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MORPHOLOGICAL VARIATION AND STATUS OF THE PLANTAIN SQUIRREL *Callosciurus notatus* (Boddaert, 1785) IN INDONESIA

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Abstract

The study of morphological variation of the plantain squirrel Callosciurus notatus *was done based on MZB (Museum Zoologicum Bogoriense) collections. A total of 160 adult specimens from Sumatra, Bangka, Serutu, Siantan-Anamba, Kalimantan, Jawa, Madura, Bali and Selayar Islands. Indonesia were examined. Thirty four skulls, dental and dentary characters were measured. Univariate and multivariate statistical analyses were applied to asses morphological variation.*

*The results show that the population of plantain squirrel from Sumatra, Kalimantan and Jawa overlaps in discriminant function space indicating low variation in skull, dentary and dental size. The Maduran was suggested as an intermediate form between Kalimantan and Jawa; Bangka, Belitung, Batam cluster together with Sumatra; Natuna with Jawa; Serutu with Kalimantan; and Siantan appears to be between Sumatra, Kalimantan and Jawa. There are two subspecies in Sumatera (*C. n. vittatus *and* C. n. tapanulius*) and one in Jawa (*C. notatus notatus*) and Kalimantan (*C. n.dulitensis*). The colour differences detected between populations within an island of Sumatra is not sufficient to justify that they subspecifically distinct within an island, except for the Tapanuli populations.*

Keyword: Squirrel, *Callosciurus notatus*, Morphology, Indonesia.

Introduction

The plantain squirrel *Callosciurus notatus* (Boddaert, 1785) is a medium sized member of the subfamily Sciurinae. It is widely distributed from Thailand through Malaya, Sumatra, Kalimantan, Jawa, Bali, Lombok, Selayar and surrounding islands. In Indonesia hitherto, 49 subspecies *Callosciurus notatus* have been recognized (Boddaert, 1785; van Strien, 1986; Corbet and Hill, 1992; Hofmann *et al.*, 1993).

The number of described subspecies leads to some confusion, especially when more than one subspecies are reported from a small island. It is a likely that in such circumstances each subspecies should be recognized as a species (Mayr, 1977). For example in Jawa and Madura there are six subspecies of *C. notatus*. The Madura population is *C. n. madurae* (Thomas, 1910) and the Jawa population has five subspecies *i.e. C. n. notatus* (Boddaert, 1785), West Jawa; *C. n. balstoni* (Robinson and Wroughton, 1911), south of Cilacap (Central Jawa); *C. n. tamansari* (Kloss, 1921), East Jawa; *C. n. van heurni* (Sody, 1929), Garut (West Jawa); *C. n. verbeeki* (Sody, 1929), northern Central Jawa from Rembang to Bojonegoro (East Jawa); and another possible subspecies is distributed in the southern part of West Jawa (Sody, 1949).

A similar situation occurred in Kalimantan which has three subspecies; *C. n. conipus* (Lyon, 1911), South East Kalimantan; *C. n. dilutus* (Miller, 1913), East and North Kalimantan; and *C. n. dulitensis* (Bonhote, 1901), West Kalimantan; and another subspecies indet in Perbuwah (Sody, 1949).

Sumatra has six subspecies: *C. n. kalianda* (Sody, 1949), South Sumatra; *C. n. nicotianae* (Sody, 1936), North and East Sumatra; *C. n. peninsularis* (Miller, 1903), South-East Sumatra; *C. n. albescens* (Bonhote, 1901), North Sumatra; *C. n. vittatus* (Raffles, 1822), Bengkulu, Dempo Mountain, and West Lampung; and *C. n. tapanulius* (Lyon, 1907), North-West Sumatra.

There has been a conjecture concerning with the validity of some of these subspecies. For example in Jawa, Chasen (1940) considered *C. n. notatus, C. n. balstoni* and *C. n. vanheurni* are synonymous, while Dammerman (1931) and Chasen (1940) stated that *C. n. verbeeki* synonym of *madurae*. However, Hill (1960) argued that *verbeeki* was intermediate between *madurae* and *tamansari*, and that *vanheurni* was intermediate between *balstoni* and *notatus*.

Other subspecies of *Callosciurus notatus* on small Indonesian islands that also being examined in this study are *C. n. stresemanni* (Thomas, 1913), Bali; *C. n. microtis* (Jentink, 1879), Selayar Island; *C. n. anambensis* (Miller, 1900), Siantan Is., Anamba Islands *C. n. billitonus* (Lyon, 1906), Belitung Island; *C. n. serutus* (Miller, 1906), Serutu Island; and *C. n. tedongus* (Lyon, 1906), Bangka Island.

In this study we examine the taxonomic status of some of the subspecies from Sumatra, Kalimantan and Jawa and from several small islands in Indonesia based on statistical analysis of the measurements of skull, dentary and dental characters.

Materials and Methods

A total of 160 adult specimens from Sumatra, Bangka, Serutu, Siantan-Anamba, Kalimantan, Jawa, Madura, Bali and Selayar islands in Indonesia were used in this study (Figure 1). Details of specimens examined are listed in Appendix 1.

Thirty three skull, dental and dentary characters were measured and recorded to two decimal places using vernier calipers. Age classes were judged from the molar wear pattern and the extent of the basioccipital and basisphenoid/presphenoid sutures. The terminology used in measurements of the characters are as follows: BH, bulla height; BL, bulla length; BB, bulla breadth; BW, Braincase width; DL, lower dentary length; GSL, greatest skull length; IFB, Incisive foramina breadth; IFL, Incisive foramina length; LIB, Least interorbital breadth; POB, post orbital breadth check; M1L, first upper molar length; M1M1, distance between first upper molar; M1W, first upper molar width; M2L, second upper molar breadth; M2M2, distance between second upper molar; M2W, second upper molar breadth; M3L, third upper molar breadth; M3M3, distance between third upper molar; M3W, third upper molar width; M4L, fourth upper molar length; M4M4, distance between fourth upper molar; M4W, fourth upper molar width; MB, mastoid breadth; MSF, mesopterygoid fossa breadth; NB, nasal breadth; NL, nasal length; P1L, first upper premolar length; P1P1, distance between first upper premolar; P1W, first upper premolar width; PL, palatal length; RAP1, distance from base of angular process to coranoid process; RAP2, distance from base of angular process to condylar process; TRL, upper tooth row length; ZB, zygomatic breadth. The external character were not examined because all specimens were prepared as scientific 'cabinet skin', that could not be measured accurately.

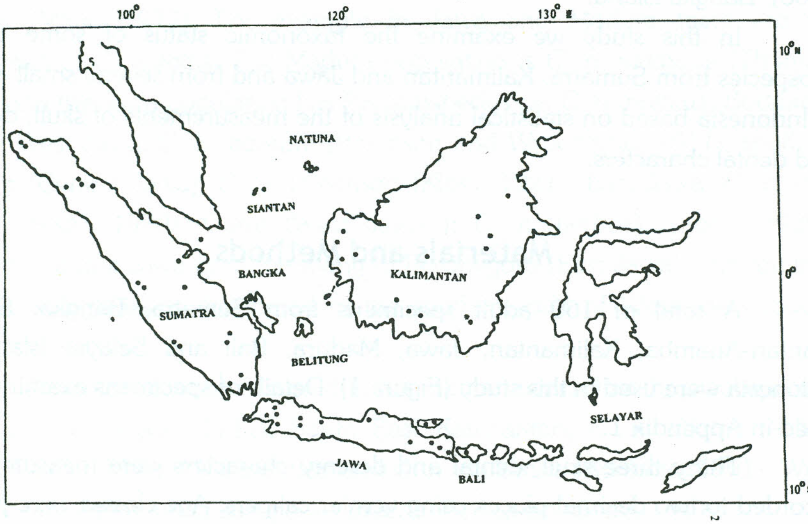

Figure 1. Locality of the plantain squirrel (*Callociurus notatus*) specimens examined in this study.

Specimens included in the statistical analysis were checked for the effect of sex and island, as well as the interaction between sex and island. First, canonical variate (discriminant function) analysis (DFA) was run for all characters (22) that showed no significant effect of sex and no two way interaction between sex and island. The DFA was then run again used a reduced set of 3 - 8 characters that maximize F values (minimize Wilks' lambda values). The reduced set of characters produced very similar discriminant function plot to those using the complete characters. Consequently, we present only the analysis of the reduced set characters.

Results and Discussion

Univariate analysis

Summary of skull, dentary and dental measurements are shown in Table 1. From this table it is clear that almost all characters (except, BH, IFL, M1W, M2W, P1L, P1W in the male) for the Tapanuli specimens are longer than those from Sumatra and other islands. This table also shows that several females skull characters of Tapanuli specimens (*e.g.* BH, BW, DL) are longer or wider than those of the males.

Tabel 1. Measurements in mm, for skull, dental and dentary of adult *Callociurus nottatus* from Sumatra, Tapanuli, Bangka, Belitung, Batam, Jawa, Bali, Siantan, Natuna, Kalimantan, Serutu, Selayar (mean ± sd). For explanation of character codes see material and methods section.

Var	SUMATRA		TAPANULI		KALIMANTAN		SERUTU
	Male	Female	Male	Female	male	Female	male
BB	6.95±0.46	6.98±0.54	8.04±0.73	8.23±0.38	7.22±0.39	7.22±0.34.	6.31
BH	8.96±0.44	8.89±0.42	8.52±0.21	9.52±0.21	9.02±0.38	8.88±0.42	9.29
BL	9.71±0.45	9.62±0.38	10.06±0.16	10.42±0.42	9.92±0.30	9.74±0.44	10.04
BW	21.61±0.68	21.15±0.64	22.07±0.14	22.33±0.35	21.53±0.40	21.42±0.57	21.15
DL	29.47±0.84	29.69±0.93	31.27±1.19	31.81±0.06	30.07±0.71	30.15±0.75	29.46
GSL	48.70±1.13	48.44±0.91	51.70	53.03±0.25	49.24±0.99	49.67±1.10	49.24
IFB	2.05±0.25	2.11±0.21	2.09±0.43	2.47±0.03	2.05±0.20	2.09±0.21	1.93
IFL	3.21±0.46	3.24±0.32	3.06±0.05	3.50±0.53	3.03±0.34	3.24±0.42	2.76
LIB	16.87±0.90	16.98±0.77	18.05±1.23	18.05±0.14	17.35±0.57	17.35±0.82	16.54
POB	17.37±0.62	17.25±0.58	18.71±0.85	17.90±0.03	17.68±0.45	17.48±0.54	17.30
M1L	1.89±0.12	1.92±0.15	1.93±0.19	2.09±0.03	1.93±0.09	2.01±0.10	1.90
M1M1	10.29±0.32	10.12±0.35	11.13±0.23	11.26±0.07	10.23±0.27	10.34±0.42	10.01
M1W	2.23±0.14	2.26±0.09	2.22±0.12	2.42±0.12	2.20±0.09	2.27±0.11	2.13
M2L	1.94±0.12	1.94±0.13	2.02±1.11	2.09±0.26	2.04±0.27	2.07±0.31	1.79
M2M2	10.91±0.36	10.82±0.37	11.95±0.53	12.14±0.12	10.92±0.26	11.02±0.35	10.70
M2W	2.49±0.17	2.49±0.11	2.44±0.08	2.69±0.20	2.28±0.29	2.32±0.22	2.24
M3L	2.02±0.12	2.03±0.12	2.11±0.06	2.22±0.21	2.01±0.11	2.06±0.10	1.90
M3M3	11.15±0.38	11.09±0.38	12.08±0.44	12.36±0.26	11.27±0.23	11.35±0.37	10.95
M3W	2.58±0.14	2.56±0.13	2.61±0.17	2.82±0.15	2.57±0.11	2.58±0.13	2.44
M4L	2.19±0.15	2.20±0.11	2.25±0.01	2.26±0.01	2.22±0.12	2.29±0.15	2.17
M4M4	10.42±0.30	10.47±0.37	11.17±0.18	11.46±0.40	10.78±0.23	10.71±0.40	10.63
M4W	2.31±0.13	2.38±0.11	2.33±0.10	2.55±0.03	2.40±0.07	2.38±0.11	2.29
MB	20.97±0.64	20.81±0.70	21.83±0.38	22.56±0.12	21.38±0.48	21.18±0.53	21.17
MSF	3.86±0.26	3.74±0.20	4.10±0.11	4.26±0.16	4.01±0.16	3.9±0.21	3.92
NB	7.01±0.26	7.06±0.42	7.57	7.49±0.33	7.14±0.37	7.30±0.39	7.58
NL	14.32±0.78	14.10±0.68	15.24	15.33±0.44	14.48±0.62	14.48±0.78	14.45
P1L	0.92±0.14	0.94±0.13	0.90±0.09	0.95±0.04	0.84±0.14	0.91±0.14	0.71
P1P1	8.33±0.37	8.21±0.31	8.93±0.14	9.06±0.23	8.30±0.27	8.32±0.43	8.18
PIW	1.02±0.14	1.04±0.10	1.00±0.07	1.15±0.18	0.97±0.11	1.03±0.10	0.89
PL	22.25±0.79	22.30±1.08	22.89±0.12	23.25±0.35	22.35±0.84	22.40±0.60	21.04
RAP1	15.77±0.61	15.55±0.49	16.22±0.11	16.54±0.47	15.80±0.55	16.17±0.64	16.02
RAP2	13.89±0.61	13.75±0.53	14.34±0.65	14.06±0.30	15.01±0.67	14.90±0.81	14.80
TRL	8.92±0.38	9.00±0.39	8.91±0.64	9.52±0.27	9.02±0.31	9.15±0.41	8.57
ZB	28.22±0.76	28.24±0.94	28.84±0.91	30.61±0.32	28.84±0.91	29.06±0.84	28.02

Table 1. Continued

Var	JAWA		BALI		SELAYAR	
	Male	Female	Male	Female	Male	Female
BB	7.19±0.37	7.16±0.61	6.73±0.78	6.89±0.58	7.05	7.03±0.41
BH	8.71±0.39	8.72±0.39	8.10±0.36	8.32±0.17	9.08	8.48±0.53
BL	9.35±0.32	9.39±0.32	8.85±0.03	9.30±0.17	9.18	9.03±0.42
BW	21.62±0.70	21.46±0.70	21.04±0.36	21.02±0.31	21.20	21.28±0.09
DL	30.53±1.03	31.18±0.97	28.96±0.31	29.71±0.97	28.94	28.98±1.31
GSL	49.58±1.24	49.79±1.33	47.01±0.16	47.07±0.72	45.55	47.11±1.04
IFB	1.93±0.21	2.05±0.22	2.05±0.07	2.20±0.17	2.05	1.90±0.19
IFL	2.73±0.26	2.92±0.25	2.63±0.45	2.77±0.26	2.58	3.10±0.04
LIB	16.55±0.63	16.81±0.78	15.79±0.44	15.85±0.66	16.40	16.47±0.50
POB	17.59±0.74	17.20±0.74	16.36±0.20	16.32±0.62	15.92	16.06±0.15
M1L	2.05±0.14	2.06±0.10	2.00±0.11	2.17±0.07	2.14	2.01±0.02
M1M1	10.69±0.48	10.58±0.33	10.81±0.21	10.39±0.37	10.46	9.88±0.18
M1W	2.33±0.14	2.38±0.14	2.25±0.09	2.31±0.17	2.25	2.26±0.05
M2L	2.00±0.12	2.02±0.10	1.95±0.01	1.91±0.10	2.01	1.96±0.08
M2M2	11.35±0.38	11.28±0.39	11.47±0.02	11.04±0.28	11.11	10.71±0.21
M2W	2.60±0.17	2.61±0.14	2.51±0.13	2.49±0.13	2.67	2..52±0.05
M3L	2.14±0.11	2.09±0.10	2.04±0.06	2.06±0.17	2.10	2.12±0.12
M3M3	11.64±0.29	11.59±0.34	11.46±0.45	11.16±0.43	11.32	10.99±0.30
M3W	2.68±0.14	2.69±0.13	2.59±0.14	2.67±0.11	2.76	2.65±0.11
M4L	2.36±0.14	2.31±0.15	2.16±0.16	2.28±0.11	2.30	2.30±0.07
M4M4	11.06±0.34	11.04±0.41	10.50±0.33	10.52±0.33	10.66	10.33±0.35
M4W	2.47±0.13	2.50±0.14	2.34±0.07	2.33±0.04	2.36	2.41±0.05
MB	20.73±0.40	20.66±0.58	20.41±0.46	19.70±0.65	20.92	20.83±0.69
MSF	3.89±0.27	3.97±0.19	3.75±0.06	3.62±0.07	4.06	3.88±0.26
NB	6.89±0.47	7.11±0.38	6.77±0.18	6.80±0.23	7.26	7.27±0.20
NL	14.47±0.70	14.70±0.60	14.35±0.38	14.14±0.30	13.92	14.94±0.42
P1L	0.96±0.15	0.88±0.17	0.78±0.01	0.98±0.06	1.10	1.09±0.02
P1P1	8.53±0.53	8.49±0.32	8.35±0.04	8.20±0.10	8.15	7.97±0.25
PIW	1.03±0.10	0.99±0.09	0.99±0.01	0.83±0.34	1.15	1.15±0.08
PL	22.30±0.70	22.69±0.94	20.48±0.23	21.32±0.39	20.05	20.51±0.66
RAP1	15.86±0.54	16.17±0.74	15.16±0.11	15.58±0.34	15.71	15.95±0.77
RAP2	14.19±0.68	14.27±0.77	13.58±0.38	13.76±0.09	13.70	14.08±0.72
TRL	9.29±0.37	9.19±0.48	8.50±0.16	8.88±0.04	9.10	9.33±0.17
ZB	27.98±0.74	28.44±0.81	27.07±0.24	27.56±0.94	27.73	27.84±0.84

Table 1. Continued

Var	Madura	Siantan	Natuna	Bangka	Batam	Belitung
	Male	Male	Female	Male	Female	Female
BB	7.65±0.20	7.84±0.12	7.28	7.20	7.43	7.28
BH	8.38±0.32	9.07±0.32	8.41	9.01	9.41	9.29
BL	8.91±0.31	9.73±0.40	9.00	9.69	10.22	9.37
BW	20.78±1.81	21.85±0.08	20.61	21.28	22.44	22.39
DL	30.59±0.14	30.71±0.84	29.25	28.75	31.75	30.12
GSL	48.81	49.61±1.65	48.32	47.62	50.27	49.74
IFB	2.07±0.45	2.12±0.06	1.91	1.86	1.85	2.25
IFL	3.00±0.62	3.27±0.17	2.50	2.52	3.33	3.10
LIB	16.67±0.30	17.23±0.33	15.88	17.08	16.97	17.05
POB	17.80±0.58	17.33±0.15	16.17	17.40	18.34	17.68
M1L	1.91±0.37	1.92±0.04	1.57	1.90	1.88	2.08
M1M1	10.27±0.31	10.85±0.12	10.46	10.41	10.05	10.88
M1W	2.24±0.24	2.13	2.16	2.22	2.16	2.34
M2L	2.15±0.75	1.94±0.10	1.82	1.91	1.95	2.14
M2M2	11.12±0.45	11.41±0.33	11.59	11.04	11.05	11.65
M2W	2.51±0.35	2.44±0.22	2.41	2.42	2.32	2.76
M3L	2.04±0.22	2.06±0.04	1.90	2.12	2.07	2.26
M3M3	11.44±0.38	11.42±0.47	11.60	10.95	11.24	11.95
M3W	2.58±0.10	2.62±0.07	2.57	2.41	2.51	3.01
M4L	2.24±0.19	2.21±0.01	2.36	2.13	2.35	2.53
M4M4	10.42±0.53	10.61±0.49	11.20	10.58	10.98	11.18
M4W	2.48±0.35	2.36±0.09	2.52	2.22	2.46	2.69
MB	20.01±0.88	21.65±0.43	20.11	21.02	22.24	21.83
MSF	4.07±0.12	4.01±0.14	3.73	3.85	3.92	3.95
NB	6.89	7.32±0.38	7.16	7.07	7.92	7.56
NL	14.77	14.60±1.10	14.46	14.01	13.74	15.65
P1L	0.91±0.16	0.94±0.04	1.00	0.98	0.79	1.00
P1P1	8.46±0.06	8.69±0.19	8.65	8.71	8.32	8.80
PIW	1.03±0.22	1.03±0.06	1.11	1.07	0.98	1.30
PL	21.80±0.39	23.04±0.68	22.13	21.41	23.49	21.61
RAP1	16.01±0.65	16.70±0.77	15.14	15.46	17.68	15.90
RAP2	14.67±0.08	14.66±0.77	12.76	13.51	14.73	14.69
TRL	8.87±0.39	9.14±0.35	8.99	9.07	8.99	10.06
ZB	27.90±0.15	29.71±1.12	27.24	28.55	29.66	29.48

The effects of sex and island, as well as the interaction between these two factors were examined. The results indicated a number of characters (BW, DL, IFB, POB, M1W, M4L, M4W, TRL, ZB) are significantly ($P < 0.05$) and IFL ($0.05 \geq P \geq 0.01$) influenced by sex. Most characters (25 characters) show significant effect of island except for BB, IFB, M2L, MSF, NL, P1L, P1W, P1P1 (Table 2). While M1L and RAP1 ($P<0.05$) have significant influence from the effect of an interaction between sex and island (Table 2).

Table 2. Multiple regression on sex and locality for skull, dental and dentary. F values are presented for the main effects and their interaction. For explanation of character codes see material and methods section. Probability levels are *, 0.05>P>0.01, **, 0.01>P>0.001 and ***P<0.001

VARIABLE	SEX	LOCATION	INTERACTION
BB	0.01	1.622	1.130
BH	0.465	3.109***	1.020
BL	0.728	6.180***	1.540
BW	4.695*	1.139	1.660
DL	4.220*	4.919***	0.830
GSL	1.269	4.279***	0.470
IFB	5.092*	1.096	1.150
IFL	6.810**	4.737***	1.32
LIB	0.627	3.179***	0.490
POB	5.099*	3.994***	1.360
M1L	3.301	4.893***	1.730*
M1M1	2.034	3.101***	1.480
M1W	6.230*	2.885**	0.790
M2L	0.201	1.270	0.490
M2M2	0.142	2.875**	0.960
M2W	0.665	5.773***	0.380
M3L	0.299	2.182**	0.960
M3M3	0.467	3.279***	0.710
M3W	0.005	2.168*	1.020
M4L	4.390*	2.910**	0.780
M4M4	1.719	6.029***	0.590
M4W	4.728*	3.314***	1.090
MB	0.083	4.748***	1.800
MSF	0.233	1.364	0.700
NB	1.053	2.024*	1.420
NL	0.383	0.758	0.750
P1L	1.743	1.264	1.050
P1P1	3.833	1.432	0.620
P1W	0.133	0.537	1.050
PL	1.551	4.670***	1.098
RAP1	2.248	3.434***	2.130*
RAP2	0.144	7.451***	0.660
TRL	6.018*	2.297*	0.800
ZB	5.760*	3.804***	1.460

Multivariate analysis

1. Variation between islands

Discriminant function analysis (DFA) was carried out for all 22 characters that show no significant effect of sex and two way interaction between sex and island. Because of their small sample size (Batam, 1; Bangka, 1; Belitung, 1; Madura, 2; Siantan, 3; Serutu, 1), these islands were unallocated in the following DFA. Consequently, only five islands were allocated in the analysis; *i.e.* Selayar, Bali, Jawa, Sumatra and Kalimantan.

The DFA was run on a reduced set of 8 selected characters (RAP2, M4M4, BL, M2W, BH, MB, PL and M1M1). This analysis reflects similar configuration in discriminant function space using full set of characters. This DFA based on reduced set of characters produces three significant functions, which combined explained 96% of the variation. Function 1 explained 51.9%; Function 2, 33.7% and Function 3, 10.4%. The characters which have high values (>0.5) on the function 1 were M2W, MB and M1M1 (Table 3).

Table 3. Canonical variate function coefficient for three locality groups: Sumatra, Kalimantan, Jawa, Madura, Bali, Selayar, Batam, Bangka, Belitung, Serasan Natuna, Serutu. Standarized values followed by (in brankets) unstandardised values for eight skull, dental and dentary characters. For codes of characters codes see material and methods section.

Characters	Function 1	Function 2	Function 3
RAP 2	-0.333 (-0.508)	0.786 (1.199)	-0.068 (-0.104)
M4M4	0.243 (0,645)	0.941 (2.504)	0.086 (0.231)
BL	-0.217 (-0,556)	-0.122 (-0.312)	0.182 (0.466)
M2W	0.623 (3.484)	-0.254 (-1.424)	0.056 (0.316)
BH	-0.075 (-0.181)	-0.509 (-1.214)	0.219 (0.525)
MB	-0.721 (-1.166)	-0.115 (-0.186)	-0.299 (-0.485)
PL	0.092 (0.111)	-0.104 (-0.125)	0.957 (1.147)
M1M1	0.564 (1.359)	-0.241 (-0.583)	-0.097 (-0.234)
Variation explained	51.9 %	33.7 %	10.4 %
Constant	6.466	-13.875	-23.877

This DFA indicates that 81% of individual are classified to their correct island. All specimens from Bali and Selayar are correctly classified to their appropriate island. Misclassifications result at specimens from Sumatra being misclassified to Kalimantan (6.7%), Jawa (10%) and Bali (5 %); a number of specimens from Kalimantan are misclassified to Sumatra (8.3%) and Jawa (11.1%); also Jawa specimens are classified incorrectly to Sumatra (7.3%), Bali (7.3%) and Selayar (4.9%). The plot of Functions 1 and 2 indicates that specimens from Sumatra, Kalimantan and Jawa are overlap (Figure 2). Function 1 separates Sumatra and Jawa - Bali, Bali and Selayar, Kalimantan and Jawa-Bali. Function 2 separates betwen Sumatra and Kalimantan, Function 3 separates Selayar from Sumatra Kalimantan, and Jawa. Batam, Bangka and Belitung are clustered with the Sumatra population, Natuna Islands with Jawa and Serutu Island with Kalimantan. Also Figure 2 suggesting that Madura is an intermediate form between Kalimantan and Jawa; and Siantan is a somewhat to be an intermediate between Sumatra, Kalimantan and Jawa.

The morphological differences among populations in Sumatra, Kalimantan and Jawa population are also shown by bivariate plots of M4M4 and M1M1, M2W and BL (Figures 3).

2. Variation within islands

2.1. Sumatra

Bonhote (1901) described new subspecies from Aceh based on coloration and dimensions from skin as *albescens*. Chasen (1940) stated that the specimens from Aceh were readily distinguished by its colour, smaller size and skull differences from *nicotianae* and *tapanulius*. Sody (1949) observed *nicotianae* from North, East Sumatra appeared to be similar with those *tapanulius* from West Sumatra, South Aceh, Kutacani and Tapanuli. However, the previous studies contrast with variation in Sumatra detected in this present study.

Figure 2A.

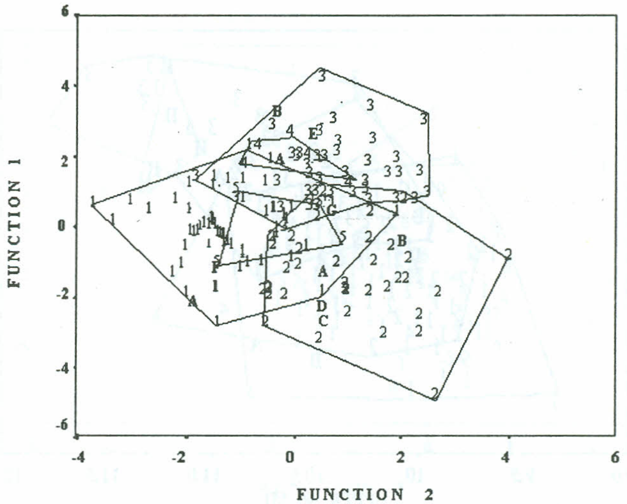

Figure 2B.

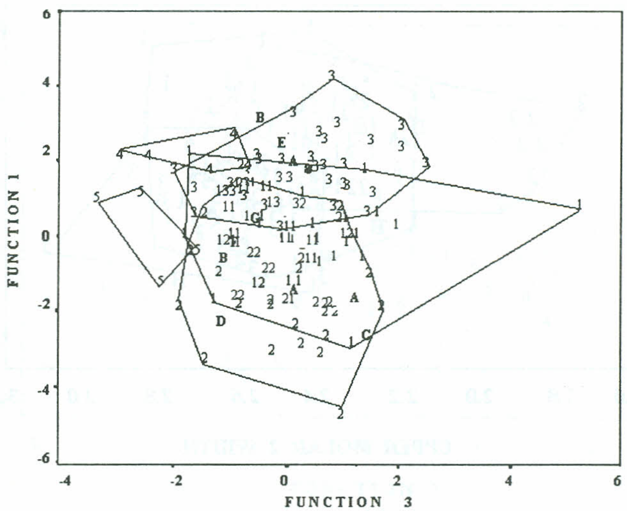

Figure 2. Plot of Functions 1 and 2 (A), 1 and 3 (B) from canonical variate analysis of the Islands group. **1**, Sumatra; **2**, Kalimantan; **3**, Jawa; **4**, Bali; **5**, Selayar; **A**, Siantan; **B**, Madura; **C**, Batam; **D**, Serutu; **E**, Natuna; **F**, Bangka; **G**, Belitung

Figure 3A

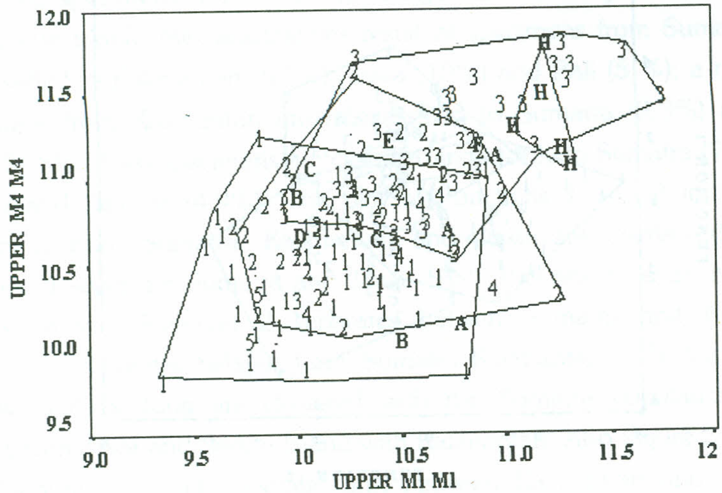

Figure 3B

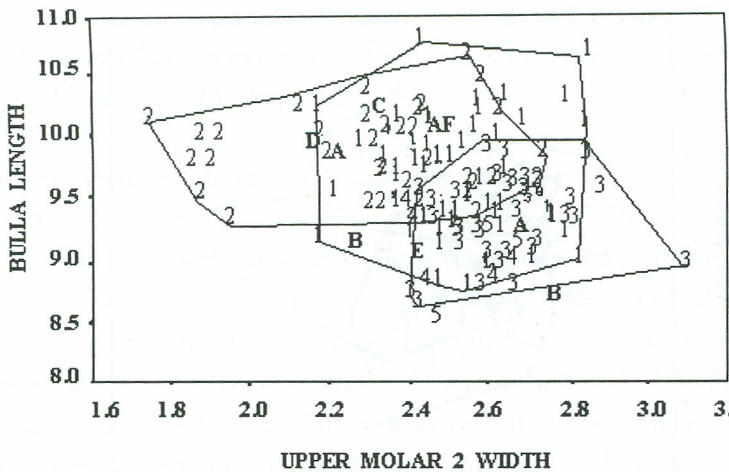

Figure 3. Plot of upper M1 M1 between upper M4 M4 and upper molar 2 between bulla length. **1**, Sumatra (non Tapanuli) ; **2**, Kalimantan; **3**, Jawa; **4**, Bali; **5**, Selayar; **A**, Siantan; **B**, Madura; **C**, Batam; **D**, Serutu; **E**, Natuna; **F**, Bangka; **G**, Belitung and **H**. Tapanuli

Figure 4A

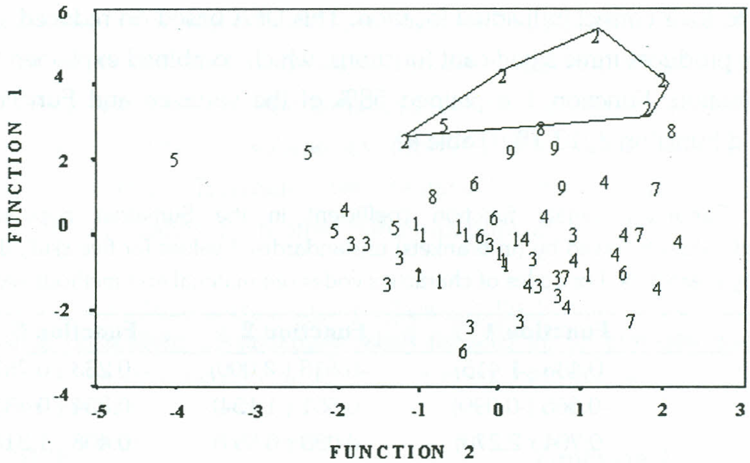

Figure 4B

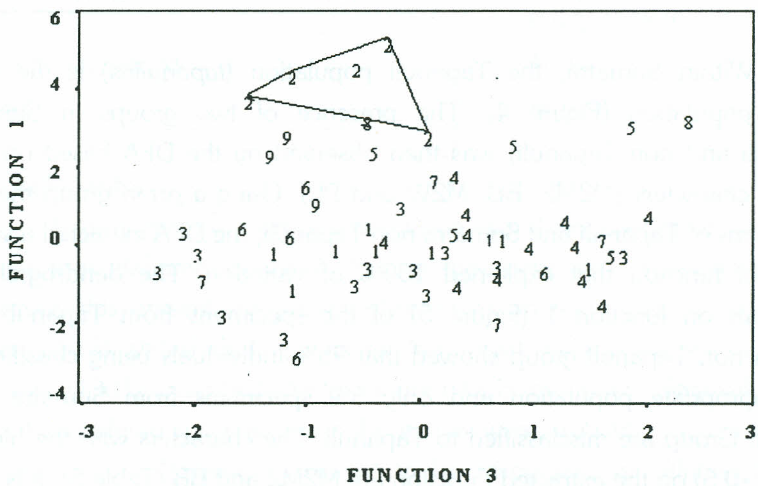

Figure 4. Plot of Function 1 against 2 (A), Function 1 against 3 (B) from canonical variate analysis of Sumatran group. **1**, Lampung; **2** Tapanuli; **3**, Aceh; **4**, Medan; **5**, Tebing Tinggi; **6**, Bengkulu; **7**, Sitiung; **8**, Riau, Batang Hari; **9**, Palembang.

DFA on island of Sumatra based on five selected characters (M2M2, BL, LIB, P1P1, MB) was run. This DFA indicates that 54.72 % of individual are classified to their correct individual location. This DFA based on reduced set of characters produces three significant functions, which combined explained 96% of the variation. Function 1 explained 58% of the variance and Function 2 24.9% and Function 3, 13.1% (Table 4).

Table 4. Canonical variate function coefficient in the Sumatran populations. Standarized values followed by (in brankets) unstandardised values for five skull, dental and dentary characters. For codes of characters codes see material and methods section.

Variable	Function 1	Function 2	Function 3
P1P1	0.436 (1.415)	-0.618 (-2.000)	0.233 (0.757)
LIB	-0.666 (-0.090)	0.851 (1.154)	0.354 (0.481)
BL	0.704 (2.270)	0.030 (0.097)	0.408 (1.314)
M2M2	0.581 (1.545)	0.372 (1.052)	-0.919 (-2.599)
MB	0.166 (0.025)	-0.212 (-0.329)	0.310 (0.482)
Variation expalined	58%	24.3%	13.0%
Constant	-50.701	-8.454	-8.968

Within Sumatra, the Tapanuli population (*tapanulius*) is the most distinct population (Figure 4). The presence of two groups in Sumatra (Tapanuli and non Tapanuli) was then observed by the DFA based on four selected characters (M2M2, BB, M2W and PL). Using *a priori* group the two populations of Tapanuli and Sumatra non Tapanuli, the DFA extracted a single significant function that explained 100% of variation. The dendrogram of individuals on function 1 (Figure 5) of the specimens from Tapanuli and Sumatra non Tapanuli group showed that 95% individuals being classified to their appropriate population and only 5% specimens from Sumatra Non Tapanuli Group are misclassified to Tapanuli. The characters with the highest values (>0.5) on the extracted Function are M2M2 and BB (Table 5). It is clear that the Tapanuli population is distinct from Lampung, South Sumatera, Bengkulu, Sitiung, Batang Hari-Jambi, Riau, Medan and Aceh populations (Figures 4ab and 5). The differences between Tapanuli and the other populations of Sumatra are also apparent from bivariate plot of M2M2 and BB (Figure 6). However, no clear distinction among the rest of Sumatera populations. *C. n. albescens* (North Sumatra) has similar colouration pattern with *C. n. vittatus* (West and South Sumatera), except the buff colour tends to be fulvous, especially on the flank and feet. These colour differences are not considered as distinct subspecies (Sody 1949). While waiting for more specimens from Tapanuli, we tentatively treat Tapanuli population subspecifically distinct from other Sumatran populations.

Table 5. Canonical variate function coefficient in the Sumateran (Non Tapanuli) and Tapanuli populations . Standarized values followed by (in brankets) unstandardised values for four skull, dental and dentary characters. For codes of characters codes see material and methods section.

Variable	**Function 1**
M2M2	0.910 (2.432)
PL	-0.114 (-1.124)
M2W	-0.342 (-2.303)
BB	0.542 (1.063)
Variation explained	100%
Constant	-25.650

2.2 Kalimantan

Examination of variation within an island population of *Callosciurus notatus* from Kalimantan reveals that all specimens are considerable overlap. However, this present study contradicts other previous studies. For example Miller (1913) stated that specimens from East Kalimantan as *dilutus* and Bonhote (1901) described *dulitensis* from Dulit mountain, Sarawak. Chasen (1935) considered specimens from Pontianak were probably also *dilutensis* and specimens from Perbuwah seemed to be recognized as *dilutus*. However, Gydenstolpe (1920) argued that the *dilutus* and *dulitensis* were synonym. Sody (1949) described specimens from Sampit (Central Kalimantan) mainly based on colour and some skull characters as *vinocastaneus*; in fact this is synonim with *dulitensis*. Lyon (1911) described specimens from South Kalimantan as *conipus*.

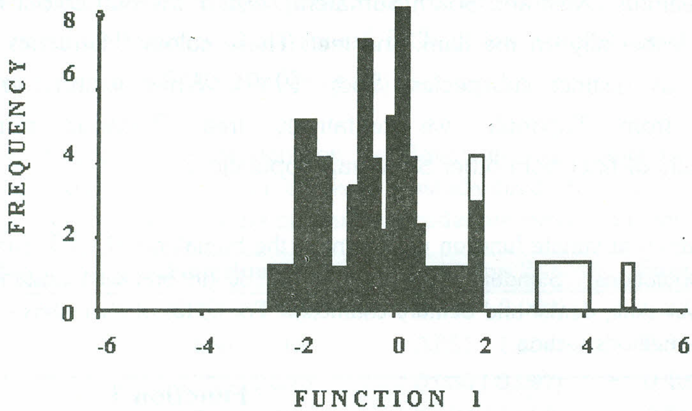

Figure 5. Plot of Functin 1 and frequency from canonical variate analysis of Sumatra non Tapanuli (Black) and Tapanuli (White) groups

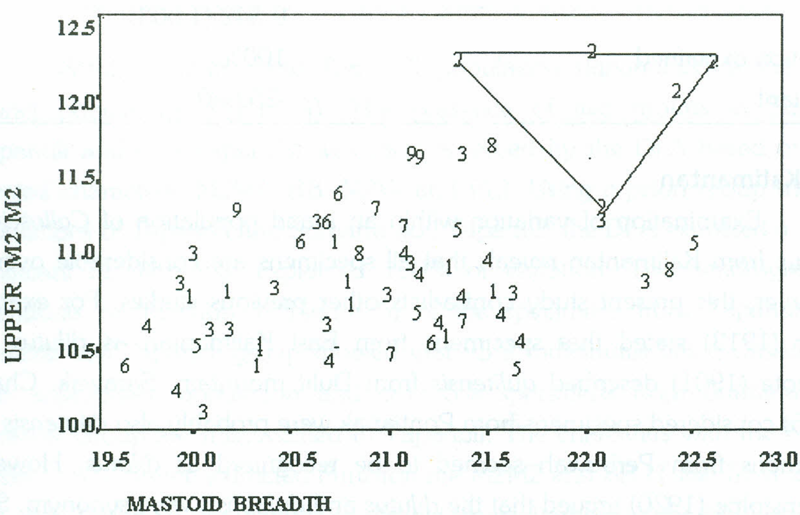

Figure 6. Plot of Mastoid breadth and Upper M2 M2 from The Sumatran island. (2 is Tapanuli and other Sumatra Non Tapanuli).

The DFA for Kalimantan populations was run using three selected characters (MB, M2W, BL). This DFA indicates that 72.73 % of individual are classified to their correct individual of specimens location collected. The DFA also extracted two significant function that explained 100% of variation. Function 1 explained 56.37% of the variance and Function 2, 43.63% (Table 6). Plot of Functions 1 against 2 (Figure 7) shows specimens from West, East, South and Central Kalimantan are clustered together tightly. This indicating that populations in Kalimantan are morphologically similar. We treat that Kalimantan populations of *Callosciurus notatus* as a single subspecies.

Table 6. Canonical variate function coefficient in the Kalimantan populations. Standarized values followed by (in brankets) unstandardised values for three skull, dental and dentary characters. For codes of characters codes see material and methods section.

Characters	Function 1	Function 2
NB	0.395 (1.188)	-1.047(-3.149)
M2W	0.763 (3.210)	0.546 (2.300)
BL	0.470 (1.253)	0.702 (1.851)
Variation explain (%)	56.37	43.63
Constant	-28.249	-0.627

2.3. Jawa

Subspecies in Jawa have been described poorly based on colour and a few skull characters differences (Kloss 1921; Robinson and Wroughton 1911; Sody 1929). Chasen 1940 and Hill 1960 stated *C. n. verbeeki* from Rembang and Bojonegoro (Central and East Jawa) apparently is an intermediate between *madurae* (Madura Island) and *tamansari* from Yang, Besuki, Banyuwangi (East Jawa). In addition, Kloss (1921) referred *tamansari* probably very similar to *Stresemanni* from Bali. Hill (1960) considered *vanheurni* from Garut (West Jawa) is an intermediate between *balstoni* from South Cilacap (Central Jawa) and *notatus* from West Jawa. Referred to the warm color of the underside of Cirebon specimens, Sody (1949) stated that specimens from

Cilacap was similar in measurements with *balstoni* and *vanheurnii*. Dammerman (1931) was able to recognize from the pelage colour and skull characters and justify there were two Jawanese races; one in the West and the other in the East of Jawa. The border of the distribution of these two races was contentious and probably between Cirebon in the west and Cilacap in the east. He also stated all other Jawanese forms as an intergradations or individual variation.

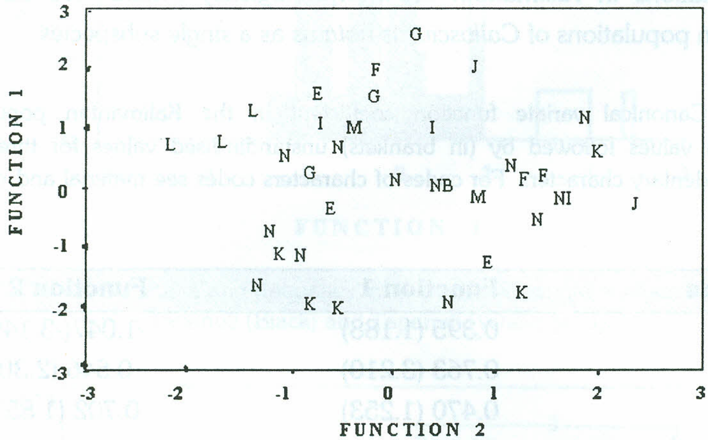

Figure 7. Plot of Functions 1 and 2 from canonical variate analysis of Kalimantan group. **E**, Long petah; **F**, Pontianak; **G**, Perbuah; **H**, Muara Ancalong; **I**, Melawi; **J**, Hantakan South Kalimantan; **K**, Gunung Pari; **L**, Kayan river; **M**, Kota waringin, Sampit

DFA on island of Jawa based on three selected characters (M4M4, PL, P1W) was run. The DFA extracted three significant function that explained 100% of variation, Function 1 explained 85.58% of the variance, Function 2, 14.37% and Function 3, 0.06% (Table 7). Only 83.33% of specimens are classified to their correct populations. Specimens from Jakarta, Bogor, Tangerang, Garut, Cirebon, Kudus, Cilacap, Banyuwangi and Besuki are clustered together (Figures 8a-b). This suggests that little morphological differentiation have occurred between populations in Jawa. This observation is supported by the plot of Function 1 against longitude (Figure 9) indicating there is no morphological variation along the longitude of specimens' locality sites. From these findings, we suggest the Jawanese *Callosciurus notatus* consist of a single subspecies.

Table 7. Canonical variate function coefficient in the Jawa populations. Standarized values followed by (in brankets) unstandardised values for three skull, dental and dentary characters. For codes of characters codes see material and methods section.

Variable	Funtion1	Function2
M4M4	0.728 (3.031)	0.761 (3.167)
PL	0.383 (0.759)	-0.923 (-1.832)
P1W	0.671 (8.574)	0.165 (2.112)
Variation explain (%)	85.58	14.37
Constant	-59.441	4.016

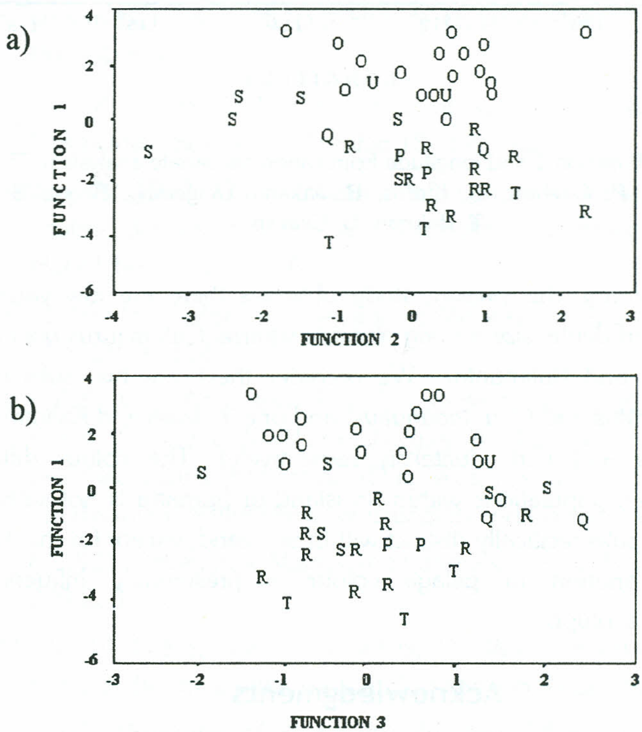

Figure 8. Plot of Function 1 againt 2 (A), Function 1 againt 3 (B) from canonical variate analysis of The Jawan group. **O**, Garut; **P**, Cirebon; **Q**, Kudus, **R**, Jakarta, Tangerang, Bogor; **S**, Besuki; **T**, Baluran; **U**, Cilacap

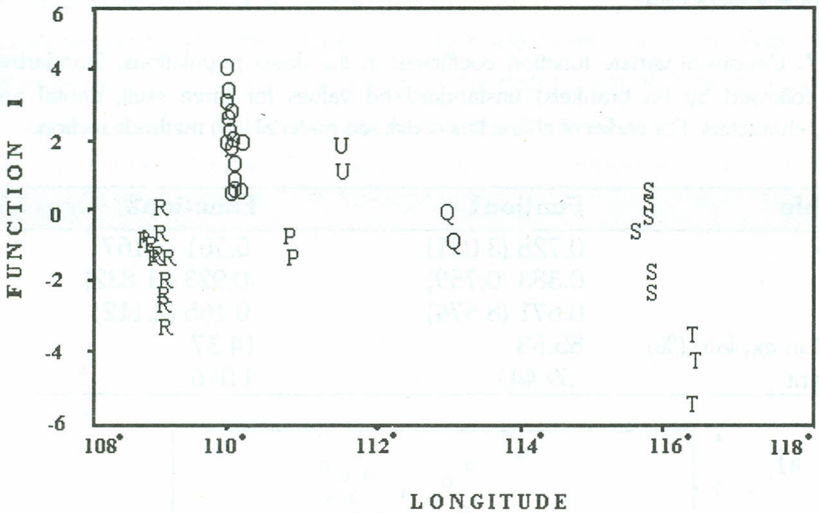

Figure 9. Plot of Function 1 and longitude from canonical variate analysis of The Jawan group. **O**, Garut; **P**, Cirebon; **Q**, Kudus, **R**, Jakarta, Tangerang, Bogor; **S**, Besuki; **T**, Baluran; **U**, Cilacap

In summary, this present study observes there are low variation in skull, dentary and dental size among plantain squirrel *Callosciurus notatus* from Jawa, Sumatra and Kalimantan. We consider there are two subspecies in Sumatra (*C. vittatus* and *C. n. tapanulius*) and one in Jawa and Kalimantan (*C. notatus notatus* and *C.n. dulitensis* respectively). The colour differences detected between populations within an island of Sumatra is not sufficient to justify that they subspecifically distinct within an island, except for the Tapanuli populations. Variation in pelage colour is presumably influenced by environment or ecotype.

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Apendix 1. List of MZB catalog number of specimens examined

Sumatra, Aceh, 3124, 3126, 6039, 6045, 6048 (male), 3125, 3127, 3129, 6040, 6047; South Aceh 13417, 13418 (male), 13416 (female); Medan 1936, 1938, 1940, 1942, 1943 (male), 1932, 1934, 1935, 1937, 1939, 1944, (female); Tebing Tinggi 1946, 1947, 1948, 1949 (male), 1945 (female); Kotacani 6051 (female), Pematang Siantar 6052 (female); Sitiung-West Sumatra 11795, 11796, 11802 (male), 11803 (female); Siak-Riau 8346 (female); Batang Hari-Jambi 13846, 13847 (male); Sanggul Bengkulu 6053, 6060 (male), 6061, 6063, 6064 (female); Palembang , 6073 (male), 6057, 6078 (female); West lampung, 343, 379 (male), 336, 342, 363, 378 (female); Kalianda Lampung, 6066 (male), 6068, 11358 (female); Central Lampung 11351 (male); Tapanuli 1950, 1951, 1952 (male), 1953, 1954 (female). **Kalimantan,** Melawi West Kalimantan, 1028, 1030, 1031 (male); Pontianak 6112, 2895 (male) 2894, 6111 (female); Perbuwah 6122, 6124, 6125, 6127 (female); Hantakan-South Kalimantan 12007 (male), 12010 (female); Kota Waringin 6133 (female); Sampit 6139 (female); Muara Ancalong 1212, 1237 (male), 1213 (female); Marah East Kalimantan 1215, 1234 (male), 1228, 1229, 1231 (female); Long Pedak 1218 (male), 1222, 1224 (female); Gunung Pari East Kalimantan 8170, 8171 (male), 8173, 8175 (female); Tabang East Kalimantan 8176, 8178 (male), 8179 (female); Berau East Kalimantan 8957 (female); Bulungan 6114 (male), 6115, 6116 (female).

Jawa, Tangerang 2320 (male); Bogor 40, 720, 2050, 6091, 15221 (Male), 6081, 15216 ; Jakarta 54 (male), 57 (female); Pelabuhan Ratu 6080 (male); Garut 2108, 2109, 2527, 2528, 2535, 2537, 2538, 2539, 2540, 2541, (male), 2102, 2103, 2531, 2533, 2542 (female); Cianten 3310 (male); Cikajang 6079 (female); Cirebon 1740, 1741 (male); Cilacap1629 (male) Kudus 1623, 1624 (male); Tengger 3619 (female); Besuki 6099, (male), 230, 6097, 6101, 6102 (female); Baluran 231, 232 (female); Banyuwangi 6094 (female). **Madura island,** Sumenep 1625 (male); Pamekasan 1627 (male). **Bali,** Gigit 1984,1988 (female), 1992 (female); Bratan lake 6103 (male), 6104 (female). **Batam island,** 8342 (female). **Bangka island** 552 (male) **Belitung island** 633 (female). **Siantan-Anamba islands** 6141, 6142, 6144 (male) **Sadanau-Natuna islands** 6143 (female).**Serutu island,** 2931 (male). **Selayar island** 6109 (male), 6106, 6107, 6110 (female)