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Relationship Between Wing Morphology and Forging Strategy of Megachiropteran Bats

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KEYWORDS
Wing morphology, aspect ratio, wing span, wing loading, fruit bats and foraging pattern**)**

ABSTRACT:
Morphology provides the set of tools that organisms use to interact with their physical environment. Although bats are nocturnal, their ecology is equivalent to birds, but morphological adaptations of bats for flight and foraging are vastly different Foraging strategy in bat species is totally depend on wing morphology. The fruit eating bats differ from insect eating bats in their foraging patterns. Low aspect ratio, short wingspan and high wing loading in respect to that of the body size has provided them with commuting foraging flights covering wider area. *Rousettus leschenaulti*, *Pteropus giganteus* and *Cynopterus sphinx* of mega chiropteran species of the present study show remarkable variation in their flight patterns depending on their wing morphology. All of them show broad wing with high wing loading enabling them to attain a moderate flight speed which provide them sufficient foraging time and long distance commuting flight. But they show variation in their wingspan, aspect ratio and wing tip length and wing tip shape. This variation helps each one of them to attain species-specific manoevrability flight in cluttered area, low cost of transport and agility. This variation in turn reflects their foraging pattern and selection of food items. The present study has made an attempt to focus on their variation in foraging strategy based on morphology of wing.

INTRODUCTION

Bats exploit a wider range of food types such as insects, amphibians, fish, fruits, nectars and pollen than any other mammalian order. This extensive range of dietary niches is reflected in their morphological diversity such as skull and wing. Knowledge about the diet of an organism is essential for a study in ecology and behaviour of any organism. Such dietary information is essential for proper management and conservation of any species. The dietary adaptations of bats are commonly reflected in the morphology of their wing (flight apparatus). Flight has allowed bats to do various flight patterns in relation to their foraging behaviour (1,2). Body mass, wingspan and wing area are the primary measures of design in flying organisms. From these parameters, wing loading and aspect ratio are derived, which describe the size and shape of the wings respectively (1,3,4,5). The study on the wing morphology of bats will reveal their foraging strategy and food selection. So it is needed to study the wing morphology in terms of aerodynamic principles which has its impact on the foraging behaviour of bat species. Only a few studies have approached the relationship among feeding behaviour and morphological diversity in wing in mammals. In the absence of dietary evidence, food selection can be suggested based on the morphology of the skull and wing. Observations on the wing morphology have been co-related with their foraging strategy. The present study is an attempt to investigate the wing morphology of three fruit bats. *Rousettus leschenaulti, Pteropus giganteus* and *Cynopterus sphinx.*

MATERIALS AND METHODS

The diversity in the morphology and its impact on the ecology of the three fruit bats *Rousettus leschenaulti*, *Pteropus giganteus and Cynopterus sphinx* were assessed by studying the flight apparatus. The flight adaptations like the body size, tail and wing morphology were studied on three bat species captured in fields by using mist nets either near the roosting sites or in the foraging grounds. *P. giganteus* were found electrocuted near the feeding trees (6). Measurements were taken from the electrocuted *P. giganteus*. *Rousettus leschenaulti* and *Cynopterus sphinx* bats were released immediately after taking measurements.
The wing morphological parameters Wing area S (m^2), Hand wing area Shw and Arm wing area Saw were measured by following methods described by Norberg and Rayner 1987. The various wing parameters were

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measured for each bat species. Each individual was placed on a graph sheet extending the wing and the tail membranes and the perimeter was traced. The overall size of the bat was measured by the total body mass M (kg) weighed to the nearest 05 g using Avinet spring scales. The wing area, hand wing area and arm wing area were measured to the nearest 1 mm^2 by directly counting the squares (mm) from the tracings on the graph sheet. Wingspan B (m), Arm wing length law and Hand wing length lhw parameters were also measured directly from the tracings on the graph sheet. From these measured values the wing loading, aspect ratio, tip area ratio and tip shape index (M, B & S) were calculated.

Statistical analysis includes statistical tools, expressed as mean ± SD. The aerodynamic structural relationship of the bat species was studied by correlating wing morphological parameters (wingspan, wing area, aspect ratio and wing loading) and body mass. The results were expressed in power regression lines. The variation in the wing morphology of Megachiroptera is shown in Plate 1. The resulting values were tabulated and correlated with the isometric scaling model of Norberg and Rayner (1987) to predict the flight performance and the foraging behaviour.

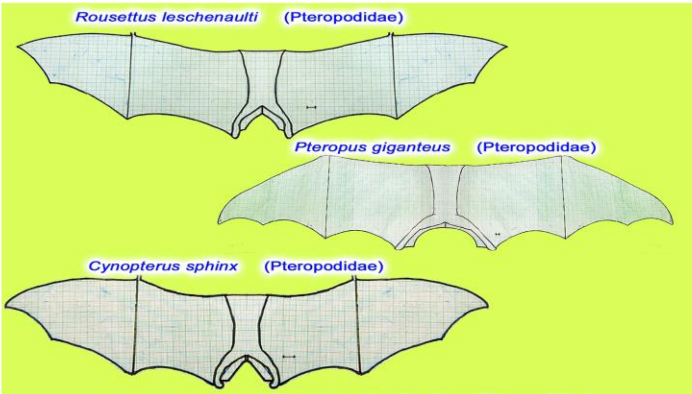

Figure 1: Variation in the wing morphology of *Rousettus leschenaulti, Pteropus giganteus and Cynopterus sphinx*

RESULTS

Body mass and wing dimensions of the studied fruit bats were shown in Table 1.The variation in the wing morphology of three fruit bat species is described as follows. Abbreviations used to denote bat species were *Rol*, *Ptg* and *Cys* for *Rousettus leschenaulti*, *Pteropus giganteus*, *Cynopterys sphinx* respectively in the figures.

Wing morphology

Correlation between the wing morphology (wing span, wing area, wing loading and aspect ratio) and mass expressed in power log regression are given in Figures 2 to 5. The scatter plots explain that mass has linear relationship with wingspan, wing area and wing loading. As the mass increases these morphological factors also increase. The plot of mass against aspect ratio reveals an unusual phenomenon and explains that the mass apparently has no influence on the aspect ratio in all three species (Figures 5).

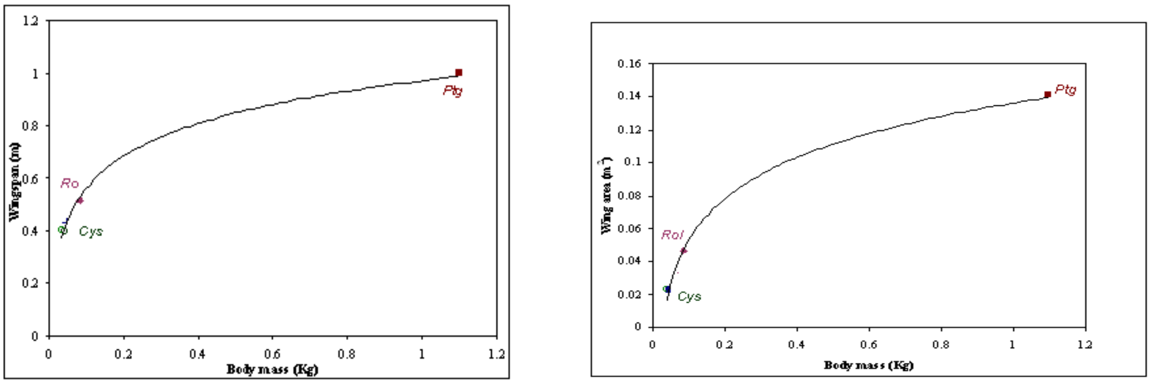

Figure 2,3: Wing span and wing area plotted on power regression lines against Body mass in *Rousettus leschenaulti, Pteropus giganteus and Cynopterus sphinx*

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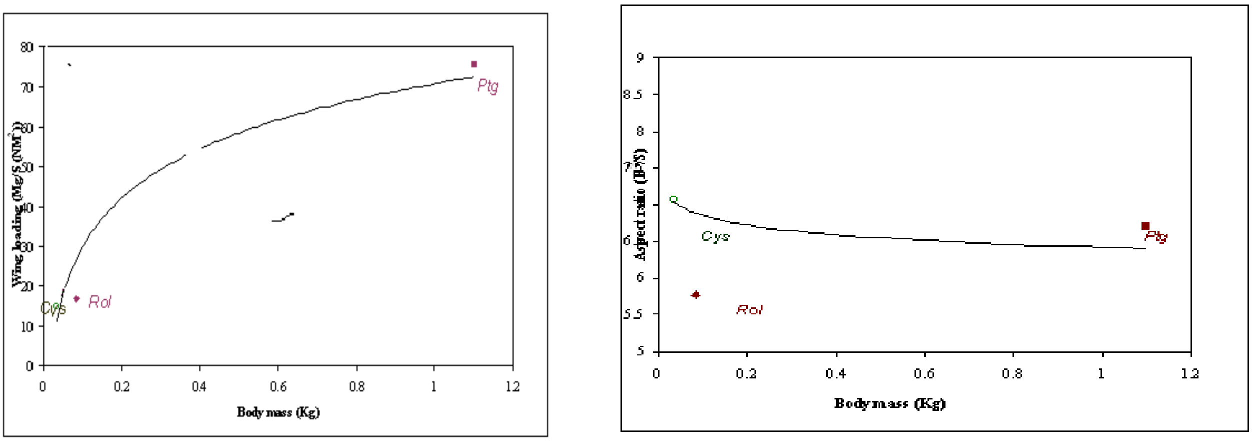

Figure 4,5: Wing loading and aspect ratio plotted on power regression lines against Body mass in *Rousettus leschenaulti, Pteropus giganteus and Cynopterus sphinx*

Wing tip shapes

Scatter plots of wing tip length against wing tip area (Figures 6) indicates the bat species, plotted above the solid line (1 = triangular wing tip) have rounded wing I > 1 and plotted below the line have long pointed wing tips I < 1. *P. giganteus* and *C. sphinx* fruit bats have more rounded wings. But *R. leschenaulti* has narrow wing tips (I < 1).

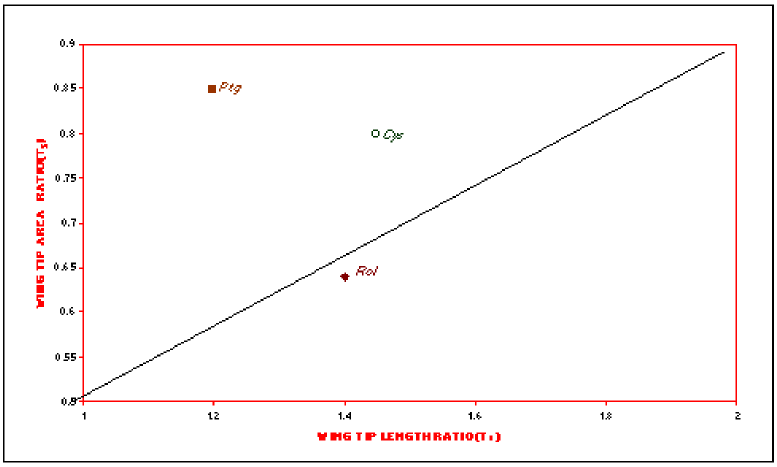

Figure 6: Wing Tip area plotted on power regression lines against Wing Tip length in *Rousettus leschenaulti, Pteropus giganteus and Cynopterus sphinx*

Maneuverability and agility

Maneuverability and agility are the two factors that are strongly influenced by flight adaptation. These two factors explain the ability of bats to change the flight direction without loss of speed and with small turning radius. These aerodynamic abilities of the bat species are expressed when wing loading index is plotted against aspect ratio. Since the wing loading varies with mass $M^{1/3}$ wing loading index $M^{2/3}$ / S which is independent of body mass has been calculated. Now both the wing loading and aspect ratio are non dimensional. Figure 7 explains wing loading index against aspect ratio, the slow fliers are marked on the left side of the diagram and faster fliers on the right. Those with high aspect ratios have lower flight costs than those with lower aspect ratio. The most inexpensive flight is obtained by those, which have a high aspect ratio in combination with a low wing loading. The figure also shows the bats with most expensive flight towards the bottom left side of the plot and inexpensive flight on the top right side of the plot.

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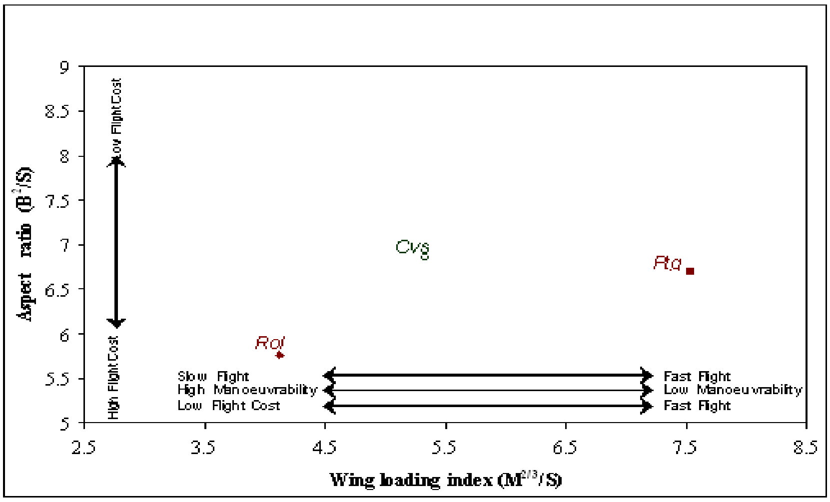

Figure 7: Aspect ratio plotted on power regression lines against Wing loading index in *Rousettus leschenaulti*, *Pteropus giganteus* and *Cynopterus sphinx*

S. No.	Name of the bat species	Body mass M (Kg)	Wingspan B (m)	Wing area S (m^2)	Aspect ratio (A)	Wing loading (Mg/S (NM^{-2})	Tip length ratio Tl	Tip area ratio Ts	Tip shape index I	Wing loading index $M^{2/3}$ /S	No. of individuals
1	*Rousettus leschenaulti*	0.0846±0.001	0.518±0.02	0.0468±0.04	5.76±0.4	16.93±1.5	1.4±0.02	0.64±0.01	0.841±0.03	4.12±0.03	27
2	*Pteropus giganteus*	1.100±0.3	1.000±0.03	0.1415±0.05	6.7±0.03	75.37±1.6	1.198±0.02	0.849±0.01	2.68±0.03	7.53±0.04	2
3	*Cynopterus sphinx*	0.0430±0.001	0.398±0.03	0.0230±0.002	6.86±0.72	18.5±1.6	1.448±0.31	0.8±0.75	1.170±0.85	5.340±0.04	10

Table 1. Body mass and wing dimensions of the studied Pteropodidae family members.
Value: Mean ± Standard deviation.

DISCUSSION

Flying animals have need of different wing designs to do flight performance to match their ecological role. To suit their diet preference they show considerable diversity in wing morphology (7) and flight style (8). In the present study three bat species show a marked variation in their wing morphology, which denote their diversity in food selection and preference. Bat show considerable diversity in wing morphology (9, 7, 10) flight style (8). Analysis of data predicted that the bat species forage in different places. They differ in their choice of foraging sites and flight behaviour.. These variations are the result of different flight demands and minimization of flight costs. Wingspan and wing area in fruit bats are increased slightly faster with body mass. Megachiroptera may fly long distances nightly between roosting and feeding places (11). Yalden and Morris (1975) compared two species of bats of different size but with identical wing morphology and proved the larger had a high wing loading and fast flight, than the smaller species. Most Pteropodidae use flight to reach food source and do not feed while foraging, they usually fly straight and relatively fast. Their body size and broad wing enable them to carry fruits from the tree to the retiring sheltered place or to the roost. But some species have good maneuverability and slow flight in clutter and hover while taking fruit or nectar. They have reduced tail membranes or lack tail altogether. Absence of uropatagium gives freedom of hind limbs to crawl over vegetation. All the three fruit bats of the present study have high wing loading which enables them to attain high flight speed with sufficient time during their foraging flight. They may fly up to 31 miles to find food. By pollinating plants and dispersing seeds they provide great benefit to humanity (6). The large wing area with average wingspan and low aspect ratio give them moderate maneuverability to avoid obstacles and fly fairly fast with in vegetation.

P. giganteus is a larger bat (1.5 Kg) that can handle large fruits, and often carries to their feeding roosts.

They have average aspect ratio and very high wing loading. They are fast fliers with low maneuverability. *R. leschenaulti* commutes long distance from and to the roosting place and also to the feeding areas (11). They are strong and direct fliers and not highly maneuverable, can fly with slow wing beats (12,13). It also has low aspect ratio, narrow wing with short wingspan and high wing loading, which is a characteristic of fast fliers (1). The low aspect ratio causes a very high cost of transport. They can fly fast within vegetation. *C. sphinx* has average wing tip length. The wing tips are characteristic of the maneuverable flight (14), this species hovers while feeding on fruit or nectar and is more agile than larger pteropodids (15).

The consequences obtained here point out the distinct wing morphological modification associated with diet. The outcomes accessible here specify that small differences in wing morphology can have significant effect on feeding performance.

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