MORPHOLOGICAL VARIATION IN THE EBONY AND SILVER LEAF MONKEYS [*TRACHYPITHECUS AURATUS* (E. GEOFFROY, 1812) AND *TRACHYPITHECUS CRISTATUS* (RAFFLES, 1821)] FROM SOUTHEAST ASIA

IBNU MARYANTO
Research and Development Centre for Biology , LIPI. Jl. Ir.H.Juanda 18 Bogor, Indonesia.
I. MANSJOER
Primate Research Centre- Bogor Agricultural University, Indonesia.
D. SAJUTHI
Primate Research Centre- Bogor Agricultural University, Indonesia.
J. SUPRIATNA
Center for Biodiversity and Conservation Studies, University of Indonesia, Depok 16424, Indonesia

ABSTRACT

*The morphological variation in the ebony and silver leaf monkeys (*Trachypithecus auratus *and* T. cristatus*) from Southeast Asia; Thailand, Malaya, Bintan, Sumatra, Serasan-Natuna, Kalimantan and Java were studied using multivariate analysis approaches. The results showed that clinal variation in skull, dental and dentary morphology was found in Java. The skull, dental and dentary characters showed an increase from West to East with Central Java as an intermediate form. Consequently, in Java there should be only one subspecies,* T. a. auratus. *Meanwhile, there are four morpholgical groups of* Trachipithecus cristatus, *those are of Thailand, Malaya-Sumatra-Kalimantan, Bintan and Natuna. The Malayan population, presumably is the same as Bintan population while Sumatra-Kalimantan forms an intermediate.*

INTRODUCTION

The ebony and silver leaf monkeys (*Trachypithecus auratus* and *T. cristatus*) are widely distributed throughout Southeast Asia from Thailand and Malay peninsula in the north to Lombok island in the south (Groves 1993). Both species are well adapted to various habitats; montane forest, lowland, peat swamp and mangrove forests. They are also found in secondary forests and close to human habitation (Furuya 1961; Medway 1978; Kitchener *et al*, 1990; Kool 1992).

The taxonomic status of *T. auratus* and *T. cristatus* is still uncertain. The silver leaf monkeys have been included in three genera, namely *Presbytis*, *Trachypithecus* and *Semnopithecus* at various times. Lyon (1907) described this species as *Presbytis cristata*, and some authors suggested that Indonesia has seven subspecies of *P. cristata*, namely *P. cristata cristata* (Sumatra)

P. c. vigilans (Natuna islands), *P. c. ultima* (Kalimantan), *P. c. pullata* (Batam, Riau Isl.) *P. c. sondaica* (West Java), *P. c. pyrrha* (East Java) and *P.c. kohlbruggei* (Lombok and Bali) (Sody 1931; Robinson and Kloss 1919 ; Thomas and Wroughton 1909, Miller 1913; Hooijer 1962, Strien 1986), .

Wolf and Fleagle (1977) concluded that silver leaf monkeys (*Presbytis, Semnopithecus* and *Trachypithecus*) have shown many morphological similarities. These problems in taxonomy was questioned by Hooijer (1962), who described this species as *Trachypithecus,* but later treated as *Semnopithecus* a superspecies, by Brandon-Jones (1995). Weitzel and Groves (1985), Weitzel *et al* (1988) reinstated the species as *Trachypithecus* and divided it into two species, namely *Trachypithecus auratus* and *Trachypithecus cristatus. T. auratus* has three subspecies, *T.a. sondaicus* (West Java), *T.a. auratus* (East Java) and *T. c kohlbruggei* (Bali and Lombok), while *T. cristatus* has three subspecies, *T. c. cristatus* (Malaya, Sumatra, Kalimantan, Bintan), *T. c. vigilans* (Natuna Isl.), *T. c. germanii* (Thailand).

This paper is intended to describe morphological variations analyzed by multivariate statistics based upon their localities, a study which has never been carried out before.

MATERIAL AND METHODS

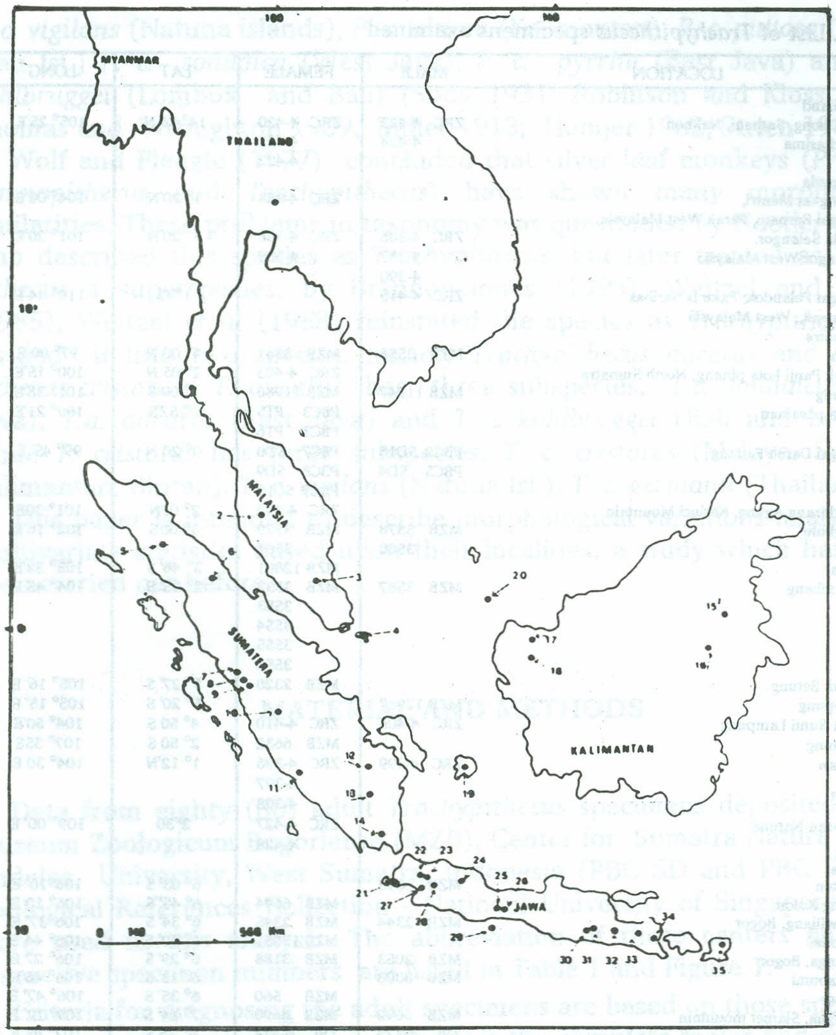
Data from eighty (80) adult *Trachypithecus* specimens deposited at the Museum Zoologicum Bogoriense (MZB), Center for Sumatra Nature Study, Andalas University, West Sumatra, Indonesia (PBC SD and PBC PT) and Zoological References Collection - National University of Singapore (ZRC) were used in this analysis. The abbreviation of these centers and their respective specimen numbers are listed in Table 1 and Figure 1.

Criteria for diagnosing the adult specimens are based on those specimens with two category combinations, firstly is the complete molar and secondly is the following sutures fused: basioccipital-basisphenoid, basisphenoid-presphenoid and palatine-maxillary. Additionally, three adult age classes were established based on completely fusion, their age classes are categorized as follows : class I, 90-100 % ; class II, 80-90 % and class III, 70-80 %.

Twenty eight skull, dental, dentary specimens were measured by digital caliper and two body characters by tape measure (all in mm). Complete measurement points for skull, dental and dentary specimens are shown in Figure 2. Fur and skin colour were determined according to Konerop and Wanscher (1983) and capitalised.

Table 1. List of *Trachypithecus* specimens examined

NO	LOCATION	MALE	FEMALE	LAT	LONG
A	Thailand				
1.	PakChong, Sathani, Nakhon	ZRC 4-423	ZRC 4-420	14°42' N	105° 25'E
	Ratchasima	4-424	4-421		
			4-422		
B.	Malaysia				
1	Changkat Mentri,		ZRC 4-383	1° 20'N	104° 00'E
	Sungai Bernam, Perak West Malaysia				
2	Kuala Selangor,	ZRC 4-386	ZRC 4-388	3 °20'N	101° 20'E
	Selangor West Malaysia	4-387	4-389		
		4-390			
3	Sungai Pelandok, Paku Is Saribas	ZRC 4-415		1°32	110° 44 E
	Sarawak,, West Malaysia				
C	Sumatra				
1	Aceh	MZB 3558	MZB 3561	4° 00 N	97° 00 E
2	Teluk Panji kota pinang, North Sumatra		ZRC 4-403	2° 05 N	100° 15'E
3	Sitiung	MZB 11747	MZB 11786	1° 00 S	101° 38'E
4	Panti pasaman		PBC3 PT5	0° 57'S	100° 21'E
			PBC3 PT6		
5	Sungai Dareh Padang	PBC2 SD18	PBC7 SD8	0° 20 N	99° 45' E
		PBC5 SD4	PBC8 SD9		
			PBC9 SD10		
6	Sandarang Agung, Kerinci Mountain		ZRC 4-402	2° 07N	101° 30E
7	Bengkulu	MZB 3578	MZB 3579	3° 00'S	102° 16'E
		3580	3581		
8	Lahat		MZB 12801	3° 48' S	103° 32'E
9	Palembang	MZB 3587	MZB 3552	2° 55' S	104° 45 E
			3553		
			3554		
			3555		
			3556		
10	Teluk Betung		MZB 2328	5° 27' S	105° 16' E
11	Lampung	MZB 12967		5° 20' S	105° 15' E
12	Kota Bumi Lampung	ZRC 4-406	ZRC 4-410	4° 50 S	104° 50'E
D	Belitung		MZB 6632	2° 50 S	107° 55E
E	Bintan	ZRC 4-399	ZRC 4-396	1° 12'N	104° 30 E
			4-397		
			4-398		
F	Serasan Natuna		ZRC 4-427	2°30	109° 00' E
			4-428		
G	Java				
1	Banten	MZB 6693		6° 03' S	106°10' E
2	Ujung Kulon		MZB 6694	6° 45' S	106° 10 E
3	Leuwiliang, Bogor	MZB 2344	MZB 2345	6° 34' S	106°37' E
4	Cibodas		MZB 15851	6° 50' S	106° 44 E
5	Jasinga, Bogor	MZB 2053	MZB 3188	6° 29' S	106° 27 E
6	Sukabumi	MZB 8008		6 °13' S	106° 46 E
7	Bogor		MZB 560	6° 35' S	106° 47' E
8	Kaligua, Slamet mountain	MZB 6692	MZB 6690	7° 14' S	109° 12' E
9	Subang	ZRC 4-375	ZRC 4-374	6° 35 S	107° 45 E
10	Tamansari Central Java		ZRC 4-376	7° 57'S	111° 31'E
11	Karang Bolong, Central Java	ZRC 4-377		7° 50'S	109° 25'E
12	Blitar	MZB 3372		8° 06'S	112° 09'E
13	Arjuna mountain	ZRC 4-378	MZB 1732	7° 45 S	112° 34'E
		4-379			
14	Iyang mountain		MZB 1927	7° 58 S	113° 38'E
15	Banyuwangi	MZB 6696	MZB 6697	5° 26 S	106° 05'E
		6699			
		6700			
16	Jember	MZB 6698		8° 10' S	113° 42 E
H	Nusakambangan		MZB 2094	7° 45' S	108° 55' E
I	Sapit, Lombok	MZB 6689		8° 27' S	116° 32' E
J	Kalimantan				
1	Kembang jenggut	MZB 8133	MZB 8134	0° 08'N	116° 22' E
2	Bulungan		MZB 6701	2° 55' N	117° 35' E
3	Perbuah		MZB 6702	0° 53' N	110° 10' E
			6704		
			6705		



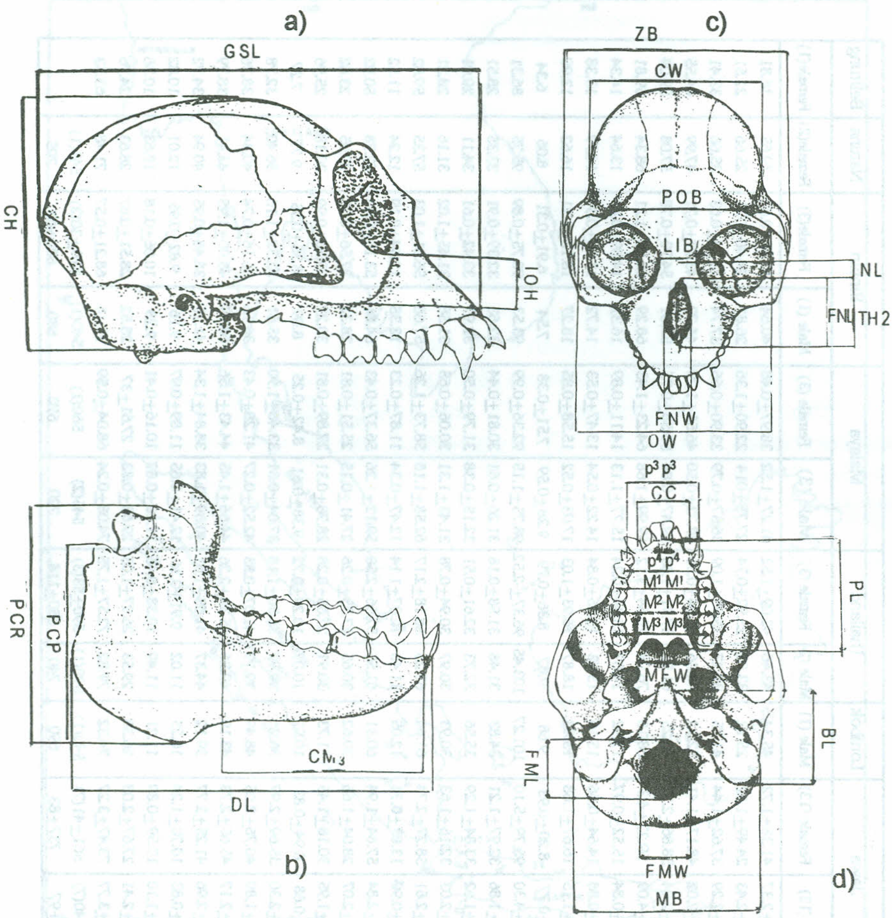
Legend :

1 Pak Chong Sathani, Thailand
2 Changkat Mentri, Bernam River
3 Kuala Selangor
4 Bintan Island
5 Leuser Mountain, Aceh
6 Teluk Panji, Kota Pinang
7 Panti Pasaman, West Sumatra
8 Sitiung, West Sumatra
9 Sungai Dareh, Padang
10 Sandaran agung, Kerinci Mountain
11 Bengkulu
12 Palembang
13 Lahat
14 Teluk Betung
15 Bulungan
16 Kembang Jenggut
17 Pelanduk River, Sarawak
18 Perbuah
19 Belitung Island
20 Serasan, Natuna Islands
21 Ujung Kulon
22 Banten
23 Bogor
24 Subang
25 Slamet Mountain
26 Tamansari
27 Sukabumi
28 Cibodas
29 Nusakambangan
30 Blitar
31 Arjuna Mountain
32 Iyang Mountain
33 Jember
34 Banyuwangi
35 Sapit, Lombok

Figure 1. Locality of *Trachypithecus* specimens in this study

Table 2. Measurements (in mm) for skull and body character for male and female adults of *Trachypithecus* based on localities.

Var/n	Sumatra		Kalimantan		Jawa		Lombok	Thailand		Malaya		Bintan		Natuna	Belitung
	Male (10)	Female (18)	Male (2	Female (5)	Male (13)	Female (13)	Male (1)	Male (2	Female (3)	Male (3)	Female (3)	Male (1)	Female(3)	Female(2)	Female(1)
BL	42.40±2.28	38.86±1.56	41.31	39.16±2.56	43.20±2.37	41.38±1.72	45.34	43.46	42.09±1.52	41.27±1.52	38.97±0.48	40.64	37.38±0.82	39.65	38.81
C-C	27.56±1.92	23.50±1.14	27.62	23.52±1.88	28.97±2.43	24.49±1.62	25.12	33.08	25.92±0.74	27.75±014	22.90±1.36	26.81	24.40±075	25.66	21.51
CM3	36.84±1.50	34.97±1.40	35.46	34.65±1.58	40.93±2.29	37.62±1.44	41.75	39.27	35.93±1.09	36.57±0.79	33.90±0.66	37.74	33.78±0.63	35.66	33.41
CH	48.47±1.04	47.48±1.73	47.69	47.78±1.91	50.31±2.02	48.17±1.41	52.22	48.36	48.34±0.56	47.72±0.50	46.55±1.79	44.79	43.77±0.71	47.99	44.55
CW	60.07±2.57	56.47±2.34	60.36	56.89±2.21	61.81±2.04	58.86±2.72	62.25	61.50	57.91±1.35	59.47±0.84	56.56±0.75	55.81	54.70±0.78	57.08	59.04
DL	70.94±3.08	64.50±2.74	69.70	64.12±4.20	75.36±4.09	69.27±4.3	68.18	76.94	70.64±3.12	69.99±1.68	64.23±1.43	68.29	65.66±1.21	68.34	59.81
FML	14.17±0.85	14.18±0.96	15.45	15.19±1.25	15.76±0.84	15.52±0.97	17.92	14.07	13.34±0.24	15.77±1.13	14.11±0.89	16.32	14.89±0.43	13.64	14.34
FMW	13.85±1.01	13.58±0.74	14.44	13.55±0.45	14.57±0.88	14.64±0.66	15.19	15.13	13.26±0.84	14.22±0.54	13.47±0.53	14.72	13.58±0.39	14.79	13.38
FNL	17.77±1.03	15.18±0.85	17.15	16.12±1.33	18.31±1.15	16.67±1.68	15.88	18.87	16.93±1.03	17.03±0.52	15.58±0.85	18.27	18.12±1.21	16.62	13.99
FNW	9.45±1.17	7.46±0.62	9.21	7.46±0.97	9.02±0.77	8.20±0.93	9.68	9.87	8.36±0.79	9.28±0.59	7.51±0.38	7.54	6.91±0.31	8.06	6.34
GSL	97.34±3.86	90.73±3.29	96.82	90.63±3.68	04.21±4.30	95.79±5.10	101.27	103.45	96.37±-2.52	98.75±1.15	92.36±0.99	93.53	90.75±0.89	95.75	86.31
M1-M1	32.84±1.76	31.10±0.98	31.75	30.93±1.22	34.76±1.86	32.97±1.21	34.83	31.48	31.58±0.18	31.26±0.61	30.81±0.44	32.63	32.39±0.91	33.35	28.51
M2-M2	33.17±1.24	31.68±1.12	32.60	31.49±1.29	35.08±1.62	33.84±1.29	35.56	32.73	32.61±0.51	32.15±0.38	31.79±0.50	32.97	33.42±0.61	34.11	29.91
M3-M3	31.42±1.20	29.59±1.39	30.61	29.86±1.10	33.13±2.03	32.16±1.63	30.93	30.97	30.94±0.78	31.43±1.31	30.06±0.65	31.58	31.45±1.02	31.16	28.21
MB	61.93±2.72	57.68±2.65	61.44	59.41±2.96	62.38±2.61	58.27±2.74	61.69	63.25	58.18±2.17	62.58±1.18	58.73±1.26	57.68	56.61±1.03	57.35	59.82
MFW	13.00±0.58	11.87±0.46	12.56	12.08±0.65	13.34±0.90	13.07±0.76	12.05	11.43	12.07±1.14	12.47±0.34	11.87±0.23	13.35	12.54±0.19	12.24	11.52
OW	59.05±3.10	56.06±2.20	57.72	55.43±2.62	61.56±2.84	57.84±1.94	60.31	61.55	57.66±2.50	59.12±1.26	56.37±0.43	54.86	53.13±0.65	52.78	50.92
P3-P3	28.80±1.58	26.76±1.33	27.54	26.33±1.27	30.65±2.07	28.04±1.66	30.62	30.65	27.35±0.26	27.41±0.15	25.51±0.81	28.32	27.56±0.29	29.05	23.62
P4-P4	30.26±1.24	28.48±1.37	29.20	27.86±1.40	32.64±1.95	30.18±1.45	31.73	30.91	27.65±0.28	28.78±0.31	27.89±0.81	30.27	29.58±0.99	30.18	25.96
LIB	9.47±0.80	8.74±0.66	9.22	8.39±1.01	9.00±0.68	8.94±0.83	10.52	10.07	10.29±0.72	9.38±0.61	8.42±0.25	8.89	8.35±0.35	9.77	7.27
PL	36.70±1.59	33.72±1.51	36.06	32.9±2.07	39.99±2.30	35.69±2.97	36.26	39.97	35.50±1.18	37.04±0.81	33.46±1.90	35.81	32.32±1.16	36.40	32.78
POB	41.03±1.41	40.63±1.32	40.65	40.62±1.24	42.01±1.89	40.76±2.05	48.49	39.79	41.07±0.53	42.52±0.27	41.28±0.43	36.16	36.16±0.74	40.44	38.76
PCR	44.98±2.85	42.54±2.71	43.84	41.25±2.31	47.86±2.17	45.65±2.73	43.19	49.26	45.32±2.26	44.66±1.45	44.43±1.56	68.29	45.00±1.95	43.41	38.79
PCP	42.06±2.63	38.13±2.44	41.45	37.51±2.38	43.65±2.96	41.25±2.77	39.12	44.37	41.03±1.61	40.89±1.83	38.84±1.34	41.11	38.48±0.95	40.94	34.72
NL	10.89±1.47	10.03±1.17	10.12	9.46±1.12	11.87±0.83	10.70±1.24	10.25	11.02	9.91±0.36	12.41±0.65	11.89±0.97	9.16	9.82±0.95	12.01	10.82
IOH	11.01±0.92	9.93±0.78	9.54	9.23±1.77	12.44±1.10	10.59±0.89	11.21	11.49	10.38±0.45	11.16±0.87	10.16±0.41	9.28	10.06±0.18	10.63	10.36
TH2	28.64±1.44	25.27±1.61	27.51	25.48±1.66	29.87±2.41	27.67±2.08	26.38	29.53	26.97±1.03	29.68±0.33	27.61±37	28.52	28.51±0.67	28.63	24.76
ZB	75.17±2.30	69.66±3.28	74.06	68.45±3.95	78.98±3.77	73.47±3.27	74.32	79.82	72.57±1.75	74.08±0.24	68.04±0.59	71.16	68.21±0.57	71.48	63.53
SVL(n)	542±18(5)	507±41(10)	510(1)	505±28(4)	567±40(7)	561±41(7)	540(1)	590(1)	590±53(3)	545(2)	560(1)	540(1)	510±30(3)	545(1)	
TL (n)	756±58	686±48	670	660±53	738±97	737±83	690	740	880±118	720	670	680	680±68	795	



Legend :

BL	=	Bulla length	M3-M3	=	Upper outer molar 3 width
C-C	=	Upper outer canine width	MB	=	Mastoid breadth
CW	=	Cochlea width	MFW	=	Mesopterigoid fossa width
C-M3	=	Canine-Molar 3 mandibula	OW	=	Orbit width
CH	=	Cranial Height	P3-P3	=	Upper outer premolar 3 width
D L	=	Dentary condyle to tip dentary	P4-P4	=	Upper outer premolar 4 width
FNL	=	Foramen nasal lengh	PCP	=	Ramus condylar process
FNW	=	Foramen nasal width	PCR	=	Ramus coranoid process
FML	=	Foramen magnum length	POB	=	Post orbital breadth
FMW	=	Foramen magnum width	PL	=	Palatal length
GSL	=	Greatest skull length	NL	=	Nasal length
IOH	=	Infra orbital hight	TH2	=	Ramus condylar process
LIB	=	Least interorbital breadth	ZB	=	Zygomatic breadth
M1-M1	=	Upper outer molar 1 width	SVL	=	Snout vent length (not cited in the figures)
M2-M2	=	Upper outer molar 2 width	TL	=	Tail length (not cited in the figures)

Figure 2a–d. Measurement point of skull, dental and dentary of *Trachypithe*
a) Cranium, lateral view, b) Mandible, lateral view,
c) Cranium, frontal view, d) Cranium, ventral view.

Sexual dimorphism of skull, dental, dentary and external characters were investigated by multiple regressions on sex, age and locality group. Canonical variate (discriminant) analysis (DFA) was computed for skull, dental and dentary characters. All analyses were performed on a computer using SPSS/PC program.

RESULTS

Univarite analysis

Mean and standard deviation values and sample size of skull, dental, dentary and external body characters of each locality are presented in Table 2.

Multiple regression

Multiple regression of skull, dental, dentary and external body characters on sex, age and locality are presented in Table 3.

Sex: All the skull, dental, dentary, external body characters except for foramen magnum length (FML), foramen magnum width (FMW), mesopterygoid fossa width (MFW), least inter orbital breadth (LIB), post orbital breadth (POB), nasal length (NL), snout vent length (SVL) and tail length (TL) showed significant difference.

Age: Only upper canine breadth (C-C), dentary length (DL), upper premolar 2 (P2-P2), anterior nasal spine to nasal length (TH2) characters showed significant relationship at $P \geq 0.001$ level; while relationship was found on upper molar 1 and 3 breadth (M1-M1 and M3-M3), upper premolar 1 breadth (P1-P1) and zygomatic breadth (ZB) characters at $0.001 \geq P \geq 0.01$ level; and the remaining characters of foramen magnum width (FMW), foramen nasal width (FNW), greatest skull length (GSL), upper molar 2 breadth (M2-M2), ramus coronoid process (PCR), ramus condylar process (PCP) showed significant relationship at $0.01 \geq P \geq 0.05$.

Locality: Only snout vent length (SVL) did not show any significant relationship ($P > 0.05$).

Interaction: Except for sex and age interaction of ramus condylar process (PCP) and location-age-sex interaction of bulla length (BL), all interactions of sex-age, sex-location, age-location and sex-age-location did not show any significant relationship.

Table 3. Multiple regressions on *Trachypithecus auratus* and *T. cristatus*, sex, location and age based on skull and external characters.

VAR	Main Factor			Interaction			
	Sex	Age	Location	Loc-Sex	Loc-Age	Sex Age	Loc-Age-Sec
BL	16.56 ***	1.32	2.28 *	1.30	1.51	1.13	1.91 *
C-C	92.66 ***	66 ***	3.47 ***	1.04	0.61	0.01	0.80
CH	6.07 *	0.55	3.59 ***	1.38	1.89	2.05	1.32
CM3	37.50 ***	0.75	10.40 ***	0.90	1.22	0.02	1.27
CW	26.83 ***	3.26	4.79 ***	0.44	0.54	0.19	0.54
DL	38.66 ***	7.39 ***	6.21 ***	0.61	1.15	0.11	0.45
FML	2.54	0.95	4.72 ***	1.00	0.70	0.25	1.32
FMW	0.50	3.35 *	2.56 **	1.51	0.58	0.35	1.36
FNL	29.16 ***	1.14	3.42 ***	0.86	1.07	4.01	1.16
FNW	26.63 ***	4.54 *	2.34 **	1.10	0.55	0.09	0.81
GSL	41.23 ***	3.34 *	5.58 ***	0.32	0.78	0.25	0.48
IOH	18.94 ***	2.83	2.76 **	1.08	0.36	2.91	1.02
LIB	1.60	1.85	2.79 **	0.59	0.92	0.25	0.85
M1-M1	9.87 **	5.54 **	6.49 ***	1.12	0.62	0.65	0.71
M2-M2	4.16 *	3.89 *	7.02 ***	0.57	0.73	0.45	0.85
M3-M3	1.71	6.30 **	4.66 ***	0.55	0.50	0.07	0.71
MB	32.10 ***	2.70	2.70 **	0.39	1.03	0.04	0.66
MFW	3.01	2.93	2.82 **	1.46	1.51	1.75	1.67
NL	3.70	2.08	2.46 **	0.72	0.49	0.12	0.70
OW	19.24 ***	0.43	3.15 ***	0.46	0.80	0.05	0.83
P3-P3	27.00 ***	5.44 **	6.19 ***	0.57	0.64	0.21	0.60
P4-P4	17.71 ***	8.43 ***	8.78 ***	0.81	0.58	0.13	0.84
PCP	13.26 ***	4.95 *	2.67 **	1.82	1.66	4.47*	1.42
PCR	5.42 *	4.53 *	4.83 ***	0.99	1.34	1.37	0.93
PL	37.19 ***	2.42	3.65 ***	0.30	0.36	0.08	0.33
POB	3.39	0.53	2.41 ***	0.83	0.35	0.58	0.75
SVL	0.04	2.27	2.17	0.54	0.69	0.35	0.92
TH2	16.62 **	7.25 ***	3.02 ***	1.37	1.60	4.08	0.78
TL	4.22	1.13	4.22 **	1.04	1.90	0.60	0.83
ZB	37.55 ***	6.22 **	5.49 ***	0.43	0.61	0.12	0.74

Remarks : F values are presented for the basic effects and their significant level are *,0.05 > P > 0.01; ** 0.01 > P > 0.001 and *** P < 0.001

The analysis showed that the majority of skull and external body characters vary between sexes but few characters vary with age. Consequently, the discriminant analysis needs to be scaled out the effects of sex and age for characters showing significant.

Canonical variate analyses: Canonical variate (discriminant) analysis (DFA) for 28 skull dental and dentary characters were performed and primarily was based on locality except Serasan-Natuna islands due to small sample size (n=2). After reducing sexual dimorphism and age effects by scaling out the effects of sex and age for characters showing significant, both sex and age groups were combined. However this analysis was carried out only after deleting two skull characters shown in the multiple regression analysis which is significant in the relationship between sex, age or location (BL and PCP). The number of characters used was reduced to three in order to reduce the effect of overfitting data (Kitchener and Maryanto, 1995). These three characters were selected to minimize the value of Wilks's lambda. The three characters (canine to molar 3 mandible, canine breadth, and mastoid breadth) provided similar cluster values in discriminant function space as it had been done in the full set of 28 skull, dental and dentary characters. Consequently, all the coeficient function extracted from the DFA were statisticaly significant. Function 1, 2 and 3 accounted for 76.52%, 19.18% and 4.30% of variation between populations respectively (Table 4).

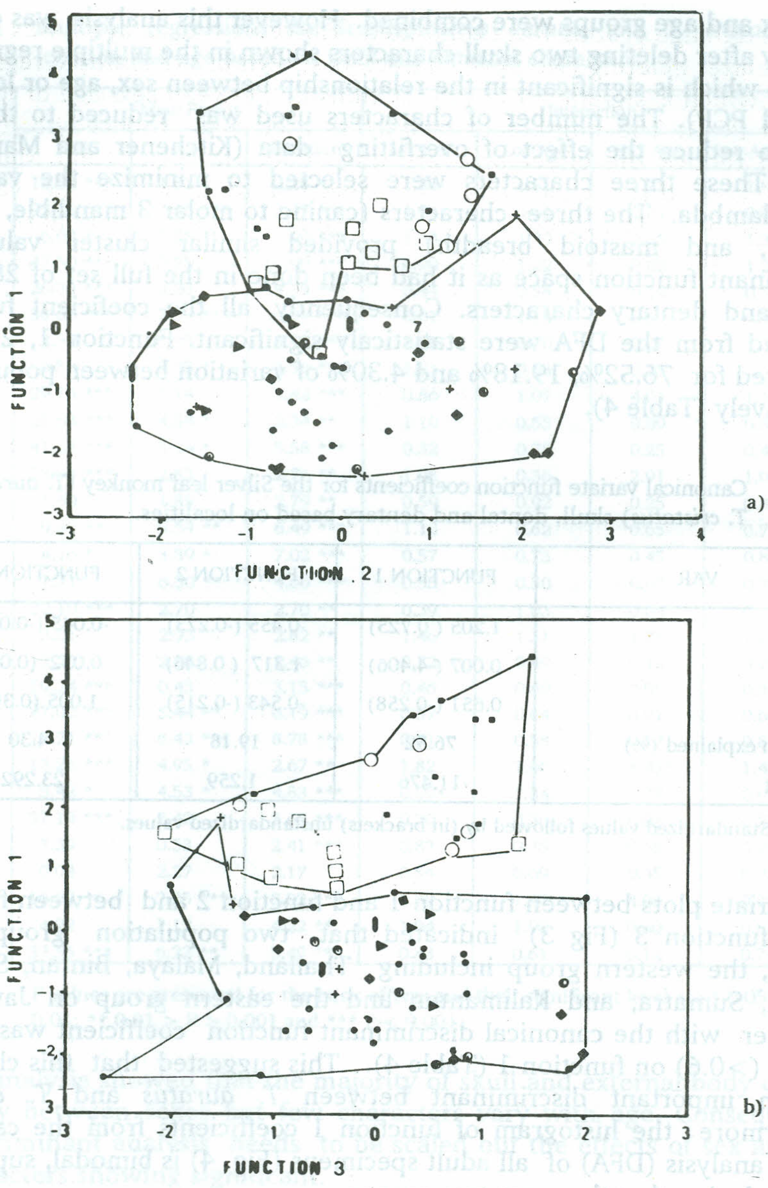
Table 4. Canonical variate function coefficients for the Silver leaf monkey (*T. auratus* and *T. cristatus*) skull, dental and dentary based on localities.

VAR	FUNCTION 1	FUNCTION 2	FUNCTION 3
CM3	1.205 (0.725)	-0.455 (-0.273)	-0.045 (-0.027)
C-C	0.007 (4.406)	1.317 (0.846)	0.032 (0.021)
MB	0.651 (-0.258)	-0.543 (-0.215)	1.005 (0.398)
Variation explained (%)	76.52	19.18	4.30
Constant	-11.476	1.259	-23.292

Remark : Standardized values followed by (in brackets) unstandardized values.

Bivariate plots between function 1 and function 2 and between function 1 and function 3 (Fig 3) indicated that two population groups were formed, the western group including Thailand, Malaya, Bintan, Serasan, Natuna, Sumatra, and Kalimantan and the eastern group on Java. The character with the canonical discriminant function coefficient was loaded heavily (>0.6) on function 1 (Table 4). This suggested that this character was an important discriminant between *T. auratus* and *T. cristatus* Furthermore the histogram of function 1 coefficients from the canonical variate analysis (DFA) of all adult specimens (Fig 4) is bimodal, supporting the conclusion that there are two groups.

The analysis of skull, dental and dentary characters from Java group (Eastern group) by plot function 1 coefficients from canonical variate analysis (DFA) vary with longitude showing that the Java population has a clinal variation. These characters showed increase in size from West Java to East Java with Central Java as an intermediate (Fig 5).



Remarks : West Java (□) Central Java (○), East Java (■), Sumatra (●), Kalimantan (◆), Natuna (I), Bintan (+), Malaya (O) and Thailand (▶).

Figure 3. Canonical variate analysis plot of function 1 and 2 (a) and 1 and 3 (b) for the *Trachypithecus* species, grouped by localities.

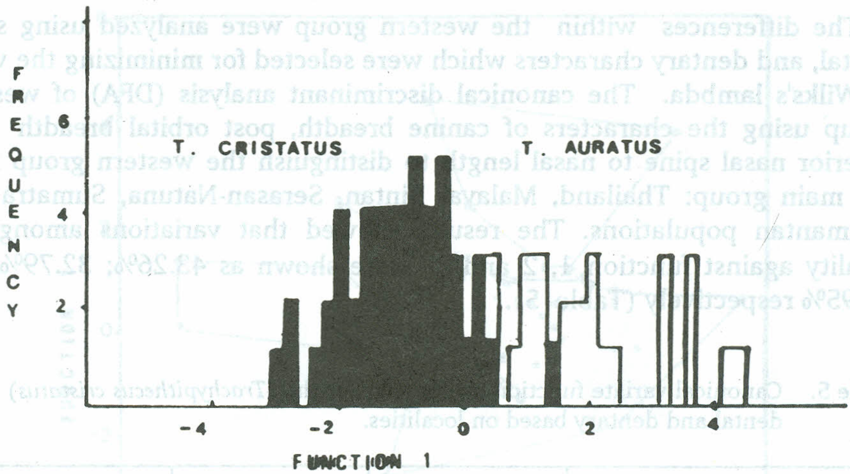
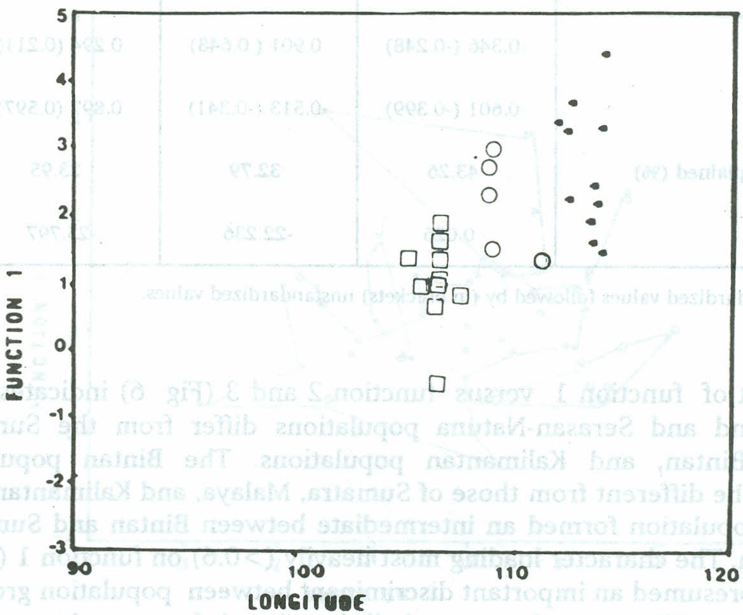


Figure 4. Histogram frequency and coefficient function 1 of *T. auratus* and *T. cristatus*.



Remarks : West Java (□) Central Java(○), East Java (■).

Figure 5. Bivariate plot of function 1 and longitude for *T. auratus* in Java.

The differences within the western group were analyzed using skull, dental, and dentary characters which were selected for minimizing the value of Wilks's lambda. The canonical discriminant analysis (DFA) of western group using the characters of canine breadth, post orbital breadth and anterior nasal spine to nasal length to distinguish the western group from the main group: Thailand, Malaya, Bintan, Serasan-Natuna, Sumatra and Kalimantan populations. The results showed that variations among the locality against function 1, 2 and 3 were shown as 43.26%; 32.79% and 23.95% respectively (Table 5).

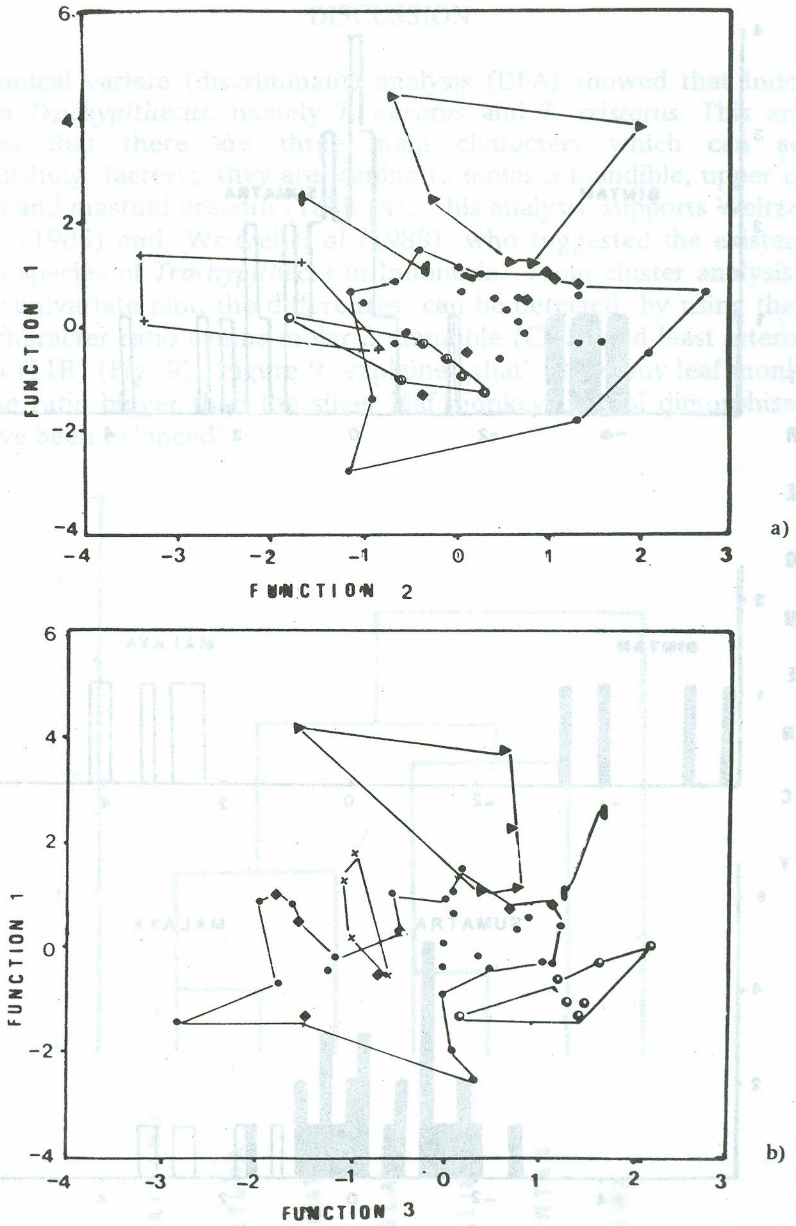
Table 5. Canonical variate function coefficients for the (*Trachypithecus cristatus*) skull, dental and dentary based on localities.

VAR	FUNCTION 1	FUNCTION 2	FUNCTION 3
C-C	1.169 (0.823)	0.274 (0.193)	0.066 (0.046)
POB	-0.346 (-0.248)	0.901 (0.648)	0.294 (0.211)
TH2	-0.601 (-0.399)	-0.513 (-0.341)	0.897 (0.597)
Variation explained (%)	43.26	32.79	23.95
Constant	- 0.026	-22.236	-25.797

Remark : Standardized values followed by (in brackets) unstandardized values.

The plot of function 1 versus function 2 and 3 (Fig 6) indicates that the Thailand and Serasan-Natuna populations differ from the Sumatra, Malayan, Bintan, and Kalimantan populations. The Bintan population appears to be different from those of Sumatra, Malaya, and Kalimantan. The Malayan population formed an intermediate between Bintan and Sumatra-Kalimantan. The character loading most heavily (>0.6) on function 1 (Table 5) and is presumed an important discriminant between population groups.

The shape differences between skull dental and dentary characters of Bintan versus Sumatra and Malaya or Sumatra, Kalimantan versus Malayan populations are shown in the histogram of coefficient function 1 from canonical variate analysis (DFA) of male and female (Fig 7).



Remarks : Sumatra (●), Kalimantan (◆), Natuna (I), Bintan (+), Malaya (O) and Thailand (▶).

Figure 6. Canonical variate analyses plot of functions 1 and 2 (a) and functions 1 and 3 (b) for *T. cristatus*, grouped by localities.

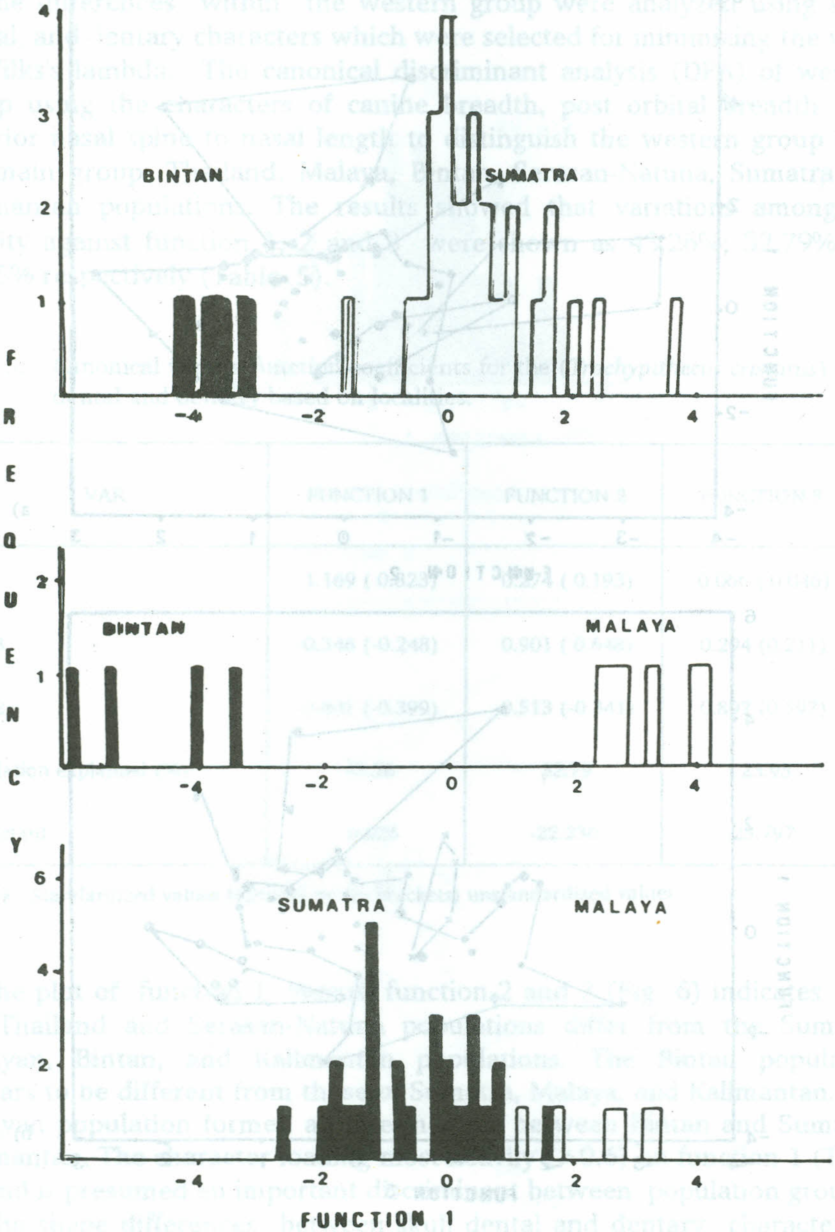


Figure 7. Histogram frequency and coefficient function 1 of skull, dental and dentary between Bintan versus Sumatra and Malaya, and Sumatra versus Malaya.

DISCUSSION

Canonical variate (discriminant) analysis (DFA) showed that Indonesia has two *Trachypithecus*, namely *T. auratus* and *T. cristatus*. This analysis indicates that there are three main characters which can act as distinguishing factors; they are canine to molar 3 mandible, upper canine breadth and mastoid breadth (Table 4). This analysis supports Weitzel and Groves (1985) and Weitzel *et al* (1988) who suggested the existence of the two species of *Trachypithecus* in Indonesia. From cluster analysis (Fig 8) and univariate plot, the differences can be detected by using the ratio of the character ratio canine-molar 3 mandible (CM3) and least interorbital breadth (L1B) (Fig 9). Figure 9 explained that the ebony leaf monkey to have the ratio bigger than the silver leaf monkey (sexual dimorphism and age, have been balanced).

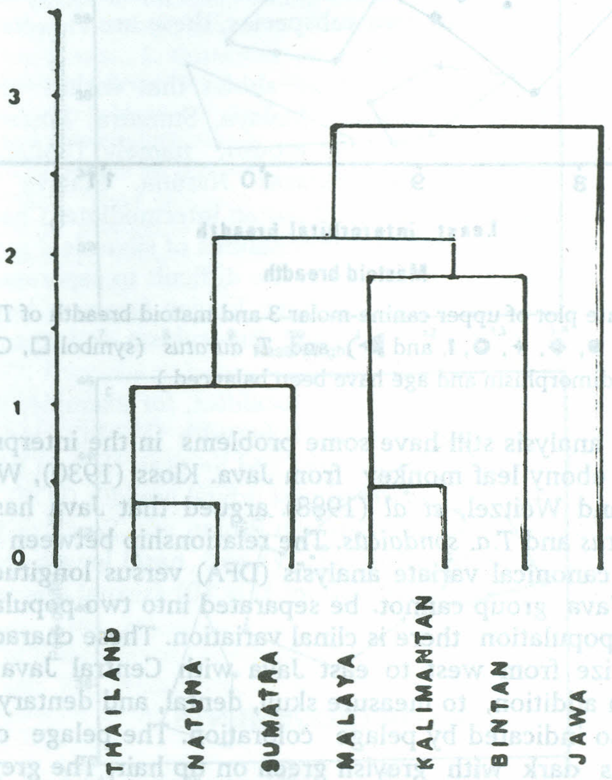


Figure 8. Plot of cluster analysis of *T. auratus* and *T. cristatus* grouped by localities.

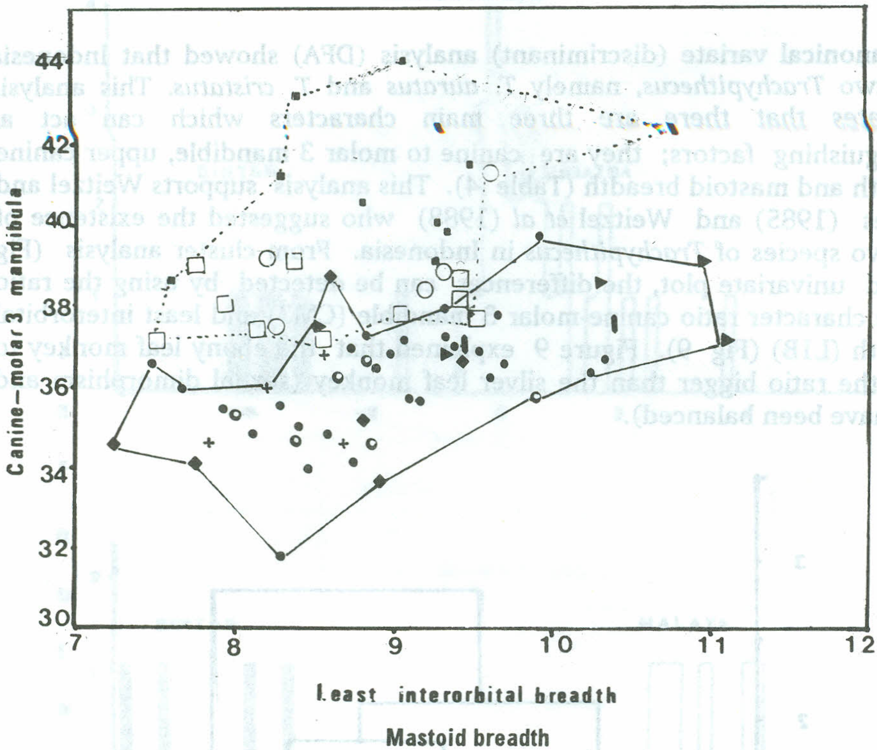


Figure 9. Univariate plot of upper canine-molar 3 and matoid breadth of *T. cristatus* (symbol ●, ◆, +, **O**, **I**, and ▶) and *T. auratus* (symbol □, O and ■). (sexual dimorphism and age have been balanced)

However, this analysis still have some problems in the interpretation of the status of the ebony leaf monkey from Java. Kloss (1930), Weitzel and Groves (1985) and Weitzel, *et al* (1988) argued that Java has two sub species, *T.a auratus* and *T.a. sondaicus*. The relationship between coefficient function 1 from canonical variate analysis (DFA) versus longitude (Fig 5) shows that the Java group cannot be separated into two populations, but within the Java population there is clinal variation. These characters show an increase in size from west to east Java with Central Java being an intermediate. In addition, to measure skull, dental, and dentary the cline variations are also indicated by pelage coloration. The pelage of the East Java population is dark with greyish green on tip hair. The greyish green is dominant on nape but the abdominal area is dark brown in color. The presence of reddish brown in some of the East Java specimens posibly is erythrism. In contrary to West Java, the color pattern of pelage on back

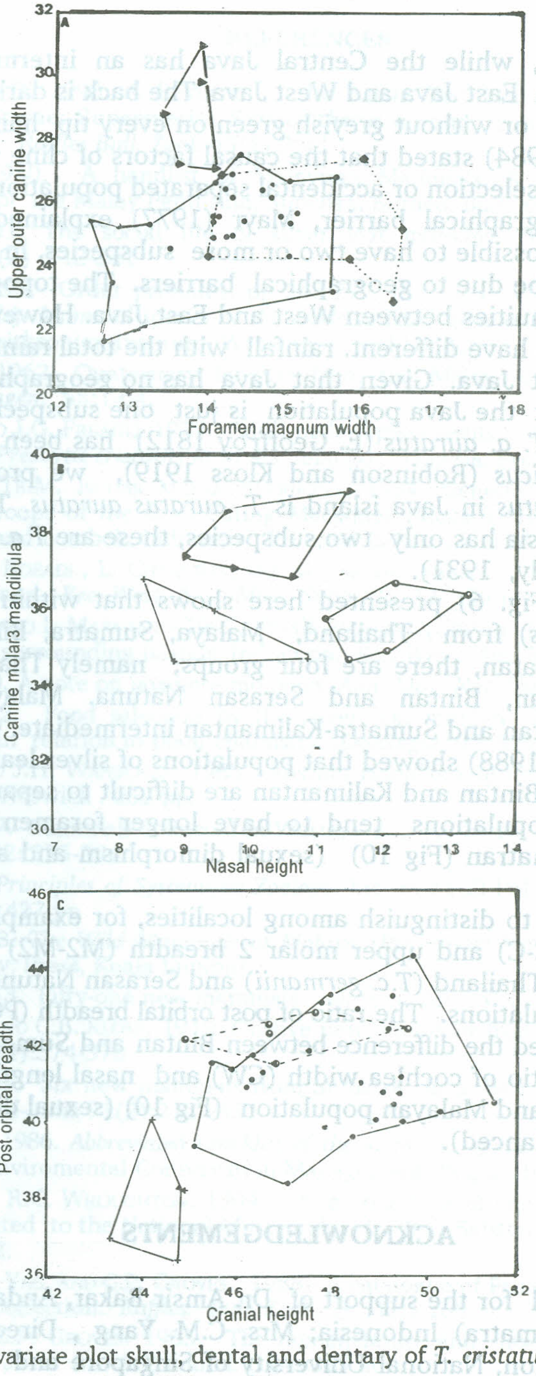


Figure 10. Univariate plot skull, dental and dentary of *T. cristatus* (sexual dimorphism and age have been balanced).

and nape is dark, while the Central Java has an intermediate pelage coloration between East Java and West Java. The back is dark and the nape is dark with a few or without greyish green on every tip hair in the nape. Kawamoto *et al* (1984) stated that the causal factors of cline variation may include migration, selection or accidental separated populations.

Without a geographical barrier, Mayr (1977) explained that in one location it is not possible to have two or more subspecies. In Java this cline variation can not be due to geographical barriers. The topography of Java shows no discontinuities between West and East Java. However, West and East Java climates have different. rainfall with the total rainfall increasing from East to West Java. Given that Java has no geographical barrier, it is more likely that the Java population is just one subspecies. Based on priority law that *T. a. auratus* (E. Geoffroy 1812) has been named earlier than *T. a. sondaicus* (Robinson and Kloss 1919), we propose that the subspecies *T. auratus* in Java island is *T. auratus auratus*. Therefore, *T. auratus* in Indonesia has only two subspecies, these are *T.a. auratus* and *T a. kohlbruggei* (Sody, 1931).

The analysis (Fig. 6) presented here shows that within the western group (*T. cristatus*) from Thailand, Malaya, Sumatra, Bintan, Serasan-Natuna and Kalimatan, there are four groups; namely Thailand, Malaya-Sumatra-Kalimantan, Bintan and Serasan Natuna. Malaya population possibly being Bintan and Sumatra-Kalimantan intermediate. Chasen (1940) and Weitzel *et al* (1988) showed that populations of silver leaf monkey from Sumatra, Malaya, Bintan and Kalimantan are difficult to separate. However, the Kalimantan populations tend to have longer foramen length (FML) than those of Sumatran (Fig 10) (sexual dimorphism and age, have been balanced).

Univariate plot to distinguish among localities, for example, the ratio of canine breadth (C-C) and upper molar 2 breadth (M2-M2) indicated that the population of Thailand (*T.c. germanii*) and Serasan Natuna islands differ from another populations. The ratio of post orbital breadth (POB) and cranial height (CH) revealed the difference between Bintan and Sumatra-Kalimantan population, the ratio of cochlea width (CW) and nasal length (NL) has the difference Bintan and Malayan population (Fig 10) (sexual dimorphism and age, have been balanced).

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