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# A Preliminary Morphometric Study in Minke Whales from Antarctic Area IV using Data from the 1989/90 JARPA Survey

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## ABSTRACT

A preliminary morphometric analysis was conducted in the southern minke whale from Antarctic Area IV using samples obtained during the 1989/90 JARPA survey in this area. The variation of 16 external measurements was examined in 326 minke whales grouped under spatial and temporal criteria. The 'growth' or 'size' is the most effective factor accounting for the variation of the measurements. A principal component analysis revealed that other factors related to the shapes of dorsal fin and flukes and size of skull, accounted for morphometric variation. An analysis of covariance that used body length as a covariate, suggested that the base length of dorsal fin and the width of flipper differed significantly among three time/area groups of males minke whales in Area IV. In females, only the base length of the dorsal fin differed among the groups. In addition, a canonical discriminant analysis revealed that the three time/area groups were not separated exactly. Whales from the eastern part of Area IV sampled in an early period of the feeding season shared almost the same range with those from the western part of Area IV sampled in a late period. A group of whales distributed in the western part of Area IV in an early period showed a wider variation than the other groups. My results are consistent with two hypothesis: 1) mixing of whales with different external characters in the western part of Area IV in an early period, 2) some of the external characters change in the feeding season due to fattiness.

## INTRODUCTION

Studies on morphology of minke whale had been conducted to identify stocks in the Antarctic (Doroshenko, 1979; Wada and Numachi, 1979). However, these authors could not conclude which morphological character is most adequate to identify the stocks. This is probably due to the variations in the characters which were caused by seasonal and temporal fluctuations of distribution pattern of minke whales in the Antarctic.

During the Japanese Whale Research Program in the Antarctic (JARPA) surveys, external characters of each minke whale sampled in Areas IV and V have been routinely measured. In addition, samples for genetic examination have been also obtained to solve the problem of stock identification. Recently, results obtained from several studies, such as genetics and segregation, suggested that the stock structure of minke whales in the research area is more complicated than it was thought previously and it may fluctuated yearly (Pastene *et al.*, 1994; Fujise *et al.*, 1994). Also a genetic study suggested that a group of whales with a different haplotype composition of mtDNA, migrated to the western part of Area IV in December and early January (Pastene *et al.*, 1995).

In this study morphological differences among minke whales from Antarctic Area IV are examined. The study was based on the analysis of sixteen external characters measured, and whales from the 1989/90 JARPA were grouped under spatial and temporal criteria.

## MATERIALS AND METHODS

### Morphometric Data

Morphological data used in this study were those obtained during the 1989/90 JARPA survey in Area IV. A total of 329 minke whales, including tree dwarf forms, were taken and measured in the survey (Fujise *et al.*, 1990). In this study, sixteen morphometric characters were examined for 326 ordinal minke whale (Fig. 1) as follows:

V1: from tip of snout to notch of flukes
V2: from tip of snout to center of blowhole
V3: from tip of snout to center of eye
V4: from tip of snout to ear
V5: from tip of snout to tip of flipper grooves
V6: from tip of snout to end of ventral ~~gloves~~
V7: from tip of snout to center of umbilicus
V8: from tip of snout to sexual apparatus
V9: from tip of snout to anus
V10: base of dorsal fin
V11: height of dorsal fin
V12: from tip of flipper to anterior insertion
V13: from tip of flipper to posterior insertion
V14: width of flipper
V15: depth of flukes
V16: width of flukes

All the measurements were made by the author.

### Grouping of Samples

Three time/area groups were divided arbitrarily by location and date as follows:

| Group | Sampling location | Sampling period |
|---|---|---|
| Eastern Early (E-E): | 100°E-130°E | Dec. 31 - Jan. 17 |
| Western Early (W-E): | 70°E-100°E | Dec. 6 - Dec. 29 |
| Western Late (W-L): | 70°E-100°E | Jan. 21 - Feb. 14 |

### Statistical analysis

In order to determine factor effect in the variation of the measurements, a principal component analysis (PCA) was adopted (Tanaka *et al.*, 1984a). In this analysis, log-transformed data of 16 measurements for 169 males and 127 females were examined, but other 33 animals were not used in this analysis because of lack of data.

The variation of the morphological measurements was assessed univariately among these groups with an analysis of covariance (ANCOV) using body length (V01) as a covariate. This was made in order to take into account the body length effect on the other measurements (Jover, 1992; Tanaka and Tarumi, 1986; Amano and Miyazaki, 1992).

To visualize the differences among the three groups, a canonical discriminant analysis was applied (Tanaka *et al.*, 1984b; Christensen *et al.*, 1990; Kato *et al.*, 1992). In this analysis, data were converted to the ratio to body length. Only fifteen items of proportion for 169 males and 127 females were examined because of lack of data. Sample size in each group (E-E, W-E and W-L) was 41, 88 and 40 for males, and 51, 28 and 48 for females, respectively.

## RESULTS AND DISCUSSION

Fifteen measurements of body proportion were plotted to their body length (Figs. 2 and 3). All the 15 items increased with growth of body length in both sexes. Larger variations are observed for items V10 and V11 for both sexes. These two items were related to the shape of dorsal fin.

The first five principal components for males are shown in Table 1, with the percentages accounted for by each component. Those for females are shown in Table 2. The eigenvector of the first principal component (PC1) is relatively high and positive for all variables in both sexes. Thus, PC1 seems to reflect the growth or 'size' axis as same as it was shown in previous studies (Christensen *et al.*, 1990; Tanaka *et al.*, 1984a). Proportion of the first component covers 86.6% of the total variation of the measurements in male animals, and 91.9% in females. The second principal component (PC2) is positive for items related with dorsal fin (V10 and V11) and negative for items related to the trunk (V2-V9). The PC3 is also positive for V10 but negative for V11. The PC2 and PC3 may be related to shape of dorsal fin. In a similar manner adopted to PC4 and PC5. The PC4 may be related to the snout or skull lengths (V2-V4), and PC5 related to the shape of the tail flukes (V15-V16).

Table 3 shows the results of the univariate comparison (ANCOV) among time/area groups for males and females. In both sexes, the slope of the covariate (V1) for all items does not differ significantly by time/area group, excepting two items for females (V2 and V10). Difference in the length of item by group was observed in V10, V12 and V14 for male groups. Base length of dorsal fin (V10) and width of flipper (V14) were significantly larger in the W-E group than in the other groups. Although length of V12 (from tip of flipper to anterior insertion) was also larger in the W-E group than other groups, the difference was not significant. For females, five lengths (V5, V10, V11, V12 and V13) were significantly different by groups. As same as in males, length of V10 was larger in the W-E groups than in the other groups. Although not all differences were statistically significant, we can summarize the following: V5 (from tip of snout to tip of flipper) and V12 were larger in the E-E group, V11 (height of dorsal fin) was larger in the Western groups (W-E and W-L), and V13 (from tip of flipper to posterior insertion) was larger in the E-E and W-L groups.

Fifteen items of body proportions were examined by a canonical discriminant analysis. Eigenvalues and eigenvectors derived from the discriminant analysis are shown in Table 4 in each canonical variate (CAN). The plots of the two canonical variates are shown in Figs. 4 and 5 for males and females, respectively. For both sexes, it seems that the E-E and W-L groups were almost overlapped within a range and the W-E group plotted wider than the other groups. This may be clear for x-axis (first canonical variate). Contribution of the first canonical variate is higher in V12 and V14 for males. In the case of females the variate is higher in V10 and V14. Considering the results for both sexes, it seems that items V10, V12 and V14 are more contributable to the variate.

From the above analyses, morphology of minke whales collected from Antarctic in the 1989/90 austral summer season reveals significant differences among three time/area groups, specially between W-E groups and the other groups. Our results are consistent with two possibilities: one is that a group of whales with different morphological characters migrated into the western part of Area IV in the early migrating season. If a similar analysis is conducted using data for the 1991/92 season (a preliminary analysis in progress), results obtained indicates two distinctive groups: early groups (W-E and E-E) and another one is later groups (W-L and E-L). This phenomenon suggests some degree of yearly variation. These results coincide with those derived from mtDNA analyses by Pastene *et al.* (1995).

Another possibility is that the external characters of minke whale change in the feeding season. The blubber thickness of lateral zone at dorsal fin of minke whale increased from 3cm up to 6cm in the feeding seasons (Kato *et al.*, 1989). However, sampling activities were conducted in a serial mode as mentioned above, and thus this could not explained the reason why morphological differences were observed between the W-E and the other groups. Future examination should be incorporated on the temporal factors for the morphological change in a feeding season.

The results from this study are preliminary, because samples used were from only one austral summer season. Further analysis covering more austral summer seasons should be conducted before reach a conclusion. If so, measurement variation among researchers participating in the survey must be examined.


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Table 1. Eigenvectors of the covariance matrix on the first five principal components (PC1-PC5) from a PCA of log-transformed 16 measurements of male minke whales

| Measurement | PC1 | PC2 | PC3 | PC4 | PC5 |
|---|---|---|---|---|---|
| V1 | 0.23507 | -0.06983 | 0.02638 | 0.06533 | -0.02179 |
| V2 | 0.27211 | -0.14403 | -0.09555 | 0.32692 | -0.01462 |
| V3 | 0.24981 | -0.17319 | -0.09383 | 0.30494 | -0.08237 |
| V4 | 0.23833 | -0.15341 | -0.07058 | 0.27473 | -0.04810 |
| V5 | 0.25023 | -0.12047 | -0.01296 | 0.03565 | -0.11082 |
| V6 | 0.24454 | -0.09833 | -0.03738 | 0.17194 | -0.06164 |
| V7 | 0.24301 | -0.10056 | -0.04358 | 0.09448 | -0.05490 |
| V8 | 0.24267 | -0.09681 | -0.01018 | 0.07035 | -0.04890 |
| V9 | 0.23957 | -0.09848 | -0.00102 | 0.08156 | -0.04955 |
| V10 | 0.23345 | 0.58999 | 0.71745 | 0.24130 | -0.11682 |
| V11 | 0.26831 | 0.70222 | -0.64369 | -0.08946 | -0.08826 |
| V12 | 0.27008 | -0.09833 | 0.09202 | -0.38233 | -0.29281 |
| V13 | 0.28640 | -0.10921 | 0.10189 | -0.50971 | -0.19781 |
| V14 | 0.26346 | -0.05858 | 0.08554 | -0.41863 | 0.07248 |
| V15 | 0.20323 | 0.03527 | 0.12498 | -0.14685 | 0.62507 |
| V16 | 0.24814 | 0.00443 | -0.04431 | 0.00217 | 0.65116 |
| Proportion | 0.86666 | 0.05861 | 0.02105 | 0.01561 | 0.01202 |

Table 2. Eigenvectors of the covariance matrix on the first five principal components (PC1-PC5) from a PCA of log-transformed 16 measurements of female minke whales

| Measurement | PC1 | PC2 | PC3 | PC4 | PC5 |
|---|---|---|---|---|---|
| V1 | 0.23868 | 0.02044 | -0.00165 | 0.11481 | 0.05169 |
| V2 | 0.27240 | -0.05772 | -0.16114 | 0.29905 | 0.07988 |
| V3 | 0.26196 | -0.10542 | -0.14919 | 0.28402 | 0.00783 |
| V4 | 0.24506 | -0.09920 | -0.09079 | 0.23670 | 0.05041 |
| V5 | 0.25556 | -0.10697 | -0.05409 | 0.06901 | -0.09804 |
| V6 | 0.24961 | -0.02852 | -0.03603 | 0.19849 | 0.08622 |
| V7 | 0.24510 | -0.02409 | -0.05304 | 0.15493 | 0.09944 |
| V8 | 0.24513 | -0.01684 | -0.04358 | 0.16077 | 0.07007 |
| V9 | 0.24427 | -0.01332 | -0.03376 | 0.15622 | 0.07059 |
| V10 | 0.20619 | 0.52770 | 0.77124 | 0.20858 | -0.14286 |
| V11 | 0.19604 | 0.76764 | -0.54333 | -0.22023 | -0.13548 |
| V12 | 0.28287 | -0.20359 | 0.10237 | -0.22957 | -0.37757 |
| V13 | 0.29657 | -0.21258 | 0.01730 | -0.30699 | -0.55710 |
| V14 | 0.27107 | -0.08564 | 0.07026 | -0.34917 | -0.00283 |
| V15 | 0.21409 | -0.01558 | 0.12474 | -0.26172 | 0.45704 |
| V16 | 0.25392 | -0.00631 | 0.11032 | -0.46143 | 0.50094 |
| Proportion | 0.91934 | 0.03473 | 0.01201 | 0.00920 | 0.00894 |

Table 3. Results of ANCOV between time/area groups (E-E: Eastern early, W-E: Western early, W-L: Western late) for each measurement, with body length (V1) as a covariate. *: $p<0.05$, **: $p<0.01$.

| | Male | | | | | | | Female | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | E-E | | W-E | | W-L | | F-value | E-E | | W-E | | W-L | | F-value |
| | Mean | n | Mean | n | Mean | n | | Mean | n | Mean | n | Mean | n | |
| V2 | 4.740 | 46 | 4.741 | 94 | 4.742 | 44 | 0.01 | 4.778 | 58 | 4.775 | 31 | 4.763 | 53 | 1.28 |
| V3 | 5.013 | 46 | 5.013 | 94 | 5.012 | 44 | 0.00 | 5.054 | 58 | 5.034 | 31 | 5.037 | 53 | 2.95 |
| V4 | 5.250 | 46 | 5.247 | 93 | 5.246 | 44 | 0.18 | 5.281 | 57 | 5.267 | 31 | 5.267 | 53 | 2.43 |
| V5 | 5.873 | 46 | 5.877 | 94 | 5.874 | 43 | 0.44 | 5.898 | 54 | 5.879 | 31 | 5.882 | 51 | 5.14** |
| V6 | 5.983 | 46 | 5.984 | 94 | 5.974 | 44 | 2.18 | 6.000 | 58 | 5.996 | 31 | 5.997 | 53 | 0.27 |
| V7 | 6.070 | 46 | 6.066 | 93 | 6.060 | 44 | 2.56 | 6.080 | 58 | 6.073 | 31 | 6.074 | 53 | 1.30 |
| V8 | 6.278 | 46 | 6.276 | 94 | 6.276 | 44 | 0.38 | 6.344 | 58 | 6.337 | 31 | 6.341 | 53 | 1.70 |
| V9 | 6.386 | 46 | 6.383 | 94 | 6.383 | 44 | 1.13 | 6.387 | 58 | 6.382 | 31 | 6.383 | 53 | 1.82 |
| V10 | 4.116 | 45 | 4.179 | 92 | 4.126 | 42 | 7.31** | 4.083 | 57 | 4.190 | 29 | 4.121 | 53 | 14.30** |
| V11 | 3.445 | 44 | 3.453 | 92 | 3.421 | 43 | 1.16 | 3.382 | 58 | 3.420 | 30 | 3.439 | 53 | 4.29* |
| V12 | 4.863 | 44 | 4.887 | 93 | 4.872 | 42 | 4.11* | 4.890 | 53 | 4.860 | 30 | 4.863 | 50 | 3.73* |
| V13 | 4.424 | 44 | 4.435 | 94 | 4.446 | 43 | 1.64 | 4.463 | 54 | 4.422 | 31 | 4.448 | 50 | 3.37* |
| V14 | 3.360 | 46 | 3.381 | 94 | 3.362 | 44 | 3.40* | 3.397 | 58 | 3.396 | 31 | 3.384 | 53 | 0.77 |
| V15 | 4.103 | 45 | 4.113 | 94 | 4.099 | 44 | 1.08 | 4.132 | 58 | 4.115 | 31 | 4.124 | 53 | 0.95 |
| V16 | 5.394 | 46 | 5.387 | 93 | 5.394 | 44 | 0.34 | 5.407 | 58 | 5.404 | 31 | 5.394 | 52 | 0.62 |

Table 4. Eigenvectors and Eigenvalues in each measurements in each canonical variate from a Canonical Discriminant Analysis using log-transformed values and proportion to body length 16 measurements of minke whales.

| Measurement | Male | | Female | |
|---|---|---|---|---|
| | CAN1 | CAN2 | CAN1 | CAN2 |
| V2 | -26.0225 | -72.1078 | 5.2643 | -11.4316 |
| V3 | -13.3628 | 126.5850 | -95.5597 | -16.2628 |
| V4 | 55.5607 | -51.0330 | 70.7812 | 56.8587 |
| V5 | -19.5900 | 17.6900 | 33.5259 | -99.2912 |
| V6 | -28.5716 | 4.0227 | -14.3346 | 45.1949 |
| V7 | -10.5471 | -94.7562 | -7.7347 | -20.8190 |
| V8 | -14.7507 | 38.4929 | -26.9821 | 108.3980 |
| V9 | 60.0062 | -28.4137 | 18.3187 | -112.5120 |
| V10 | -53.9928 | 36.1650 | 116.0920 | -0.7602 |
| V11 | 49.8202 | -56.6931 | -19.7566 | 132.7570 |
| V12 | -167.4600 | -36.1829 | 2.9459 | -37.8582 |
| V13 | 235.7490 | 71.7341 | -118.1330 | 174.3560 |
| V14 | -294.9550 | 68.2167 | 141.4120 | -21.0233 |
| V15 | -38.6368 | 7.3210 | -33.3669 | -54.6903 |
| V16 | 20.4737 | -3.0277 | -9.5419 | -0.0231 |
| Eigenvalue | 0.3858 | 0.0709 | 0.5627 | 0.1943 |

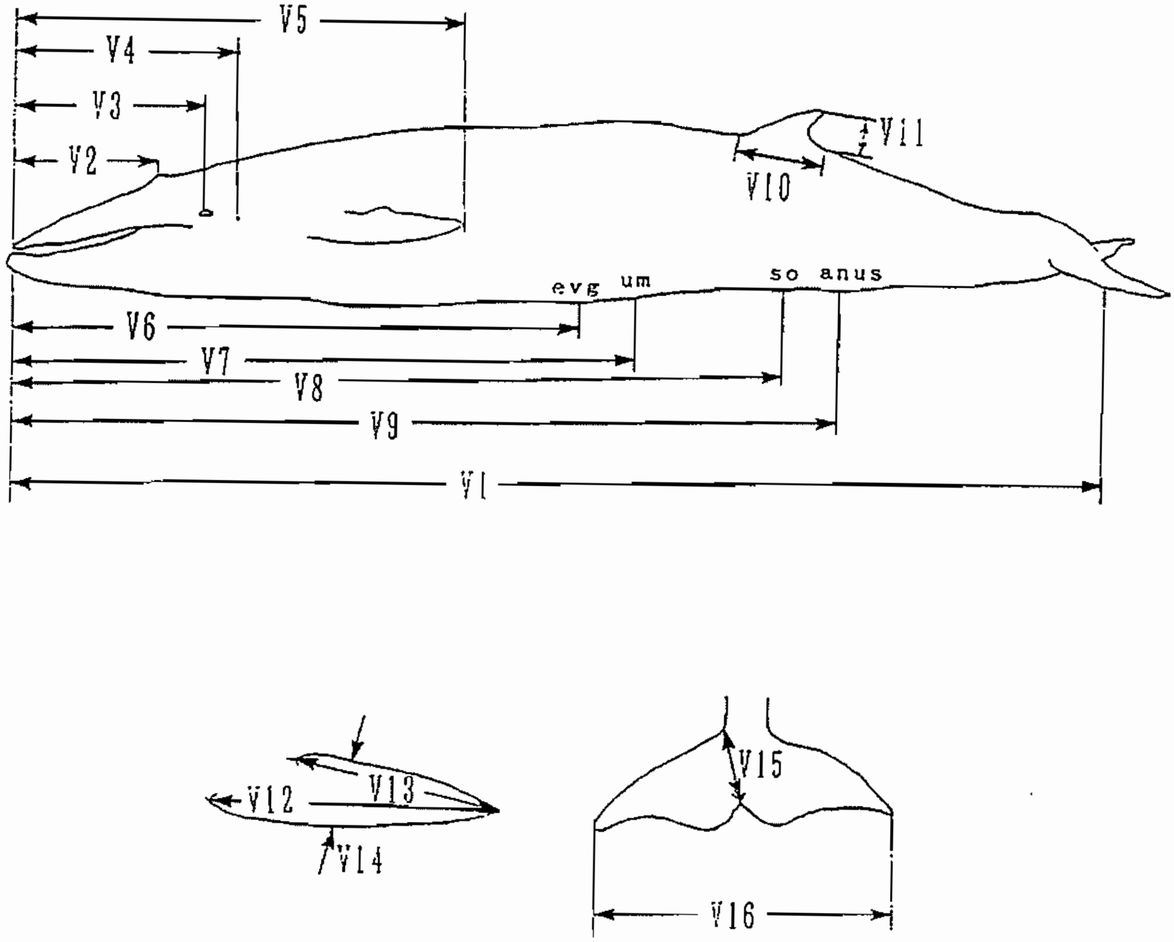


Fig. 1. Schematic diagram of body proportion measurements (See Text).

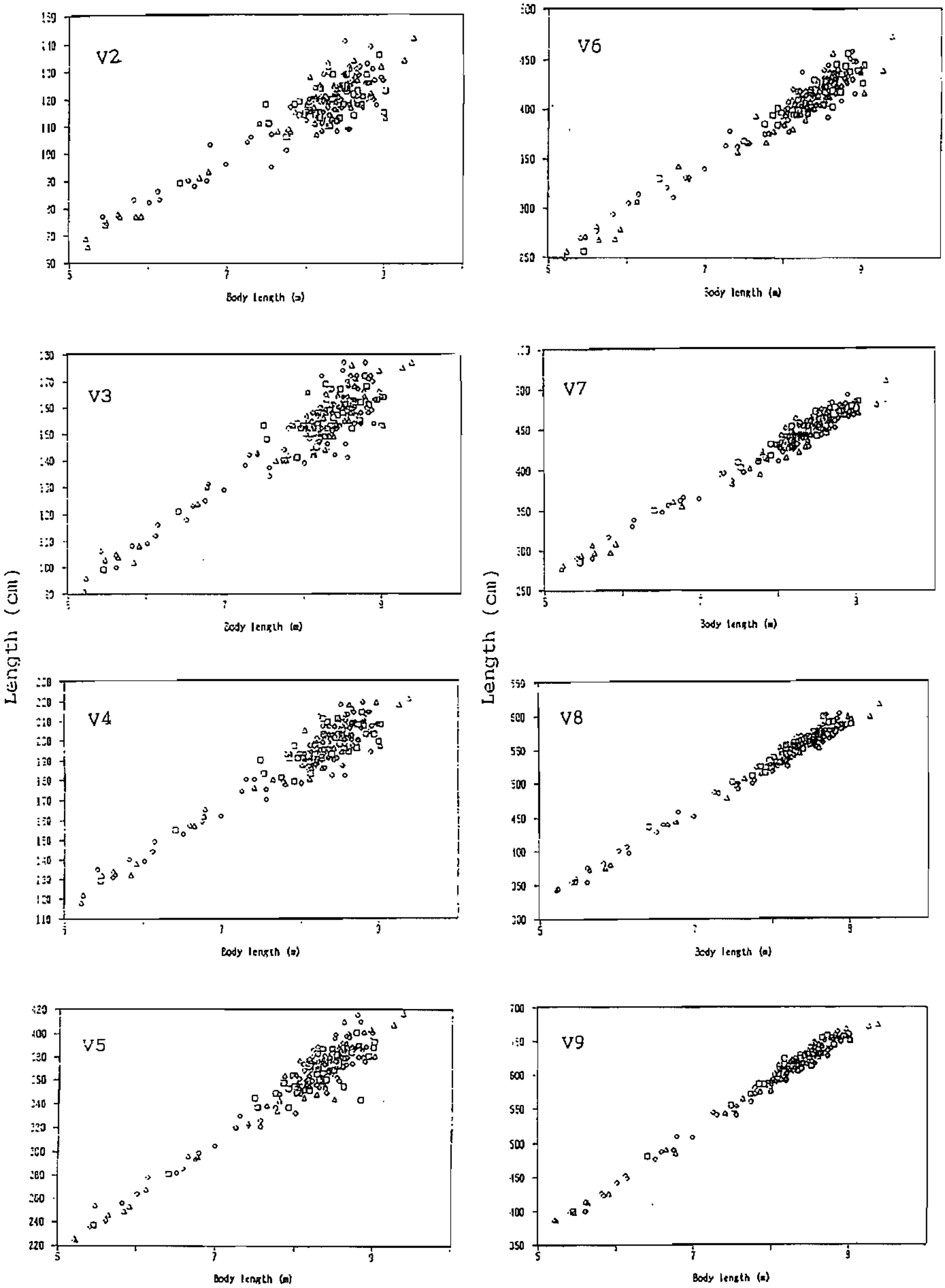


Fig. 2. Relationships between body length and 15 measurements of body proportions for male minke whales by the time/area groups.
□: E-E, ◇: W-E, △: W-L.

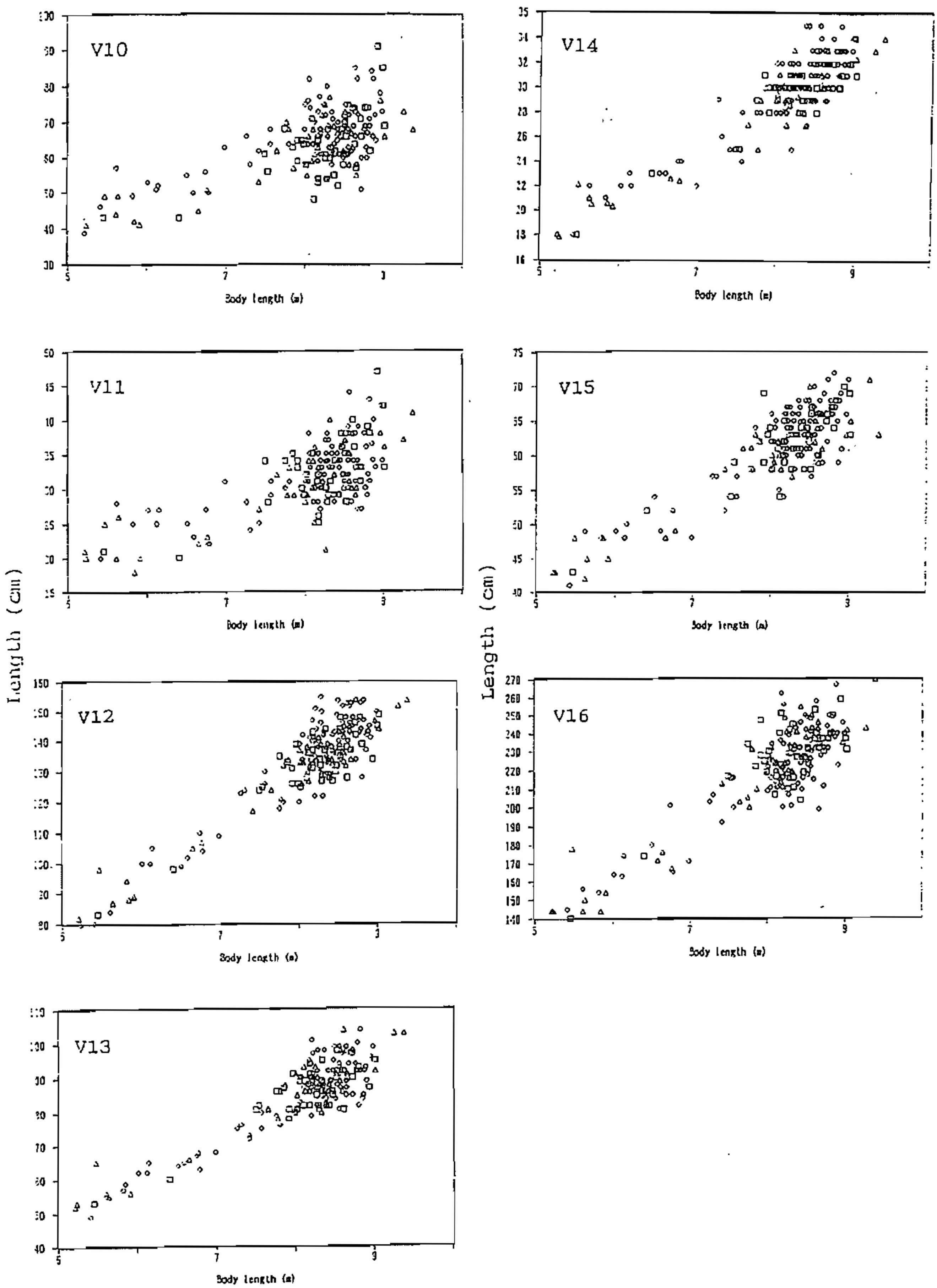


Fig. 2. (Continued).

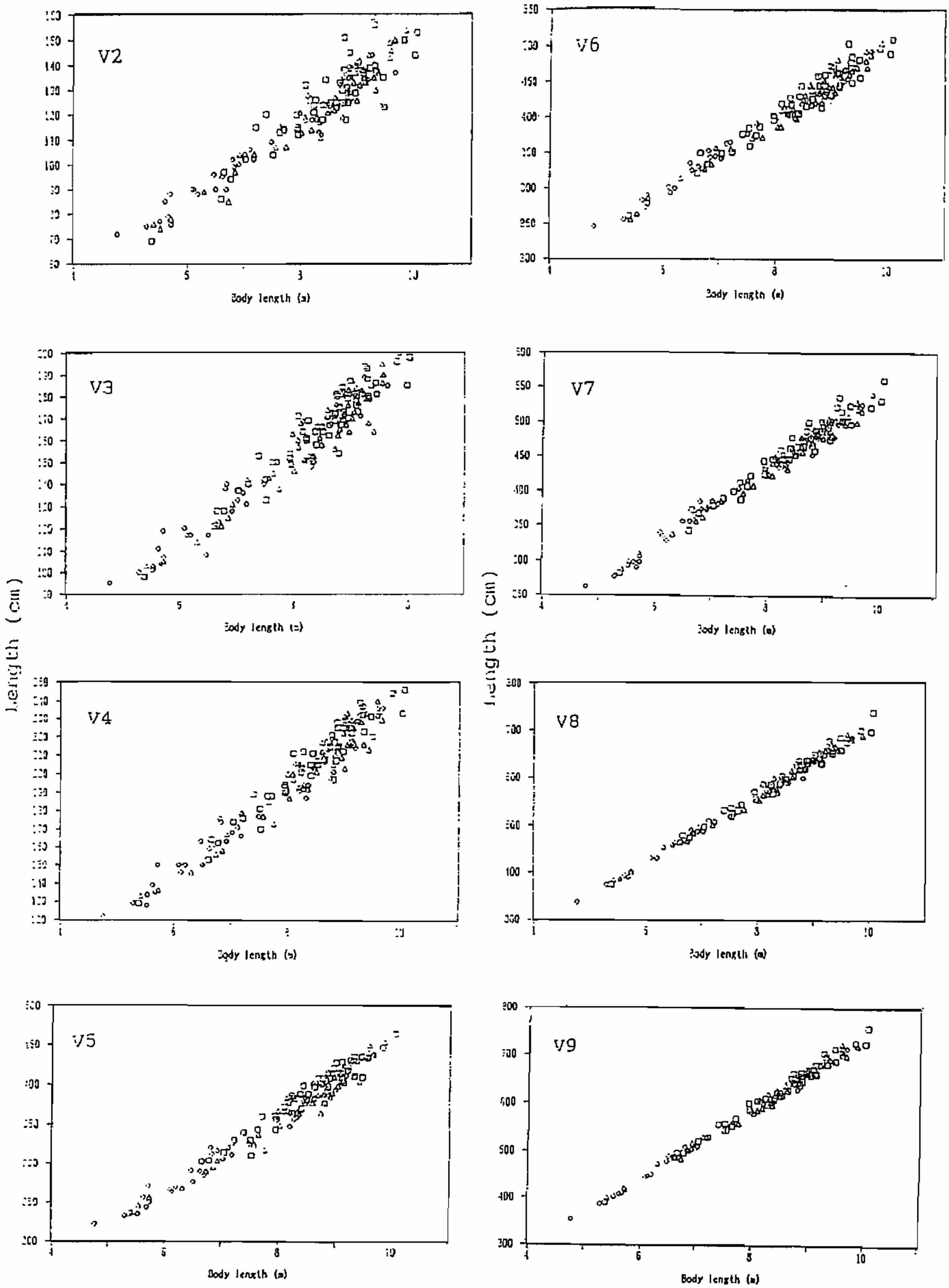


Fig. 3. Relationships between body length and 15 measurements of body proportions for female minke whales by the time/area groups. □: E-E, ◇: W-E, △: W-L.

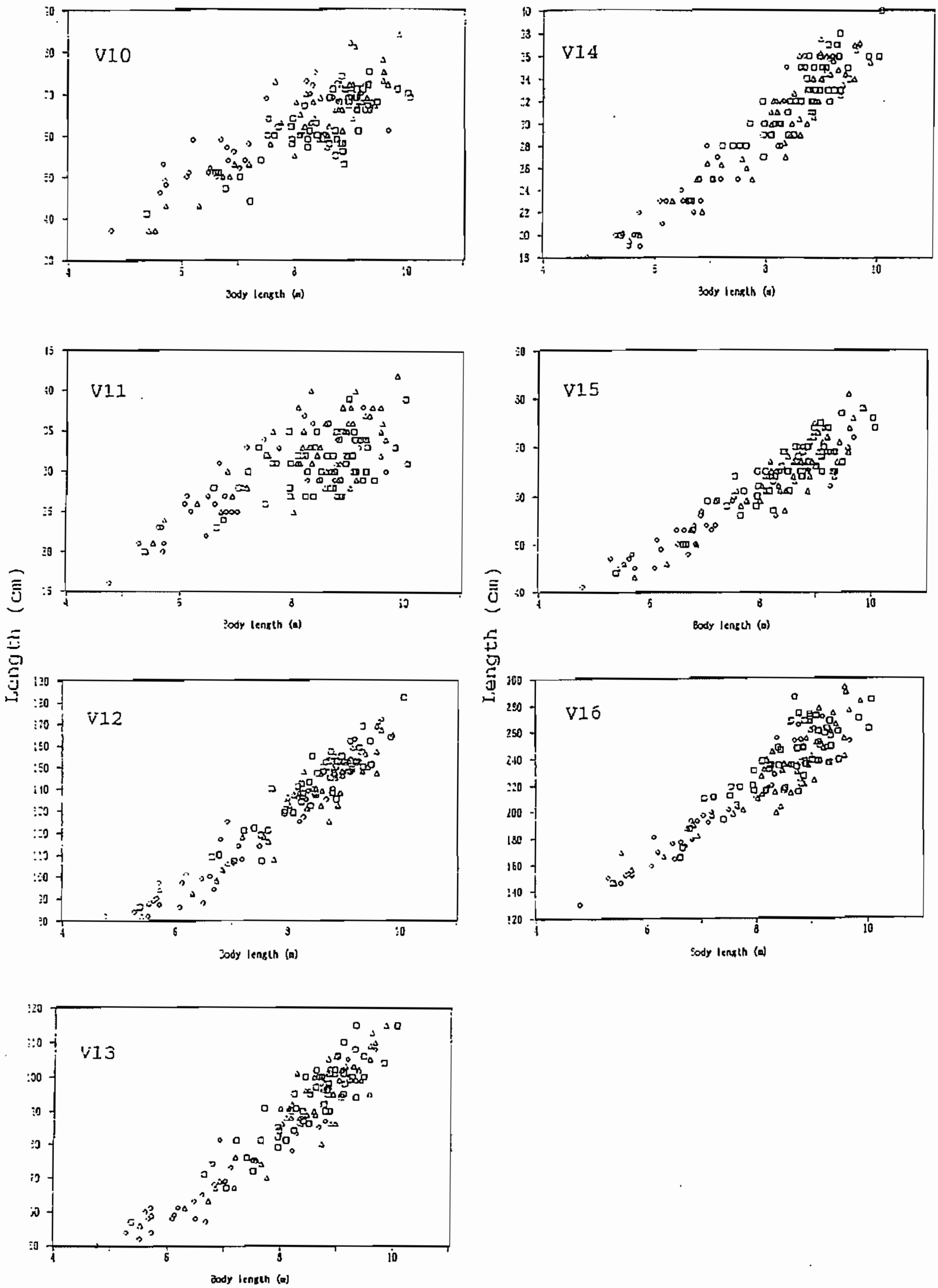


Fig. 3. (Continued).

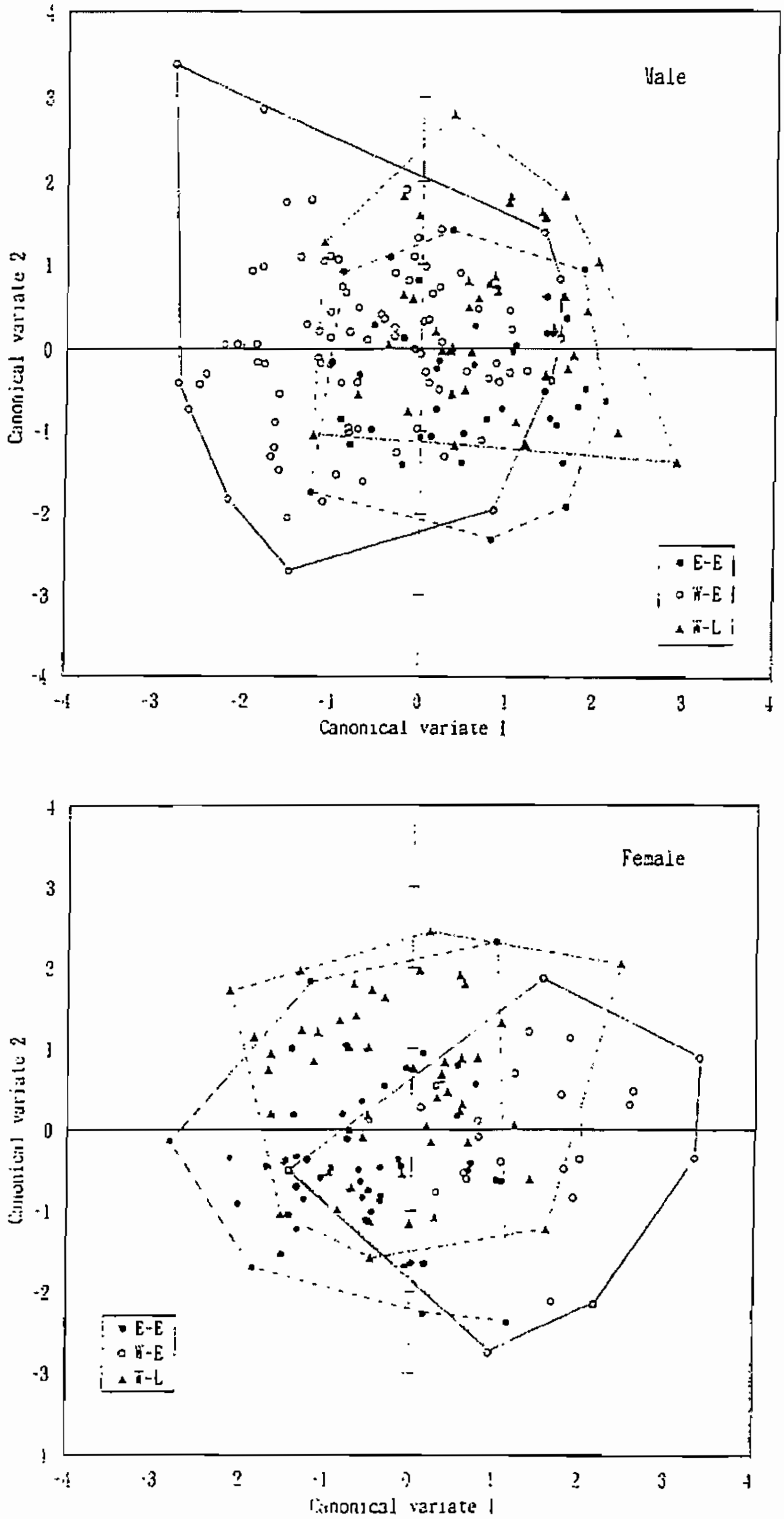


Fig. 4. Relative separation of the three time/area groups of minke whales in Antarctic Area IV based on plots of the first and second canonical variates as determined by canonical discriminant analysis using 15 items of body proportion.