MORPHOMETRIC VARIATION OF GENUS DOBSONIA FROM INDONESIAN PAPUA

(*Variasi Morfometrik* Genus *Dobsonia dari Papua Indonesia*)

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ABSTRAK

Studi morfometrik telah dilakukan dengan mengukur 32 karakter dari 176 spesimen Dobsonia dari Papua. Spesimen-spesimen Dobsonia diwakili oleh enam OTU, yaitu G, B, R, E, SP1, dan SP2. Analisis univariat menghitung seluruh spesimen dewasa yang terdiri dari 171 karakter badan dan sayap dan 176 karakter tengkorak dan gigi pada enam OTU tersebut. Selanjutnya digunakan uji-t dan PCA untuk menghitung G, B, dan R, sedangkan tiga OTU lain (E, SP1 dan SP2) tidak dihitung tetapi ikut diproyeksikan ke dalam scatter plot. Hasil uji-t ($p<0.05$) menunjukkan ada seksual dimorfisme pada D. minor dan D. beauforti. Pemisahan D. magna, D. minor, dan D. beauforti nyata pada karakter badan, sayap, dan gigi berdasarkan PCA. D. emersa terpisah dari spesies lainnya pada karakter badan dan tengkorak. Hasil scatter plot pada SP1 dan SP2 mengelompok dengan D. beauforti pada semua karakter (badan, sayap, tengkorak, dan gigi). Sebanyak 32 karakter yang diukur didapatkan karakter taksonomi yaitu WT, HB, dan TV untuk karakter badan; FA, TIB, dan DIG1P untuk karakter sayap; ONL, POW, PL, dan MH untuk karakter tengkorak; I^2M^2, M^2M^2, WM^1, dan LM^1 untuk karakter gigi. D. minor yang telah ditemukan di Pulau Waigeo tahun 2007 merupakan catatan baru penyebaran spesies ini, sebelumnya hanya tercatat di daratan utama Papua dan Pulau Yapen.

***Kata kunci**: Dobsonia, morfometrik, variasi, penyebaran, Papua*

INTRODUCTION

Dobsonia is a fruit bat group that is characterized by a pair of incisors; short rostrum (often considerably shortened); sub linear premaxilla; second finger without claw; wings attached at spinal line, with back looked bold (Andersen, 1912; Flannery, 1995a, 1995b).

In Papua, morphological characters of *Dobsonia* have been studied based on limited specimens and number of characters (Andersen, 1912; Tate, 1942; Bergmans, 1975; Bergmans & Sarbini, 1985; Flannery, 1995a, 1995b). Andersen (1912) described the size of D. *magna* and *D. minor* based on 23 external characters and 18 skull characters of nine specimens of *D. magna* and two specimens of *D. minor*. Whereas, Flannery (1995b) described seven external characters of nine *D. magna* and seven *D. minor*. Bergmans (1975) proposed *D. beauforti* as a new species based on five external characters and 12 skull characters of ten specimens. *D. emersa* was proposed as a new species by Bergmans & Sarbini (1985), based on two external characters and 19 skulls and dental characters of one specimen.

So far the studies on morphometric variation of *Dobsonia* sp. were based on limited specimen, morphometric characters and using univariate analysis. Present study uses more characters and samples from more localities and using multivariate analysis. This study aims to discover taxonomically

important characters and updates the geographical distribution of *Dobsonia* in Papua.

MATERIALS AND METHODS

Materials

Specimens of *Dobsonia* used in this study are represented in Table 1, and map of the location in Figure 1. Total specimen examined is 176 adult specimens consisting 176 skins and skulls and 171 skins.

Table 1. Specimens Examined

Location	Species	House of Collection		N	Material
		UNIPA	MZB		
Jayapura	*D. magna*		10	10	Skin & skull
	D. minor		14	14	Skin & skull
Kerom	*D. magna*		1	1	Skin & skull
Sarmi	*D. minor*		5	5	Skin & skull
Mamberamo	*D. minor*	18	6	24	Skin & skull
Waropen	*D. minor*		8	8	Skin & skull
Yapen Island	*D. magna*		6	6	Skin & skull
	D. minor		4	4	Skin & skull
Supiori Island	*D. beauforti*	10		10	Skin & skull
	D. emersa	4		4	Skin & skull
Nabire	*D. minor*		2	2	Skin & skull
Bintuni	*D. magna*		6	6	Skin & skull
	D. minor		2	2	Skin & skull
Wasior	*D. magna*		1	1	Skin & skull
Manokwari	*D. magna*	10		10	Skin & skull
Mimika	*D. minor*		4	4	Skin & skull
Wamena	*D. magna*		13	13	Skin & skull
Merauke	*D. minor*		4	4	Skin & skull
Mappi (Idenburg River)	*D. magna*		1	1	Skin & skull
Raja Ampat Islands:					
- Waigeo Island	*D. magna*		2	2	Skin & skull
	D. beauforti		9	9	Skin & skull
- Batanta Island	*D. beauforti*		10	10	Skin & skull
	D. magna		1	1	Skin & skull
- Gag Island	*D. beauforti*		16	16	Skin & skull
	D. sp		3	3	1 Skin & skull
					2 Skull
	D. sp2		6	6	3 Skin & skull
					3 Skull
	Total			176	

UNIPA: Universitas Negeri Papua (The state University of Papua) Manokwari.

MZB: deposited in Museum Zoologicum Bogoriense, Cibinong.

Methods

Dobsonia from Mamberamo, Waropen, Supiori, and Manokwari were collected by using mist nets; data on sex, age and standard measurements were recorded. Specimens were fixed in 10% formalin and preserved in 70% ethanol. They are housed in Museum Zoologicum Bogoriense (MZB) and Laboratory of Biology, The State University of Papua (UNIPA). The specimens were measured in millimeter by using digital caliper with resolution of 0.05 mm, and weight in gram. Specimens in MZB are identified as *D. magna*, *D. minor*, *D. beauforti*, *and D. emersa*. Two species, designated as SP1 and SP2, are not yet described. According to Maryanto (pers.comm) SP1 and SP2 could be new species which closely related to *D. beauforti* in size, but different in shape. Because of incomplete identification, suspected new species, and statistical analysis which treated different taxa into one sample, we used Operational Taxonomic Unit (OTU) as the basis for analysis (Rohlf & Sokal 1962). Therefore, the study used six OTUs (Table 2).

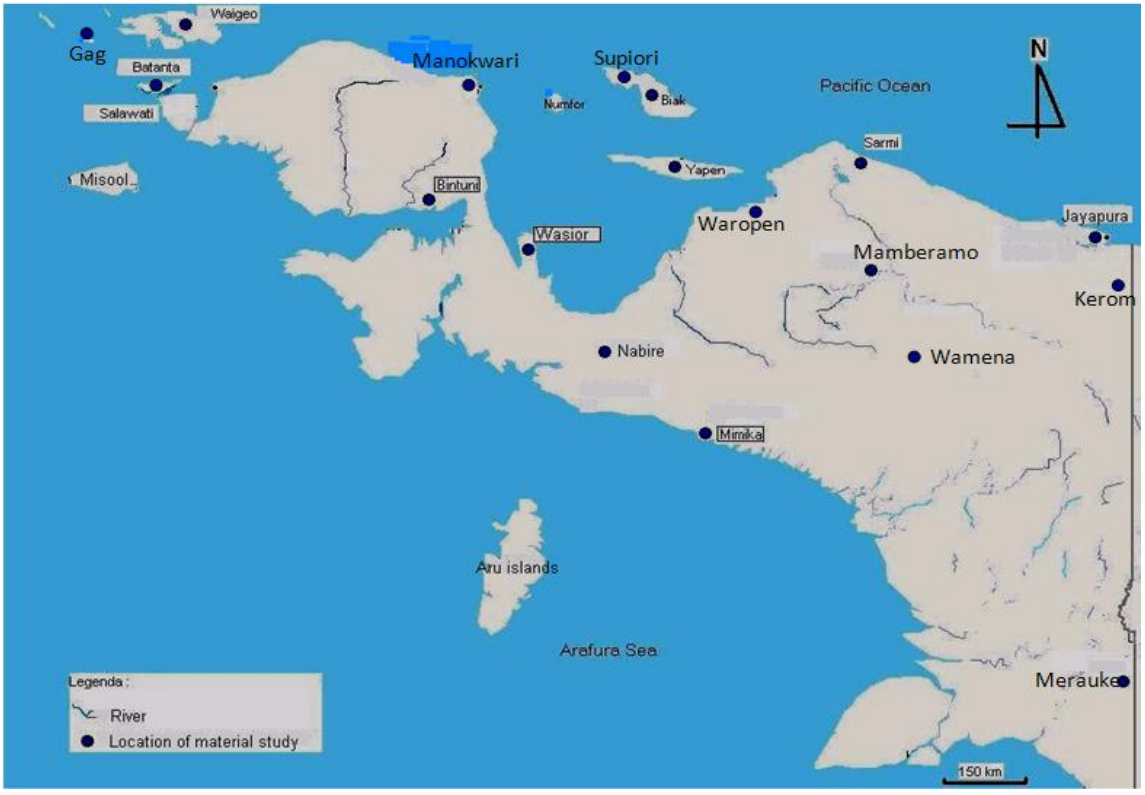

Figure 1. Map of materials studied from Papua

Table 2. Six OTUs and references

Species	References	OTU	Number of adult
D. magna	Flannery 1995a, 1995b	G	51
D. beauforti	Flannery 1995a	B	48
D. minor	Flannery 1995a, 1995b	R	71
D. emersa	Flannery 1995a	E	4
	Maryanto (pers. comm)	S1	3
	Maryanto (pers. comm)	S2	6

Morphometric Characters

The morphometric measurements are the standard ones on the body, wings, skull and teeth (Freeman 1981). There are thirty two characters illustrated in Figure 2. Explanation of figure 2 is given in Table 3.

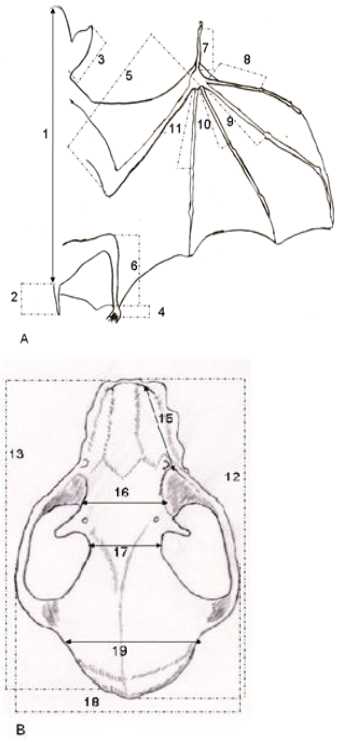

Figure 2. Characters on the body and wing (A), skull (B).

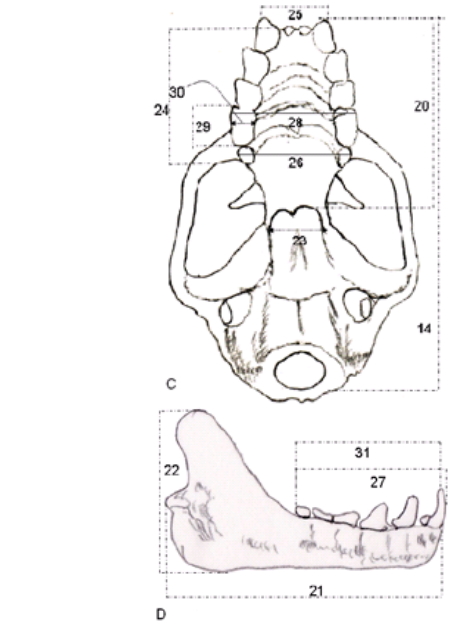

Figure 2b. Characters on the skull (C, D).

Table 3. List of Characters used in the study

No	Characters	Abbreviation	Figure
1	Head and body length	HB	1A
2	Tail vertebrate length	TV	1A
3	Ear length	E	1A
4	Hindfoot length (su)	HF	1A
5	Forearm length	FA	1A
6	Tibia length	TIB	1A
7	Digit1 phalanx length	DIG1P	1A
8	Digit2 metacarpal length	DIG2M	1A
9	Digit3 metacarpal length	DIG3M	1A
10	Digit4 metacarpal length	DIG4M	1A
11	Digit5 metacarpal length	DIG5M	1A
12	Greatest skull length	GSL	1B
13	Condylobasal length	CBL	1B
14	Condylocanine length	CCL	1C
15	Orbit to nasal	ONL	1B
16	Interorbital width	IOW	1B
17	Postorbital width	POW	1B
18	Zygomatic width	ZW	1B
19	Braincase width	BW	1B
20	Palatum length	PL	1C
21	Mandible length	ML	1D
22	Mandible height	MH	1D
23	Mesopterygoid fossa width	MFW	1C
24	Upper toothrow	I^2M^2	1C
25	Outside upper canines width	C^1C^1	1C
26	Outside upper molar2 width	M^2M^2	1C
27	Lower toothrow	I_2M_3	1D
28	Outside upper molar1 width	M^1M^1	1C
29	Upper molar1length	LM^1	1C
30	Upper molar1 width	WM^1	1C
31	Mandible teeth length	C_1M_3	1D
32	Weight	WT	

Data Analysis

Before analysis, non-normality of values was examined by residual analysis. Data processing used R software on logarithm - converted measurement for generalize of scale. Missing data was surrogated by their means. E, SP1, and SP2 did not included in computation because of very few samples, but they were projected post analytically. Univariate analysis is used to describe statistics of characters on G, B, R, E, SP1 and SP2. T test ($p<0.05$) is used to recognize sexual dimorphism on the character of G, B, and R OTUs. Multivariate analysis used principal components analysis (PCA) method (Venables & Ripley 1999; Everrit & Hothorn 2006). The principal component analysis is a multivariate information extraction and ordination technique to reveal clusters of phenetically similar taxa. In analysis PCA, 32 characters were grouped into four group, they are body, wing, skull, and teeth characters.

RESULTS

Univariate Analysis

This study succeeded to measure 171 adult specimens for body and wing characters and 176 adult specimens for skull and teeth characters. Means and sexual dimorphism are found from T test analysis ($p<0.05$) on G is not significant difference, 15% from 32 characters difference on B, and 50% from 32 characters difference on R. Table 4a and 4b demonstrated that HF (su), DIG3M, C^1C^1, $WM^1$and C_1M_3 were sexual dimorphism on B; only one characters (C^1C^1) was sexual dimorphism on G; WT, HB, FA, TIB, DIG1P, DIG2M, DIG3M, DIG4M, DIG5M, GSL, CBL, CCL, ONL, ZW, ML and PL were sexual dimorphism on R.

Univariate data of the specimens are given in Table 5a and 5b. The size of *Dobsonia* from large to small is *D. magna*; *D. emersa*, *D. beauforti*, and *D. minor*, respectively. Size of SP1 and SP2 are not difference with *D. beauforti.*

Table 4a. Means and Sexual dimorphism of B, G, and R OTUs on body and wing characters.

Characters	B			G			R		
	♂ Means	♀ Means	Sexual dimorphism	♂ Means	♀ Means	Sexual dimorphism	♂ Means	♀ Means	Sexual dimorphism
WT	122.54	131.33	No	352.78	344.86	No	63.73	74.70	Yes
HB length	140.00	136.37	No	230.06	221.95	No	113.14	121.24	Yes
E length	26.17	25.45	No	29.47	30.31	No	20.68	20.07	No
TV length	20.61	21.54	No	33.74	35.27	No	13.02	12.97	No
HF (su) length	21.81	22.70	Yes	32.71	32.87	No	16.04	16.00	No
FA length	102.31	104.60	No	146.65	147.04	No	77.45	82.59	Yes
TIB length	43.03	45.32	No	63.42	64.44	No	28.91	30.91	Yes
DIG1P length	32.93	33.26	No	47.28	47.30	No	26.98	29.12	Yes
DIG2M length	45.05	46.04	No	63.33	63.35	No	36.72	40.02	Yes
DIG3M length	62.65	65.24	Yes	88.63	87.62	No	50.62	55.26	Yes
DIG4M length	57.95	59.25	No	80.65	79.84	No	45.80	49.58	Yes
DIG5M length	59.30	60.57	No	80.21	81.24	No	49.35	53.43	Yes

Table 4b. Means and Sexual Dimorphism of B, G, and R OTUs on skull and teeth characters

Characters	B			G			R		
	♂	♀	Sexual dimorphism	♂	♀	Sexual dimorphism	♂	♀	Sexual dimorphism
	Means	Means		Means	Means		Means	Means	
GSL	42.92	42.62	No	58.47	58.54	No	36.87	37.45	Yes
CBL	40.97	40.42	No	56.83	56.90	No	35.25	35.90	Yes
CCL	40.78	40.04	No	56.71	56.42	No	35.08	35.65	Yes
ONL	10.60	10.25	No	15.89	16.05	No	9.55	9.49	Yes
IOW	7.94	7.96	No	10.84	10.65	No	7.30	7.44	No
POW	7.37	7.30	No	9.75	9.60	No	7.05	7.25	No
ZW	25.85	25.92	No	35.09	35.13	No	23.27	23.68	Yes
BW	17.18	17.30	No	22.20	22.44	No	15.38	15.49	No
ML	31.12	30.67	No	45.45	45.18	No	27.76	28.24	Yes
MH	15.92	16.07	No	22.13	22.14	No	13.02	13.20	No
PL	21.82	21.51	No	31.69	31.59	No	18.40	18.78	Yes
MFW	5.21	5.12	No	7.62	7.67	No	4.76	4.86	No
I^2M^2	17.28	16.83	No	25.40	25.05	No	13.67	13.96	No
C^1C^1	8.74	8.19	Yes	11.74	11.21	Yes	7.47	7.49	No
M^2M^2	11.38	11.35	No	16.69	16.88	No	10.35	10.49	No
I_2M_3	18.44	17.87	No	27.25	26.83	No	15.30	15.37	No
M^1M^1	13.01	12.74	No	18.36	18.33	No	11.03	11.05	No
LM^1	4.31	4.25	No	6.10	6.01	No	3.00	3.01	No
WM^1	2.41	2.31	Yes	3.40	3.55	No	1.71	1.69	No
C_1M_3	18.55	17.90	Yes	27.08	26.68	No	15.13	15.31	No

Table 5a. Body and wing measurements of *Dobsonia*

CHARACTERS TAXON		WT	HB	E	TV	HF (su)	FA	TIB	DIG1P	DIG2M	DIG3M	DIG4M	DIG5M
D. beauforti ♀	N	28	28	28	28	28	28	28	28	28	28	28	28
	X	122.54	140.00	26.17	20.61	21.81	102.31	43.03	32.93	45.05	62.65	57.95	59.30
	SD	25.64	9.83	1.89	2.92	1.74	6.74	4.23	2.19	2.91	4.16	3.94	4.01
	Min	78.0	110.9	22.37	16.89	19.90	87.8	37.10	28.73	37.32	54.27	49.53	49.05
	Max	178.0	150.0	30.00	28.20	26.00	115.0	52.60	39.06	50.84	71.32	65.69	67.95
D. beauforti ♂	N	17	17	17	17	17	17	17	17	17	17	17	17
	X	131.33	136.37	25.45	21.54	22.70	104.60	45.32	33.26	46.04	65.24	59.25	60.57
	SD	16.41	9.38	1.34	2.23	1.21	4.67	4.01	1.34	1.77	3.99	2.21	1.99
	Min	88.0	120.0	24.68	15.24	20.32	93.74	35.00	30.85	41.36	50.70	54.09	55.52
	Max	152.0	159.9	30.00	25.10	24.00	116.00	50.30	36.36	48.72	67.50	61.05	62.57
D. magna ♀	N	28	28	28	28	28	28	28	28	28	28	28	28
	X	344.86	221.95	30.31	35.27	32.87	147.04	64.44	47.30	63.35	87.62	79.84	81.24
	SD	49.87	19.23	2.51	4.28	2.23	4.52	2.87	1.83	2.60	3.86	3.27	3.26
	Min	200.0	180.0	29.00	22.15	28.90	140.0	60.00	44.07	58.32	79.39	74.14	74.37
	Max	455.0	273.0	40.00	40.00	40.00	160.0	72.00	52.51	70.25	95.76	86.27	87.07
D. magna ♂	N	23	23	23	23	23	23	23	23	23	23	23	23
	X	352.78	230.06	29.47	33.74	32.71	146.65	63.42	47.28	63.33	88.63	80.65	80.21
	SD	71.75	14.33	3.15	3.96	1.94	5.68	3.95	2.12	2.58	5.10	3.87	3.44
	Min	210.0	202.0	28.00	21.67	28.63	129.5	54.69	43.47	58.16	78.66	72.92	75.40
	Max	475.0	258.0	40.00	36.00	36.30	160.0	71.91	51.88	68.87	98.96	89.02	89.75
D. minor ♀	N	33	33	33	33	33	33	33	33	33	33	33	33
	X	74.95	120.93	20.02	12.90	16.09	82.59	30.96	29.14	40.05	55.29	49.67	53.37
	SD	8.81	12.20	1.34	2.24	1.56	1.66	1.15	1.40	2.05	1.64	1.69	1.63
	Min	62.00	97.25	18.00	8.39	12.00	76.87	27.97	25.36	35.39	50.81	44.66	48.62
	Max	110.00	150.00	23.14	17.29	18.46	84.61	32.92	31.49	45.57	58.28	52.66	56.58
D. minor ♂	N	34	34	34	34	34	34	34	34	34	34	34	34

	X	63.73	113.14	20.68	13.02	16.04	77.45	28.91	26.98	36.72	50.62	45.80	49.35
	SD	4.36	10.53	1.44	2.36	1.52	1.52	0.10	2.39	1.78	1.83	1.87	1.95
	Min	55.00	100.5	15.96	9.03	12.98	73.70	26.67	22.34	32.81	45.47	40.55	43.47
	Max	76.39	135.0	23.18	20.00	20.32	80.25	31.78	31.58	40.14	53.60	49.26	53.33
D. emersa ♂	N	4	4	4	4	4	4	4	4	4	4	4	4
	X	195.25	166.20	28.75	23.50	24.75	115.50	49.25	36.94	49.39	72.58	64.79	66.07
	SD	14.64	7.50	1.50	1.00	1.25	1.73	1.50	1.51	0.82	1.54	1.81	1.30
	Min	174.0	155.0	27.00	22.0	23.00	114.0	47.00	34.83	48.46	70.43	63.06	64.17
	Max	207.0	170.0	30.00	24.0	26.00	118.0	50.00	38.41	50.21	73.89	66.81	67.07
SP1 ♂	N	1	1	1	1	1	1	1	1	1	1	1	1
		126	120.73	25.67	20.61	21.17	103.53	44.91	31.49	44.12	65.17	56.40	58.11
SP2 ♀	N	1	1	1	1	1	1	1	1	1	1	1	1
		122	140.1	28.81	22.24	24.22	111.05	46.97	35.00	47.88	68.93	61.71	64.07
SP2 ♂	N	2	2	2	2	2	2	2	2	2	2	2	2
	X	155.0	152.3	26.05	20.27	20.82	105.6	45.90	34.75	47.73	67.31	61.22	62.64
	SD	9.90	0.78	0.73	0.11	0.25	1.58	1.20	2.06	2.50	0.29	0.49	0.71
	Min	148.0	151.7	25.54	20.20	20.65	104.5	45.05	33.30	45.96	67.11	60.87	62.13
	Max	162.0	152.8	26.57	20.35	21.00	106.8	46.75	36.21	49.50	67.52	61.56	63.14

Table 5b. Skull and dental measurements of *Dobsonia*

CHARACTERS / TAXON		GSL	CBL	CCL	ONL	IOW	POW	ZW	BW	I^2M^2	C^1C^1	M^2M^2	ML	MH	I^2M^3	M^1M^1	PL	LM^1	WM^1	MFW	C_1M_3
D. Beauforti ♀	N	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28
	X	42.62	40.42	40.04	10.25	7.96	7.30	25.92	17.30	16.83	8.19	11.35	30.67	16.07	17.87	12.74	21.51	4.25	2.31	5.12	17.90
	SD	2.12	2.31	2.38	0.76	0.62	0.42	1.64	0.55	0.97	0.38	0.64	2.12	1.67	1.02	0.68	1.32	0.28	0.14	0.30	1.06
	Min	37.89	35.20	35.00	9.14	6.95	6.41	22.38	16.41	15.30	7.35	10.22	25.77	11.48	16.49	11.83	18.66	3.87	2.06	4.62	16.35
	Max	47.30	45.94	45.36	12.56	9.12	8.39	29.21	18.66	20.05	8.87	13.42	35.61	18.30	21.39	14.97	25.48	5.22	2.61	5.94	21.38
D.	N	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17

Beaufo rti ♂	X	42. 92	40. 97	40. 78	10. 60	7.9 4	7.3 7	25. 85	17. 18	17. 28	8.7 4	11. 38	31. 12	15. 92	18. 44	13. 01	21. 82	4.3 1	2.4 1	5.2 1	18. 55
	SD	1.6 0	1.6 1	1.6 3	0.5 9	0.3 5	0.5 4	1.6 7	0.4 7	0.8 8	0.3 4	0.5 7	1.3 5	1.3 1	1.0 2	0.5 8	0.9 3	0.2 7	0.1 5	0.3 2	0.8 7
	Min	38. 41	36. 36	36. 42	9.3 2	7.2 1	6.7 9	22. 43	16. 18	15. 67	7.7 5	10. 61	27. 75	13. 68	16. 64	11. 72	19. 50	4.0 2	2.2 4	4.6 1	16. 76
	Max	45. 05	43. 18	42. 64	11. 67	8.4 2	9.0 1	28. 35	18. 00	19. 67	9.3 5	12. 81	33. 19	17. 78	21. 15	14. 29	23. 74	5.0 2	2.7 7	5.8 0	20. 80
D. magna ♀	N	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28
	X	58. 54	56. 90	56. 42	16. 05	10. 65	9.6 0	35. 13	22. 44	25. 05	11. 21	16. 88	45. 18	22. 14	26. 83	18. 33	31. 59	6.0 1	3.5 5	7.6 7	26. 68
	SD	2.4 8	2.6 5	2.7 1	1.0 4	0.6 0	0.4 4	2.0 3	0.6 5	0.9 5	0.6 1	0.6 9	2.3 2	2.4 7	1.1 2	0.8 0	1.7 5	0.4 3	0.2 1	0.4 9	1.1 1
	Min	52. 13	50. 49	50. 15	13. 25	9.5 9	8.7 3	30. 68	21. 11	23. 19	9.9 1	15. 12	39. 79	17. 11	24. 89	16. 52	26. 38	4.9 8	3.1 9	6.6 3	24. 65
	Max	61. 37	60. 36	59. 68	17. 66	11. 52	10. 48	38. 37	23. 48	27. 00	12. 56	18. 14	48. 88	25. 88	29. 32	20. 24	33. 91	6.8 0	3.9 3	8.4 9	29. 14
D. magna ♂	N	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23
	X	58. 47	56. 83	56. 71	15. 89	10. 84	9.7 5	35. 09	22. 20	25. 40	11. 74	16. 69	45. 45	22. 13	27. 25	18. 36	31. 69	6.1 0	3.4 0	7.6 2	27. 08
	SD	3.2 2	3.3 8	3.5 2	1.3 1	0.7 2	0.6 2	2.8 7	0.8 7	1.1 6	0.6 3	0.7 9	3.0 9	2.5 6	1.3 9	0.8 1	2.2 0	0.3 4	0.1 5	0.5 9	1.4 5
	Min	51. 92	49. 26	48. 30	13. 80	9.5 3	8.1 7	28. 94	20. 42	23. 72	10. 68	15. 17	38. 05	16. 31	24. 36	17. 11	27. 35	5.4 3	3.3 6	6.2 4	23. 96
	Max	64. 96	62. 89	62. 68	18. 57	12. 22	10. 69	40. 63	23. 47	27. 51	13. 06	18. 01	50. 15	25. 42	29. 99	19. 90	34. 74	6.7 6	3.8 9	8.6 9	29. 74
D. minor ♀	N	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33
	X	37. 54	36. 00	35. 74	9.5 1	7.4 6	7.2 7	23. 71	15. 53	14. 02	7.5 0	10. 49	27. 76	13. 30	15. 42	11. 10	18. 85	3.0 0	1.7 0	4.8 7	15. 13
	SD	0.8 6	0.9 0	0.8 6	0.4 5	0.5 2	0.4 7	0.6 5	0.4 0	0.4 2	0.3 5	0.3 2	0.8 3	0.9 2	0.3 8	0.3 6	0.6 1	0.1 5	0.1 0	0.2 7	0.3 4
	Min	35. 84	33. 94	33. 60	8.5 1	6.1 1	6.1 8	22. 20	14. 70	12. 92	6.4 6	9.7 5	26. 59	11. 11	14. 62	10. 03	17. 71	2.6 3	1.4 7	4.4 0	14. 58
	Max	39. 31	37. 61	37. 35	10. 50	8.3 9	8.4 3	24. 68	16. 25	14. 76	8.2 5	11. 13	29. 99	15. 04	16. 07	11. 84	19. 87	3.3 8	1.8 5	5.4 5	15. 86
D. minor ♂	N	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34
	X	36. 87	35. 25	35. 08	9.5 5	7.3 0	7.0 5	23. 27	15. 38	13. 67	7.4 7	10. 35	27. 76	13. 02	15. 30	11. 03	18. 40	3.0 0	1.7 1	4.7 6	15. 36
	SD	0.7 1	0.5 8	0.8 1	0.5 1	0.3 7	0.5 4	0.6 5	0.3 5	0.3 9	0.2 4	0.3 4	0.8 7	0.7 1	0.4 2	0.3 5	0.5 0	0.1 4	0.1 3	0.2 2	0.4 3
	Min	35. 50	34. 11	34. 09	8.6 4	6.5 0	6.2 1	22. 03	14. 80	13. 00	6.8 3	9.6 0	26. 22	11. 74	14. 23	10. 21	17. 40	2.6 8	1.4 3	4.2 6	13. 80
	M	38.	36.	38.	10.	7.9	8.2	24.	16.	14.	7.8	11.	30.	14.	16.	11.	19.	3.2	1.9	5.3	15.

	ax	75	73	77	68	4	9	76	25	74	8	08	17	76	21	62	39	1	5	2	96
D.	N	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
emersa ♂	X	49.67	48.13	47.83	13.26	9.20	8.35	30.23	19.21	20.82	9.27	13.97	38.11	19.72	22.11	15.04	26.69	5.15	2.74	5.86	22.07
	SD	1.07	0.77	0.82	0.21	0.22	0.21	1.15	0.82	0.34	0.17	0.65	0.76	0.70	0.44	0.19	0.64	0.19	0.13	0.39	0.44
	Min	48.62	47.26	46.74	12.95	9.01	8.07	28.93	18.48	20.53	9.06	13.04	37.21	19.28	21.64	14.80	26.06	4.91	2.57	5.47	21.61
	Max	51.17	49.10	48.68	13.41	9.51	8.58	31.39	20.18	21.20	9.47	14.55	39.01	20.77	22.70	15.27	27.28	5.36	2.85	6.32	22.55
SP1 ♀	N	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
	X	44.10	42.05	41.50	10.50	8.2 25	7.3 15	26.62	17.11	17.04	8.22	11.86	31.74	17.18	18.43	12.77	22.00	4.11	2.25	5.17	17.87
	SD	0.08	0.40	0.69	0.24	0.50	0.29	0.35	0.54	0.28	0.24	0.28	0.35	0.49	0.09	0.07	0.10	0.14	0.01	0.00	0.10
	Min	44.04	41.76	41.01	10.33	7.87	7.11	26.37	16.73	16.84	8.05	11.66	31.49	16.83	17.70	12.72	21.93	4.01	2.24	5.17	17.79
	Max	44.16	42.33	41.99	10.67	8.58	7.52	26.86	17.49	17.24	8.39	12.05	31.99	17.53	17.83	12.82	22.07	4.21	2.26	5.17	17.94
SP1 ♂	N	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	X	41.22	39.41	39.28	8.90	8.03	7.53	25.66	16.05	16.71	7.68	11.35	29.69	15.36	17.04	12.51	20.63	3.95	2.11	4.71	17.29
SP2 ♀	N	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
	X	44.02	41.92	41.84	10.93	8.175	7.125	27.01	17.13	17.23	8.43	11.69	32.23	16.59	18.43	12.88	22.05	4.28	2.36	4.90	18.52
	SD	0.23	0.76	0.81	0.08	0.36	0.32	0.10	0.42	0.35	0.03	0.24	0.42	0.18	0.14	0.08	0.06	0.14	0.03	0.08	0.13
	Min	43.85	41.39	41.27	10.87	7.92	6.90	26.94	16.84	16.98	8.41	11.52	31.94	16.46	18.33	12.82	22.00	4.18	2.34	4.84	18.43
	Max	44.18	42.46	42.42	10.98	8.43	7.35	27.08	17.43	17.47	8.45	11.86	32.53	16.72	18.53	12.93	22.09	4.38	2.38	4.96	18.61
SP2 ♂	N	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
	X	44.31	42.14	42.10	10.52	8.09	7.16	28.15	17.30	17.32	8.992	11.71	32.38	17.48	18.38	13.14	22.24	4.27	2.34	4.902	18.52
	SD	0.33	0.32	0.05	0.37	0.27	0.05	0.57	0.73	0.16	0.12	0.46	0.49	0.47	0.04	0.08	0.27	0.05	0.03	0.18	0.05
	Min	43.59	41.71	41.80	10.07	7.91	7.00	27.70	16.79	17.15	8.86	11.38	31.70	16.35	18.14	12.98	21.91	4.21	2.31	4.31	18.00
	Max	45.30	42.50	42.71	10.82	8.29	7.49	28.58	17.82	17.52	9.12	12.03	33.29	18.33	18.54	13.31	22.44	4.35	2.39	5.24	18.76

DISCUSSION

Morphometric study

D. magna was described by Andersen (1912) based on nine specimens of external characters (FA, TV, E, TIB, HF (cu), DIG1P to DIG5M) and six specimens of 18 skull characters. He did not separate the specimen between female and male, and it is only describe of morphology. Flannery (1995b) separated male and female in describe on seven external characters (WT, HB, E, FA, TV, TIB, HF) of nine specimens of *D. magna*, but he did not analyze sexual dimorphism. This study analyzed of *D. magna* based on 32 characters and separated into 28 females and 23 males. T test analysis ($p<0.05$) on 32 characters of *D. magna* resulted sexual dimorphism on C^1C^1 (male larger than female). The PCA demonstrated that *D. magna* separated from other species on body, wing, skull, and teeth characters.

D. minor was described based on two specimens (one specimen is immature) of external characters (FA, TV, E, TIB, HF (cu), DIG1P to DIG5M) and six specimens of 18 skull characters (Andersen 1912). Whereas, Flannery (1995b) separated male and female in describe on seven external characters (WT, HB, E, FA, TV, TIB, HF) of seven specimens of *D. minor*, but he did not analyze sexual dimorphism. Description of *D. minor* by Boeadi & Bergmans (1987) based on 39 characters and separated male and female, but they did not sexual dimorphism. This study analyzed of *D. minor* based on 32 characters and separated into 33 females and 34 males. T test analysis ($p<0.05$) on 32 characters of *D. minor* resulted sexual dimorphism in body, wing, and skull characters (WT, HB, FA, TIB, DIG1P, DIG2M, DIG3M, DIG4M, DIG5M, GSL, CBL, CCL, ONL, ZW, ML and PL). Its size of female larger than male. The PCA demonstrated that *D. minor* separated from other species on wing, and teeth characters are significant, whereas body and skull characters reach *D. beauforti*.

According to Bonaccorso *et al* (2002), females *D. minor* had significantly larger mean core-use areas than males (1.43 ± 0.61 and 0.65 ± 0.16 ha, respectively). Also, females have larger long-axes across the home range than males that indicating longer commuting flights between day roosts and foraging areas. The longer commuting flights of female are a possible cause of their external body and wing characters larger than male.

D. beauforti was proposed as a new species based on five body characters (HB, TV, E, FA, HF su) and 12 skull characters of ten specimens (Bergmans 1975). He separated male and female and use univariate analysis, but he did not analyze sexual dimorphism. According to Flannery (1995a), *D. beauforti* is sexually dimorphic in body size (WT and HB) that male larger than female; but he did not measure wing, skull and teeth characters. He measured five males and four males of specimens. This study examined a total of 32 characters on *D. beauforti* (28 females and 17 males) and use univariate and multivariate analysis. T test analysis ($p<0.05$) resulted sexual dimorphism on HF su, DIG3M, C^1C^1, WM^1, C_1M_3 of *D. beauforti*. HF su and DIG3M on female is larger than male, on the contrary C^1C^1, WM^1, C^1M^3 on male is larger than female. The PCA demonstrated that *D. beauforti* separated from other species on wing and teeth characters, whereas body and skull characters of small size to reach large size of *D. minor*.

D. emersa was proposed as a new species by Bergmans & Sarbini (1985), based on two body characters (FA and WT) and 19 skull and teeth characters of one specimen. This study examined a total of 32 characters on *D. emersa* (four males) and use univariate analysis, but it is not analyze sexual dimorphism. When *D. emersa* are projected in scatter plot, its position separate from other species on body and teeth characters. SP1 and SP2 however can not be diagnosed separately from *D. beauforti*.

This is the first study that used PCA to analyze morphometric characters on *Dobsonia*. Formerly, PCA was used in morphometric study on *Cynopterus nusatenggara* (Kitchener and Maharadatunkamsi, 1996). The study of *Cynopterus nusatenggara* to group characters into two variables, they are external variable (11 characters) and skull variable (16 characters). The PCA demonstrated that FA, TIB, DIG1P to DIG5M lengths (external), GSL, PL, C^1M^1, C^1M^2, CPL, ONL, and MFB (skull) are characters used as taxonomic character for *Cynopterus nusatenggara* (Kitchener 1996).

CONCLUSION AND FUTURE STUDIES

D. magna, *D. minor*, *D. beauforti*, and *D. emersa* are distinct in body, wing, skull, and teeth characters. SP1 and SP2 are projected into domain of *D. beauforti* in external body, wing, skull, and teeth. There are sexual dimorphisms in *D. beauforti* and *D. minor*. The characters that sexually dimorphic on *D. beauforti* are HF *su*, DIG3M, C^1C^1, WM^1, and C^1M^3; whereas on *D. minor* are WT, HB, FA, TIB, DIG1P, DIG2M, DIG3M, DIG4M, DIG5M, GSL, CBL, CCL, ONL, ZW, ML, and PL. The characters that can be used as taxonomical characters of *Dobsonia* are WT, HB and TV for body characters; FA, TIB, and DIG1P for wing characters; ONL, POW, PL, and MH for skull characters; I^2M^2, M^2M^2, WM^1 and LM^1 for teeth characters. The presence of *D. minor* from Waigeo Island is a new record.

Further study is needed to investigate SP1 and SP2 which have been grouped in *D. beauforti*.

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