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**Brief Communication: Preliminary investigation  
on the relationship of the nominate *C. brachyotis*  
with the small-sized and large-sized *C. brachyotis*  
using clustering analysis**

*By*

M.T. Abdullah and V.K. Jayaraj



SARAWAK MUSEUM DEPARTMENT

Brief Communication  
PRELIMINARY INVESTIGATION ON THE  
RELATIONSHIP OF THE NOMINATE  
*C. brachyotis* WITH THE SMALL-SIZED AND  
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ABSTRACT

Previous studies have shown that ecological habitats are the driving force that lead to genetic and morphological divergence in *Cynopterus brachyotis* populations in Malaysia. In this study, we have shown that the type specimen is clustered with a large-sized *C. brachyotis* which is normally found in open habitats. Further clustering analysis is necessary to include the five species of *Cynopterus* in order to verify if there is a new species within the *C. brachyotis* populations.

INTRODUCTION

Dog-faced fruit bats in the genus *Cynopterus* are widely distributed in the Indomalayan region (Corbet and Hill, 1992). These bats are easily recognisable by their short stout muzzle, brown fur with a yellowish or reddish tinge and contrasting whitish wing bones and rim to the ears (Payne *et al.*, 1985). The genus *Cynopterus* is limited to the five species that are generally recognised and is represented in the Indo-Malayan region by *C. brachyotis*, *C. horsfieldi*, *C. sphinx*, *C. titthaechelilus*, and *C. nusatenggara* (Corbet and Hill, 1992; Wilson and Reeder, 2005).

The nominate *C. brachyotis* type specimen was collected from Dewei River in Borneo and described by Müller in 1938. It is a small bat (weight 21 to 32g) that occurs in most habitats (but most frequently in disturbed forest) including lower montane forest, dipterocarp forest, gardens, mangrove and strand vegetation (Payne *et al.*, 1985). It prefers to roost in small groups in trees, under leaves, and in caves. The species feeds on the fruits of 54 plant species, the leaves of 14 species and the flower parts of four species (Tan *et al.*, 1998). As the understorey fruits are scarce, the species feed in the subcanopy or canopy (Francis 1994; Mohd. Azlan *et al.*, 2000). The role of *C. brachyotis* as a seed disperser in secondary habitats have been studied by Phua and Corlett (1989), Fujita and Tuttle (1991), Tan *et al.* (1998) and Hodgkison *et al.* (2003). *C. brachyotis* is widely distributed in Sri Lanka, southwest India, northeast India, Andaman and Nicobar islands, southern China, southern Burma, Indochina, Thailand, Malay Peninsula, Sumatra, Java, Bali, Sulawesi, the Philippines and also on Lesser Sunda islands (Fig. 1); from sea level up to 1600 m in Borneo (Lekagul and McNeely, 1977; Medway, 1978; Bergmans and Rozendall, 1988; Corbet and Hill, 1992; and Peterson and Heaney, 1993). The variation in morphological measurements of *Cynopterus* species from several geographical areas is shown in Table 1.

The taxonomic status of *C. brachyotis* is still uncertain given the many variations that exist within the species, which involves variation in size and colour (Corbet and Hill, 1992). The earliest classification by Andersen (1912) described the phylogeny of the Cynopterine section is represented by 11 genera, five of which occur in Malaysia, namely, *Chironax*, *Balionycteris*, *Penthetor*, *Dyacopterus* and *Cynopterus*. Andersen (1912) also proposed 30 names for *Cynopterus* species but only 16 are taxonomically valid forms (Kitchener and Maharadatunkamsi, 1991). However, Corbet and Hill (1992) listed 19 synonyms of *C. brachyotis* and of which nine are recognised subspecies by Mickleburgh *et al.* (1992) namely; *C. b. altitudinis*, *C. b. brachyotis*, *C. b. brachycysoma*, *C. b. ceylonensis*, *C. b. concolor*, *C. b. hoffeti*, *C. b. insularum*, *C. b. javanicus* and *C. b. minutus*. Most of these lack complete data on status and distribution, but are known to show morphological differences across their geographic

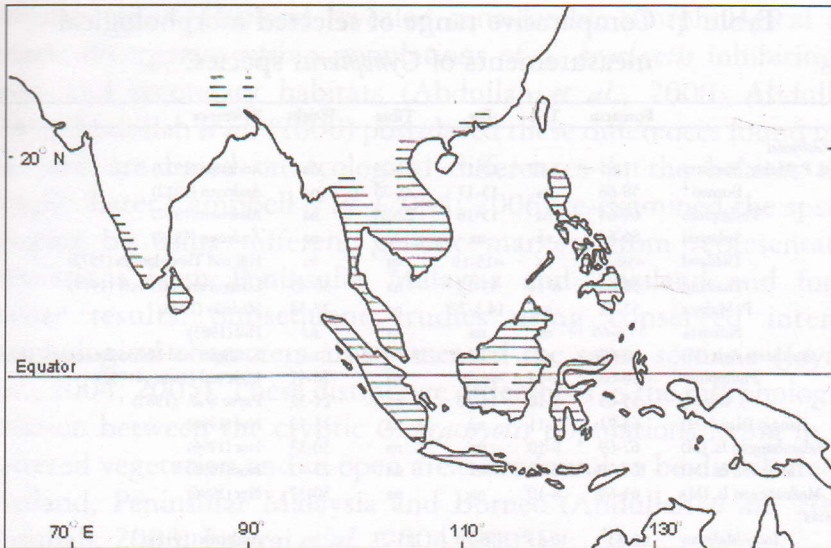


Fig. 1: Distribution of *C. brachyotis* in Indo-Malayan region (after Corbet and Hill, 1992). Mickleburgh *et al.* (1992) listed the distribution for the subspecies as the following; *C. b. altitudinis* in highlands of Peninsular Malaysia, *C. b. brachyotis* in Borneo, the Philippines, Sulawesi, Sumatra and Thailand; *C. b. brachysoma* on Andaman Islands; *C. b. ceylonensis* in Sri Lanka; *C. b. concolor* in Enggano Island; *C. b. hoffeti* in Vietnam; *C. b. insularum* on Kangean Island and Pulau Laut Kecil; *C. b. javanicus* in Bali, Java, Madura and Penida; and *C. b. minutus* on Nias Island.

distribution (Mickleburgh *et al.*, 1992). The nominate subspecies *C. b. brachyotis* is distributed from Myanmar, Thailand, Peninsular Malaysia, Borneo, Philippines and Indonesia (Mickleburgh *et al.*, 1992).

Records of morphological variation in *C. brachyotis* were documented by previous authors (Hill and Thonglongya, 1972; Lekagul and McNeely, 1977; Medway, 1978; Payne *et al.*, 1985; Ingle and Heaney, 1992; Nor, 1996). However, the forearm length differences of this species found in the primary forest and secondary habitats was first tested to be statistically significant by Francis (1990) in his work at Sepilok, Sabah in Malaysian Borneo. The earliest significant molecular and external morphometrics data on the existence of these two forms were conducted by Abdullah *et al.* (2000) and Abdullah (2003). Representatives of *C. brachyotis* populations sampled across Borneo, Peninsular Malaysia to the

Table 1: Comparative range of selected morphological measurements of *Cynopterus* species.

	Forearm	Tail	Ear	Tibia	Weight	Reference
<i>C. brachyotis</i>						
Thai, P. Malay, Sumatra	57-65	7-12	15-17	21-24	na	Andersen (1912)
Borneo <sup>1</sup>	58-66	na	15-17	21-25	na	Andersen (1912)
Philippines	62-64	na	15-16	22-23	na	Andersen (1912)
Sulawesi	60-63	na	na	22	na	Andersen (1912)
Thailand	≈59-63	na	≈15-19	na	na	Hill and Thonglongya (1972)
Thailand	58-63	6-11	15-19	na	30-45	Lekagul and McNeely (1977)
P. Malaya	57-72	na	14.5-22	na	27-34	Medway (1978)
Sumatra	55.6-65	na	na	na	na	Hill (1983)
Southeast Asia (M)	55-67	na	na	18.7-26.3	na	Kitchener and Maharadatunkamsi (1991)
Philippines	58-68	3-15	14-20	na	26-41	Ingle and Heaney (1992)
Borneo	55-65	8-10	14-16	na	21-32	Payne <i>et al.</i> (1985)
Bangi Island (M)	63-71	7-11	na	na	33-42	Nor (1996)
Balambangan Is. (M)	67-69	8-10	na	na	30-33	Nor (1996)
Malawali Is. (M)	64-70	6-12	na	na	27-42	Nor (1996)
Molleaingan Is. (M)	61-69	8-10	na	na	30-37	Nor (1996)
<i>C. sphinx</i>						
Indo-Malayan	66-83 <sup>2</sup>	10-13	18-20	25-27	-	Andersen (1912)
Thailand	≈64-75	na	≈17-24	na	na	Hill and Thonglongya (1972)
Thailand	65-74	7-12	18-20	na	33-67	Lekagul and McNeely (1977)
Peninsular Malaysia	65-76	na	18.5-22	na	na	Medway (1978)
Sumatra	64-70	na	na	na	na	Hill (1983)
Siberut	66-72	na	na	na	na	Hill (1983)
Malayan	65-76	18-22	na	na	na	Payne <i>et al.</i> (1985)
Southeast Asia (M)	58-74	na	na	21-30	na	Kitchener and Maharadatunkamsi (1991)
P. Malaysia	72-79	na	na	na	43-64	DWNP Museum <sup>3</sup>
<i>C. borsfieldi</i>						
Java and Sumatra	64-77 <sup>4</sup>	8-10	17-18	21-24	na	Andersen (1912)
Thailand	70-80	7-15	17-18	na	57-64	Lekagul and McNeely (1977)
Peninsular Malaysia	70-78	na	na	na	57-64	Medway (1978)
Borneo	68-76	14	17-20	na	50-70	Payne <i>et al.</i> (1985)
P. Malaysia	73-78	na	na	na	38-62	DWNP Museum
<i>C. titthaecbeilus</i>						
Sumatra	73.1-81.0	na	na	na	na	Hill (1983)
Krakatoa	75.1-75.4	na	na	na	na	Hill (1983)
<i>C. nusatenggara</i>						
Nusa Tenggara (F)	55-64	na	na	21-26	na	Kitchener and Maharadatunkamsi (1991)
Nusa Tenggara (M)	54-62	na	na	19-25	na	Kitchener and Maharadatunkamsi (1991)

Measurements were based on literature survey by Andersen (1912), Hill and Thonglongya (1972), Lekagul and McNeely (1977), Medway (1978), Hill (1983), Payne *et al.* (1985), Kitchener and Maharadatunkamsi (1991, 1996), Ingle and Heaney (1992) and Nor (1996).

<sup>1</sup> including *C. brachyotis* type locality from Dewei River, Borneo (Müller 1838 in Andersen 1912).

<sup>2</sup> page 634 Andersen (1912) listed as 66-73.5 mm.

<sup>3</sup> Department of Wildlife and National Park Museum, Kuala Lumpur.

<sup>4</sup> page 636 by Andersen (1912) as 64.5-71 mm; na = data not available.

F = female, M = male. ≈ estimated from graphs. Measurements in mm and weight in grams.

southern tip of Thailand revealed considerable morphological and genetic divergence within populations of *C. brachyotis* inhabiting in forest and secondary habitats (Abdullah *et al.*, 2000; Abdullah, 2003). Abdullah *et al.* (2000) postulated these differences found in *C. brachyotis* are based on ecological differences in the habitat they occupy. Later Campbell *et al.* (2004; 2006) re-examined the species complex by using different genetic markers from representative populations from Peninsular Malaysia and Thailand and found similar results. Subsequent studies using conserved internal morphological characters also presented the same scenario (Jayaraj *et al.*, 2004; 2005). These distinctive differences in the morphological variation between the cryptic *C. brachyotis* populations living in the cluttered vegetation and in open areas are found to be distributed in Thailand, Peninsular Malaysia and Borneo (Abdullah *et al.*, 2000; Abdullah, 2003; Jayaraj *et al.*, 2004; 2005).

In summary, the larger form of *C. brachyotis* inhabits open areas and the smaller form is confined to closed habitat or primary forest (Abdullah *et al.*, 2000; Abdullah, 2003; Campbell *et al.*, 2004, 2006; Jayaraj *et al.*, 2004; 2005). These findings in size difference found in *C. brachyotis* populations could generate new hypothesis that the habitat clutteredness is acting as a selective force for the smaller *C. brachyotis* while the large-bodied *C. brachyotis* is selected for powerful flight to escape from nocturnal predators (Abdullah *et al.*, 2000).

The aim of this preliminary study was to investigate on the relationship of the nominate *C. brachyotis* described by Müller (1838) with the two forms of small-sized and large-sized *C. brachyotis* by using simple clustering method.

## MATERIALS AND METHOD

Representatives of *C. brachyotis* from voucher specimens held in the zoological museum at Universiti Malaysia Sarawak (UNIMAS) were used in this study. A total of 15 samples consisting of five *C. borsfieldi*, five large-sized and five small-sized *C. brachyotis* were measured for ear length, tail length, body length and wing span. The

measurements for the nominate *C. brachyotis* was taken from published paper by Müller (1838). The data for this preliminary study are shown as Table 2.

A cluster analysis using euclidean distance with unweighted pair-groups method average (UPGMA) was used following Everitt (1993) to reconstruct a morphometric-based relationship between the nominate species and other forms of *Cynopterus*.

**Table 2:** List of voucher and type specimens, locations and measurements used in this study.

Species form	Field number	Locality	Ear length	Tail length	Wing span	Body length
1 <i>Cynopterus horsfieldi</i>	IKB039	IKB, Pahang	18.04	9.07	460	90
2 <i>Cynopterus horsfieldi</i>	IKB017	IKB, Pahang	18.99	8.26	470	90
3 <i>Cynopterus horsfieldi</i>	IKB045	IKB, Pahang	18.46	10	452	92
4 <i>Cynopterus horsfieldi</i>	IKB036	IKB, Pahang	18.75	11.95	432	85
5 <i>Cynopterus horsfieldi</i>	IKB023	IKB, Pahang	17.46	11.29	458	89
6 <i>C. brachyotis</i> large form	KNP022	Kubah N.P.	12.47	7.11	388	80
7 <i>C. brachyotis</i> large form	KNP056	Kubah N.P.	15.74	5.97	392	82
8 <i>C. brachyotis</i> large form	KNP030	Kubah N.P.	15.46	6.62	400	79
9 <i>C. brachyotis</i> large form	BA0024	Batang Ai N.P.	17.37	5.55	396	87
10 <i>C. brachyotis</i> large form	KNP051	Kubah N.P.	16.28	6.42	396	88
11 <i>C. brachyotis</i> small form	UNIMAS82	Bario	14.47	5.5	364	85
12 <i>C. brachyotis</i> small form	UNIMAS262	Gading N.P.	12.14	7.28	364	75
13 <i>C. brachyotis</i> small form	BA026	Batang Ai N.P.	14.29	4.94	364	74
14 <i>C. brachyotis</i> small form	KNP035	Kubah N.P.	14.68	6.62	374	76
15 <i>C. brachyotis</i> small form	KNP033	Kubah N.P.	15.54	6.3	360	84
16 <i>C. brachyotis</i> type specimen	Leiden Museum	Dewei River	14.82	6.35	413	86

Length in mm; N.P. National Park (in Sarawak, Malaysian Borneo), IKB, Pahang = The Institute of Biological Diversity, Department of Wildlife and National Parks, Bukit Rengit, Pahang, Malaysia.

## RESULTS AND DISCUSSION

Fig. 2 illustrates the clustering of *C. brachyotis* into two forms; a large form and a small form which is consistent to Jayaraj *et al.* (2005). The type specimen (no. 16) described by Müller (1838) is clustered in large-sized *C. brachyotis*. As there was no detailed description on the habitat of the type locality, nothing can be concluded about the ecological habitat of the nominate species. However, previous studies indicated that the large form is associated with open areas (Abdullah *et al.*, 2000; Abdullah, 2003; Campbell *et al.*, 2004, 2006; Jayaraj *et al.*, 2004, 2005).

In order to verify that the small-sized *C. brachyotis* is a new species, all other remaining *Cynopterus* species (*C. sphinx*, *C. titthaechelus* and *C. nusatenggara*) must be included in the clustering analysis. Currently work is in progress to further assess the *Cynopterus* species boundary of both forms of *C. brachyotis* by multivariate statistics using conserved morphological characters and several molecular markers.

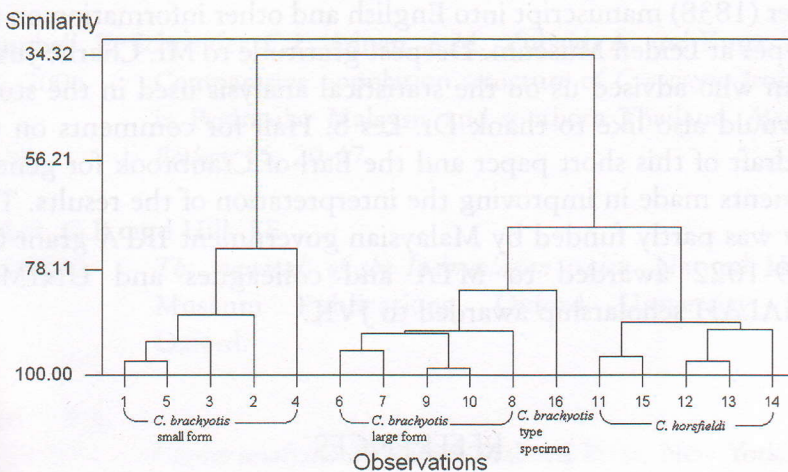


Fig. 2: UPGMA cluster analysis of *C. brachyotis* including type specimen (16). Note that the type specimen of *C. brachyotis* (sample no. 16) is clustered to the large form of *C. brachyotis*. The large form *C. brachyotis* is occasionally found in open areas and the small form is associated with cluttered habitat. *C. horsfieldi*, a member of the *Cynopterus* group is also found in Borneo.



Both forms of *C. brachyotis* might be important seed dispersal agents especially light demanding pioneer species such as *Adinandra dumosa* (Phua and Corlett, 1989). According to Kunz (1982), in theory the larger-bodied bats are commonly found in open areas as they would need a powerful flight that would aid in avoiding predators. The small-bodied bats would need a small body for better manoeuvrability in dense vegetation (Kunz, 1982) especially pteropodids which have deficient navigational capabilities to feed in the subcanopy or canopy as understorey fruits are scarce (Francis, 1994; Mohd. Azlan *et al.*, 2000). According to Begon *et al.* (1990), increases in body size can be associated with increases in species' competitive abilities, better adaptations to maintain body constancy in variable conditions, and decreased vulnerability to predation, resulting in higher survivorship.

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### Appendix A: Translation of Müller, (1838).

Müller, S.1838. Over eenige nieuwe zoogdieren van Borneo [On some new mammals from Borneo].

*Tijdschrift voor Natuurlijke Geschiedenis en Physiologie* 5: 134-150.

p. 146-147: 6 *Pachysoma brachyotis*. Nov. sp.

This species is over one third smaller than *Pachys. tithebeilum*, its body length measuring 3" 4<sup>1</sup>/<sub>2</sub>" [3 inches 4<sup>1</sup>/<sub>2</sub> lines], the thin, bare tail 3", and the wing span 1' 4" 3" [1 foot 4 inches 3 lines]. For the rest, its fur is similar to that of *Pachys. tithebeilum*, particularly regarding the body colour, but the wings in *Pachys. brachyotis* are considerably darker, virtually sooty black, whereas the wing membrane in *P. tithebeilum* is more or less yellowish brown. The hairs of the head and back in older individuals are pale grey at the base, at the tips paler or darker yellowish, but in younger animals the latter colour tends to be more or less blackish brown. The abdomen in adult specimens is yellowish grey; the slightly longer hairs at the throat and particularly on the sides of the neck are pale yellowish red. The eyes are brown, and the ears, 7" long with the outer margin bluntly rounded off, have the same dull, sooty black colour of the wings.

I found this species only once, far in the interior of Borneo, where it lived in fairly large numbers in a deep limestone cave, situated in an extensive cliff on the bank of the Dewej. The Malay who accompanied me called this animal *Krawar*, like all small bats, but to the *Bejadjoe*-Daijak it is known under the name *Pandan*, whereas they call the true Vespertilionids *Pandan lieli*.

Type locality from Mullër (1847: 388, map):

Müller, S., 1847. Reis in het zuidelijke gedeelte van Borneo [Journey in the southern part of Borneo]: 321-446, pls.

In: C.J. Temminck (eds.). *Verhandelingen over de natuurlijke geschiedenis der Nederlandsche overzeesche bezittingen, door de leden der Natuurkundige commissie in Indië en andere schrijvers. Land- en volkenkunde.*

p. 388:

The following day [i.e. 12 September 1836] we sailed further up to Teweij. Soon we came at a Pekoepaij hamlet called Kampong Djâmoet, consisting

of eight houses, also surrounded by strong stockades. The population was estimated at 130 people.....

About 45 minutes' rowing above Kampong Djâmoet we saw, also on the left bank, two long, newly built Dajak houses, within a fence of partly split stems; and a little further we noticed a cave called Liang Naga, in a cliff between 30 and 40 feet high. At the entrance, this cave was 6-8 feet wide, with an estimated depth of 15-18 feet. It was inhabited by a multitude of bats of at the time still unknown species, described by me under the name *Pachysoma brachyotis*. The rocks of this and of similar cliff, which we already passed before, consisted of dense limestone containing scattered petrified shells as well as corals of the genera *Astraea* and *Mendrina*.....



Plate VIII: A large-sized *C. brachyotis* from Borneo.