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Morphometrical Variations of Malaysian *Hipposideros* Species

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ABSTRACT

A study on the morphometrical variations among four Malaysian *Hipposideros* species was conducted using voucher specimens deposited in Universiti Malaysia Sarawak (UNIMAS) Zoological Museum and the Department of Widlife and National Park (DWNP) Kuala Lumpur. Twenty two individuals from four species of *Hipposideros ater*, *H. bicolor*, *H. cineraceus* and *H. dyacorum* were morphologically measured, in which a total of 27 linear parameters of body, skull and dentals of each were appropriately recorded. The statistical data were later subjected to discriminant function analysis (DFA) and canonical variate analysis (CVA) using SPSS version 15.0 and unweighted pair-group method average (UPGMA) cluster analysis using Minitab version 14.4. The highest character loadings observed in Function l, Function 2 and Function 3 were the forearm length (FA), the third digit second phalanx length (D3P2L) and the palatal length (PL) with standardised canonical discriminant function coefficient values of 21.910, 5.770 and 5.095, respectively. These three characters were identified as the best diagnostic features for discriminating these closely related species of *Hipposideros*. Hence, this morphometric approach could be a promising tool as an alternative to the molecular DNA analysis for identification of Chiroptera species.

Keywords: *Hipposideros*, morphometric, discriminant function analysis cluster analysis, species identification.

1. INTRODUCTION

Bats belong to the order Chiroptera and can be distinguished from all other mammals by their ability to fly, which is a result of the modification of their forelimbs into wings (Payne *et al.* (1985); Martin *et al.* (2001)). Bats are a remarkably successful group as they are the second largest mammalian order in terms of biodiversity after the Rodentia (Vaughan (1986); Corbet and Hill (1992); Gunnell and Simmons (2005), in which they representing about 20% to 25% of all known mammals species (Altringham (2003); Simmons (2005a; 2005b)). Bats are distributed worldwide but reach their greatest diversity in the tropical and subtropical areas (Corbet and Hill (1992); Findley (1993); Koopman (1994)).

The roundleaf bats of family Hipposideridae (suborder Microchiroptera) is widely distributed in the tropics and subtropics of the Old World throughout Africa, Arabian Peninsula, Indian Subcontinent, South East Asia to the Philippines, North Australia, Oceania and Vanuatu (Corbet and Hill (1992); Hutson *et al*. (2001)). In Malaysia, 21 species from three genera, namely, *Hipposideros*, *Aselliscus* and *Coelops* are recorded, in which 20 species are distributed in Peninsular Malaysia and 12 species in Borneo (Payne *et al*. (1985); Khan *et al*. (1992); Davison and Akbar (2007)).

Generally, hipposiderids vary from small to moderate large in size (Payne *et al*. (1985); Corbet and Hill (1992)). They have an elaborate noseleaf with a horse-shoe shaped anterior leaf with exception in *Coelops*, while the posterior leaf is low and rounded that is divided into several pockets by vertical septa. Moreover, the hipposiderids also have no sella (Payne *et al*. (1985); Corbet and Hill (1992); Francis (2001)). The ears vary from moderately small to large sized with a low antitragus and they have very small eyes and the tail is short to moderately long which is completely enclosed in the interfemoral membrane (Payne *et al*. (1985); Corbet and Hill (1992)). According to Corbet and Hill (1992), the fossils of hipposiderids are recorded from the Eocene in Europe, the Miocene in Africa and Australia and also the Pleistocene in Asia.

Hill (1963) was the first who extensively studied on the morphological variations among *Hipposideros* species. This followed by Bogdanowicz and Owen (1998) who studied on the phylogenetic relationships of the genus using 45 morphometric parameters (metrical data) and 30 discrete-state (non-metrical data) morphological characters. In this study, it was aimed to elucidate the morphometric variations among four Malaysian hipposiderids using 27 morphometrical characters as well as to determine which diagnostic character(s) that effectively contributes to the differentiation of these particular species.

2. METHODOLOGY

All the 27 morphological characters of body, skull and dentals (see details in Sazali *et al.* (2008a; 2008b)) from four *Hipposideros* species namely, Hater, H. bicolor, H. cineraceus and *H.* dyacorum were measured using a digital caliper (Mitutoyo^{TM}; calibrated to 0.01 mm), a steel ruler and with the aid of microscope following Kitchener *et al.* (1993) and Sazali *et al.* (2008a; 2008b) and recorded appropriately in measurement data form. These data were further analysed for discriminant function analysis (DFA) and canonical variate analysis (CVA) using Statistical Package for Social Science (SPSS) program version 15.0 and also cluster analysis in Minitab version 14.4 using Euclidean distance of unweighted pair-group method average (UPGMA) method. A probability of $p < 0.05$ was considered significant in all analysis.

3. RESULTS AND DISCUSSION

The descriptive statistics for the understudied species can be summarized as in Table 1. The DFA successfully extracted three significant functions; Functions 1, 2 and 3 explained 94.9%, 4.3% and 0.8% of the variance respectively (Table 2). Function 1 with higher character loadings has higher variability of characters in the analysis. The Wilk's lambda statistic (Table 3) for the tests of both Function 1 and Function 2 through 3 function (Wilk's lambda = 0.000) have a probability of $p = 0.000$ respectively, whereas the Function 3 (Wilk's lambda = 0.032) has the probability of $p = 0.005$, which all has a significance level of $p < 0.05$.

The highest character loadings observed in Function 1 is the forearm length (FA), Function 2 is the third digit second phalanx length (D3P2L) and Function 3 is the palatal length (PL) (Table 4). Thus, these diagnostic parameters were useful to discriminate those four *Hipposideros* species of H. ater, H. bicolor, H. cineraceus and H. dyacorum. Both CVA (Figure 1) and cluster analysis (Figure 2) also show clear separation and grouping by each species, respectively.

Moreover, the morphometric analyses also subsequently revealed some misidentified specimens examined in the study. Misidentifications of closely related species of the *Hipposideros* often occurred since their morphological features are very similar. Although Payne *et al.* (1985) and Corbet and Hill (1992) had classified the hipposiderids based on the range of their body sizes, particularly using the forearm and ear lengths, it is clearly observed that those understudied species having an overlapping morphological characters, such as the forearm length, possessing similar noseleaves structure as well as the absent of lateral leaflets.

TABLE 1: Descriptive statistics of four examined *Hipposideros* species.

Species	***H. ater* (n=5)**			***H. bicolor* (n=6)**			***H. cineraceus* (n=6)**			***H. dyacorum* (n=5)**		
Character	**Mean ± SD**	**Min**	**Max**	**Mean ± SD**	**Min**	**Max**	**Mean ± SD**	**Min**	**Max**	**Mean ± SD**	**Min**	**Max**
FA	42.71±0.51	42.03	43.26	44.76±0.84	43.79	46.09	36.88±1.43	35.04	39.13	39.75±0.80	38.89	40.66
E	12.02±1.85	9.71	11.59	14.58±1.64	11.54	15.86	11.19±1.67	9.57	13.46	13.86±0.78	13.05	14.84
TB	17.45±1.27	16.58	19.66	20.32±0.34	19.85	20.67	16.69±1.07	15.12	17.83	15.96±0.44	15.31	16.40
PES	6.56±0.81	5.25	7.16	6.31±0.78	5.82	7.89	5.94±0.48	5.14	6.48	5.81±0.36	5.38	6.24
TVL	22.72±1.80	20.68	24.67	30.69±2.04	28.23	33.67	23.64±1.80	21.35	25.28	18.83±2.47	14.97	21.06
D3MCL	33.34±0.62	32.73	34.35	33.34±0.63	32.62	34.29	28.83±1.77	25.80	30.81	31.64±0.47	30.89	32.05
D3P1L	16.63±0.45	16.14	17.29	18.02±0.85	17.46	19.72	14.74±0.92	13.34	16.02	13.37±0.33	13.01	13.91
D3P2L	17.77±0.60	17.14	18.50	17.54±0.62	16.92	18.42	15.54±1.28	14.06	17.24	14.87±0.49	14.36	15.58
D4MCL	34.43±0.77	33.44	35.58	36.16±0.90	35.29	37.83	30.40±1.32	28.67	32.33	30.70±0.37	30.20	31.24
D5MCL	32.61±0.55	31.87	33.05	35.09±0.47	34.76	35.96	29.13±1.13	27.75	30.60	29.71±0.44	29.25	30.34
GSL	18.23±0.33	17.84	18.70	18.77±0.10	18.66	18.90	15.44±0.57	14.75	16.00	16.36±0.28	15.97	16.61
IOW	2.91 ± 0.13	2.70	3.05	2.91 ± 0.10	2.80	3.05	2.50 ± 0.32	2.15	2.86	2.42 ± 0.24	2.15	2.70
CW	7.13 ± 0.15	6.93	7.35	7. 44±0.20	7.22	7.69	6.25 ± 0.52	5.60	7.05	6.79 ± 0.38	6.18	7.16
MW	8.77 ± 0.31	8.58	9.32	9.04 ± 0.28	8.71	9.38	8.24 ± 0.34	7.59	8.55	8.47 ± 0.24	8.29	8.88
ZW	8.14 ± 0.27	7.91	8.60	8.37 ± 0.26	7.91	8.68	7.50 ± 0.16	7.32	7.73	7.78 ± 0.11	7.64	7.95
PPL	8.75 ± 0.36	8.41	9.33	8.79 ± 0.44	8.22	9.18	7.76 ± 0.51	7.09	8.46	7.88 ± 0.28	7.61	8.34
PL	6.67 ± 0.14	6.48	6.86	6.70 ± 0.24	6.31	6.99	5.20 ± 0.66	4.43	5.92	5.59 ± 0.16	5.43	5.77
DBC	4.55 ± 0.54	4.10	5.33	4.89 ± 0.29	4.64	5.39	4.15 ± 0.27	3.78	4.44	4.34 ± 0.18	4.06	4.50
BL	2.71 ± 0.22	2.54	3.05	2.53 ± 0.15	2.43	2.81	2.19 ± 0.20	1.89	2.37	2.62 ± 0.32	2.25	2.97
GBPL	7.08 ± 0.45	6.84	7.88	6.95 ± 0.44	6.37	7.51	6.35 ± 0.49	5.69	6.83	6.40 ± 0.27	6.16	6.73
DL	11.20±0.25	10.87	11.57	11.44±0.16	11.18	11.67	9.21 ± 0.51	8.47	9.73	10.27±0.20	10.04	10.48
C1BW	1.16 ± 0.12	1.01	1.35	1.23 ± 0.13	1.11	1.44	1.04 ± 0.04	0.98	1.08	1.26 ± 0.11	1.12	1.37
C1C1B	3.38 ± 0.32	3.16	3.94	3.40 ± 0.18	3.19	3.70	3.06 ± 0.22	2.73	3.37	3.55 ± 0.13	3.34	3.64
M3M3B	5.43 ± 0.31	5.20	5.97	5.55 ± 0.15	5.31	5.69	5.01 ± 0.17	4.67	5.15	5.73 ± 0.12	5.60	5.87
C1M3L	4.81 ± 0.24	4.50	5.16	5.15 ± 0.18	4.92	5.36	3.95 ± 0.46	3.49	4.50	4.47 ± 0.36	4.14	5.09
M2L	1.23 ± 0.16	1.07	1.40	1.28 ± 0.11	1.14	1.38	1.00 ± 0.12	0.87	1.16	1.30 ± 0.16	1.10	1.45
M2W	1.49 ± 0.07	1.42	1.57	1.36 ± 0.04	1.30	1.40	1.27 ± 0.10	1.09	1.35	1.41 ± 0.09	1.26	1.49

TABLE 2: Eigenvalues for DFA of four selected *Hipposideros*.

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	3605.450*	94.9	94.9	1.000
2	162.541*	4.3	99.2	0.997
3	30.504*	0.8	100.0	0.984

* First 3 canonical discriminant functions were used in the analysis.

TABLE 3: Wilks' Lambda for DFA of four selected *Hipposideros*.

Test of Function(s)	Wilks' Lambda	Chi-square	df	Sig.
1 through 3	0.000	167.376	54	0.000
2 through 3	0.000	85.472	34	0.000
3	0.032	34.501	16	0.005

TABLE 4: Standardised Canonical Discriminant Function coefficients of four selected *Hipposideros*.

Character	**Function**		
	1	**2**	**3**
FA	**21.910***	2.436	0.748
E	-3.471	-2.049	-1.112
TB	-6.950	-0.872	-0.226
PES	5.663	0.792	-0.876
TVL	-1.211	4.414	1.039
D3MCL	7.157	1.584	3.328
D3P1L	-4.955	2.669	1.642
D3P2L	4.650	**5.770***	3.446
D4MCL	-14.063	0.173	0.053
D5MCL	-6.876	-3.585	-4.738
GSL	9.922	-4.746	-3.786
IOW	-5.019	0.936	0.134
CW	-3.905	1.464	-0.540
MW	4.597	-0.133	-1.763
ZW	6.557	0.819	2.413
PPL	-6.282	-0.502	1.153
PL	0.992	3.151	**5.095***
C1BW	0.506	-0.361	1.422

* Diagnostic character in each function.

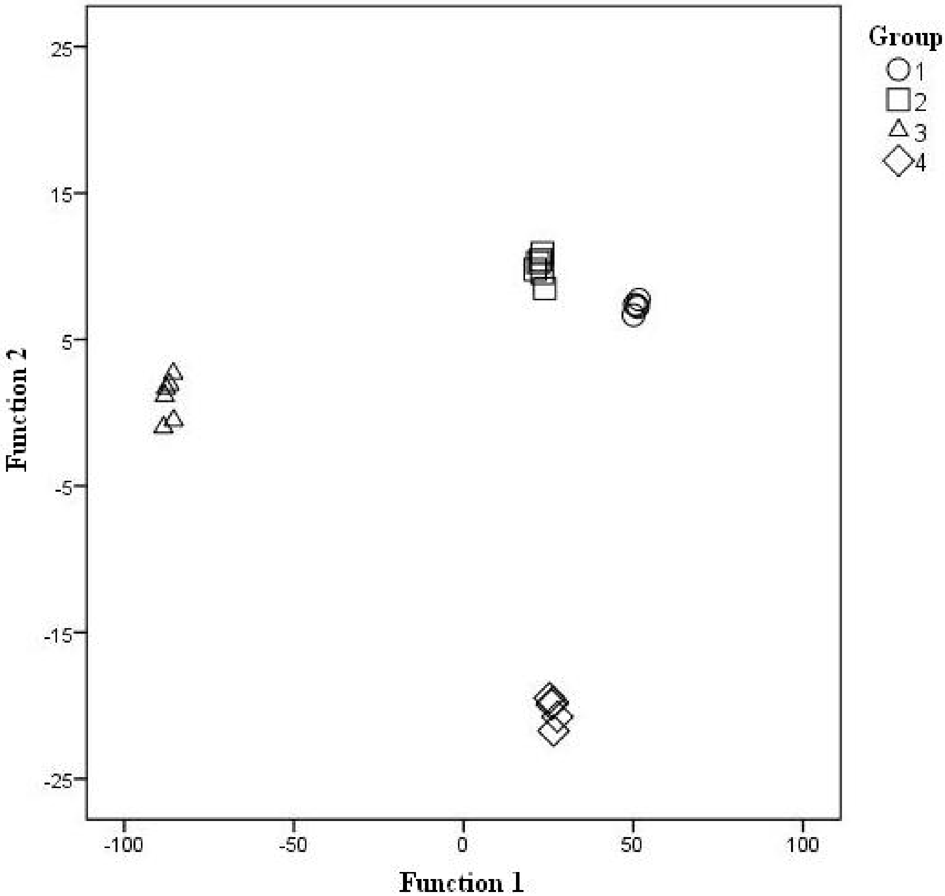

Figure 1: CVA plot of Functions 1 and 2 of four selected *Hipposideros*.
1 = *H. ater*, 2 = *H. bicolor*, 3 = *H. cineraceus*, 4 = *H. dyacorum*.

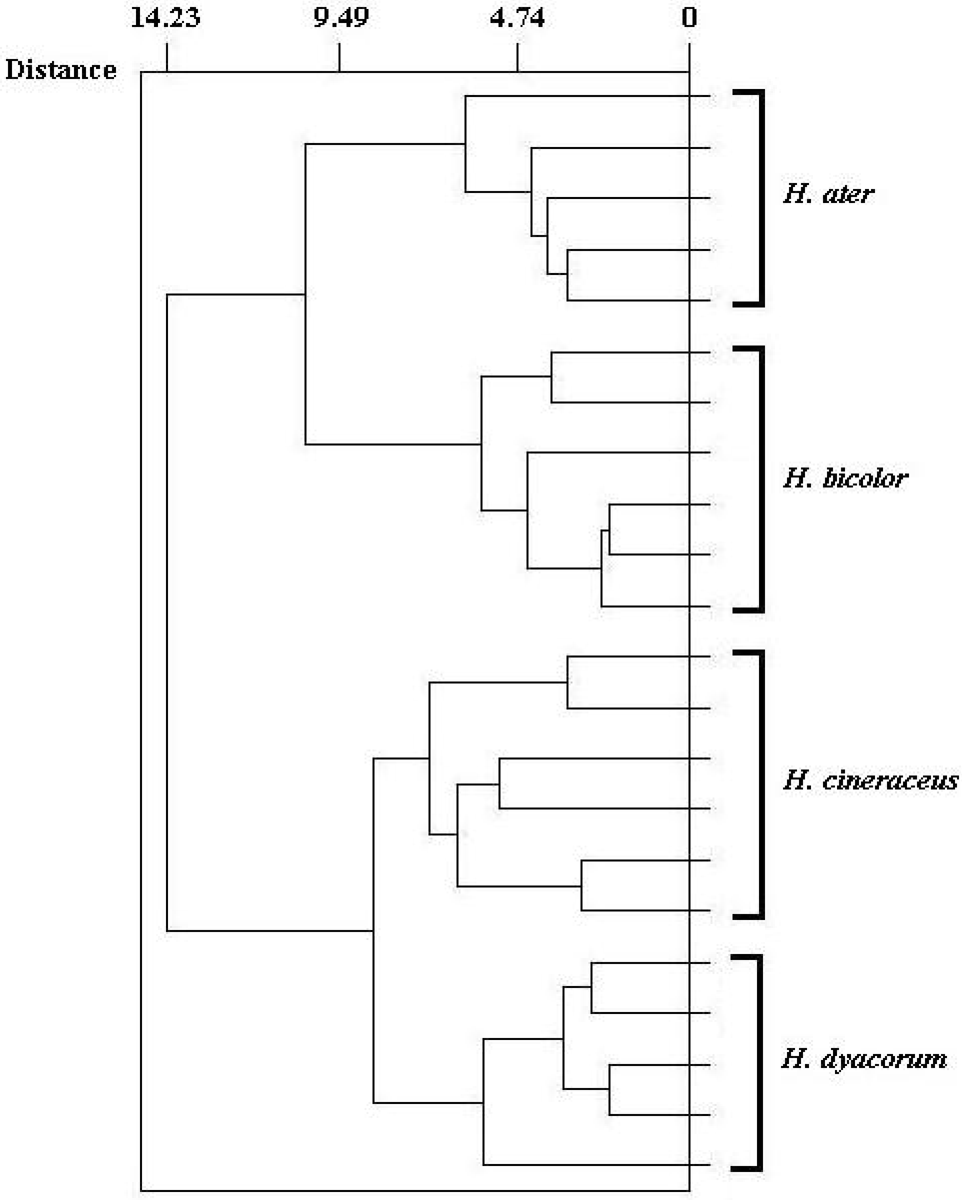

Figure 2: UPGMA cluster analysis of four selected *Hipposideros* species.

4. CONCLUSION AND RECOMMENDATION

Correct field identification of species is vital for accurate documentation of biological diversity and its ecological information. Overall, the analysis of morphological data of *Hipposideros* statistically is reliable and convincing, as it provides rapid assessment and evaluation and it is very cost effective. In fact, normal classical identification procedure as practised by experienced zoologists in the field, may still encounter some misidentification problem (Sazali *et al*. (2008a)). Hence, this morphometric approach could be promoted as a promising tool of another alternative to the molecular DNA sequencing analysis for aiding in species identification, particularly for the Chiroptera species.

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