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A study on stock structure in the Antarctic minke whale from the JARPA research area based on analysis of body length of physically matured whales

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ABSTRACT

Stock structure of the Antarctic minke whales in the Antarctic feeding ground was investigated by analysis of mean body length of physically matured whales collected during JARPA surveys from 1987/88 to 2004/05 austral summer seasons in Areas IIIE, IV, V and VIW. Samples were grouped into the six longitudinal strata used by JARPA surveys: IIIE (35° -70° E); IVW (70° -100° E) (north and south); IVE (100° -130° E); VW (130° -165° E); VE (165° E-170° W) (north and south) and VIW (170° -145° W). Seasonal, latitudinal and longitudinal comparison of mean body length of physically matured whales was conducted. Significant differences of body length between longitudinal strata were found. Such differences are not consistent with a single stock scenario. Rather such differences suggest the occurrence of different stocks in the JARPA research area. The body length of physically matured whales in the western strata (IIIE, IVW, IVE, and VW) was significantly larger than that in the eastern strata (VE, VIW) for both sexes. Results of our analysis are consistent with the results of the genetic analysis, which suggest at least two stocks in the JARPA research area.

KEYWORDS: ANTARCTIC MINKE WHALE; STOCK IDENTITY; PHYSICAL MATURITY

INTRODUCTION

'Elucidation of the stock structure of the Southern Hemisphere minke whales to improve stock management' is one of the major objectives of JARPA and such information is indispensable to define units for the estimation of biological parameters and management areas for the RMP *Implementation* (Government of Japan, 1996; Hatanaka *et al.*, 2006). In addition to genetic analysis, non-genetic analyses such as morphometry and biological parameters are desirable as the most effective way to investigate stock structure is the use of multiple approaches (Donovan, 1991).

Biological parameters related to body length, such as body length at sexual/physical maturity are one of the effective tools for stock structure study (see Ohsumi, 1983; Perrin, 2001). This paper examined stock structure of Antarctic minke whale in the JARPA research area based on analysis of body length of physically matured whales.

MATERIALS AND METHODS

Biological samples

A total of 2,359 Antarctic minke whales collected during 1987/88 to 2004/05 JARPA surveys and classified as physically mature were used in this study (Table 1). The research area was divided into the six strata used by JARPA surveys (IIIE, IVW (IVWN, IVWS), IVE, VW, VE (VEN, VES) and VIW) (Fig. 1). In the 1998/99 austral summer season JARPA research vessels were unable to enter into Ross Sea because of pack ice expansion, so samples from stratum VES (Ross Sea) were mostly collected in stratum VEN of ordinary years. This sample was treated in following two methods considering sampling position.

Option A: Samples of VES in 1998/99 season were excluded from all analysis.

Option B: Samples of VES in 1998/99 season were included in samples of VEN.

Determination of physical maturity

Physical maturity condition was identified by examination of vertebrae. The fusion of the vertebral epiphysis to the centrum was known to start at anterior cervical, then at posterior caudal vertebra, and is completed on the middle or posterior dorsal vertebrae (Kato, 1988). Physical maturity was determined by examination of the 6^{th} dorsal vertebrae stained by 0.25% toluidine blue-O solution. Cartilage between epiphyses and centrum was observed by naked eye or stereoscopic microscope and whales of which epiphyses fused to centrum even a part was defined as physically mature. Mean body length of physically matured whales (MBLM) was calculated for each stratum and sex.

Method for analysis

Statistical analysis was conducted following a stepwise fashion. At first, monthly comparison of MBLM was conducted in each stratum. In this analysis samples in November were included in December samples because of small sample size. If no significant deference was detected, samples were pooled and latitudinal comparison was made in strata IVW and VE (second step). Finally, comparison was made between longitudinal strata. Analysis was made for each sex.

Statistical method

ANOVA or t-test was used for comparison of MBLM. If significant deference was detected by ANOVA, multiple comparisons (LSD test) were conducted.

RESULTS

Seasonal comparison

No significant monthly variation was detected in each stratum and sex (Table 2). Therefore, samples of each month were pooled in the following analysis.

Latitudinal comparison

Significant difference was detected in male MBLM between north and south strata of VE (Table 3). Therefore, these samples were treated separately (VEN, VES). Female samples of VE and samples of IVW were pooled in the following analysis, as there was no difference between north and south strata.

Longitudinal comparison

Significant difference was detected in both sexes by ANOVA test (Table 4, Fig. 2). Multiple comparisons revealed following results (Table 5).

Male: MBLM in western strata (IIIE, IVW, IVE and VW) were significantly larger than eastern strata (VEN, VES and VIW). MBLM in VEN was significantly larger than that in VES. Same results

were derived in both options.

Female: MBLM in western strata (IIIE, IVW, IVE and VW) were significantly larger than eastern strata (VE and VIW).

DISCUSSION

Body length of physically matured Antarctic minke whale is assumed in our analysis to reflect genetic differences among whales. However differences in this parameter differ not only by genetic bases but also nutritional condition during the growth period (Kato, 1987). If whales has feeding site fidelity in the research area and nutritional condition of whales in the eastern strata was worst than those in the western strata, observed difference in MBLM might be caused by just reflection of segregation. However analysis of blubber thickness from JARPA samples revealed that blubber was thicker in eastern strata than western strata (Konishi and Tamura, 2006), which suggests that observed difference in MBLM was not caused by segregation. Furthermore differences were observed between eastern and western strata by the genetic analysis of similar samples of the Antarctic minke whale (Pastene *et al*., 2006).

MBLM in western strata was significantly larger than eastern strata for both sexes. This suggests that at least two stocks, which have different MBLM, migrate into the research area. Our study supports the hypothesis, suggested by genetic analysis (Pastene *et al*., 2006), that at least two distinct biological stocks, one related to breeding area in the Indian Ocean and the other related to breeding areas in the western south Pacific, migrate into research area of JARPA.

Although existence of two stocks was revealed by this study, boundary could not be defined. Significant differences were detected in male MBLM between north and south strata of VE, which might suggest mixing of two stocks in these strata. The division between Areas VW and VE at 165° E is located in the western coast of the Ross Sea and significant yearly variation of pack ice distribution was observed in this area during JARPA research period, which might hamper free migration of whales (Nishiwaki *et al*. 2006). This suggest the possibility that boundary of two stocks is not hard but could fluctuate according the environmental condition such as sea ice expansion and distribution pattern of prey species. Further monitoring is needed for elucidation of yearly variation in distribution pattern of each stock.

The western and eastern boundaries of the proposed stocks should be investigated in the future.

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Table 1. Sample size of physically matured Antarctic minke whales collented during 1987/88 to 2004/05 JARPA surveys.

	Stratum									
	IIIE	IVWN	IVWS	IVE	VW	VEN (Option A)	VEN (+98/99VES) (Option B)	VES (-98/99)	VIW	Total
Male	88	129	199	263	321	180	217	89	122	1428
Female	50	31	129	157	178	37	42	312	32	931
Total	138	160	328	420	499	217	259	401	154	2359

Table 2. Monthly comparison of body length of physically matured Antactic minke whales caught in each stratum. P-value shows results of ANOVA test.

	Male									Female								
	Nov.+Dec.		Jan.		Feb.		Mar.		p-value	Nov.+Dec.		Jan.		Feb.		Mar.		p-value
Stratum	mean	n	mean	n	mean	n	mean	n		mean	n	mean	n	mean	n	mean	n	
IIIE	8.60	69	-	0	8.73	2	8.65	17	0.700	9.17	41	-	0	-	0	9.09	9	0.592
IVWN	8.59	30	8.57	67	8.50	32	-	0	0.376	9.23	4	9.09	20	9.14	7	-	0	0.768
IVWS	8.58	51	8.50	50	8.50	79	8.62	19	0.174	9.26	7	9.11	20	9.13	94	9.03	8	0.584
IVE	8.57	16	8.61	124	8.56	100	8.58	23	0.721	8.90	11	9.15	59	9.12	79	9.27	8	0.104
VW	8.54	48	8.53	76	8.53	102	8.59	95	0.542	9.14	23	9.07	56	9.20	64	9.04	35	0.106
VEN (Option A)	8.45	7	8.42	145	8.49	24	8.39	4	0.832	-	0	9.01	37	-	0	-	0	-
VEN(+98/99VES) (Option B)	8.45	7	8.42	145	8.45	27	8.49	38	0.705	-	0	9.01	37	-	0	9.24	5	0.107
VES(-98/99VES)	-	0	8.41	22	8.31	55	8.33	12	0.347	-	0	8.95	66	8.94	170	8.88	76	0.372
VIW	8.40	104	8.47	2	-	0	8.43	16	0.898	8.91	29	-	0	-	0	8.80	3	0.596

Table 3. Latitudinal comparison of body length of physicaly matured Antarctic minke whales caught in norhtern and southern strata in IVW and VE. P-value shows results of t-test.

	Male					Female				
	North		South		p-value	North		South		p-value
Stratum	mean	n	mean	n		mean	n	mean	n	
IVW	8.56	129	8.53	199	0.389	9.12	31	9.13	129	0.937
VE (-98/99VES) (Option A)	8.43	180	8.34	89	**0.024**	9.01	37	8.93	312	0.193
VE (98/99VES→VEN) (Option B)	8.44	217	8.34	89	**0.014**	9.03	42	8.93	312	0.064

Table 4. Longitudinal comparison of body length of physicaly matured Antarctic minke whales caught in each stratum. P-value shows results of ANOVA test.

	Stratum																		
	IIIE		IVW		IVE		VW		VE		VEN		VEN (+98/99VES)		VES (-98/99)		VIW		p-value
	mean	n	mean	n	mean	n	mean	n	mean	n	mean	n	mean	n	mean	n	mean	n	
Male (-9899VES) (Option A)	8.61	88	8.54	328	8.58	263	8.55	321			8.43	180			8.34	89	8.40	122	**<0.01**
Male (9899VES→VEN) (Option B)	8.61	88	8.54	328	8.58	263	8.55	321					8.44	217	8.34	89	8.40	122	**<0.01**
Female	9.16	50	9.13	160	9.13	157	9.12	178	8.94	354							8.90	32	**<0.01**

Table 5. Regional multiple comparison of MBLM within longitudinal strata. P-values of LSD test are shown in each box.

Option A

Male	n	mean	IIIE	IVW	IVE	VW	VEN	VES (-98/99)	VIW
IIIE	88	8.61	-	0.054	0.414	0.085	**0.000**	**0.000**	**0.000**
IVW	328	8.54		-	0.113	0.758	**0.000**	**0.000**	**0.000**
IVE	263	8.58			-	0.198	**0.000**	**0.000**	**0.000**
VW	321	8.55				-	**0.000**	**0.000**	**0.000**
VEN	217	8.44					-	**0.009**	0.321
VES (-98/99)	89	8.34						-	0.120
VIW	122	8.40							-

Option B

Male	n	mean	IIIE	IVW	IVE	VW	VEN (+98/99VES)	VES (-98/99)	VIW
IIIE	88	8.61	-	0.052	0.411	0.082	**0.000**	**0.000**	**0.000**
IVW	328	8.54		-	0.111	0.757	**0.000**	**0.000**	**0.000**
IVE	263	8.58			-	0.195	**0.000**	**0.000**	**0.000**
VW	321	8.55				-	**0.000**	**0.000**	**0.000**
VEN (+98/99VES)	180	8.43					-	**0.018**	0.457
VES (-98/99)	89	8.34						-	0.117
VIW	122	8.40							-

Female	n	mean	IIIE	IVW	IVE	VW	VE	VIW
IIIE	50	9.16	-	0.583	0.585	0.496	**0.000**	**0.001**
IVW	160	9.13		-	0.998	0.855	**0.000**	**0.001**
IVE	157	9.13			-	0.853	**0.000**	**0.001**
VW	178	9.12				-	**0.000**	**0.001**
VE	354	8.94					-	0.544
VIW	32	8.90						-

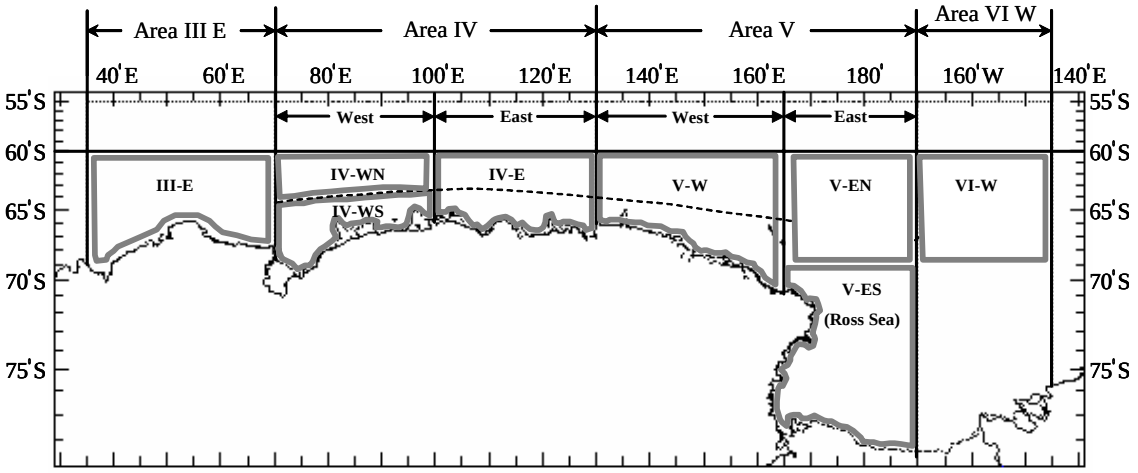

Fig. 1. Geographic strata used in the analysis.

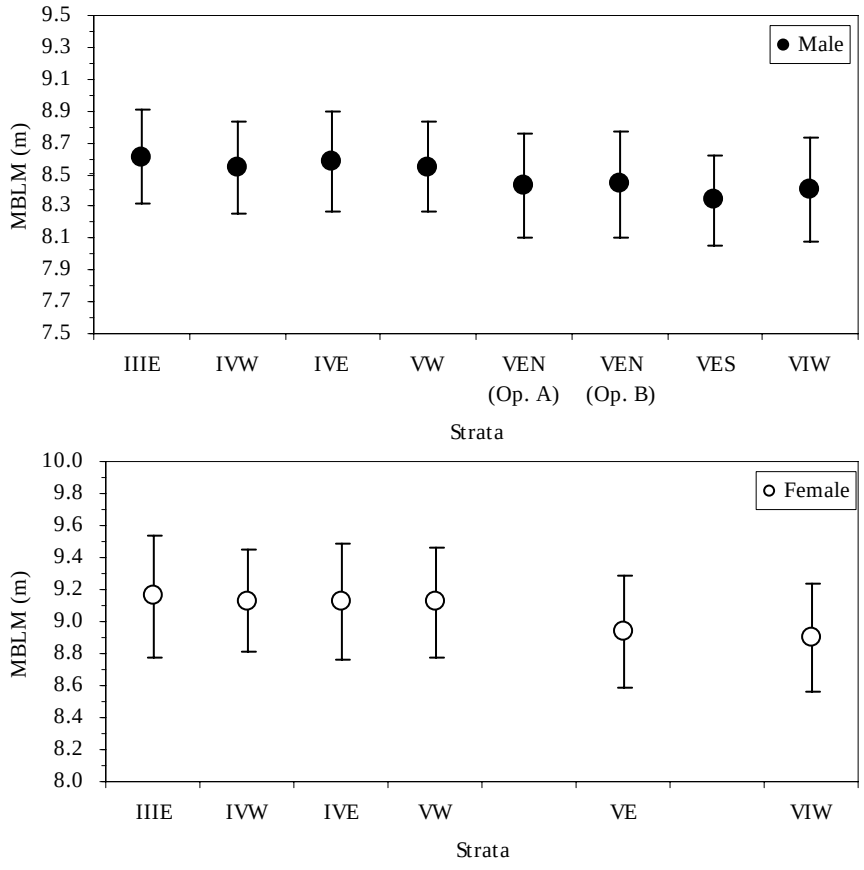

Fig. 2. Mean body length of physically matured Antarctic minke whlaes in each stratum. Circle shows mean value and solid line shows standard deviation.