Further morphometric analysis on stock structure in the western North Pacific common minke whales (*Balaenoptera acutorostrata*)

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ABSTRACT

Morphometric analysis on stock structure in western North Pacific common minke whales was conducted based on Principal Component Analysis (PCA) and discriminant analysis, following a recommendation from the JARPN II Review Workshop. Results of this analysis suggested significant difference in morphometrics between the 'J' and the 'O' stocks but no significant differences among 'O'-stock common minke whales from longitudinal sectors in the western North Pacific. Results from the PCA are consistent with those presented by Hakamada and Bando (2009) to the JARPN II Review Workshop (SC/J09/JR27).

INTRODUCTION

The International Whaling Commission's Scientific Committee (IWC SC) carried out a Workshop to review the progress made in the research conducted under the Japanese Whale Research Programme under Special Permit in the North Pacific-Phase II (JARPN II) in its first six years (2002-2007). The review was carried out by an Independent Expert Panel (IEP) who examined primary papers related with the research objectives of JARPN II.

One of the objectives of the JARPN II is the elucidation of stock structure in large whales and regarding to this objective a total of eight primary papers on common minke, Bryde's, sei and sperm whales were presented to the review workshop. Hakamada and Bando (2009) (SC/J09/JR27) presented the results of a morphometric analysis of common minke whales, based on ANCOVA using body length as a covariate. Differences were found between 'J' and 'O'-stocks animals identified by the genetic analyses, however, no significant differences were found among 'O'-stock animals from sub-areas 7, 8 and 9.

During the review workshop the IEP suggested that another option for the analysis would be to use a Principle Component (or similar) Analysis (PCA) of individuals that does not require a priori decisions about group membership. It noted that PCA does not attempt to define groups but can reveal patterns in the data related to time or place of sampling (IWC, 2009). In response additional morphometric analysis based on PCA were conducted to investigate further stock structure of western North Pacific common minke whales. The first objective of the study was to compare external measurements between 'O' and 'J'-stocks animals as identified by the microsatellite analysis. The second objective of this study was to compare O-stock minke whales from several longitudinal sectors in the western North Pacific.

MATERIALS AND METHODS

Materials

Minke whales sampled by JARPN II surveys in sub-areas 7 (140°-150°E), 8 (150°-157°E), and 9 (157°E-170°E) between 2000 and 2007, were used in the analysis. Only mature male animals were used because body proportion could be different between mature and immature animals and because the very limited number of mature females in the research area. Males of minke whales were defined as sexually

mature by testis weight (larger side) of more than 290g (Bando *et al*., unpublished data).Although the effect of the difference among researchers has not been fully examined, at this stage the data from a single researcher who measured samples in all longitudinal sectors in different years, were used. As a consequence sample size for 'J' stock is small (n=2).

To compare external measurements between 'O' and 'J' stocks, whales were separated into two groups, 'J' (n=2) and 'O' (n=118) stocks according to the results of the microstellite analysis (Kanda *et al*., 2009). To compare O-stock minke whales from different longitudinal sectors the 118 O-stock whales were divided according to the six longitudinal sectors used during JARPN surveys: 7W (140°-147°E), 7E (147°-150°E), 8W (150°-153°E), 8E (153°-157°E), 9W (157°E-162°E), 9E (162°-170°E) (Figure 1 SC/J09/JR27). External measurements that were considered to be less susceptible to measuring error were selected for the analysis. Selection of these measurements took into consideration the opinion of experienced researchers. We also excluded girth because they are likely to change in the feeding season, according to sampling date. The ten external measurements used are shown in Figure 2 of Hakamada and Bando (2009) (SC/J09/JR27). Logarithms of the measurements were used for the analyses.

Analytical procedure

First PCA was used to extract principal components (PC) from the 11 measurements used in Hakamada and Bando (2009) (SC/J09/JR27). A total of 11PCs was obtained from 11 measurements. Component matrix is shown in Table 1. The first PC (PC1) is positively correlated to all measurements V1-V11 and therefore it can be interpreted as an index of growth. Consequently PC1 was eliminated from the analysis. Second, discriminant analysis was conducted using the second to the eleventh PCs (PC2-PC11). To determine the discriminant function, stepwise variable selection was conducted. If F-statistics is more than 3.84, the PC was included in the discriminant function. If F-statistics was less than 2.71, the PC was removed from the function. This procedure is a combination of forward selection and backward selection (Landau and Everitt, 2001).

RESULTS AND DISCUSSION

For the comparison between the 'J' and 'O' stocks, PC2 and PC8 were selected as variants of discriminant function. This implies that the score of the 2 PCs significantly differed between 'J' and 'O' stocks. From Table 1, PC2 is interpreted an index on whether an animal has smaller heads and longer lower half of the body and PC8 is interpreted as an index on length between end of ventral gloves and center of umbilicus. From the results of discriminant analysis, morphological features of 'J'-stock animals are that they have longer head and shorter lower half of the body than 'O'-stock animals and that their lengths between end of ventral gloves and center of umbilicus is longer than those of 'O'-stock animals.

In order to evaluate the accuracy to correctly discriminate 'J' and 'O'-stocks animals, discriminant function was applied to the total samples and 88.3% of the original data were discriminated correctly as shown in Table 2. It should be noted that the small sample size of 'J'-stock animals could overestimate the accuracy of the discriminant function. Notwithstanding this result suggest that there are significant differences between the 'J' and 'O' stock in morphometric measurement.

It should be noted that 11.9% of 'O'-stock animals were discriminated incorrectly. This may be because a small fraction of the 'O'-stock animals have features of body proportions of 'J'-stock animals due to individual differences in morphometric measurements.

With regard to PC2, 'J'-stock animals have lower score than 'O'-stock animals. This means that 'J'-stock animals have longer heads and shorter half of the body. This agrees with the results of the estimated marginal mean of external measurements by ANCOVA in Hakamada and Fujise (2000) and Hakamada and Bando (2009) (SC/J09/JR27).

In the comparison among whales from different longitudinal sectors in the western North Pacific, no PC was selected for the discriminant function. In other words, there is no significant difference in morphometric measurements among O-stock whales from the longitudinal sectors.

In general results of this analysis based on PCA are consistent with those presented by Hakamada and Bando (2009) based on ANCOVA.

REFERENCES

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Table 1. Component matrix extracted by PCA. Bold letter indicates the PC's selected for discriminant function. PC*x* indicates the *x* th PC.

	PC1	**PC2**	PC3	PC4	PC5	PC6	PC7	**PC8**	PC9	PC10	PC11
V1	0.92	**0.30**	0.08	0.02	0.12	0.02	-0.06	**-0.01**	0.04	0.10	0.15
V2	0.81	**-0.46**	-0.18	-0.30	0.05	-0.03	-0.05	**0.01**	0.01	-0.01	-0.01
V3	0.83	**-0.49**	-0.10	0.17	-0.04	-0.14	0.03	**-0.03**	-0.10	-0.04	0.04
V4	0.88	**-0.39**	-0.01	0.20	-0.03	-0.13	0.02	**-0.01**	0.12	0.06	-0.06
V5	0.91	**-0.16**	0.07	0.21	0.07	0.18	-0.23	**0.04**	-0.01	-0.04	-0.03
V6	0.71	**0.58**	0.09	0.01	0.35	-0.09	0.10	**0.12**	-0.04	0.00	-0.04
V7	0.79	**0.56**	0.01	-0.03	0.08	0.03	0.02	**-0.23**	-0.01	-0.01	-0.03
V8	0.75	**0.64**	-0.07	0.01	-0.10	-0.03	0.02	**0.04**	0.08	-0.10	0.03
V9	0.74	**0.60**	-0.19	-0.03	-0.19	0.02	-0.01	**0.05**	-0.06	0.07	-0.03
V10	0.83	**-0.46**	0.01	0.02	-0.02	0.23	0.21	**0.02**	0.01	0.00	0.01
V11	0.71	**-0.08**	0.67	-0.14	-0.13	-0.05	-0.01	**0.01**	-0.02	0.00	-0.01

Table 2. Percentage of correction classified the 'J' and 'O'-stocks animals by the discriminant function.

			discriminated		
			O	J	total
original data	frequensy	O	104	14	118
		J	0	2	2
	%	O	88.1	11.9	100
		J	0.0	100.0	100