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Preliminary Examination of the heterogeneity of external measurements of minke whales in the western part of the North Pacific, using data collected during 1994-1999 JARPN surveys

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ABSTRACT

In order to examine the morphological heterogeneity of O/W-group minke whales in the western North Pacific, the geographical heterogeneity of external measurements of minke whales was examined using data collected during the JARPN surveys in sub-areas 7, 8, 9 and 11 from 1994 to 1999. From the analysis of covariance (ANCOV) using 12 different measurements, no significant differences were observed among Pacific sub-areas (sub-areas 7, 8 and 9), except for one measurement (V11). The result suggest that no morphological differences of minke whales were observed between the Pacific sub-areas (i.e. the hypothetical W stock was absent). Secondly, morphological differences were examined between O and J stocks of western North Pacific minke whales using the analysis of variance (ANOVA) and discriminant analysis (DA). From these analyses, significant differences were observed between J and O stocks for some measurements. The discriminant function derived from the DA provides good basis to separate one stock from the other.

INTRODUCTION

Morphological and morphometric studies related to stock identification have been conducted (Omura and Sakiura, 1956; Ohsumi, 1983; Kato *et al.*, 1992; Fujise and Kato, 1995; 1996). Pastene *et al.* (2000) provides a summary of these studies.

The elucidation of stock structure in western North Pacific minke whales is one of the objectives of the JARPN surveys. Fujise and Kato (1995, 1996) conducted morphological analyses using data from minke whales collected in sub-area 9 during the JARPN surveys 1994-1995. The external morphological data from western North Pacific minke whales collected in sub-area 9 as well as in sub-areas 7, 8 and 11 during the JARPN surveys from 1994 to 1999 are examined in this study.

MATERIALS AND METHODS

During 1994-1999 JARPN surveys, external measurements of 498 individual minke whales were made. Thirteen different morphological characters including body length are used in this study as shown in Fig.1. Only the data from males are used because data from females were too small. Individuals having missing values for one or more morphological characters are excluded to apply the principal component analysis (PCA). Therefore, the number of sample used in this study is 352 as shown in Table 1. The external measurements were made by five researchers. From a preliminary analysis of morphological data of North Pacific minke whales, it has been suggested that significant differences may results from different researchers making measurements (Fujise and Kato, 1996). In this paper we used morphological characters measured by the researcher who measured the largest numbers of samples in 1995 and 1996, in order to eliminate this possible bias from our analysis.

In this study, two issues are examined. One is the morphological heterogeneity within the O stock group of minke whales in the sub-areas 7, 8, 9 and 11. The other is the morphological differences between O stock and J stock. Individual animals for this study were identified by the mtDNA analysis (Goto *et al.,* 2000). As stock identity has not been confirmed, we called for "J group" to represent J stock and "O group" to represent O stock identified by mtDNA.

For examination of morphological heterogeneity within O stock, a total of 126 "O group" individuals consisting of 22 individuals from the sub-area 7, 15 individuals from the sub-area 8, 81 individuals from the sub-area 9 and 8 individuals for the sub-area 11, were examined. Furthermore, to examine the temporal and geographical variation, an additional 123 individuals were used for the limited measurement point V11 (flipper, maximal width). In the later examination (comparison between "J and O groups"), a total of 122 individuals of the "O group" and 6 individuals of the "J group" were compared.

The following three methods were used: (1) the analysis of covariance (ANCOV) taking body length as a covariate. (2) the analysis of variance (ANOVA). (3) the PCA and the discriminant analysis (DA). Log-transformed data for length are used for the ANCOV analyses. Proportions of the length to the body length are used on performing the ANOVA. Both of these data are also analysed by the PCA and DA. The computer program SPSS ver 7.5 for Windows is used to conduct these statistical procedures.

RESULTS

The heterogeneity of the O stock in the western part of the North Pacific

To examine the geographical heterogeneity of the O stock in the western part of the North Pacific, the external measurement data taken from animals in sub-areas 7, 8, 9 and 11 are examined by using the ANCOV. Results are shown in Table 2. Significant difference among sub-areas was not detected in 10 morphological characters out of 12. However, significant difference was detected in 1 item (V11: Flipper, maximal width) and it is suggested that the estimated marginal mean of the length was larger in sub-area 8 than in sub-areas 7 and 9 (Table 3).

Similarly, proportions of length to body length were examined by ANOVA. Table 4 shows the results. It is suggested that the mean of the proportion of the length of V11 to the body length was larger in sub-area 8 than in sub-areas 7 and 9 (Table 5). Heterogeneity of the proportions of the length of V5 (tip of snout to tip of flipper) and V10 (behind the pectoral) among the sub-areas were also detected, which were not detected by using ANCOV.

Further, to examine the geographical heterogeneity of the length of V11 among the sub-areas, the difference between sub-area 8 and sub-area 9 in 1997 and between sub-area 7 and sub-area 8 in 1998 are examined in the same way. Table 5 shows that no significant differences in the proportion of the length of V11 to body length among the sub-areas were detected.

Moreover, yearly changes of the proportion of the length of V11 to body length in each sub-area were examined. In this case, the difference or bias of researcher was not taken into account because significant difference among the researchers was not detected in V11. Table 6 shows that no significant difference was observed between years in sub-areas 7 and 9 and that no significant difference was observed in sub-area 8 except in the data from 1996.

The differences in the V11 observed in the animals collected in the sub-area 8 in the 1996 season do not occur consistently, and thus it is reasonable to treat this difference as an exceptional case. Therefore, it may be concluded that no geographical difference was observed for the morphology of the O-group-individuals within the Pacific sub-areas and the sub-area 11.

The morphometric difference between the J stock and the O stock

Difference between the "J group" and the "O group" is examined. Significant difference was detected in V2, V3 and V4 in addition to the differences in V11 and V12. As for former (V2,V3 and V4), the estimated marginal mean for "J group" was larger and as for latter (V11 and V12), the estimated marginal mean for "O group" is larger, as shown in Table 8.

Two discriminant analyses are also performed to separate the "O group" from the "J group". First, log-transformed data of the length are examined by PCA. Table 9 shows the coefficient and the cumulative contribution rate (CCR) of the 1st – 4th principal components, which accounts for more than 95% of the total variance. The 1st principal component was excluded from the discriminant analysis to eliminate the effect of growth or size because all the coefficient of 1st principal component was positive and because 1st principal component can be regarded as a factor of growth or size. Therefore the 2nd to 4th principal components are used as a variables for DA. As a result of the DA, the discriminant function is:

$$Z = 296.558(PC2) + 269.061\ (PC3) - 22.025.$$

Table 10 shows results from the discriminant function. Taking the discriminant function and the coefficient of the principal component into consideration, it was found that V2, V3, V4, V11 and V12 are effective measurements to classify the "O group" and the "J group". This agrees with the result of the ANCOV mentioned above. The percentage of correct classification is 84.6%.

Second, DA taking proportions of length to the body length as variables was conducted (Table 11). The discriminant function is:

$$Z = -\ 1.502(V2\%) + 5.448\ (V11\%) - 1.576.$$

V2 and V11 are selected as variables of the discriminant function. Results agree with those of the ANCOV mentioned above. The percentage of correct classification is 80.3%.

DISCUSSIONS

The heterogeneity in the O stock group in the western part of the North Pacific

As a result of examination of the heterogeneity of external measurements of O stock animals, no difference among the sub-areas was detected except for V11 where heterogeneity was detected only in sub-area 8 in 1996. This heterogeneity does not support the existence of the W stock, since it was not consistently observed in other sub-areas or in other years. At present, however, the cause of this heterogeneity is not unknown.

The difference in the external measurements between O and J stock animals.

Some differences in the external measurement are detected between the "O group" and the "J group" identified by mtDNA analysis. This suggests that it may be possible to discriminate between O stock and J stock animals on the basis of external measurements. However, the number of samples of "J group" is very small. Therefore, more samples are necessary to conclude that the O stock and the J stock can be identified by the external measurements.

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Table 1. Numbers of samples used in this analysis by sub-areas and seasons

	sub-area 7	sub-area 8	sub-area 9	sub-area 11	Total
1994			17		17
1995			81		81
1996	22	15		14	51
1997	2	29	53		84
1998	39	29			68
1999	30			21	51
Total	93	73	151	35	352

Table 2. Results of analysis of covariance using
22 data in sub-area 7, 15 data in sub-area 8,
81 data in sub-area 9 and 7 data in sub-area 11 in 1995 and 1996

measurement	significance
V2	n.s.
V3	n.s.
V4	n.s.
V5	n.s.
V6	n.s.
V7	n.s.
V8	n.s.
V9	n.s.
V10*	
V11	p<0.01
V12	n.s.
V13	n.s.

n.s. : no significant difference
* : ANCOV isn't applied because
the null hypothes of equal slope is rejected.

Table 3. Estimated margnal means of a length of V11 by sub-area
with 95% confidencial interval (95%C.I).

sub-area	sub-area 7	sub-area 8	sub-area 9	sub-area 11
mean	26.9	28.4	27.4	27.5
95% C.I.	26.5-27.4	27.8-29.0	27.1-27.6	26.8-28.2

Table 4. Results of analysis of variance
using 22 data in sub-area 7, 15 data in sub-area 8,
81 data in sub-area 9 and 7 data in sub-area 11 in 1995 and 1996.

measurement	significance
V2%	n.s
V3%	n.s
V4%	n.s
V5%	p<0.05
V6%	n.s
V7%	n.s
V8%	n.s
V9%	n.s
V10%	p<0.01
V11%	p<0.01
V12%	n.s
V13%	n.s

n.s. : no significant difference

Table 5. Means of V11% by sub-areas with 95% confidencial interval (C.I.).

measurement	sub-area 7	sub-area 8	sub-area 9	sub-area 11
mean	3.7	3.9	3.8	3.8
95% C.I.	3.7-3.7	3.8-4.0	3.7-3.8	3.7-3.9

Table 6. Results of statistical tests for the length of V11 among sub-areas

	ANCOV	t-test
sub-area 8 and 9 in 1997	*	n.s.
sub-area 7 and 8 in 1998	n.s.	n.s.

* : ANCOV isn't applicable because the null hypothes of equal slope is rejected.
n.s. : no significant difference

Table 7. Means of V11% by year in each sub-areas and their 95% confidential interval (95%C.I.)

		1995	1996	1997	1998
sub-area 7	mean		3.7		3.73
	95%C.I.		3.63-378		3.66-381
sub-area 8	mean		3.87	3.70	3.71
	95%C.I.		3.80-3.95	3.65-3.76	3.65-3.77
sub-area 9	mean	3.75		3.70	
	95%C.I.	3.72-3.78		3.65-3.74	

Table 8. Results of ANCOV between "J group" and "O group". "J group" and "O group" are explained in the text.

measurement	significanc	"J stock"	"O stock"
V2	p<0.05	95.0	91.0
V3	p<0.05	114.1	109.8
V4	p<0.05	151.0	146.8
V5	n.s.	305.0	299.8
V6	n.s.	398.1	399.6
V7	n.s.	344.9	345.5
V8	n.s.	236.5	238.0
V9	n.s.	190.6	191.0
V10	n.s.	72.2	73.4
V11	p<0.01	25.9	27.3
V12	p<0.05	199.2	210.2
V13	n.s.	204.4	206.6

n.s. : no significant difference

Table 9. Coefficients of the 1st - 4th principal components and their cumulative contribution rate (CCR)

variable	principal components (PC)			
	PC1	PC2	PC3	PC4
V1	0.077	-0.001	0.004	0.004
V2	0.076	0.030	-0.002	0.008
V3	0.070	0.027	0.001	0.001
V4	0.067	0.021	0.001	-0.001
V5	0.071	0.010	0.001	-0.007
V6	0.080	-0.011	0.009	0.005
V7	0.084	-0.009	0.009	0.006
V8	0.081	-0.011	0.014	0.006
V9	0.082	-0.010	0.013	0.005
V10	0.093	-0.005	-0.005	-0.031
V11	0.080	-0.007	-0.017	-0.013
V12	0.081	-0.012	-0.037	0.018
V13	0.083	-0.010	0.010	0.003
CCR (%)	89.1	92.3	94.8	96.7

Table 10. Result of DA using log-transformed length

discriminant function : Z = 296.558*(PC2)+269.061*(PC3)-22.025

			predicted group		total
		group	"J group"	"O group"	
original data	freqency	"J group"	6	0	6
		"O group"	18	104	122
	percentage	"J group"	100.0	0.0	100.0
		"O group"	14.8	85.2	100.0

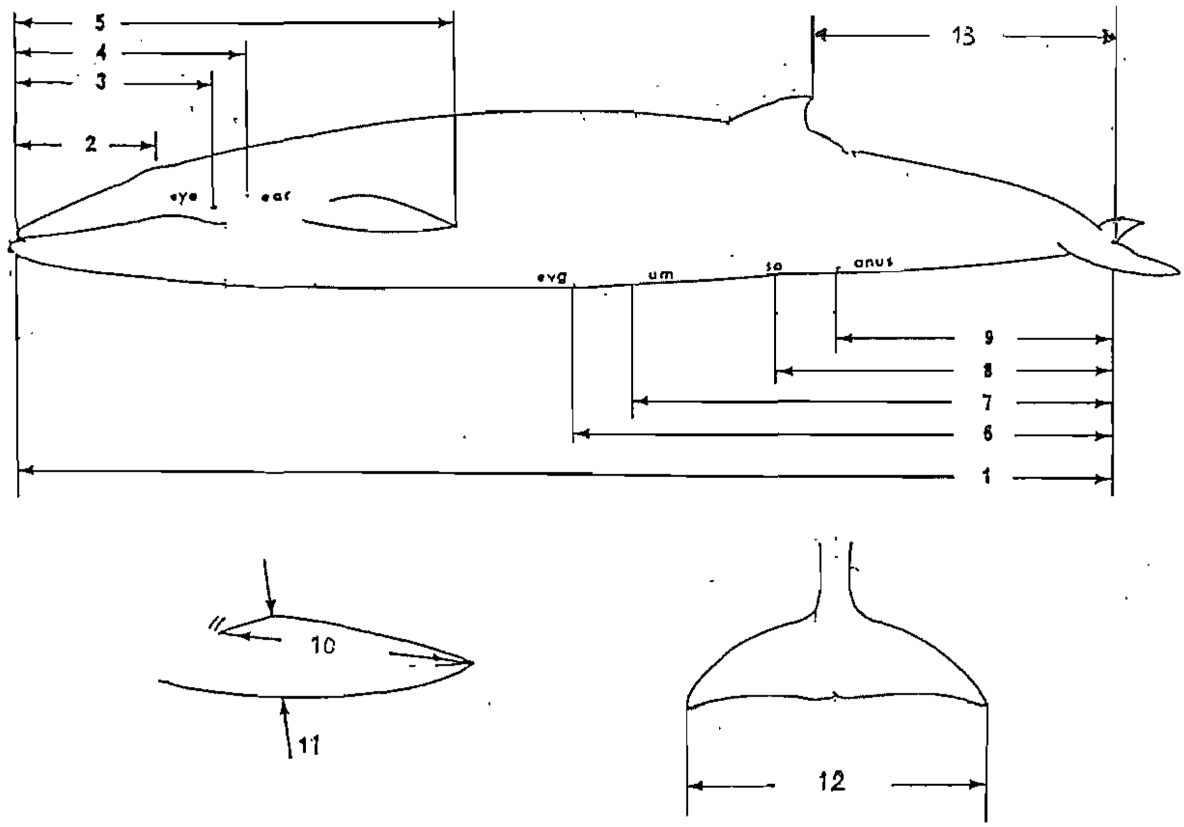
The percentage of correct classification 85.9%

Table 11. Result of DA using the proportion to body length

discriminant function : Z = -1.502*(V2%)+5.448*(V11%)-1.576

			Predicted group		total
		group	"J group"	"O group"	
original data	freqency	"J group"	6	0	6
		"O group"	22	100	122
	percentage	"J group"	100.0	0.0	100.0
		"O group"	18.0	82.0	100.0

The percentage of correct classification 82.8%



V1. Total length
V2. Tip of snout to blowhole
V3. Tip of snout to eye
V4. Tip of snout to ear
V5. Tip of snout to tip of flipper
V6. Notch of flukes to end of ventral groove
V7. Notch of flukes to umbilicus
V8. Notch of flukes to reproductive aperture
V9. Notch of fluke to anus
V10. Flipper, tip to posterior insertion
V11. Flipper, maximal width
V12. Flukes, tip to tip
V13. Notch to flukes to tip of dorsal fin

Fig. 1 List of measurements used for this study

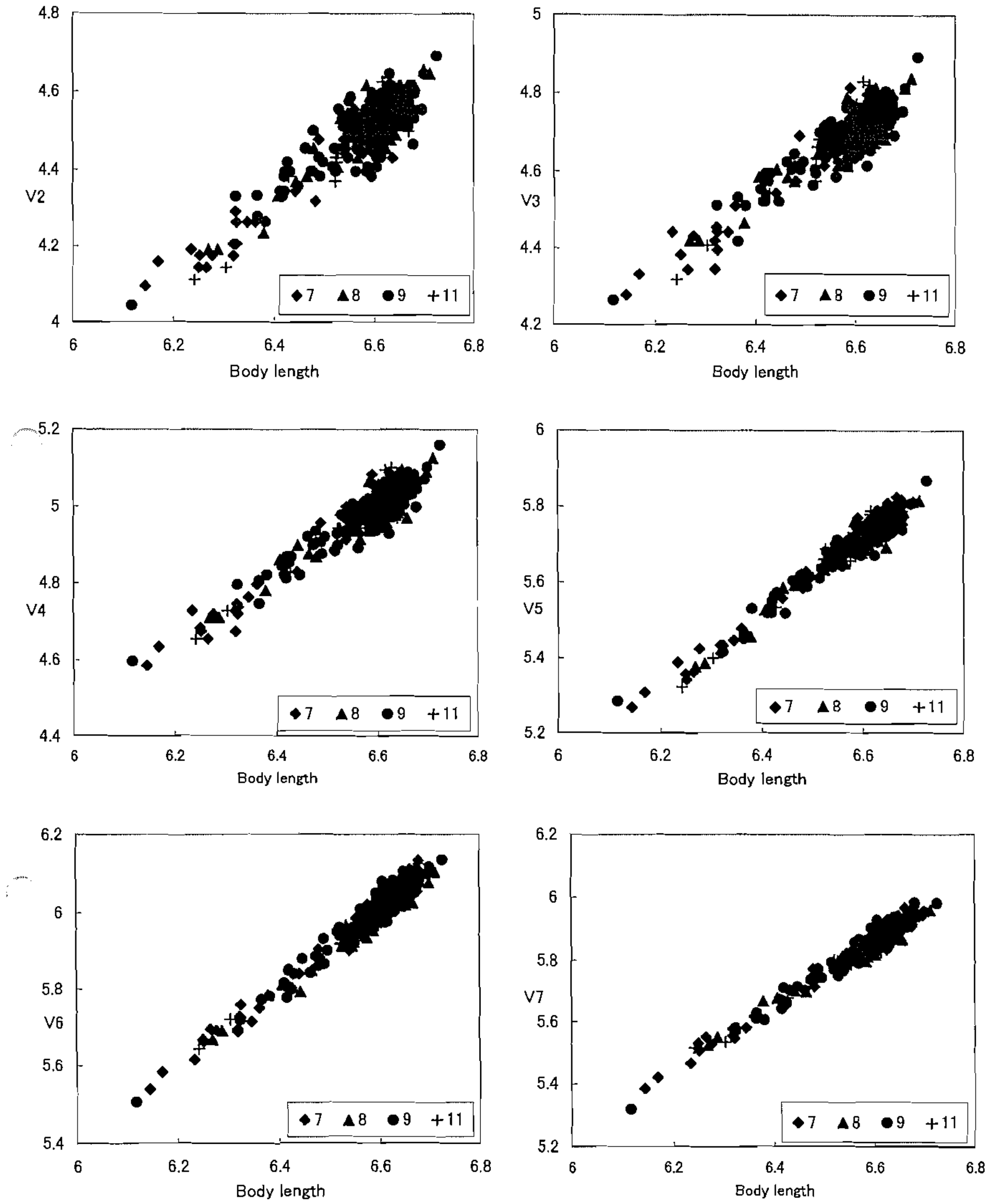


Fig. 2. Plots of logarithms of length of V2–V13 to one of body length

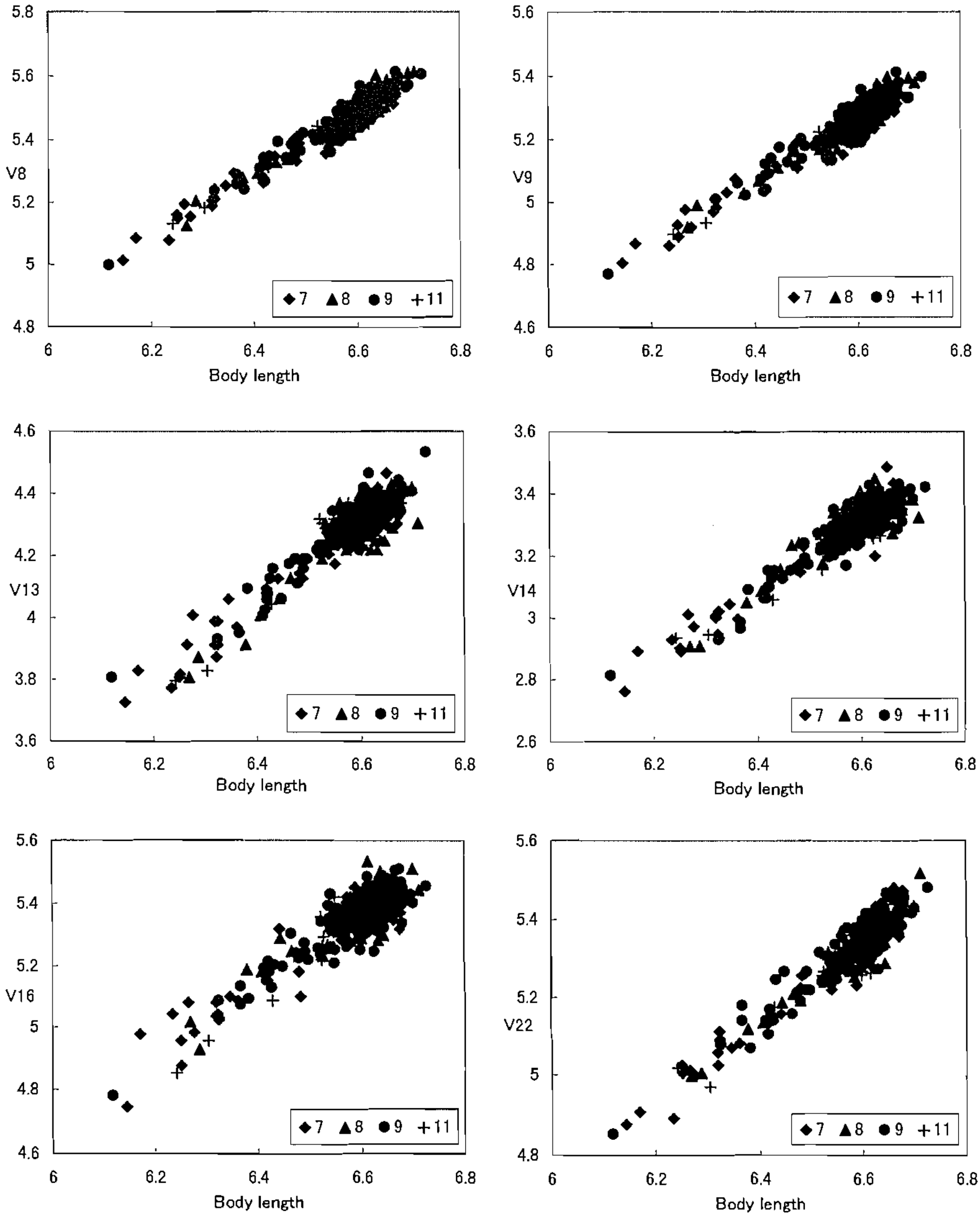


Fig. 2. (continued)