represent two different families that show difference for every species representing the families. It can be observed that different species have a diverse and various wing loading results, however, it also indicated that some of the species in the same family have similar values such as *E. spelaea and R. amplexi caudatus (*Pteropodidae) and *M. horsfieldii and P. javanicus* from (Vespertilionidae).

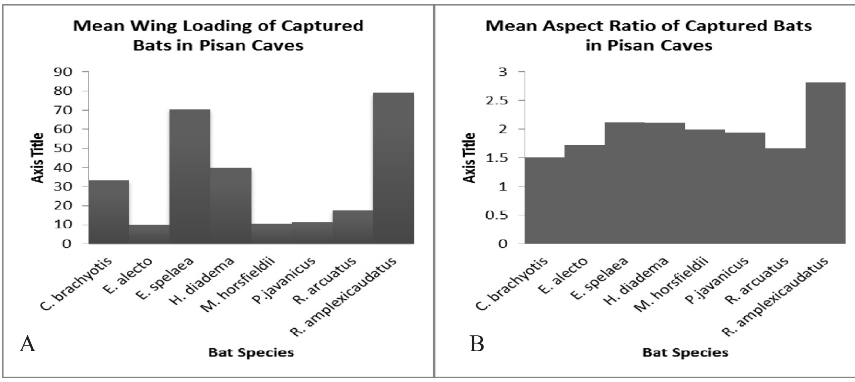

Fig. 1. Mean Values of a. Wing Loading b. Aspect Ratio

Highest aspect ratio was recorded in *R. amplexi caudatus* (2.8217) and lowest in *C. brachyotis* (1.5129). *M. horsfieldii* and *P. javanicus* have similar aspect ratio. Other species under Rhinolophidae, Pteropodidae and Emballonuridae have varying aspect ratio.

Flight correlation between wing loading to mass (r= 0.970) and wing area (r= 0.948) was revealed to have strong relationship and was determined to be highly significant (p-value< .01) and that of the wing area (p-value<.01) while relationship of aspect ratio to mass (r=0.438) was not significant.

According to Kalcounis and Brigham (1995) bats with higher mass relatively have higher wing loading. Norberg, Brooke and Trewhella (2000) have shown that morphological differences cause visible differences in soaring and gliding performance. The gliders and soarers turn out to have lower minimum sinking speeds, lower glide speeds and smaller turning radii that the non-soarers.

Theoretical characterization of flight performance of bats using flight parameters leads to the prediction of the flight capability of bats in Pisan caves. Three species (*Emballonura alecto, Myotis horsfieldii,* and

Pipistrellus javanicus) were recorded to have average wing loading and low aspect ratio. The average wing loading and low aspect ratio may indicate a transitional speed flight and remarkable maneuverability. These characteristics are indicative for bats that catch moving preys such as insects that are the primary diet of the species. The remarkable maneuverability of the *E. alecto, M. horsfieldii* and *P. javanicus* enables them to drift insects from foliage and these characteristics favor them to adapt in cluttered environments (Kalcounis and Brigham 1995).

The results agree with Duya, Alviola, Balete and Heaney (2007) that the three species mentioned usually prefer similar habitats. They also mentioned that *Myotis horsfieldii* is usually found in secondary and old-growht lowland, montane and mossy forest and in agricultural areas. *Pipistrellus javanicus* is common in urban and agricultural areas, and in secondary and primary lowland and montane forest, this species is also commonly found caves and crevices (Heaney, et al. 1991). *Emballunora alecto* is common in lowland areas, in disturbed forest, and agricultural areas with scattered remnant forest; and, records of this species is usually from caves (Heaney, et al. , 1991). Three species were common in agricultural areas however their capability to adapt in cluttered environments allows them to dwell in various vegetation type and this might be the reason of their wide spread distribution.

The five species namely *C. brachyotis, E. spelaea. H. diadema, R. arcuatus* and *R. amplexicaudatus* have high wing loading and low aspect ratio. This indicates that the species are fast flyers but with less maneuverability. Increase in body mass results in an increase of minimum flight speed and thereby decrease maneuverability (Pennycuick, 1975). The increase in mass results in poor flight performance especially in open areas. This predicted flight performance of the five species confirms the preferred habitats and foraging areas which include agricultural, urban, caves and other open environments and avoids or uncommon in vegetation like primary forest and old-growth forest were cluttered materials are abundant (Heaney 1989; Esselstyn,Widmann, Heaney 2004; and Duya et al. 2007).

CONCLUSIONS AND RECOMMENDATIONS

This study was designed for theoretical predictions of flight performance using flight parameters on bat wing ecomorphology. Bats with average wing loading and low aspect ratios are intermediately fast flyers with good maneuverability that can adapt in cluttered environments. These characteristics are manifested by small sized insect bats in our samples. Bats with high wing loading and low aspect ratio are exceptionally good flyers but with the increase in mass.

Maneuverability decreases resulting to poor flight performance in cluttered areas as minifested by all the fruit bats and of the large sized insect bats.

Based on the results, wing ecomorphology affects wing performance and habitat preference of bats. Bat habitat preferences is not only influenced by the availability of food in the area but also by its body structure that plays an important role in flight.

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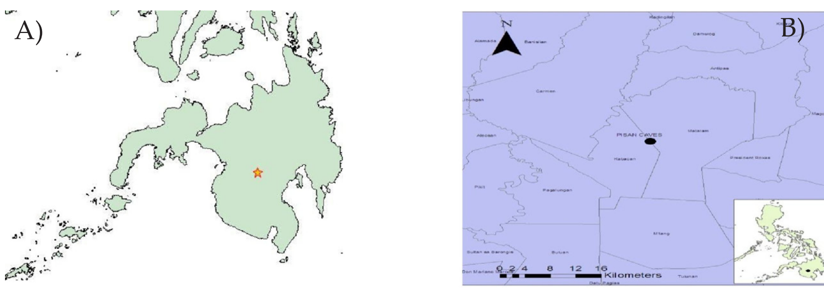

Legend: A. Map of Mindanao B. Location of Pisan Caves

Plate no 1. Location Map of the Study Site

Plate 2. The Sampling Site

Fig. 1. *Cynopterus brachyotis*

Fig. 2. *Emballonura alecto*

Fig. 3. *Eonycteris spelaea*

Fig. 4. *Hipposideros diadema*

Fig. 5. *Myotis horsfieldii*

Fig. 6. *Pipisrellus javanicus*

Fig. 7. *Rhinolophus arcuatus*

Fig. 8. *Rousettus amplexicaudatus*

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