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Geographical Variation of Mandible Size and Shape in the Wild Pig (*Sus scrofa*) from Taiwan and Japan

Hideki Endo[1,2,*], Yoshihiro Hayashi[3], Kyomi Yamazaki[4], Masaharu Motokawa[5], Jai-Chyi Kurtis Pei[6], Liang-Kong Lin[7], Cheng-Han Chou[7] and Tatsuo Oshida[8]

[1]*Department of Zoology, National Science Museum, Tokyo, Shinjuku-ku, Tokyo 169-0073, Japan*
[2]*Department of Zoology, Faculty of Science, Kyoto University, Kyoto 606-8501, Japan*
[3]*Graduate School of Agricultural and Life Sciences, The University of Tokyo, Bunkyo-ku, Tokyo 113-8657, Japan*
[4]*Iwaki Junior College, Iwaki-shi, Fukushima 970-8567, Japan*
[5]*The University Museum, Kyoto University, Kyoto 606-8501, Japan*
[6]*Department of Wildlife Conservation, National Pingtung University of Science and Technology, Pingtung, Taiwan 91207, R.O.C.*
[7]*Laboratory of Wildlife Ecology, Department of Biology, Tunghai University, Taichung, Taiwan 407, R.O.C.*
[8]*Laboratory of Molecular Ecology, Department of Biology, Tunghai University, Taichung, Taiwan 407, R.O.C.*

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Hideki Endo, Yoshihiro Hayashi, Kyomi Yamazaki, Masaharu Motokawa, Jai-Chyi Kurtis Pei, Liang-Kong Lin, Cheng-Han Chou and Tatsuo Oshida (2002) Geographical variation of mandible size and shape in the wild pig (*Sus scrofa*) from Taiwan and Japan. *Zoological Studies* **41**(4): 452-460. We examined osteometrical characters in the mandibles of the wild pigs (*Sus scrofa*) from Taiwan, and compared them with those from the Japanese mainland and Iriomote Island (Okinawa Prefecture). Mandibles from Iriomote Island were smaller in size than those from the other localities. Specimens from the Taiwanese population significantly differed from the Mie or Tanba (Honshu) samples in some important measurements such as length of the mandible, although the Mie samples were similar to the Taiwanese ones in many measurements especially in males, while the principal component charts showed that the Taiwanese population is separated from the Oita and Miyazaki (Kyushu) populations for older age classes. Therefore, we concluded that the morphology of the wild pig from Taiwan relatively resembles that of the Japanese wild pig from the Honshu area (Mie and Hyogo (Tanba) Prefectures). The osteological characters in the mandibles of the Taiwanese population have been affected and determined by the following 3 geographical and climatic factors in the habitat: 1) being from 22° to 25° north latitude, 2) being from about 2000 m in elevation, and 3) having experienced the isolation effect on an island of 36 000 km^2. We suggest that these factors make the mandibles from Taiwan similar to those from the Japanese mainland such as those from Mie. http://www.sinica.edu.tw/zool/zoolstud/41.4/452.pdf

Key words: Wild pig, Mandible, Osteometry, Taiwan.

The wild pig (*Sus scrofa*) is distributed from Tohoku and Hokuriku Districts to the Nansei Islands, the southwesternmost part in Japan. The osteometrical characters of both the Japanese mainland and Nansei Island populations have been examined by many authors (Hayashida 1960, Senba 1960 1964, Imaizumi 1973, Hayashi 1975, Hayashi et al. 1983, Endo et al. 1994 1998a,b 2000). Some reports have pointed out that the population on Iriomote Island is obviously smaller than that of the Japanese mainland in skull size (Imaizumi 1973, Endo et al. 1994 1998a,b). So, the population on the Nansei Islands including Iriomote Island has been considered to be an independent subspecies, the Ryukyu wild pig (*Sus scrofa riukiuanus*), and is distinguished from the Japanese mainland population (*Sus scrofa leucomystax*) (Kuroda 1940, Ellerman and Morrison-Scott 1951, Haltenorth and Trense 1956, Miura 1997). We suggested that the island-isolation

*To whom correspondence and reprint requests should be addressed. Fax: 81-3-3364-7104. E-mail: endo@kahaku.go.jp

effect and Bergmann's rule would result in dwarfism of *Sus scrofa riukiuanus* (Endo et al. 1994 1998a,b). Although the Island of Taiwan is close to Iriomote Island (200 km) and has a large population of wild pig (*Sus scrofa taivanus*), osteometrical data have not been detailed in this population except for a preliminary report (Yang and Chen 1962). In this study, we examined mandible specimens from 2 Taiwanese populations to confirm the morphological similarities or differences among the populations of Taiwan, Iriomote Island, and the Japanese mainland. Our aim was also to clarify whether island-isolation dwarfism and Bergmann's rule can be established for the Taiwanese and Iriomote populations.

MATERIALS AND METHODS

Measurements (Table 1; Fig. 1), and sex, and age determinations were based on methods of previous reports (Duerst 1926, Hayashi 1975, Driesch 1976, Hayashi et al. 1977). For the Japanese mainland and Iriomote populations, we used specimens examined in some previous reports (Hayashi 1975, Hayashi et al. 1977 1983, Endo et al. 1994 1998a,b 2000). The collection from the Japanese mainland is stored by Dr. Yoshihiro Hayashi in the Faculty of Agriculture of the Univ. of Tokyo (Hayashi 1975). The mandibles from Iriomote Island are kept in the Department of Zoology, National Science Museum, Tokyo (Endo et al. 1994 1998a,b, Endo 1998). The specimens from Taiwan are stored at the National Pingtung Univ. of Science and Technology, and the National Museum of Natural Science (Taichung, Taiwan). We examined a total of 219 mandibles of the age groups III and IV-V from various populations (Table 2; Fig. 2).

Nineteen characters of the mandible (Table 1; Fig. 1) were measured with a vernier caliper. To clarify the geographical tendency in size among the populations of Mie, Tanba, Oita, Iriomote Island, and Taiwan, statistical differences among mean values for each character were examined by Student's *t*-test. For males of age group IV-V, data from the Miyazaki population were used instead of the Oita population, since we could obtain only 1 mandible from the latter locality in that age class. We distinguished the mandibles of Wutai from

Table 1. List of the measurements and their abbreviations

Length from the angle to anterior-most point of symphysis	LA
Length from the condyle to anterior-most point of symphysis	LC
Aboral height of the vertical ramus	AHR
Oral height of the vertical ramus	OHR
Middle height of the vertical ramus	MHR
Height of the mandible at M_1	HM1
Height of the mandible at Gnathion	HG
Length of symphysis	LS
Length of the ramus between the angle and M_3	LR
Length of canine alveolus	LCA
Breadth at caudal point of I_3	BI
Breadth at canine alveori	BC
Least breadth of the mandible	LBM
Breadth of 2 halves between the most lateral points of the 2 angles	BLP
Breadth of 2 halves between the condylar processes	BCP
Breadth between medial and lateral points of the condylar process	BML
Thickness between rostral and caudal points of the condylar process	TC
Breadth of the mandible at M_1	BM
Thickness of the mandible at middle point of M_1	TM

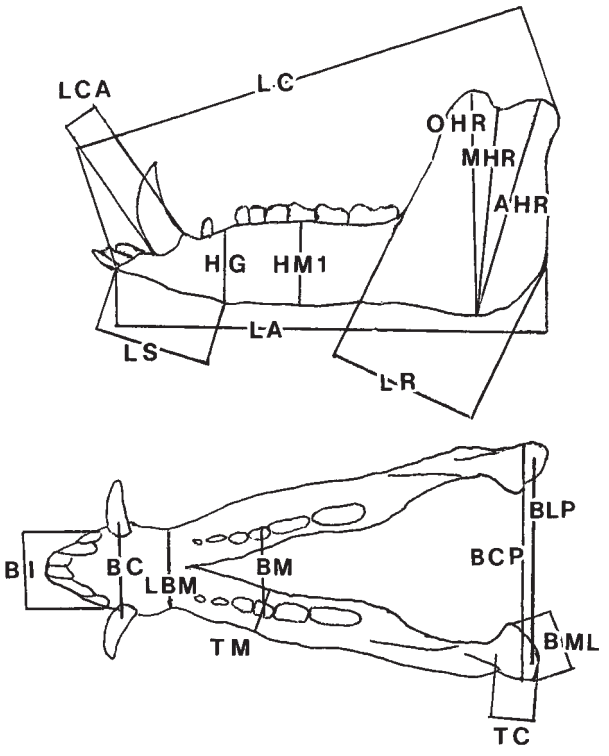

Fig. 1. Measurements of the mandible. Upper: lateral aspect. Lower: dorsal aspect. Abbreviations are explained in table 1.

those of Taroko National Park in Taiwan in this study. However, Student's *t*-test was applied to the 2 populations together, since only a few specimen numbers were available from both localities. The principal component analysis was applied to measure data from all populations examined to elucidate factors affecting the size and shape. A package software for multivariate analysis (Shakai-Joho Service, Tokyo) added to Microsoft Excel 98 was used for this analysis.

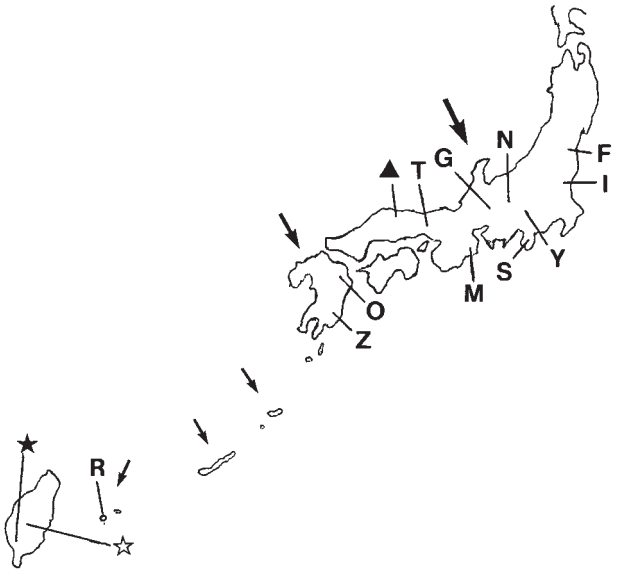

Fig. 2. Map showing specimen localities. F: Fukushima, I: Ibaraki, Y: Yamanashi, S: Shizuoka, N: Nagano, G: Gifu, M: Mie, T: Hyogo (Tanba), ▲: Tottori, O: Oita, Z: Miyazaki, R: Iriomote, ★: Wutai (Taiwan), ☆: Taroko National Park (Taiwan). Large arrow indicates the Honshu area, and intermediate arrow shows Kyushu Island in Japanese mainland. Small arrows point to the area of the Nansei Islands.

RESULTS

Mean values and standard errors of the 19 measurements are given in table 3. Statistical differences in these measurements between all combinations of populations are shown in table 4. We visually present the mean values and standard deviations of LA, AHR, LCA, and BLP in figures 3-6 to compare these values between specimens from Taiwan and those from some localities in Japan. The principal component charts between the 1st and 2nd transformed variables from 19 measurements in each sex and age group are shown in figures 7-10.

Many mean values of the Iriomote population were significantly smaller than those of both the Taiwanese and Japanese mainland populations (Tables 3, 4; Figs. 3-6). We could not confirm a significant difference in the Iriomote population from the other populations in the following 4 measurements: BI from the Miyazaki population in male age group IV-V, TC from the Oita population in female age groups III and IV-V, and LS from the Taiwanese population in female age group III (Table 4). Mandibles of the Iriomote population were significantly smaller than those of the

Table 2. Locality, Age group, and sex composition of mandible specimens

Locality	Age group III		Age group IV-V	
	Male	Female	Male	Female
Fukushima (Iwaki)	3	1	2	1
Ibaraki	0	0	0	1
Nagano (Shimo-Ina)	1	2	0	0
Yamanashi	0	0	0	1
Shizuoka (Izu)	0	0	1	2
Gifu	1	0	0	0
Mie	4	7	10	30
Hyogo (Tanba)	7	5	9	10
Tottori	0	0	0	1
Oita	4	26	1	35
Miyazaki (northern district)	0	2	5	2
Iriomote Island	4	6	7	9
Wutai, Pingtung Co. (Taiwan)	8	6	1	2
Taroko National Park (Taiwan)	0	0	1	1
Total	32	55	37	95

Taiwanese population in many measurements, except for LS in female age group III and TM in female age groups III and IV-V (Table 4).

In contrast, many characters of the mandibles of the Taiwanese populations did not significantly differ from those of the Japanese mainland populations. The Taiwanese populations differed from the Tanba population in LA in age groups III and IV-V of males and age group III of females. The Taiwanese populations also differed from age group IV-V males of the Mie population in LA, and from age group IV-V males of the Tanba population and from females of the Oita population in LC (Table 4). This shows that the important measurements of the mandible, such as LA and LC, from Taiwan were significantly smaller than those from Mie and Tanba, but larger than those from Oita for these genders and ages (Tables 3, 4). However, the number of measurements for which significant differences were demonstrated suggests that male specimens of the Mie population may be morphologically similar with those of the Taiwanese populations (Table 4). We could confirm only 4-6 measurements which showed significant differences among the Taiwanese, Mie, and Tanba populations.

The characters which largely contribute to the 1st principal component are described in the legends of figures 7-10. The 1st principal component was affected by the size factors LC and LA, whereas the 2nd principal component was mainly affected by BLP, HM1, and TC which represent proportional factors.

The series of principal component charts (Figs. 7-10) show that the cluster of the 1st and 2nd axes of the Taiwanese populations overlaps with that for the Mie population in the charts of age group IV-V, but is separated from the plots or cluster of the Oita and Miyazaki populations (Figs. 7, 9). We can show that the size and shape of the Taiwanese mandibles were not similar to those of the Kyushu (Oita and Miyazaki) populations, but were similar to those of the Honshu populations (including Mie, Hyogo (Tanba), Fukushima,

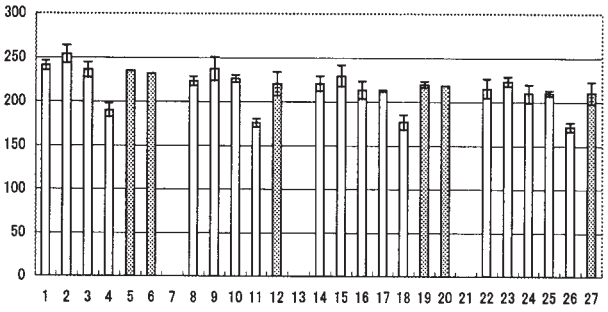

Fig. 3. Mean values (mm) and standard deviations of LA. Numbers on the horizontal axis represent the following: 1-6. Males of age group IV-V. 1. Mie; 2. Hyogo (Tanba); 3. Miyazaki; 4. Iriomote; 5. Wutai (Taiwan); 6. Taroko (Taiwan). 8-12. Males of age group III. 8. Mie; 9. Hyogo (Tanba); 10. Oita; 11. Iriomote; 12. Wutai (Taiwan). 14-20. Females of age group IV-V. 14. Mie; 15. Hyogo (Tanba); 16. Oita; 17. Miyazaki; 18. Iriomote; 19. Wutai (Taiwan); 20. Taroko (Taiwan). 22-27. Females of age group III. 22. Mie; 23. Hyogo (Tanba); 24. Oita; 25. Miyazaki; 26. Iriomote; 27. Wutai (Taiwan). The dotted bars indicate mean values for Taiwanese specimens (5, 6, 12, 19, 20, and 27).

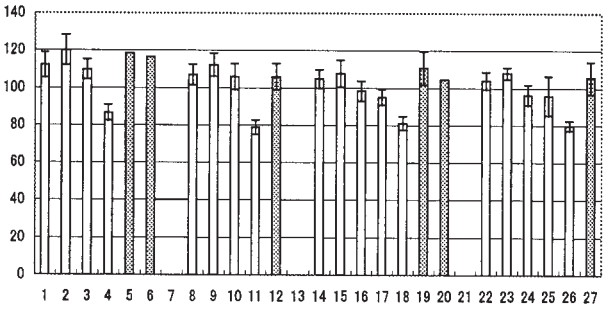

Fig. 4. Mean values (mm) and standard deviations of AHR. Numbers on the horizontal axis are described in the legend of figure 3.

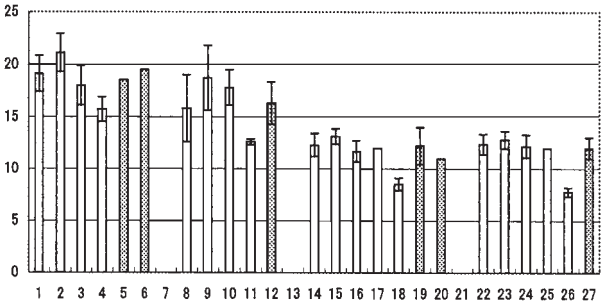

Fig. 5. Mean values (mm) and standard deviations of LCA. Numbers on the horizontal axis are described in the legend of figure 3.

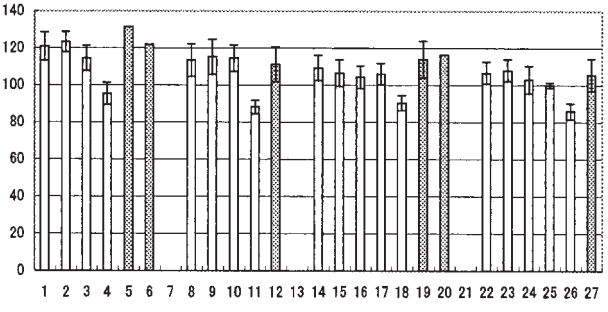

Fig. 6. Mean values (mm) and standard deviations of BLP. Numbers on the horizontal axis are described in the legend of figure 3.

Nagano, Gifu, Ibaraki, and Yamanashi Prefectures) in the age group IV-V (Figs. 7, 9). Many plots from the Taiwanese populations were divided by the 1st axis from plots of the Japanese mainland populations in female age group III (Figs. 8, 10). The Iriomote population was obviously distinguished from all other localities by the 1st principal component except for age IV-V females of the Oita population.

DISCUSSION

The LA size is correlated with the head and body length in the wild pig (Abe 1989). Thus, we suggest that Taiwanese wild pigs might not be same as those of the Mie, Tanbe, and Oita populations in external body size, although external measurements have not been obtained for the

Table 3. Mean values (mm) and standard deviations of measurements of mandibles from various localities

	Locality	LA	LC	AHR	OHR	MHR	HM1	HG	LS	LR	LCA	BI	BC	LBM	BLP	BCP	BML	TC	BM	TM
1. Male																				
Age IV-V	Fukushima	252.5	271.5	115.5	118.5	104.0	43.0	46.0	80.0	80.5	23.0	41.5	63.0	52.0	127.5	123.5	32.0	27.0	64.5	25.0
		3.54	9.19	3.54	0.71	0.00	1.41	1.41	8.49	4.95	1.41	0.71	4.24	2.83	2.12	4.95	4.24	2.83	2.12	5.66
	Shizuoka	257.0	258.0	118.0	125.0	110.0	42.0	42.0	80.0	75.0	19.0	35.0	53.0	37.0	110.0	112.0	25.0	26.0	51.0	21.0
	Mie	241.0	249.3	112.1	116.5	101.3	44.0	44.0	69.5	76.3	19.1	35.7	53.0	35.1	120.7	114.9	27.5	25.3	54.9	24.9
		5.19	7.01	6.79	3.81	3.77	3.53	4.32	7.34	4.72	1.73	3.62	6.6	9.23	7.54	7.68	1.78	2.63	2.33	2.77
	Tanba	253.7	262.0	120.2	124.6	108.2	46.1	45.2	79.6	78.0	21.1	38.1	58.6	40.7	123.2	120.1	28.3	27.6	53.7	25.4
		9.80	9.43	7.98	6.82	6.91	2.76	2.49	6.15	4.00	1.62	2.67	3.28	1.32	7.77	5.46	1.58	1.94	2.24	1.51
	Oita	245.0	254.0	104.0	109.0	94.0	36.0	38.0	72.0	71.0	19.0	38.0	57.0	38.0	117.0	112.0	24.0	23.0	51.0	21.0
	Miyazaki	236.0	243.0	109.8	110.2	97.5	41.2	40.7	74.0	72.5	18.0	33.2	53.2	36.2	114.5	111.8	26.8	23.8	50.0	24.3
		8.37	11.03	5.23	7.03	5.50	3.43	2.58	5.55	7.01	1.90	1.72	3.66	1.47	6.89	6.18	1.47	2.48	2.45	2.50
	Iriomote	190.2	207.3	86.6	89.5	78.1	34.7	35.2	59.6	58.5	15.7	32.2	44.5	36.1	95.3	95.1	19.8	19.0	45.9	19.4
		7.74	9.37	4.13	3.49	4.21	1.91	1.81	4.75	2.15	1.19	1.48	2.45	1.78	5.98	4.56	1.13	1.83	2.01	1.12
	Wutai	235.0	249.0	118.5	121.0	107.5	48.5	51.0	71.0	70.0	18.5	39.0	53.0	42.0	131.5	119.0	33.0	23.5	56.5	21.5
	Taroko	232.0	248.5	116.5	115.0	103.5	41.5	45.0	66.5	76.0	19.5	38.5	53.3	43.0	122.0	110.5	28.0	22.0	57.0	24.5
Age III	Fukushima	234.0	255.7	113.7	118.0	103.7	42.3	43.7	68.7	72.0	17.7	37.0	54.3	46.0	117.3	116.0	27.3	25.3	58.0	21.7
		5.57	2.52	1.15	2.00	1.53	1.53	1.53	3.21	2.65	4.04	1.00	2.52	0.00	7.57	6.56	1.15	2.31	3.61	0.58
	Nagano	228.0	245.0	107.0	106.0	97.0	38.0	38.0	68.0	66.0	17.0	35.0	49.0	42.0	106.0	105.0	23.0	23.0	56.0	21.0
	Gifu	240.0	258.0	120.0	118.0	105.0	42.0	46.0	71.0	76.0	17.0	37.0	52.0	42.0	120.0	111.0	24.0	26.0	58.0	20.0
	Mie	223.5	233.0	107.0	112.5	98.3	39.8	38.8	60.3	69.5	15.8	35.0	50.3	36.5	113.5	108.8	26.3	23.5	52.5	22.0
		5.26	6.38	5.48	5.57	4.57	1.26	3.50	4.65	5.07	3.20	2.83	5.74	1.73	8.74	5.38	2.06	1.29	3.70	1.83
	Tanba	237.4	245.9	112.3	114.4	100.7	40.6	42.6	71.4	71.9	18.7	35.7	54.6	39.0	115.3	109.3	26.1	23.4	54.1	23.1
		13.43	14.09	6.16	7.30	6.52	3.87	4.89	5.88	4.06	3.09	1.25	4.61	2.45	9.43	5.88	1.77	2.51	4.06	3.44
	Oita	226.3	234.3	106.0	108.8	95.3	38.5	39.8	65.0	66.5	17.8	37.3	53.8	37.5	114.5	110.3	26.0	11.3	50.8	21.8
		4.03	4.57	6.93	2.36	2.22	1.00	0.96	4.32	1.91	1.71	1.71	1.89	1.00	7.05	5.91	0.82	2.50	2.63	1.26
	Iriomote	176.1	189.5	78.9	84.9	71.8	30.9	32.0	50.6	52.6	12.6	28.9	38.5	31.9	88.3	89.8	18.6	16.8	43.5	17.3
		4.73	6.56	3.92	3.88	3.20	1.49	1.91	4.55	2.25	0.25	1.03	1.08	0.85	3.52	4.43	1.93	0.65	1.35	0.50
	Wutai	220.7	236.8	106.0	108.0	95.3	39.6	42.9	58.9	67.4	16.3	37.4	49.2	41.3	111.2	110.3	25.1	23.4	55.8	22.3
		13.44	14.58	6.96	5.73	5.41	2.99	3.81	4.41	3.81	2.03	3.28	3.68	2.76	9.23	6.71	1.85	1.38	2.62	2.20
2. Female																				
Age IV-V	Fukushima	229.0	246.0	118.0	107.0	97.0	38.0	40.0	67.0	65.0	13.0	36.0	45.0	40.0	116.0	113.0	26.0	24.0	56.0	18.0
	Ibaraki	223.0	229.0	116.0	109.0	100.0	44.0	45.0	66.0	72.0	11.0	32.0	48.0	36.0	131.0	123.0	26.0	27.0	54.0	24.0
	Yamanashi	240.0	264.0	113.0	113.0	103.0	42.0	42.0	62.0	79.0	13.0	37.0	46.0	44.0	120.0	113.0	28.0	27.0	60.0	21.0
	Shizuoka	212.5	218.0	99.0	102.5	90.5	37.5	39.0	59.5	62.5	13.0	32.5	45.5	35.0	105.5	106.5	25.0	21.5	50.5	20.0
		7.78	8.49	1.41	0.71	0.71	2.12	2.83	2.12	3.54	1.41	0.71	2.12	1.41	2.12	0.71	0.00	0.71	0.71	0.00
	Mie	220.7	227.2	104.8	105.3	94.4	38.2	36.4	61.0	67.6	12.3	32.1	44.6	34.7	109.3	107.5	26.3	23.2	51.0	19.9
		8.43	8.45	4.92	4.07	3.55	2.16	2.24	4.50	4.73	1.09	2.32	2.24	1.98	6.85	5.58	9.20	2.04	2.08	1.51
	Tanba	229.4	236.2	107.7	109.9	98.0	39.6	37.1	63.6	67.9	13.1	32.6	45.6	36.7	106.6	108.4	24.3	22.5	52.1	20.3
		11.89	11.62	7.15	6.54	6.68	3.24	3.14	6.33	5.09	0.74	2.12	2.27	2.41	7.21	4.97	0.95	1.58	3.28	1.89
	Tottori	234.0	258.0	115.0	118.0	105.0	44.0	42.0	65.0	74.0	13.0	37.0	52.0	46.0	112.0	122.0	28.0	28.0	62.0	22.0
	Oita	213.6	223.5	98.4	98.2	87.8	33.9	33.8	59.4	63.7	11.7	33.0	43.3	34.3	104.5	104.3	22.5	16.5	48.2	18.1
		9.88	10.44	5.23	5.16	4.50	2.29	2.92	4.68	3.86	1.01	2.60	3.30	2.32	6.03	5.92	1.68	5.56	2.33	1.58
	Miyazaki	212.5	220.0	95.0	96.0	86.5	36.0	34.0	56.5	64.0	12.0	30.0	46.0	34.5	106.0	103.5	23.0	20.5	49.0	17.0
		0.71	0.00	4.24	4.24	3.54	1.41	1.41	0.71	1.41	0.00	0.00	1.41	0.71	5.66	0.71	1.41	0.71	0.00	1.41
	Iriomote	177.0	192.2	81.1	84.7	74.0	32.0	30.8	50.0	54.6	8.6	27.7	34.6	30.9	90.4	91.2	18.8	16.3	46.7	17.4
		6.59	6.64	3.74	3.76	3.28	2.49	2.35	3.54	4.37	0.58	1.56	1.91	1.52	4.01	3.77	1.12	1.70	1.89	0.82
	Wutai	220.0	235.3	110.8	112.3	100.0	41.8	41.5	55.8	68.3	12.3	34.0	42.3	39.3	114.0	110.0	26.3	24.5	55.8	17.0
		3.54	8.13	8.84	5.30	6.36	3.18	0.71	1.06	0.35	1.77	0.71	2.47	2.47	9.90	7.78	3.89	0.71	1.06	1.41
	Taroko	218.5	237.0	104.5	100.5	94.0	41.0	38.5	55.5	71.5	11.0	34.5	42.5	39.5	116.5	108.5	23.5	24.0	56.0	18.5
Age III	Fukushima	227.0	237.0	108.0	111.0	98.0	36.0	38.0	62.0	67.0	12.0	38.0	46.0	42.0	114.0	113.0	23.0	21.0	54.0	18.0
	Nagano	215.0	233.0	105.0	103.0	94.5	34.0	35.5	55.0	68.0	12.5	32.0	38.5	35.5	105.0	101.0	25.0	21.5	55.0	17.5
		11.31	14.14	9.90	11.31	6.36	4.24	3.54	8.49	2.83	0.71	1.41	0.71	0.71	9.90	7.07	2.83	0.71	1.41	4.95
	Mie	215.3	222.9	104.0	103.9	92.3	37.1	35.0	57.9	64.1	12.4	31.7	43.4	34.0	106.7	105.0	24.4	20.9	51.9	19.6
		10.78	9.19	4.65	7.36	4.79	3.08	3.06	5.46	3.24	0.98	1.89	6.97	3.27	5.77	6.35	2.64	1.21	3.63	1.99
	Tanba	223.6	232.6	108.0	108.8	97.0	37.4	37.0	61.6	68.2	12.8	34.2	44.0	36.2	108.0	105.8	23.8	21.6	51.6	20.0
		5.18	3.44	3.16	4.82	3.39	2.07	2.74	4.88	2.86	0.84	0.84	0.71	1.10	5.92	4.87	1.30	0.55	1.67	1.00
	Oita	209.7	219.5	96.3	96.9	86.2	32.3	32.9	58.6	61.0	12.2	33.0	41.3	33.3	103.1	101.8	22.3	16.0	48.1	18.0
		10.29	11.06	5.48	4.94	4.37	2.25	2.70	4.59	3.40	1.12	2.27	2.77	2.04	7.36	6.84	1.77	5.92	1.81	1.73
	Miyazaki	210.0	216.5	95.5	98.0	85.0	34.5	35.5	61.0	60.0	12.0	33.5	41.5	34.0	100.0	96.0	21.0	18.5	50.0	18.0
		2.83	4.95	10.61	7.07	9.90	0.71	2.12	1.41	0.00	0.00	4.95	2.12	2.83	1.41	2.83	1.41	0.71	2.83	0.00
	Iriomote	171.8	186.2	79.7	83.3	72.9	29.5	29.3	47.8	52.1	7.8	27.8	33.3	30.6	86.0	87.8	18.3	15.1	44.3	16.5
		5.09	3.52	2.60	3.46	2.35	1.41	2.11	1.81	2.15	0.41	0.52	0.94	0.49	4.22	3.86	1.21	1.16	1.17	0.63
	Wutai	210.6	225.3	105.5	103.8	94.8	36.4	39.0	50.8	65.3	12.0	34.2	40.3	37.8	105.6	106.2	24.1	21.7	55.8	18.7
		12.29	12.14	8.64	8.91	8.55	3.01	3.07	6.78	5.70	1.00	2.56	2.96	2.86	8.68	6.00	2.54	1.63	2.75	3.01

Mean values are shown in the upper rows, and standard deviations in the lower rows. Only mean values are shown for localities which includes only one specimen.

Taiwanese populations.

The small LA size of the Mie population was reported previously (Hayashi 1975, Endo et al. 2000). As Mie Prefecture is situated in the southern part of the elongated Kii Peninsula of Honshu, dwarfism by Bergmann's rule might be observed in this population. Between the Mie and Taiwanese populations, a significant difference in LA was detected only in age group IV-V males. In this respect, we should point out that the ecological and behavioral factors related to age or sex such as the mating system in each population might influence the determination of body size in each locality.

Morphological differences between the Taiwanese and Iriomote populations are noteworthy. Both islands are situated within 22° to 25° north latitude, and the distance between them is only about 200 km. However, Taiwan has an area of 36 000 km^2, whereas that of Iriomote is only 320 km^2 (Hatsushima and Nakajima 1979). Since Taiwan is as large as Kyushu Island including Oita and Miyazaki Prefectures on the Japanese mainland, the island-isolation effect on body size might not significantly differ between the Taiwanese and Japanese mainland populations. So, we suggest that the Iriomote population has been much more heavily affected by island-isolation than has the Taiwanese one. Dwarfism as confirmed in mandibles from Iriomote Island may be strongly related to the small area of this Island (Imaizumi 1973, Endo et al. 1998a,b), in addition to higher annual average temperature.

The effect of Bergmann's rule depends on the

Table 4. Results of Student's *t*-test between localities

	Locality	LA	LC	AHR	OHR	MHR	HP1	HG	LS	LR	LCA	BI	BC	LBM	BLP	BCP	BML	TC	BM	TM	NMS[a]
1. Male																					
Age IV-V	Mie x Tanba	0.12	0.19	1.41	0.25	0.68	8.39	23.36	0.25	20.57	0.91	6.01	1.79	4.58	24.15	5.51	14.90	2.52	12.83	30.37	10
	Mie x Miyazaki	2.52	3.39	14.39	0.51	2.24	6.59	3.17	29.19	6.20	5.79	2.90	32.89	34.89	5.07	12.93	17.27	8.31	0.31	42.40	7
	Mie x Iriomote	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.38	0.00	0.03	1.58	0.29	39.47	0.00	0.00	0.00	0.00	0.00	0.01	18
	Mie x Wutai+Taroko	3.99	45.85	15.28	31.31	8.62	36.70	12.94	44.66	19.16	46.97	13.94	48.80	15.05	16.00	49.00	4.24	10.99	15.30	19.33	2
	Tanbe x Miyazaki	0.16	0.17	0.76	0.08	0.36	0.43	0.23	4.93	3.67	0.23	0.08	0.53	0.00	2.23	0.86	4.37	0.31	0.51	14.99	18
	Tanba x Iriomote	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	19
	Tanba x Wutai+Taroko	1.06	4.46	32.76	11.74	30.47	32.77	11.35	2.18	7.34	5.69	37.64	2.62	4.89	28.52	12.31	8.93	0.47	4.73	4.03	8
	Miyazaki x Iriomote	0.00	0.00	0.00	0.00	0.00	0.08	0.06	0.02	0.02	1.28	16.21	0.02	46.16	0.01	0.01	0.00	0.12	0.40	0.03	17
	Miyazaki x Wutai+Taroko	35.21	25.52	4.94	9.94	5.31	12.73	1.10	13.25	46.47	25.58	0.25	49.77	0.07	3.57	29.13	3.15	29.31	0.51	26.44	7
	Iriomote x Wutai+Taroko	0.01	0.04	0.00	0.00	0.01	0.10	0.02	2.60	0.01	0.61	0.05	0.16	0.15	0.03	0.10	0.01	2.07	0.01	0.67	19
Age III	Mie x Tanba	7.42	42.99	29.99	47.46	49.31	47.47	25.64	2.40	29.28	9.97	42.42	10.75	17.08	44.35	29.12	44.30	20.71	28.33	11.11	2
	Mie x Oita	21.92	38.04	41.42	13.06	14.12	8.54	30.07	9.25	15.52	15.63	11.11	14.53	17.80	43.22	36.01	41.45	0.01	23.49	41.45	1
	Mie x Iriomote	0.00	0.00	0.01	0.01	0.00	0.00	0.74	1.27	0.04	4.98	0.33	0.35	0.15	0.09	0.08	0.08	0.00	0.19	0.12	19
	Mie x Wutai	35.04	31.71	40.41	11.25	18.30	45.42	4.80	31.37	21.52	35.74	11.75	35.09	0.52	34.33	34.80	17.99	44.16	4.99	40.63	2
	Tanba x Oita	7.30	7.55	7.65	8.63	7.30	16.50	14.67	4.53	1.85	29.22	5.94	37.30	14.00	44.44	39.99	44.21	0.00	8.59	23.14	3
	Tanba x Iriomote	0.00	0.00	0.00	0.00	0.00	0.05	0.14	0.01	0.00	0.20	0.00	0.00	0.02	0.02	0.01	0.01	0.03	0.04	0.44	19
	Tanba x Wutai	1.58	12.25	4.44	3.92	4.97	28.94	43.66	0.02	2.30	4.75	10.73	1.30	5.62	20.56	37.97	14.89	47.96	17.73	29.08	8
	Oita x Iriomote	0.00	0.00	0.02	0.00	0.00	0.01	0.02	0.19	0.00	0.05	0.01	0.00	0.01	0.03	0.07	0.02	0.27	0.14	0.03	19
	Oita x Wutai	22.32	37.19	50.00	40.51	50.00	25.69	6.92	2.29	33.95	12.73	45.90	2.25	1.28	27.26	49.39	19.76	0.00	0.51	32.53	5
	Iriomote x Wutai	0.00	0.01	0.00	0.00	0.00	0.02	0.02	0.64	0.00	0.27	0.03	0.01	0.00	0.04	0.01	0.01	0.00	0.00	0.06	19
2. Female																					
Age IV-V	Mie x Tanba	1.29	1.16	15.24	1.49	3.77	6.34	25.61	8.09	46.25	0.80	30.24	7.03	0.96	12.70	28.58	27.58	25.73	16.63	41.08	5
	Mie x Oita	0.03	2.16	0.00	0.00	0.00	0.00	0.00	7.66	0.01	3.15	8.54	6.33	27.96	0.10	1.70	1.35	0.00	0.00	0.00	15
	Mie x Iriomote	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.26	0.00	0.00	0.00	19
	Mie x Wutai+Taroko	34.71	6.89	16.41	19.08	9.67	0.86	0.28	2.58	28.51	31.20	7.60	6.92	0.03	10.59	25.66	44.65	13.16	0.04	0.31	6
	Tanba x Oita	0.00	0.05	0.00	0.00	0.00	0.00	0.13	1.03	0.25	0.01	32.38	1.79	4.88	16.89	2.01	0.07	0.14	0.00	0.02	17
	Tanba x Iriomote	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.03	19
	Tanba x Wutai+Taroko	9.59	47.99	42.06	36.60	50.00	18.50	5.36	2.97	32.51	2.88	12.19	2.22	5.50	5.52	37.43	17.43	4.06	4.20	1.88	6
	Oita x Iriomote	0.00	0.00	0.00	0.00	0.00	1.86	0.33	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	47.57	3.21	10.82	17
	Oita x Wutai+Taroko	13.72	1.78	0.07	0.09	0.02	0.00	0.01	7.82	0.61	40.34	21.51	29.72	2.50	0.28	6.37	0.47	1.48	0.00	27.33	12
	Iriomote x Wutai+Taroko	0.00	0.00	0.00	0.00	0.00	0.01	0.00	1.17	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	43.16	18
Age III	Mie x Tanba	7.23	2.47	6.43	11.04	4.48	43.75	13.56	12.50	2.45	25.37	1.06	43.03	9.13	35.71	40.93	31.82	11.73	44.33	33.48	3
	Mie x Oita	10.62	23.64	0.10	0.28	0.15	0.00	4.41	35.57	1.70	27.98	9.66	10.83	24.48	11.83	13.76	0.92	1.97	0.02	2.11	10
	Mie x Iriomote	0.00	0.00	0.00	0.01	0.00	0.02	0.30	0.15	0.00	0.00	0.06	0.47	1.78	0.00	0.01	0.02	0.00	0.06	0.34	19
	Mie x Wutai	23.87	34.18	34.89	49.79	25.62	33.83	1.93	3.13	32.28	22.58	3.63	16.77	2.58	39.20	37.06	40.76	16.38	2.53	26.48	5
	Tanba x Oita	0.33	0.75	0.00	0.00	0.00	0.00	0.22	9.85	0.01	11.64	12.19	2.07	0.23	8.54	11.28	4.60	2.24	0.02	0.86	14
	Tanba x Iriomote	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	19
	Tanba x Wutai	2.79	11.53	27.88	14.75	30.48	27.64	14.40	0.80	16.79	9.48	48.93	1.25	14.26	30.56	45.76	41.36	46.64	0.75	18.58	4
	Oita x Iriomote	0.00	0.00	0.00	0.00	0.00	0.34	0.45	0.00	0.00	0.00	0.00	0.00	0.19	0.00	0.00	0.00	37.58	0.00	2.94	18
	Oita x Wutai	42.43	13.22	0.12	0.64	0.06	0.03	0.00	0.09	0.93	37.99	13.05	22.42	0.01	23.59	8.08	2.72	1.39	0.00	22.15	11
	Iriomote x Wutai	0.00	0.00	0.00	0.03	0.01	0.04	0.01	18.16	0.03	0.00	0.02	0.03	0.02	0.06	0.01	0.03	0.00	0.00	6.80	17

Each value indicates the limit percentage in which significant differences are confirmed.

Values less than 5% are underlined.

[a]NMS indicates the number of measurements in which significant differences are demonstrated.

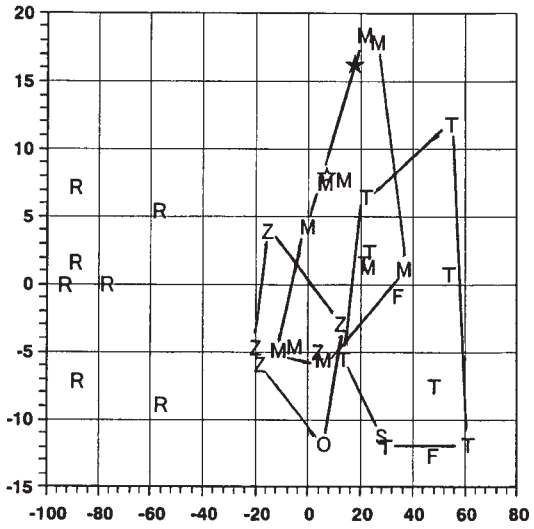

Fig. 7. Principal component chart for male age group VI-V mandibles between the 1st and 2nd transformed variables from 19 measured items. Horizontal axis: the 1st principal component (PC1). Vertical axis: the 2nd principal component (PC2). F: Fukushima, S: Shizuoka, M: Mie, T: Tanba, O: Oita, Z: Miyazaki, R: Iriomote, ★: Wutai (Taiwan), ☆: Taroko National Park (Taiwan). Plots of the Mie, Tanba, Oita and Miyazaki (Kyushu) populations are each enclosed by a polygon. The percentage of variation explained by PC1 is 88.4%, and by PC2 is 3.3%. Characters which largely contribute to the 1st principal component are LC, LA, and AHR, and to the 2nd principal component are BLP, HM1, and HG.

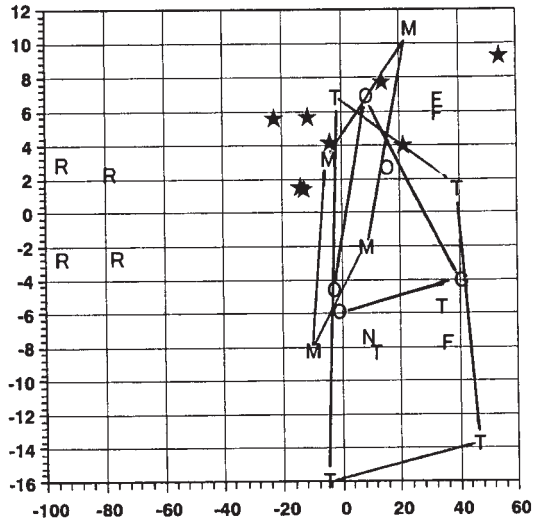

Fig. 8. Principal component chart for male age group III mandibles. Horizontal axis: the 1st principal component (PC1). Vertical axis: the 2nd principal component (PC2). F: Fukushima, N: Nagano, M: Mie, T: Tanba, O: Oita, R: Iriomote, ★: Wutai (Taiwan). Plots of the Mie, Tanba, and Oita populations are each enclosed by a polygon. The percentage of variation explained by PC1 is 89.3%, and by PC2 is 2.7%. Characters which largely contribute to the 1st principal component are LA, LC, and MHR, and to the 2nd principal component are BCP, BLP, and LBM.

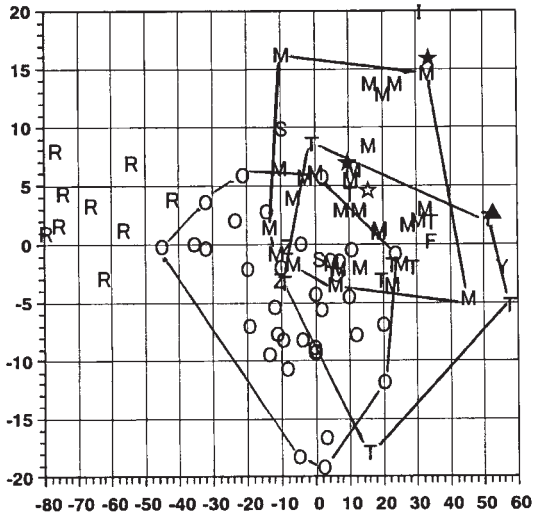

Fig. 9. Principal component chart for female age group IV-V mandibles. Horizontal axis: the 1st principal component (PC1). Vertical axis: the 2nd principal component (PC2). F: Fukushima, I: Ibaraki, Y: Yamanashi, S: Shizuoka, M: Mie, T: Tanba, ▲: Tottori, O: Oita, Z: Miyazaki, R: Iriomote, ★: Wutai (Taiwan), ☆: Taroko National Park (Taiwan). Plots of the Mie, Tanba, Oita, and Miyazaki (Kyushu) populations are each enclosed by a polygon. The percentage of variation explained by PC1 is 80.7%, and by PC2 is 5.1%. Characters which largely contribute to the 1st principal component are LA, LC, and AHR, and to the 2nd principal component are TC, HM1, and BLP.

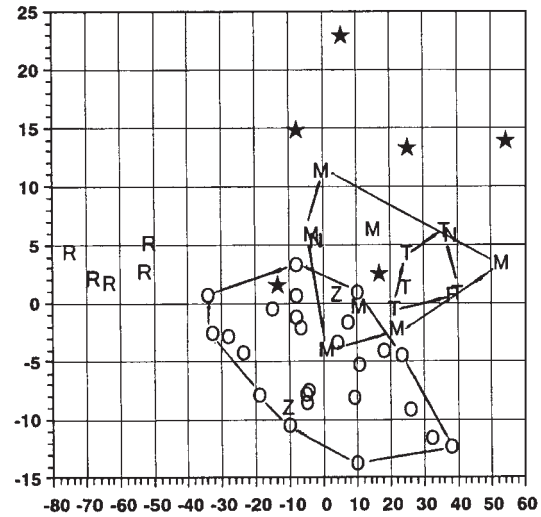

Fig. 10. Principal component chart for female age group III mandibles. Horizontal axis: the 1st principal component (PC1). Vertical axis: the 2nd principal component (PC2). F: Fukushima, N: Nagano, M: Mie, T: Tanba, O: Oita, Z: Miyazaki, R: Iriomote, ★: Wutai (Taiwan). Plots of the Mie, Tanba, Oita, and Miyazaki (Kyushu) populations are each enclosed by a polygon. The percentage of variation explained by PC1 is 84.8%, and by PC2 is 4.8%. Characters which largely contribute to the 1st principal component are LC, LA, and OHR, and to the 2nd principal component are BM, HM1, and TC.

annual average temperature at each locality. Since detailed locality data and elevations of hunting sites are not recorded for each specimen, we refer to the climatic conditions of lowland towns near the sites in table 5. The towns of Owase, Kobe, Hualien and Kaohsiung are all located at less than 200 m in elevation, however, each town is not so far from the sites of Mie, Tanba, Taroko, and Wutai, respectively.

The highest point on Iriomote Island is 470 m, whereas Taiwan has mountains which reach about 4000 m. The districts of Wutai and Taroko are situated at 500-2000 m in elevation, and the annual average temperature is obviously lower in Wutai and Taroko than on Iriomote Island. We think that all hunting sites in Mie, Tanba, Oita, and Miyazaki are located below 1500 m in elevation. Although the average temperature does not obviously differ between the hunting sites at Mie, Tanba, Oita, and Miyazaki and those of Wutai and Taroko National Park, it is impossible to exactly compare the temperature effect between the Honshu and Kyushu localities in Japan and localities in Taiwan.

Osteometrical characters of the mandible in Taiwan have been affected by the following 3 geographical and climatic factors of the habitat: 1) being from 22° to 25° north latitude, 2) being from about 2000 m in elevation, and 3) having experienced the isolation effect of the island with an area of 36 000 km^2. Latitude fundamentally determines the average temperature at each elevation. In addition, we suggest that the elevation and the island-isolation effect mainly affect skull size and shape. As a result, some mandible measurements from the Taiwanese populations have become similar to those from the Mie, Oita, and Miyazaki populations in each sex and age group (Tables 3, 4).

Table 5. Climatic conditions in lowland towns near the collection sites

Localities[a]	Annual average temperature (°C)	Annual precipitation (mm)
Mie (Owase)[b]	15.6	4002
Hyogo (Kobe)[b]	15.6	1316
Oita	15.7	1638
Miyazaki	17.0	2435
Iriomote	23.3	2343
Taiwan (Hualien)[b]	23.5	2326
Taiwan (Kaohsiung)[b]	25.2	1911

[a]Data were obtained at elevation below 200 m.

[b]Since data for these collection sites have not been recorded, data from nearby lowland towns are used.

We especially suggest that mandibles of the Tanba population do not greatly differ from those of the Taiwanese populations in males. The present principal component analysis also supports these suggestions concerning the morphological characters of the Taiwanese specimens at least in age group IV-V (Figs. 7, 9).

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比較臺灣和日本山豬下顎骨大小及形態的地理變異

遠藤秀紀[1,2] 林 良博[3] 山崎京美[4] 本川雅治[5] 裴家騏[6] 林良恭[7] 周政翰[7] 押田龍夫[8]

本研究利用骨骼測量檢驗法檢視臺灣山豬的下顎骨，並與取自日本主要島嶼(本州，九州)及西表島(沖繩縣)的山豬族群作比較。其中取自西表的山豬族群下顎骨比其他採樣點較小，而取自臺灣的山豬族群標本與三重或兵庫並沒有太大的差異；從主成分分析圖中可看出，臺灣的族群分布在大分及宮崎中。是故我們可以得知臺灣族群的形態與本州地區(三重與兵庫)相似。在骨骼學上，臺灣山豬下顎骨的特徵受到以下三個地理及氣候因子作用而造成：(1)分布於北緯22度到25度間，(2)分布於海拔2000公尺以上，(3)島嶼的隔離效應(臺灣本島面積36 000 km²)。我們推測這就是造成臺灣山豬的下顎骨會與日本本州族群如此類似的原因。

關鍵詞：山豬，下顎骨，骨骼測量檢驗法，臺灣。

[1]東京，國立科學博物館動物研究部
[2]京都大學理學院動物學系
[3]東京大學農學生命科學研究所
[4]日本福島縣岩木市，岩木短期大學
[5]京都大學博物館
[6]國立屏東科技大學野生動物保育學系
[7]私立東海大學生物學系野生生物生態學研究室
[8]私立東海大學生物學系分子生態學研究室