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Relationship between skull morphology and foraging strategy of Megachiropteran bats.

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ABSTRACT: Morphology of bats relates to their ecology. The rapidly growing base of knowledge about the diet of bats facilitates a priori predictions about feeding performance, morphology and feeding behaviour. The structure of feeding apparatus, particularly the skull, teeth and the form of the jaw in each species of bat provides a perfect evidence of its diet. Skull and dentition not only reflect the size and shape, but are also associated with static mechanical models of masticatory function. The study on the skull morphology of bats will reveal their foraging strategy and food selection. It is proved that there is predictable link between skull morphology and foraging strategies in these flying vertebrates. The present study is an attempt to investigate the skull morphology of six bat species. The observations on the cranial dental morphology have been co-related with their foraging strategy.

Keywords - Morphology, Skull, Cranial, Dental, Foraging strategy

Introduction

Bats are more highly diversified in their feeding strategies than any other mammalian order. The dietary adaptations of bats are commonly reflected in the morphology of their skull (feeding apparatus) (Jeyapraba, 2008)[15]. Teeth and skull are the morphological indicators with food and the relationship in dietary diversity. The differentiation of the teeth and mandibular joint provide a guide to the type of diet of differential species of bats as well as the general dietary preferences within genus (Neuweiler, 2001)[17]. The cranial morphology of bats gives the architectural details about the skull, including muscle size, muscle fiber orientation and bony morphology which contribute to variation in bite force (Dumont, 2003)[9].In all species, bite force increased with length of the skull and the jaw more than other cranial measurements(Ramírez-Fráncel *et al.*, 2021)[20].Fruits used by bats vary greatly in their hardness depending upon bite force or any other specialized feeding behaviour during mastication (Dumont, 1999; Aguirre *et al*., 2003)[8,3]. Most of the fruit-eaters have short, broad faces that are good for biting rounded fruits, while nectar feeders have long, narrow muzzles that are good for stretching into flowers. Only a few studies have approached the relationship among feeding behaviour, morphological diversity in skull (Dumont, 1999; Van Valkenburgh, 1996)[8,25], and ensemble structure in mammals. In the present studysix bat species show a marked variation in their skull morphology which denote their diversity in food selection and preference. It is proved that there is a predictable link between skull morphology (Freeman, 1984, 1988, 1995)[10,11,13], and their diet preferences in these flying vertebrates.

MATERIALS AND METHODS

The comparative study about skull and dentition were carried out in megachiropteran bat species from the voucher specimen of Research Laboratory of Zoology Department, Sarah Tucker College, Tirunelveli, India.Cranial and dental measurements were taken by using dial calipers with nearest accuracy 0.01 mm. Twenty-one skull morphological parameters were measured by the methods described by Freeman (1984, 1988, 1992)[10,11,12], Bates and Harrison (1997)[5] and Van Cakenberghe *et al* (2002)[24]. All the measurements were converted into log data. Each log-transformed measurement was regressed against a composite size character (SIZE = Sum of the natural logs of condylo-canine length, zygomatic breadth and temporal height). This composite character (SIZE) is actually an estimate of head volume which is a good estimate of size of bat. The SIZE of each bat species is correlated with other variable measures of the skull. These correlates help to predict the dental and jaw diversity. According to Freeman (1988, 1995, 1998)[11,13,14] the cranial and dental measurement ratios such as zygomatic breadth / condylo-canine length, upper canine / maxillary tooth row, dentary thickness $^{0.25}$ / dentary length can predict the important shape relationships in bat species. These ratios correlating with that of the SIZE can indicate the various adaptations in the feeding apparatus.

RESULTS AND DISCUSSION

Cranial and dental measurements of each species of Megachiroptera are tabulated in Table 1 and 2. In these said figures, symbols with different shapes and abbreviation of bat species names are used to indicate the morphological values (Table 3).

Shape of the palate

A simple bivariate plot of palatal breadth PM_3 against length of palate CM^3 (maxillary tooth row) summarizes much about the shape of the palate in all species of bats examined (Figure 1a, b). *E. spelaea* and *R. leschenaulti* fruit bat species lie below the regression line demonstrating that they have a longer palate than a wider. The rest of the fruit bat species *C. brachyotis, C. sphinx, L. salimalii* and *P. giganteus* lie above the regression line representing that they possess a wider palate than longer.

Table 1: Cranial measurements of the studied Pteropodidae family members.

Name of the bat species	SIZE (log)	Cranial measurements (mm)							
		GTL	CCL	BB	ZB	MSW	PSW	TH	UC
Rousettus leschenaulti	9.2	36.0	33.5	14.6	21.6	7.6	14.0	14.0	3.5
Pteropus giganteus	10.8	71.4	64.8	24.5	35.0	9.0	22.4	22.4	7.7
Cynopterus sphinx	8.8	30.6	28.8	14.1	20.1	7.5	12.0	11.5	3.4
Cynopterus brachyotis	8.8	30.3	29.1	13.3	19.5	6.5	12.7	11.9	3.6
Latidens salimalii	8.9	32.4	31.1	14.0	20.1	7.5	14.3	11.6	3.3
Eonycteris spelaea	8.84	33.6	31.3	14.4	19.4	7.5	13.6	11.4	3.6

Expansion of the abbreviations used in the table is given in parenthesis.
SIZE: Sum of the natural logs of condyle -canine length, zygomatic breadth and temporal height; GTL: Greatest skull length; CCL: Condylo -canine length; BB: Breadth of brain; ZB: Zygomatic breadth; MSW: Minimum skull width; PSW: Posterior skull width; TH: Temporal height; UC: Upper canine.

Table 2: Dental measurements of the studied Pteropodidae family members.

S. No	Name of the bat species	Dental measurements (mm)												
		Upper jaw				Lower jaw								
		PC	PM_1	PM_3	CM^n	CM_n	M	DD	DT	CPH	CM	Conl	CC	Concor
1	*Rousettus leschenaulti*	6.68	7.5	9.5	12.15	14.5	28.15	3.15	1.36	11.20	12.50	6.25	28.4	7.1
2	*Pteropus giganteus*	12.15	15.0	20.2	27.80	30.9	54.50	7.20	2.20	25.40	22.82	15.40	53.1	14.9
3	*Cynopterus sphinx*	6.80	8.0	9.0	10.10	11.1	23.30	2.90	1.4	12.40	10.50	6.05	23.5	7.1
4	*Cynopterus brachyotis*	6.30	8.4	9.1	9.90	11.1	22.80	2.70	1.36	11.50	10.74	5.60	22.9	7.0
5	*Latidens salimalii*	5.80	8.4	10.0	10.90	12.2	25.15	2.80	1.30	10.60	12.54	5.45	24.3	7.2
6	*Eonycteris spelaea*	5.90	7.2	9.0	11.50	13.3	26.10	2.70	1.14	10.00	11.30	5.00	27.0	6.1

Expansion of the abbreviations used in the table is given in parenthesis.
PC: Anterior palatal width; PM_1: Palatal width from M_1; PM_3: Posterior palatal width; CM^n: Maxillary tooth row; CM_n: Mandibular tooth row; M: Mandible length; DD: Dentary depth; DT: Dentary thickness; CPH: Coronoid process height; CM: Condyle to lower molar toothrow; Conl: Condyle length; CC: Condyle to canine; CC: Condyle to canine; Concor: Condyle to coronoid process.

Table 3: Symbol and abbreviation of bat species used in skull morphologyfigures

S. No	Family / Species	Abbreviation of bat species name	Symbol
	Subo Family :Pteropodidae		
1	*Rousettus leschenaulti*	*Rol*	◆
2	*Pteropus giganteus*	*Ptg*	□
3	*Cynopterus sphinx*	*Cys*	■
4	*Cynopterus brachyotis*	*Cyb*	□
5	*Latidens salimalii*	*Las*	▲
6	*Eonycteris spelaea*	*Eos*	◆

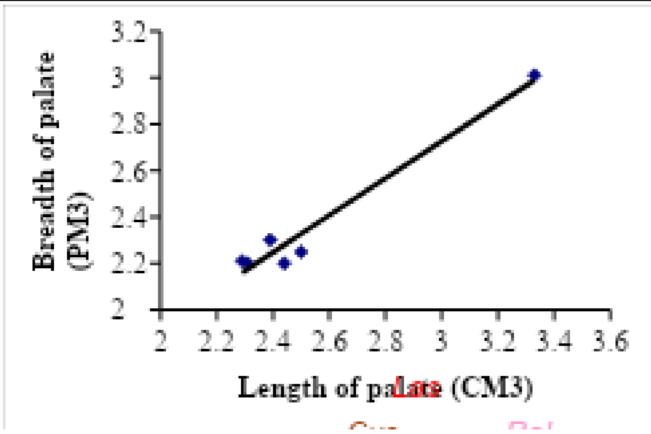

Figure: 1.A bivariate plot of length of palate versus breadth of palate

Coronoid process

A simple bivariate plot of coronoid process against SIZE variable explains the dietary choices of each bat species either hard eaters or soft eaters (Figure 2). Among the fruit bats *P. giganteus, Cynopterus* sp.and *L. salimalii*have higher coronoid process than *E. spelaea* and *R. leschenaulti.*

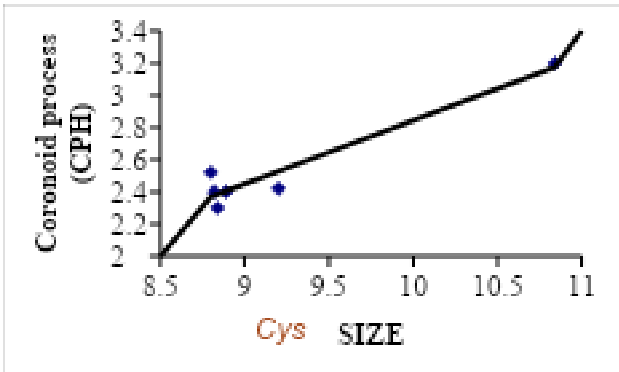

Figure 2. A bivariate plot of SIZE versus coronoid process

Shape of the skull

Ratios of zygomatic breadth / condylo-canine length, upper canine / maxillary tooth row and dentary thickness $^{0.25}$ / dentary length are correlated with SIZE to describe the changes in the proportions or shape of the skull (Figure 3a-3c). Zygomatic breadth (ZB) / condylo-canine length (CCL)ratio is plotted against SIZE (Figure 3a). *Cynopterus* sp. lie above 65-70% of the CCL explains that they have wide skull. *P. giganteus, R. leschenaulti, L. salimalii* and *E. spelaea*lie in low percentage (50 – 65%) of zygomatic breadth of CCL (ZB/CCL) indicates that they have narrow skull. Upper canine (UC) / maxillary tooth row **(**CM^n)is plotted against SIZE(Figure3b). Mostly Pteropodidae have smaller canine (25–40%). Among the fruit bats *Cynopterus* sp.have larger canine. Dentary thickness $^{0.25}$ ($DT^{0.25}$) / dentary length (DL) ratio is plotted against size (Figure 3c). When compared to insectivorous bat species, Pteropodidae have weak dentition ($DT^{0.25}$/DL 2-5%). Wide faced fruit bats *Cynopterus* sp. have thicker dentaries than narrow faced fruit bats *P. giganteus, R. leschenaulti, L. salimalii* and *E. spelaea*.

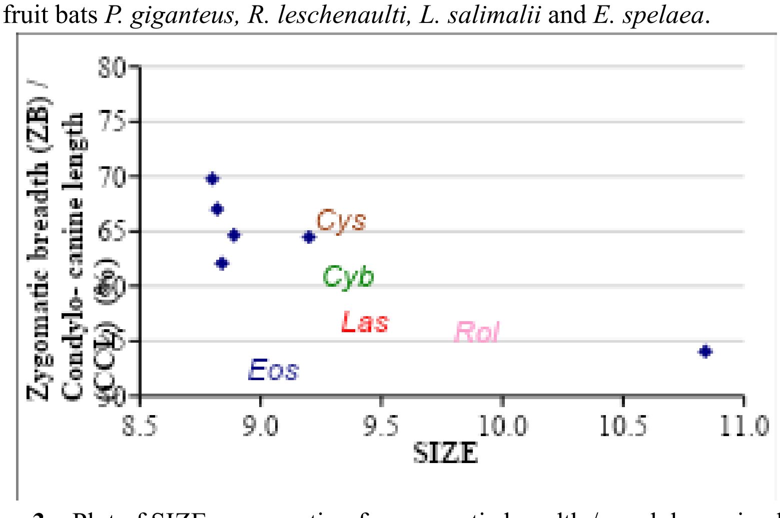

Figure 3a. Plot of SIZE versus ratio of zygomatic breadth / condylo-canine length

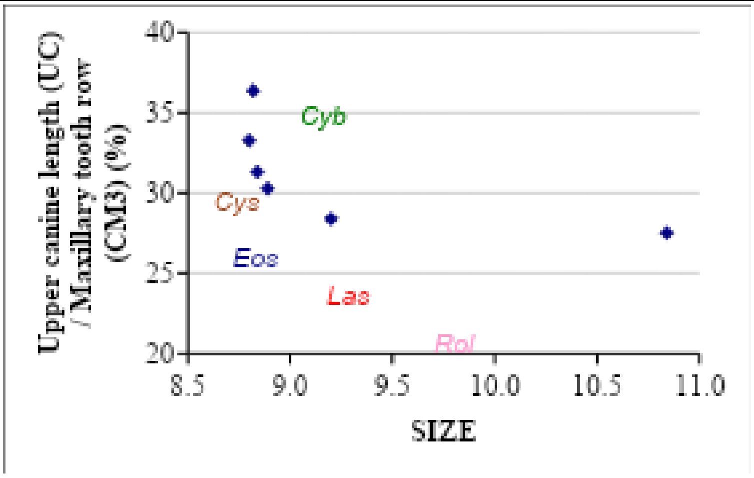

Figure 3b: Plot of SIZE versus ratio of upper canine length / maxillary tooth row

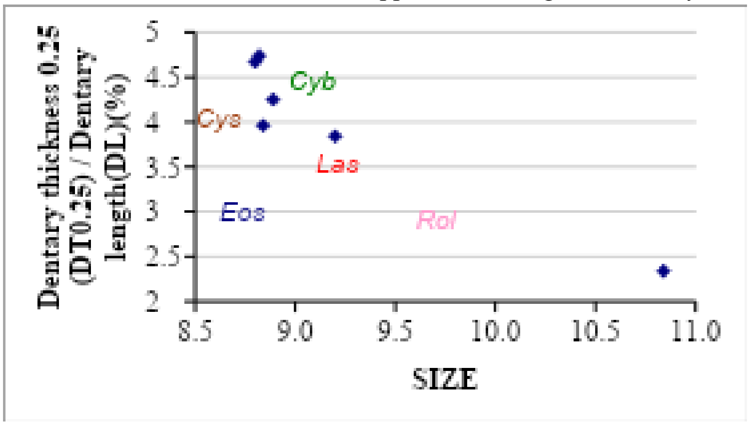

Figure 3c: Plot of SIZE versus ratio of dentary thickness 0.25/ dentary length

CONCLUSION

The selected cotton crop filed village don't have more knowledge about cotton and their insect species, insect pest, predators and pollinators. The current finding was help identified insect, insect pest, pollinators and natural enemies to local peoples and understanding of diverse group of insects' biodiversity existing in this selected area and climatic condition. Finding also assistance to know how insect important to ecosystem and maintain insect fauna on ecosystem.

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