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Craniometrical Studies on *Alouatta seniculus* — from the view point of sex differences and age changes —

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Introduction

Craniometrical studies on South American monkeys, Platyrrhini, have been done by Schultz (1926, 1960 and 1962). The number of species studied by him was limited; the species involved are *Alouatta villosa, Ateles geoffroyi* and *Cebus capucinus*. His studies comprise mostly of the analyses of morphological variation given by sex differences and age changes. And consequently his studies gave us the basic concept about infra-specific variation on cranial morphology of the above listed species of the New World monkeys.

To extend and to elaborate the Schultz's works, I made researches on morphology of platyrrhines in Colombia, S.A., as a member of the Third Upper Amazon Scientific Expedition organized by the Japan Monkey Centre, from October, 1975 to March, 1976 and a member of preliminary expedition by Kyoto University, from December, 1976 to February, 1977. The data were taken from the several species. The data given by the cranial morphology of *Alouatta ceniculus* are analized and reported here. This species was not treated by Schultz.

This study is a part of the projects to clarify the evolutionary sequences and taxonomic problems among South American monkeys.

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Material and Methods

The number of specimens studied are shown in the Table 1. They are divided into three age classes based on the dgree of eruption of teeth; individuals with fully erupted thirs molars are regarded as Adult, individuals with fully erupted first molars but without (not erupted) permanent canie and third molars are as Age Class II, and individuals without (not erupted) first molars are as Age Class I. Among the specimens studied, 33 specimens are housed in INDERENA, 33 specimens are in Universidad Nacional, Colombia, and 11 specimens are in Primate Research Institute, Kyoto University, Japan.

Table 1. Number of Specimens Studied

Age of classes	Number of specimens
Age class I	13
Age class II	7
Adult female	26
Adult male	31
Total	77

I follow Martin (1914) for the measurements of skulls. Items of measurements are as follows:

1. Cranial length: n–i
2. Cranial breadth: average of three dimensions, po–po, greatest breadth of brain case, greatest breadth of basi-cranium
3. Bizygomatic breadth: greatest breadth between zygomatic arches
4. Postorbital breadth: smallest frontal breadth behind orbital rims
5. Base length: n–ba
6. Facial length: pr–ba
7. Middle facial breadth: zm–zm
8. Upper facial height: n–pr
9. Nasal hight: n–rhi
10. Nasal breadth: greatest breadth of nasal bones
11. Interorbital breadth: smallest breadth between the medial walls of the orbits at their entrances
12. Biorbital breadth: fmo–fmo
13. Bicondylar breadth: kdl–kdl
14. Bigonial breadth: go–go
15. Symphysis height: id–gn
16. Ramus height

Results

The means of dimensions of 16 items listed above of each sex and age class and the means of indices are shown in the Tables 2–4. The sex differences seen in each dimension expressed by percentage of those of male sover those of females are shown in the Table 5. The item of dimensions with the greatest sex difference is seen in Bigonial breadth. The following is the list of items with sex difference in descending order:

Table 2. Cranial dimensions and indices of *Alouatta*

Dimensions & indices	Age class I	Age class II	Adult female	Adult male
Head length	61.99	68.02	71.14	78.98
Head breadth	47.68	51.59	52.13	56.48
Bizygomatic breadth	46.06	60.16	65.45	78.58
Postorbital breadth	41.12	43.02	41.63	40.37
Base length	48.14	56.59	61.41	71.09
Cranial index	76.73	75.93	73.14	71.53
Trans, cran. fac. I.	96.58	117.21	126.05	139.53
Vert. cran. fac. I.	96.04	112.64	121.73	133.53
Zygo. front. I.	90.17	71.07	63.60	51.46
Postorb. I.	86.42	83.64	80.09	72.29

Table 3. Facial dimensions and indices of *Alouatta*

Dimensions & indices	Age class I	Age class II	Adult female	Adult male
Facial length	59.60	76.45	86.45	105.41
Mid. fac. height	37.45	48.65	55.54	65.89
Up. fac. height	26.68	34.02	37.26	44.39
Nas. height	14.83	18.45	19.14	22.19
Nas. breadth	6.45	8.59	9.10	11.25
Interorb. breadth	7.07	9.16	10.87	12.61
Biorb. breadth	38.07	45.31	48.85	53.51
Up. fac. index	57.50	56.36	57.33	56.63
Zygo-malar I.	81.19	81.70	84.85	83.56
Alveolar I.	123.88	135.50	141.62	148.75
Nas. I.	41.73	44.67	46.08	50.17
Interorb. I.	17.42	19.45	21.38	22.92
Fronto-fac. I.	111.50	88.50	64.50	61.78

Table 4. Mandibular dimensions and indices of *Alouatta*

Dimensions & indices	Age class I	Age class II	Adult female	Adult male
Bi-condyl. breadth	43.30	52.59	55.89	63.59
Bigonial breadth	22.30	30.02	36.20	53.85
Symphysis height	18.22	23.45	24.49	29.12
Ramus height	29.60	45.45	52.30	66.68
Zygo-gonial index	47.96	49.36	54.68	68.83
Mand. breadth I.	51.19	56.93	63.75	84.00

Table 5. Average value and sexual dimorphism in cranial dimensions of *Alouatta seniculus*

Dimensions	Average value Male ($n = 31$)	Female ($n = 26$)	F/M × 100
Cranial length	78.98	71.14	90.07
Cranial breadth	56.48	52.13	92.30
Postorbital breadth	40.37	41.63	103.12
Base length	71.09	61.41	86.38
Facial length	105.41	86.45	82.01
Bizygomatic breadth	78.58	65.45	83.29
Mid. facial breadth	65.89	55.54	84.29
Up. facial height	44.39	37.26	83.94
Nasal height	22.19	19.41	87.47
Nasal breadth	11.25	9.10	80.89
Interorbital breadth	12.61	10.87	86.20
Biorbital breadth	53.51	48.85	91.29
Bicondylar breadth	63.59	55.89	87.89
Bigonial breadth	53.85	36.20	67.22
Symphysis height	29.12	24.49	84.10
Ramus height	66.68	52.30	78.43

Ramus height, Nasal breadth, Facial length, Bizygomatic breadth, Upper facial height, Symphysis height, Middle facial breadth, Interorbital breadth, Base length, Nasal height, Bicondylar breadth, Cranial length, Biorbital breadth, Cranial breadth, Postorbital breadth. The value of the item, Postorbital breadth exceeds 100% showing that the dimension seen in females is greater than that of males. As for the parts of skulls, the greatest sex difference is seen in the mandible, the facial part follows next to it, and the brain case shows the smallest degree in sex difference. Among the mandible, the fact that the degree of sex difference seen in Bicondylar breadth is small is surely correlated to the mode of development of the basicranial part of skulls with which the condyle of mandible articulates.

Among age changes from Age Class I to Adult Male, the differences with age are greater in Bigonial breadth and Ramus height as in sex differences. The difference with age seen in Postorbital breadth is very minor. In compared with the trend seen in sex differences, the different trends are seen in age changes of Middle facial breadth, Interorbital breadth, and Biorbital breadth. They represent the transverse dimensions of the facial part, and age changes of these are comparatively greater than sex differences.

According to the indices calculated, the greatest value both in age changes and sex differences is seen in Mandibular breadth index (Biognial breadth/Bicondylar breadth $\times 100$). This indicates that the lateral development of the gonial region in compared with that of the cranial base is prominent in Adult males. Zygomatic gonial index (Bigonial breadth/Zygomatic breadth $\times 100$) also shows greater value for both age changes and sex differences, and this indicates that the degree of development of the gonial region is prominent for facial dimension. Cranial index (Cranial breadth/Cranial length $\times 100$) decrees with age, and the value of it in males is smaller than that of females. These results indicate that Adult males have more dolicho-cephalic cranium than Adult females. This morphological characteristic is surely correlated

Table 6. Sex differences and growth rate on indices

	Alouatta seniculus	*Macaca fuscata*	Growth rate of *Aluoatta*
Mand. br. Index	+31.77	+ 5.52	+64.09
Zygo.-gonial. I.	+25.88	+11.45	+43.52
Zygo.-front. I.	−10.99	− 7.37	−42.93
Front.-orb. I.	−17.07	− 3.19	−44.59
Trans. cran.-fac. I.	+10.69	+ 8.28	+44.47
Postorb. I.	− 9.74	+ 0.31	−16.35
Vert. cran.-fac. I.	+ 9.69	—	+39.04
Nas. I.	+ 8.88	− 8.84	+20.22
Interorb. I.	+ 7.20	+ 0.27	+31.57
Alve l. I.	+ 5.03	—	+20.08
Cran. I.	− 2.20	+ 1.49	− 6.78
Zygo.-mal. I.	− 1.52	− 5.93	+ 2.93
Up. fac. I.	− 1.22	− 0.93	− 1.51

Table 7. Sex differences and growth rate on dimensions

	Alouatta seniculus	*Macaca fuscata*	Growth rate of *Alouatta*
Bigonial Br.	+48.76	+13.70	+141.48
Ramus Ht.	+27.50	+ 7.95	+125.27
Nas. Br.	+23.63	+ 3.37	+ 74.42
Fac. Lg.	+21.93	+14.70	+ 76.86
Bizyg. Br.	+20.06	+12.85	+ 70.60
Up. fac. Ht.	+19.14	+11.66	+ 66.38
Symph. Ht.	+18.91	+16.73	+ 59.82
Mid. fac. Br.	+18.64	+ 7.55	+ 75.94
Interorb. Br.	+16.01	+ 9.63	+ 78.22
Base Lg.	+15.76	+ 6.10	+ 47.67
Nas. Ht.	+13.32	+13.59	+ 49.63
Bi-condyl. Br.	+13.78	+ 8.18	+ 46.89
Cran. Lg. (n-i)	+11.02	+ 3.63	+ 27.41
Biorb. Br.	+ 9.54	+ 7.55	+ 40.56
Cran. Br.	+ 8.34	+ 4.27	+ 18.86
Postorb. Br.	− 3.03	+ 4.45	− 1.82

with the well-developed nuchal crest of Adult males. Upper facial index (Upper facial height/Bizygomatic breadth × 100) which shows the relative development of the facial part along vertical and transverse dimensions indicates no age changes and sex differences.

The Table 6 shows the amounts of age changes and sex differences introduced by indices. The amounts of sex differences are shown by percentage of the relative differences between males and females over Adult females. The amounts of age changes are shown by percentage of the relative changes from Age Class I to Adult male over Age Class I. For comparison, sex differences seen in Japanese monkeys (*Macaca fuscata*) reported by us (Ikeda & Watanabe, 1966) are tabled. The Table 7 also shows the data of dimensions as in the Table 6.

Discussion

The greatest sex differences and age changes seen in skulls of Red Howler monkeys (*Alouatta seniculus*) are seen in the mandibular part, especially in gonial region. The greater development of gonial region in Adult males of Howler monkeys is surely correlated with the greatest development of the hyoid. This characteristic development of the hyoid is seen among the species of this genus in general. The lateral and ventral developments of gonial region indicate the relationships with the development of the hyoid. However, Hill (1962) reported the variation of the degree of the developments of the hyoid among the species of the genus *Alouatta*. Unfortunately, Schultz (1926, 1960 and 1962) did not mention about the differences in the mandible. The problems about the functional relationships between the mandible and the hyoid remain unsolved, and to solve the problems, extensive comparisons of morphology among species and the studies from the view points of comparative and functional morphology are needed.

As seen in Cranial index and Upper facial index, the differences of the degree of development of length and breadth of the parts of brain case and facial region are minor among age classes. However, Alveolar index which indicates the degree of prognathism of the facial part varies from one age class to another. Moreover, the observation of skulls shows that the angle between the facial part and the cranial part which indicates the differences in the orientation of the development varies among age classes. To analyse the growth of the skull as a whole of *Alouatta seniculus*, the measurements of various angles given by the projection methods and of the curvature of the dental row are necessary.

As for the difference in weight between males and females, *Alouatta seniculus* and *Macaca fuscata* show almost no differences. But the former shows greater differences in cranial morphology between males and females. The greater differences between *A. eniculus* and *M. fuscata* are seen in the developments of the mandibular and the nasal parts. Schlutz (1962) gave the mean values of sex differences calculated by the measurements of 14 items. According to him, the mean value of *Alouatta villosa* is +10.1; *Cebus capucinus*, +6.7; *Atelus geoffroyi*, +0.7. These values indicate that in compared with the other genera of South American monkeys, the genus *Alouatta* has greater differences in cranial morphology depending on sexes. To compare the results given by *Alouatta villosa* studied by Schlutz with those given by *A. seniculus* studied by me, among 8 items in common, Postorbital breadth and Interorbital

Table 8. Average value and sexual dimorphism in foot length in the Platyrrhini

Genus		*n*	Average value of foot length	F/M ×100
Saguinus	Male	13	65.50 mm	102.67
	Female	12	67.24	
Callithrix	Male	4	64.25	95.92
	Female	6	61.63	
Callicebus	Male	23	93.15	96.15
	Female	16	85.56	
Aotus	Male	6	86.83	101.35
	Female	4	88.01	
Pithecia	Male	7	124.71	95.06
	Female	9	118.56	
Saimiri	Male	3	85.67	
	Female	3	82.00	95.72
Cebus	Male	24	126.58	97.17
	Female	16	123.00	
Alouatta villosa	Male	22	147.23	96.32
	Female	26	141.81	
Alouatta seniculus	Male	4	138.75	90.99
	Female	4	126.25	
Lagothrix	Male	4	148.50	95.40
	Female	6	141.67	
Brachyteles	Male	4	177.75	97.05
	Female	2	172.50	
Ateles	Male	15	178.93	104.12
	Female	26	186.31	

breadth of *A. villosa* show greater differences according to sexes. However, the other items, Cranial length, Cranial breadth, Base length, Bizygomatic breadth, Facial length and Upper facial height seen in *A. seniculus* show greater differences depending to sexes than those of *A. villosa*. According to the data (Table 8) of length of hind feet given by Hill (1957, 1960 and 1962), the sex differences of *A. senivulus* are greater than those of *A. villosa*. According to Malinow et al. (1966), the sex differences of *A. caraya* in the length of hind feet are greater than those of *A. seniculus*.

It is safely concluded that among the skulls of Platyrrhini, the genus *Alouatta* shows the greatest sex differences in cranial morphology. Among the genus *Alouatta*, the sex differences seen in *A. seniculus* are obviously greater than those of *A. villosa*. According to the data of the length of hind feet, the sex differences seen in *A. caraya* are the greatest. I have hypotheses on possible correlation between the sex differences mentioned above and the differences in mode of life of these species. This problem is out of scope for the present paper. This problem will be discussed in a separate paper. But only the following point must be mentioned here; the phenomenological correlations between the sex differences and the types of social organization, especially troop size among three species of the genus *Alouatta* mentioned above.

Conclusions

From above discussion, the following points are concluded;

1. Among three parts of cranial skeleton of *Alouatta seniculus*, namely, facial, brain case, and mandibular parts, both age changes and sex differences seen in mandibular part are the greatest and those of brain case part are the smallest.
2. As for mandibular part, the degree of lateral and ventral development of gonial

region in Adult males is prominent, and consequently it gives the greater sex differences and age changes.

3. Based on the relation between length and breadth of brain case part given by Cranial index, the brain case of Adult males is developed to having dolichocephalic type. This development is probably resulted by the greater development of nuchal crest in Adult male.
4. Based on the relation between length and breadth of facial part given by Upper facial index, the age changes and sex differences are not observable.
5. The relative position of three parts of cranial skellton varies according to age. But the detailed studies have not been done as yet.
6. To compare three species of the genus *Alouatta, A. seniculus, A. villosa,* and *A.* caraya, the greatest sex differences are seen in *A. caraya,* and *A. seniculus*, *A. villosa* follow that species in descending order.

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