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An Examination of the Random Sampling Scheme of the JARPA Surveys

Yoshihiro Fujise, Shigetoshi Nishiwaki and Luis A. Pastene

The Institute of Cetacean Research
4-18, Toyomi-cho, Chuo-ku, Tokyo 104, Japan

ABSTRACT

We examined the minke whale sampling schemes used by the JARPA in the period 1987/88-1995/96. Two sampling schemes have been implemented by the JARPA: the 'two-whale sampling' scheme between 1987/88 and 1991/92 and the 'one-whale sampling' scheme between 1992/93 and 1995/96. The technical sampling efficiency has increased after the implementation of the later. An examination on the randomness condition of the former scheme is conducted by comparing body lengths and maturity stage between the first and second whale sampled (by school size of two or more). In both cases, no significant statistical differences were found. In addition, yearly variation in body length frequencies, by stratum and school size, is examined statistically for the entire period (1987/88-1995/96). These frequencies were not statistically different among years in any school size nor stratum. Therefore, no significant differences were found between the two sampling schemes used in that period.

INTRODUCTION

Surveys of the Japanese Whale Research Program Under Special Permit in the Antarctic (JARPA) have been conducted since the 1987/88 austral summer season. Sampling of minke whales is necessary to cover two major objectives of the research program: 1) the estimation of biological parameters such as natural mortality, recruitment rate, in this species, and 2) a preliminary investigation of the role of the minke whales in the Antarctic ecosystem. In order to obtain these information, especially the former one, the application of a random sampling method for taking minke whales was required.

Detailed information of the annual JARPA surveys are available in the cruise reports, which have been presented to the annual meetings of the IWC/SC. These reports have also included some preliminary biological analyses of the minke whales sampled (Kato *et al.*, 1989, 1990; Fujise *et al.*, 1990, 1993a, 1993; Kasamatsu *et al.*, 1993; Nishiwaki *et al.*, 1994, 1995, 1996).

In this paper we review the sampling schemes used by the JARPA surveys and we also conduct some statistical analyses to evaluate the randomness of the sampling scheme.

SAMPLING SCHEME OF THE JARPA SURVEY

The sampling scheme adopted by the JARPA survey was originally described by Kato *et al.* (1989). Sampling are conducted only on primary sightings of minke whales. Schools sighted within a range of 3n miles from the track line, are approached for sampling in a closing mode searching. Schools sizes are determined and the whales to be targeted for sampling within the school are chosen using a series of tables of random sampling numbers (TRS), which are prepared according the size of the schools.

Numbering of whales within a school

Within 0.2 n. miles from the school, the number of individuals in the school are counted and their relative positions are sketched. A serial number is then assigned to each individual, from left to right.

Choice of individuals to be sampled

The sampling scheme depend mainly upon the school size. If a solitary whale was encountered it was sampled. If a school of two whales was encountered, the whale to be sampled first was determined using the TRS. After it had been taken, attention was directed to the other whale. For schools of three or more, the first whale to be sampled was chosen using the TRS. After it was taken, the remaining individuals were re-numbered according to their relative position and the second target whale was chosen using the TRS appropriate for the new school size (i.e. original school size less 1).

If a school separated into sub-groups during the vessel approach, a procedure based on sub-group sizes was adopted. For example, if a school of seven whales separated into sub-groups of five (sub-group A) and two animals (sub-group B), the target sub-group was determined in the following manner. Serial numbers were assigned considering a single school of seven animals, beginning with the larger group. If the value from the TRS was within the 1-5 series, then the larger sub-group (A) was chosen the target sub-group. If the value was 6 or 7, then sub-group B was chosen the target sub-group. If sub-group A was chosen, the first target whale was chosen from that sub-group following the procedures for school of five animals. The second target whale was determined by repeating the above procedure for school sizes of sub-group A=4 (5-1).

Sampling of a maximum of two individuals from each school was carried out using TRS prepared for each school sizes. This sampling procedure was called the 'two-whale sampling' and it was implemented during the surveys from the 1987/88 to 1991/92 seasons. However, to attach greater importance to the representativeness of the samples, this sampling method was modified so that only one whale would be sampled, regardless of the school sizes. This new procedure was called the 'one-whale sampling' and it was implemented since the 1992/93 season.

Sampling re-selection manners

If the selected whale could not be taken for some reason, the re-selection of target whale was applied to the school. This re-selection was applied only one time by school.

Chasing of any targeted whale ceased after a maximum of one hour, regardless of school size. In order to avoid an excessive burden of the research base vessel and to biases that sampling concentration in a particular time of the day, there were cases in which sample numbers were

adjusted, especially in areas in which minke whales were densely distributed.

Distribution of minke whales sampled during JARPA surveys

Fig. 1 show the distribution of minke whales sampled by JARPA surveys during 1987/88-1995/96, based on their sighting position. Catch distribution almost covers the whole research area.

Sampling efficiency

The sampling efficiency values in the JARPA surveys are shown in Table 1. Distributions of the technical efficiency values in each stratum is shown in Fig. 2.

The technical sampling efficiency is the ratio of the number of whales sampled to the number of whales targeted for sampling. The true sampling efficiency is the ratio of the number of whales sampled to the number of whales sighted. The technical sampling efficiency in each stratum was higher for the later surveys (1992/93-1995/96) than that reported in the previous surveys (1987/88-1991/92), but specially before 1991/92.

Under the 'two-whale sampling' scheme, implemented before the 1992/93 season, a maximum of two whales were sampled from school sizes of two or more. The main reason of failure in sampling under this scheme was the losing in sight of the second whale targeted, during the chasing of the first targeted whale (Fujise *et al.*, 1989, 1993; Kasamatsu *et al.*, 1993). Therefore, it seems that the implementation of the 'one whale sampling' scheme (from the 1992/93 season) contributed to increase the technical sampling efficiency.

SOME EXAMINATION OF THE SAMPLING SCHEMES RANDOMNESS

In order to examine the randomness of the sampling scheme, the body lengths and maturity status are compared between the first and second whales collected during the 'two-whale sampling' scheme. Additionally, we compared the body length frequencies of the whale samples collected in the entire period (198788-1995/96), which involved the two sampling schemes ('two-whale sampling' and 'one-whale sampling' schemes).

Comparison of body lengths between the first and second whales taken under the 'two-whale sampling' scheme

Fig. 3 show the relationship of body lengths between the first and second whales sampled under the 'two-whale sampling' scheme, by school size. Correlation coefficient and equation of body lengths between the first and second whales by linear-regression analysis are shown in Table 2, by school size. All coefficients are low. Table 3 show the results of sign test and signed Wilcoxon and Wilcoxon-Mann-Whitney test. No significant differences were found between body lengths of the first and second whales sampled.

Comparison of the sexual maturity stage between the first and second whales sampled under the 'two-whale sampling' scheme

Table 4 show the maturity of two whales collected in the same school by the two-whale sampling. Combination of mature animals (MM and MF, MM and MM, and MF and MF) are 70.5%, 64.8%, 67.0% and 67.5% for school size of 2, 3, 4 or more and all school combined,

respectively. If these include the combination of immature animals (IM and IF, IM and IM, IF and IF), these percentages become 76.8%, 72.5%, 72.2% and 73.6%, respectively. This suggest that minke whale tend to be make a school with individuals of the same maturity status, regardless of the sex of the individuals.

Combination of different sex and maturity stages are examined in order of sample collection, using the sign and signed Wilcoxon tests. No trend were observed for sampling order (Table 5). These results show that the 'two-whale sampling' scheme functioned randomly in the early JARPA surveys.

Yearly variation of body length frequencies of the whale samples

Figs. 4 to 7 show the body length frequencies, by stratum and school size. These figures also show the mean body length of these animals. The frequency and mean value are almost similar between surveys, and also similar between the 'two-whale sampling' (1987/88-1991/92) and 'one-whale sampling' schemes (1992/93-1995/96).

In order to examine the yearly variation of these body length frequencies, a ANOVA test was applied for each set of data. The results obtained for Areas IV and V are shown in Tables 6 and 7, respectively. The results of the ANOVA test can not be considered as conclusive. However, they suggest that the sampling scheme by JARPA are almost implemented constantly every year. Furthermore, these results suggested that no bias related to sampling schemes exist at all.

However, it should be mentioned that there are evidences of yearly variation in the migration pattern of minke whales (Fujise and Kishino, 1994) and that a low sampling rate for smaller animals has been reported for a few JARPA surveys (Fujise *et al.*, 1992, 1993). Further analysis on sampling rate taken in consideration body length data, are required.

ACKNOWLEDGMENT

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Table 1. Sighted, targeted and sampled minke whales in each JARPA survey. Technical and true efficiencies are also shown.

Survey area and season	Sighted animals	Targeted animals	Sampled animals	Technical efficiency	True efficiency
Area IV					
1987/88 *	664		272		0.41
1989/90 *	1928	477	327	0.69	0.17
1991/92 *	927	386	288	0.75	0.31
1993/94	940	417	330	0.79	0.35
1995/96	1439	509	440	0.86	0.31
Area V					
1988/89 *	743	428	236	0.55	0.32
1990/91 *	1623	617	323	0.52	0.2
1992/93 *	1180	390	327	0.84	0.28
1994/95	965	389	330	0.85	0.34

*: data used only ordinary form minke whales.

Table 2. Correlation coefficients of body length between the first and second whales sampled under the 'two-whale sampling' scheme, by school size.

School size	Regression formula	r	n
2	$Y = 0.3115\,X + 5.6985$	0.2486	112
3	$Y = 0.1501\,X + 7.0186$	0.1460	91
4 or more	$Y = 0.0620\,X + 7.7817$	0.0537	176
Combined	$Y = 0.1660\,X + 6.9076$	0.1440	376

Table 3. Statistical analysis of body length of the first and second whales sampled under the 'two-whale sampling' scheme.

School	First samples				Second samples				n	Sign*	SWT**	WMW***
size	Mean	SD	Min	Max	Mean	SD	Min	Max		p	p	p
2	8.44	0.70	5.40	9.90	8.33	0.87	5.24	10.1	112	0.171	0.227	0.230
3	8.31	0.70	6.60	9.70	8.27	0.72	5.26	9.90	91	0.500	0.295	0.382
4 or more	8.41	0.64	6.20	9.80	8.30	0.74	5.60	9.60	176	0.092	0.083	0.092
Total	8.40	0.67	5.40	9.90	8.30	0.77	5.24	10.1	379	0.078	0.052	0.063

*: Sign Test
**: Signed Wilcoxon Test
***: Wilcoxon-Mann-Whitney Test

Table 4. Combination of sex and maturity status of the first and second whales sampled under the 'two-whale sampling' scheme, by school size.
IM: immature male, MM: mature male, IF: immature female, MF: mature female, Ov: ovulating, R: resting, P: pregnant, L: lactating, PL: pregnant lactating, Uk: Unknown female.

School size: 2

		First whale sampled									
		IM	MM	IF	MF	Ov	R	P	L	PL	Uk
Second whale sampled	IM	[1]	6	1	3			3			
	MM	3	[25]	1	16	1		13	1	1	
	IF	4	3	[12]	4			4			
	MF	0	17	6	[21]						
	Ov					[2]					
	R		3				[5]	2			
	P		12	6		2	2	[16]			
	L								[3]		
	PL		2					1		[4]	
	Uk										[1]

School size: 3

		First whale sampled									
		IM	MM	IF	MF	Ov	R	P	L	PL	Uk
Second whale sampled	IM	[2]	5	1	1		1				
	MM	3	[25]	5	9	2		7			
	IF	1	4	[5]	2	1		1			
	MF	0	12	5	[15]						
	Ov					[3]					
	R		1				[3]				
	P		10	5			1	[14]			
	L								[5]		
	PL									[3]	
	Uk		1								[2]

School size: 4 or more

		First whale sampled									
		IM	MM	IF	MF	Ov	R	P	L	PL	Uk
Second whale sampled	IM	[2]	5	0	2			2			
	MM	2	[37]	13	20	1	2	17			
	IF	2	10	[15]	10			10			
	MF	0	21	7	[40]						
	Ov					[4]		1			
	R						[1]	1			
	P		21	7		1	3	[31]			1
	L								[5]		
	PL									[4]	
	Uk							1			[3]

All schools

		First whale sampled									
		IM	MM	IF	MF	Ov	R	P	L	PL	Uk
Second whale sampled	IM	[3]	16	2	6		1	5			
	MM	8	[85]	19	45	4	2	37	1	1	
	IF	7	17	[32]	16	1		15			
	MF	0	50	18	[76]						
	Ov					[9]		1			
	R		4				[4]	3			
	P		43	18		3	6	[59]			1
	L								[8]		
	PL		2					1		[7]	
	Uk		1					1			[3]

Table 5. Order of sample by sex and maturity of the first whale sampled under the 'two-whale sampling' scheme, by school size, and their statistical tests. IM: immature male, MM: mature male, IF: immature female, MF: mature female.

Combination	First whale sampled				Sign test	SWT*
	IM	IF	MM	MF	p	p
School size = 2						
IM-IF	4	1				
IM-MM	3		6			
IM-MF	0			3		
IF-MM		1	3			
IF-MF		6		4		
MM-MF			17	16	0.659	0.147
School size = 3						
IM-IF	1	1				
IM-MM	3		5			
IM-MF	0			1		
IF-MM		5	4			
IF-MF		5		2		
MM-MF			12	9	0.659	0.583
School size >= 4						
IM-IF	2	0				
IM-MM	2		5			
IM-MF	0			2		
IF-MM		13	10			
IF-MF		7		10		
MM-MF			21	20	0.342	0.071
All schools						
IM-IF	7	2				
IM-MM	8		16			
IM-MF	0			6		
IF-MM		19	50			
IF-MF		18		18		
MM-MF			50	45	0.659	0.663

*: Signed Wilcoxon test

Table 6. Results of an ANOVA test to examine body length frequencies between surveys in the western and eastern sectors of Area IV, by school size.

WESTERN SECTOR

School size = 1

PHIst value	-0.002
P value	0.689

Pair-wise comparison

	89/90	91/92	93/94	95/96
89/90		0.9660	0.5834	0.9391
91/92			0.0679	0.9061
93/94				0.3097
95/96				

School size = 2

PHIst value	0.001 (0.3906)
P value	0.391

Pair-wise comparison

	89/90	91/92	93/94	95/96
89/90		0.6633	0.1039	0.1588
91/92			0.5854	0.4446
93/94				0.6454
95/96				

School size = 3

PHIst value	0.004
P value	0.249

Pair-wise comparison

	89/90	91/92	93/94	95/96
89/90		0.6124	0.1439	0.2378
91/92			0.2098	0.4496
93/94				0.1888
95/96				

School size = all

PHIst value	0.000
P value	0.398

Pair-wise comparison

	89/90	91/92	93/94	95/96
89/90		0.6763	0.5824	0.3307
91/92			0.1958	0.7672
93/94				0.1768
95/96				

EASTERN SECTOR

School size = 1

PHIst value	0.007
P value	0.121

Pair-wise comparison

	89/90	91/92	93/94	95/96
89/90		0.1039	0.1059	0.6543
91/92			0.3606	0.1189
93/94				0.1598
95/96				

School size = 2

PHIst value	0.005
P value	0.356

Pair-wise comparison

	89/90	91/92	93/94	95/96
89/90		0.2468	0.1409	0.4286
91/92			0.4805	0.6973
93/94				0.2288
95/96				

School size = 3

PHIst value	-0.005
P value	0.762

Pair-wise comparison

	89/90	91/92	93/94	95/96
89/90		0.3217	0.6733	0.7333
91/92			0.7792	0.3846
93/94				0.6424
95/96				

School size = all

PHIst value	0.002
P value	0.152

Pair-wise comparison

	89/90	91/92	93/94	95/96
89/90		0.4196	0.1349	0.5674
91/92			0.4446	0.3197
93/94				0.0420
95/96				

Table 7. Results of an ANOVA test to examine body length frequencies between surveys in the western and eastern sectors of Area V, by school size.

WESTERN SECTOR

School size = 1

PHIst value	-0.001
P value	0.502

Pair-wise comparison

	90/91	92/93	94/95
90/91		0.522	0.297
92/93			0.740
94/95			

School size = 2

PHIst value	0.076
P value	<0.001

Pair-wise comparison

	90/91	92/93	94/95
90/91		0.000	0.025
92/93			0.022
94/95			

School size = 3

PHIst value	0.002
P value	0.374

Pair-wise comparison

	90/91	92/93	94/95
90/91		0.495	0.247
92/93			0.600
94/95			

School size = all

PHIst value	0.009
P value	0.005

Pair-wise comparison

	90/91	92/93	94/95
90/91		0.004	0.068
92/93			0.074
94/95			

EASTERN SECTOR

School size = 1

PHIst value	0.003
P value	0.257

Pair-wise comparison

	90/91	92/93	94/95
90/91		0.370	0.055
92/93			0.698
94/95			

School size = 2

PHIst value	-0.017
P value	0.960

Pair-wise comparison

	90/91	92/93	94/95
90/91		0.927	0.818
92/93			0.880
94/95			

School size = 3

PHIst value	-0.003
P value	0.623

Pair-wise comparison

	90/91	92/93	94/95
90/91		0.659	0.386
92/93			0.687
94/95			

School size = all

PHIst value	0.002
P value	0.158

Pair-wise comparison

	90/91	92/93	94/95
90/91		0.272	0.077
92/93			0.393
94/95			

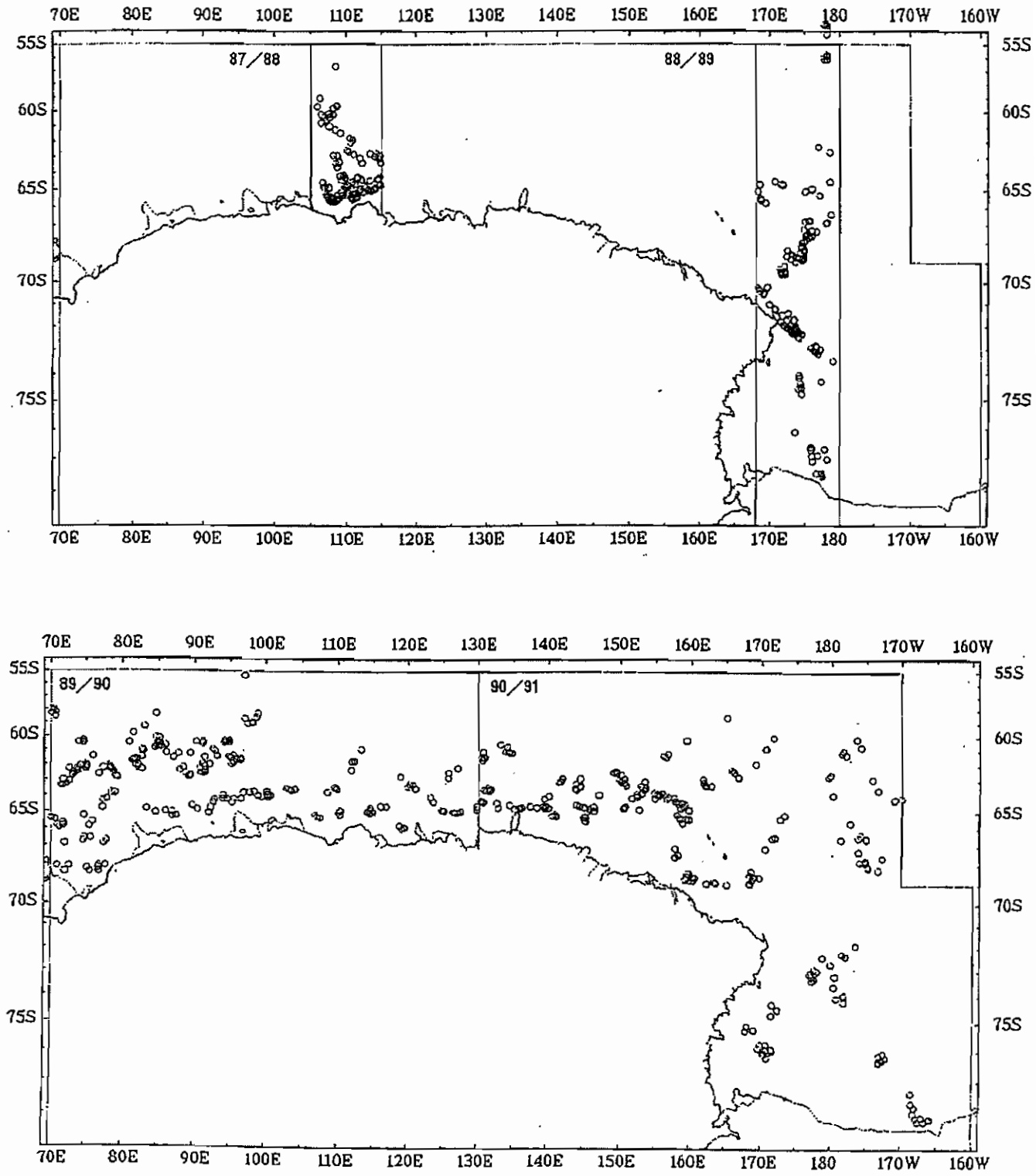
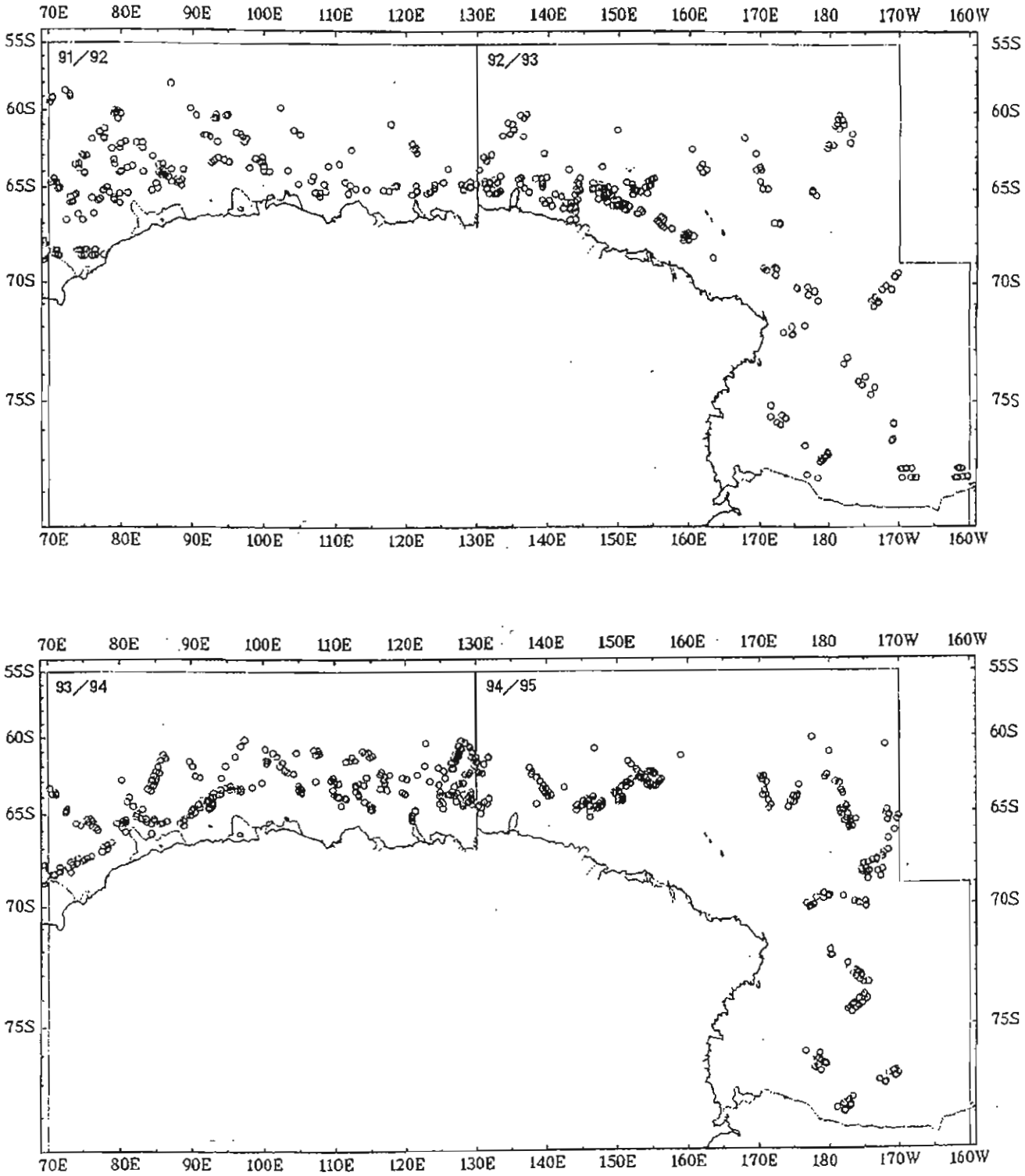


Fig. 1. Dstribution of whale samples collected by JARPA survey during 1987/88-1995/96, based on their sighting location.



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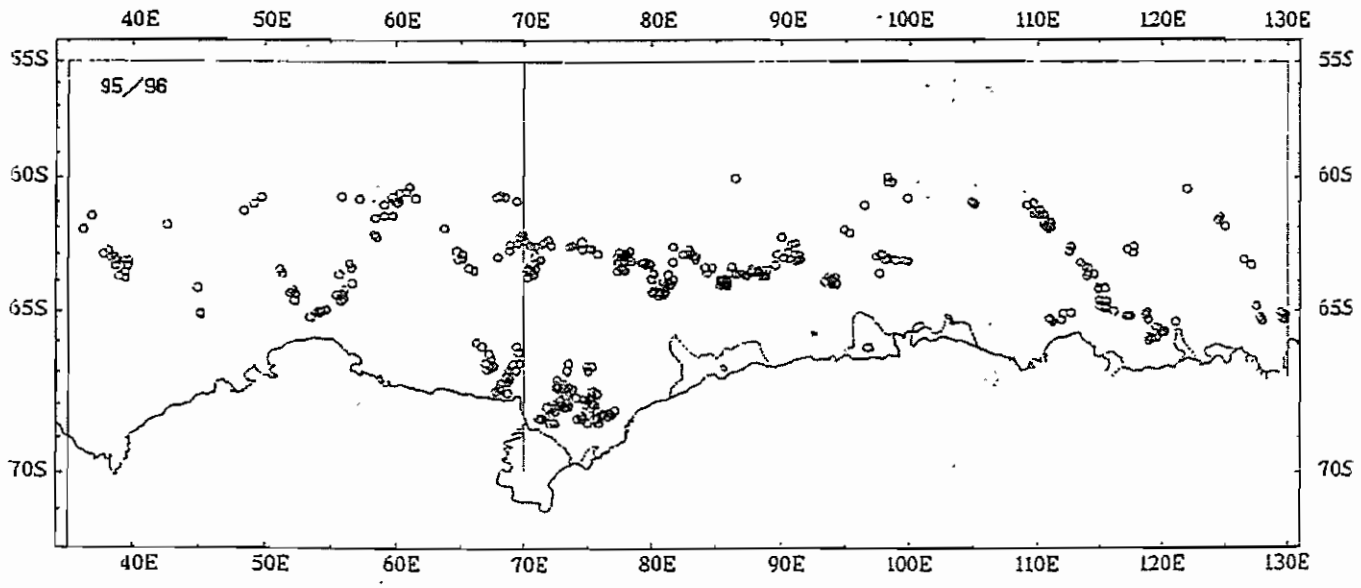

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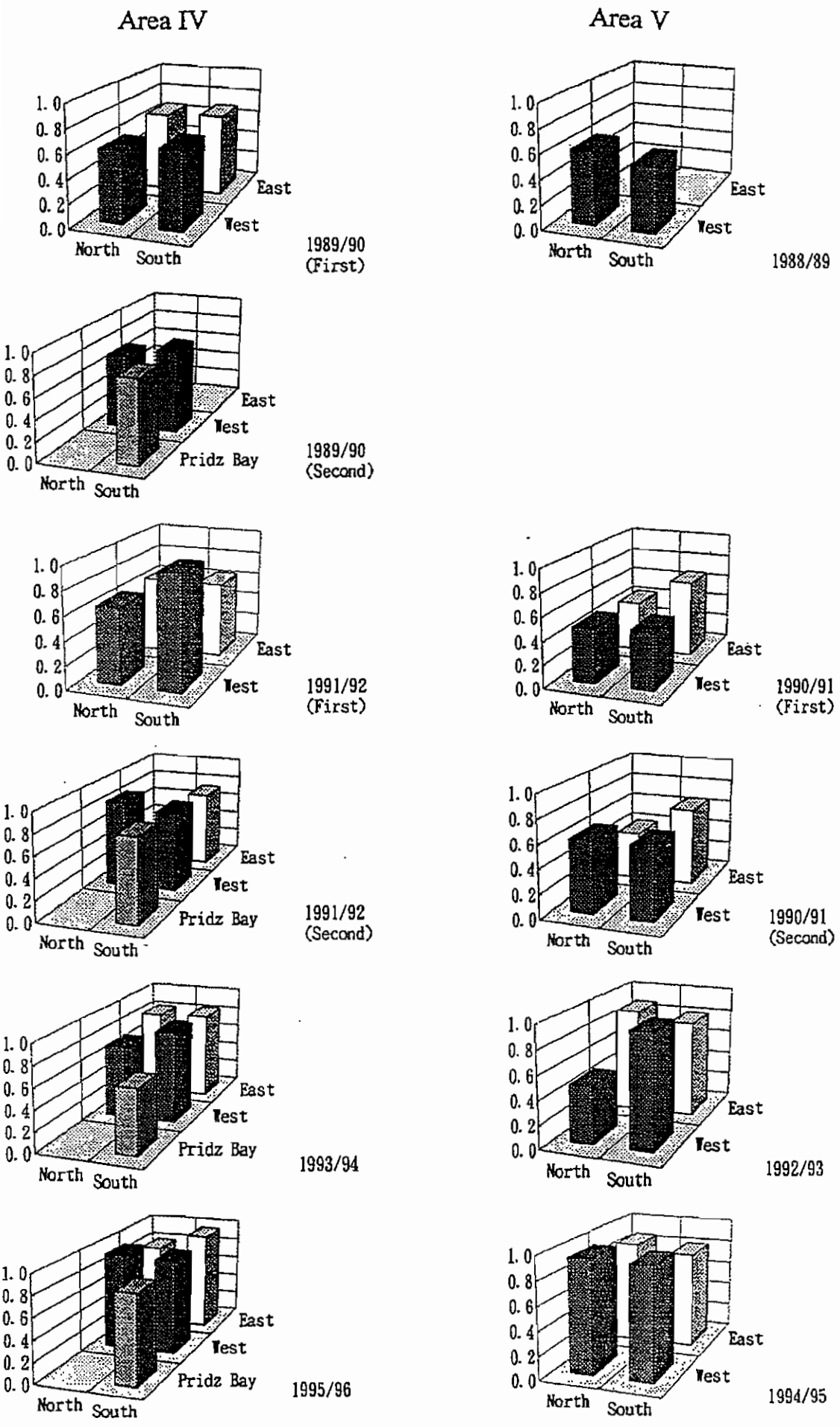
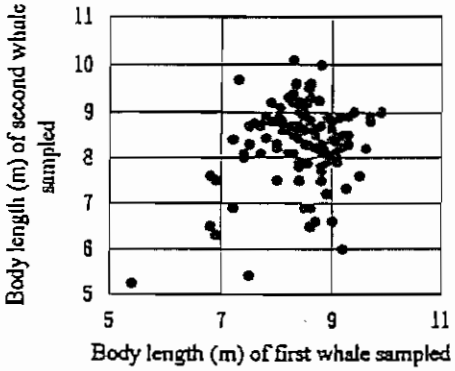
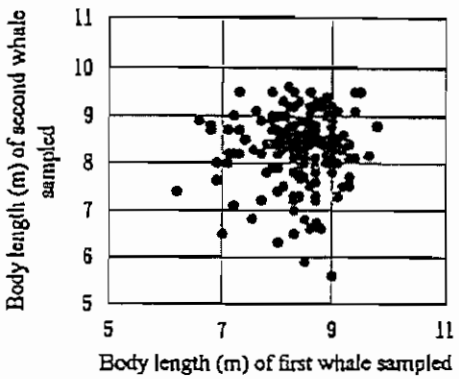


Fig.2. Distribution of the technical efficiency by stratum and survey season.

School size: 2



School size: 4 or more



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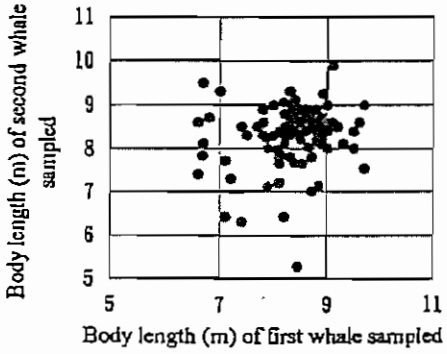

All school combined

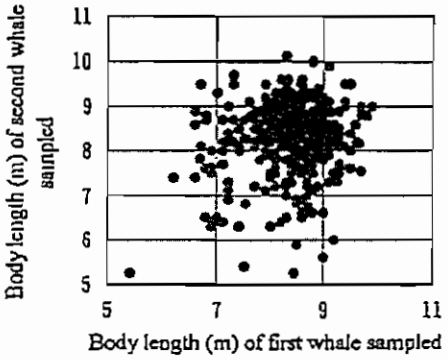

Fig. 3. Plots of the body lengths (m) of the first and second whales sampled under the 'two-whale sampling' scheme (1987/88-1991/92), by school size.

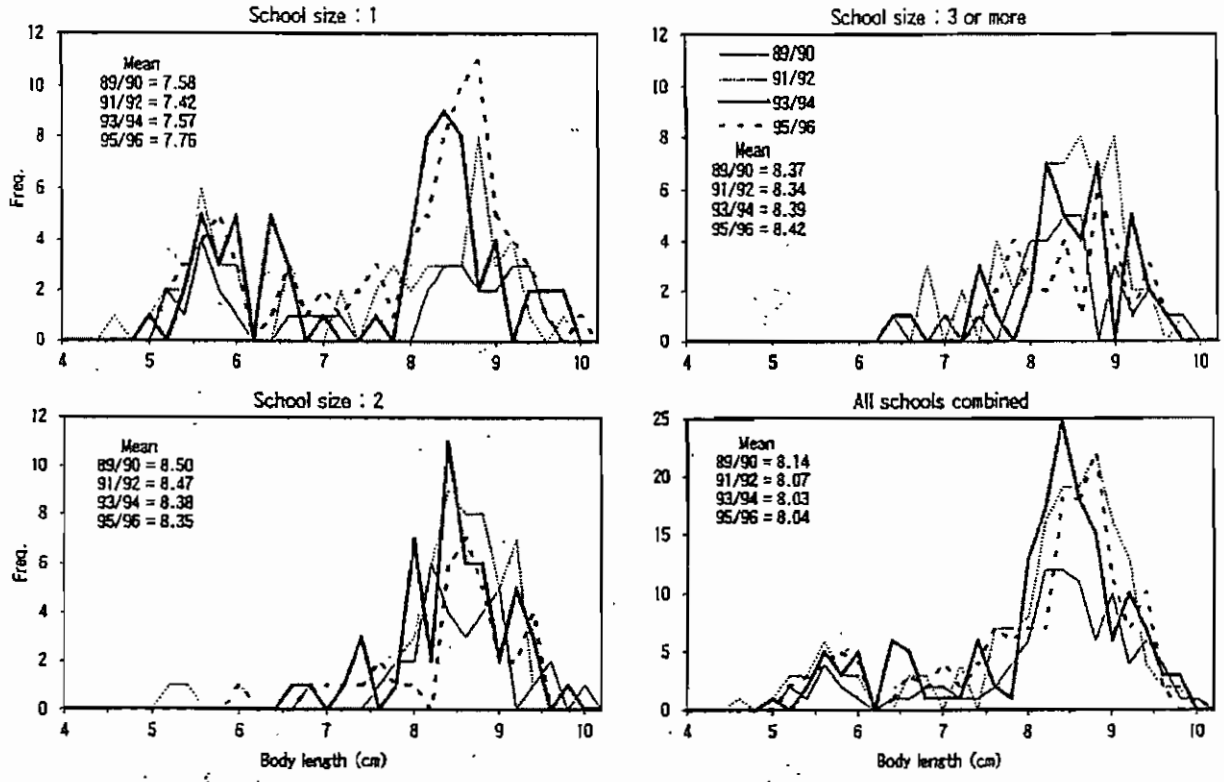

Fig. 4. Comparison of body length frequencies of minke whales in the western sector of Area IV, by thier school size.

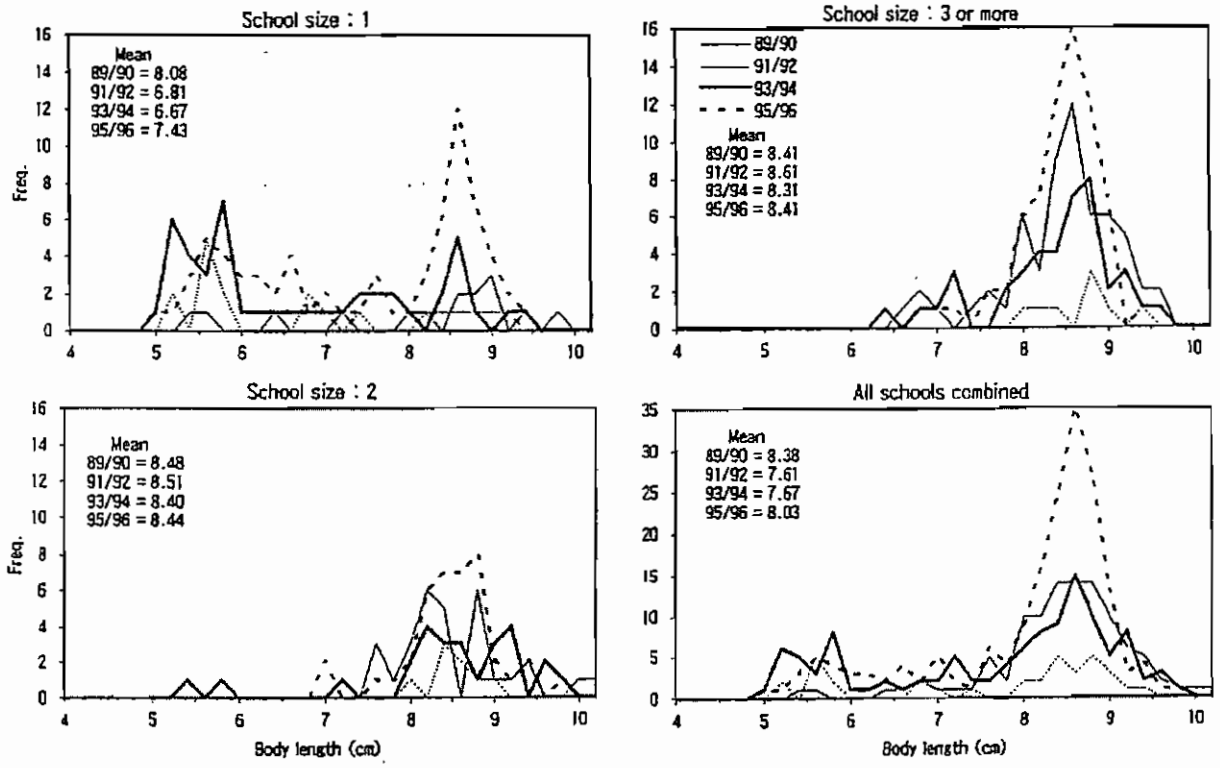

Fig. 5. Comparison of body length frequencies of minke whales in the eastern sector of Area IV, by thier school size.

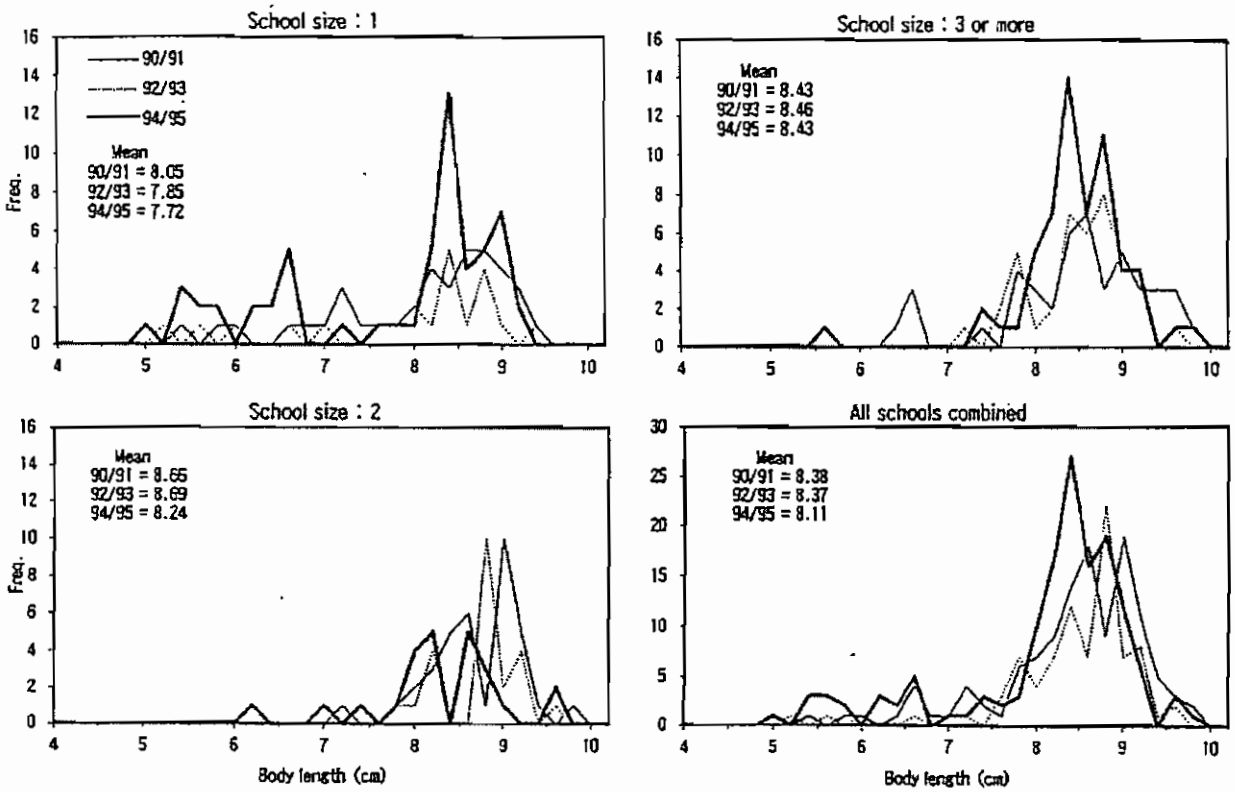

Fig. 6. Comparison of body length frequencies of minke whales in the western sector of Area V, by thier school size.

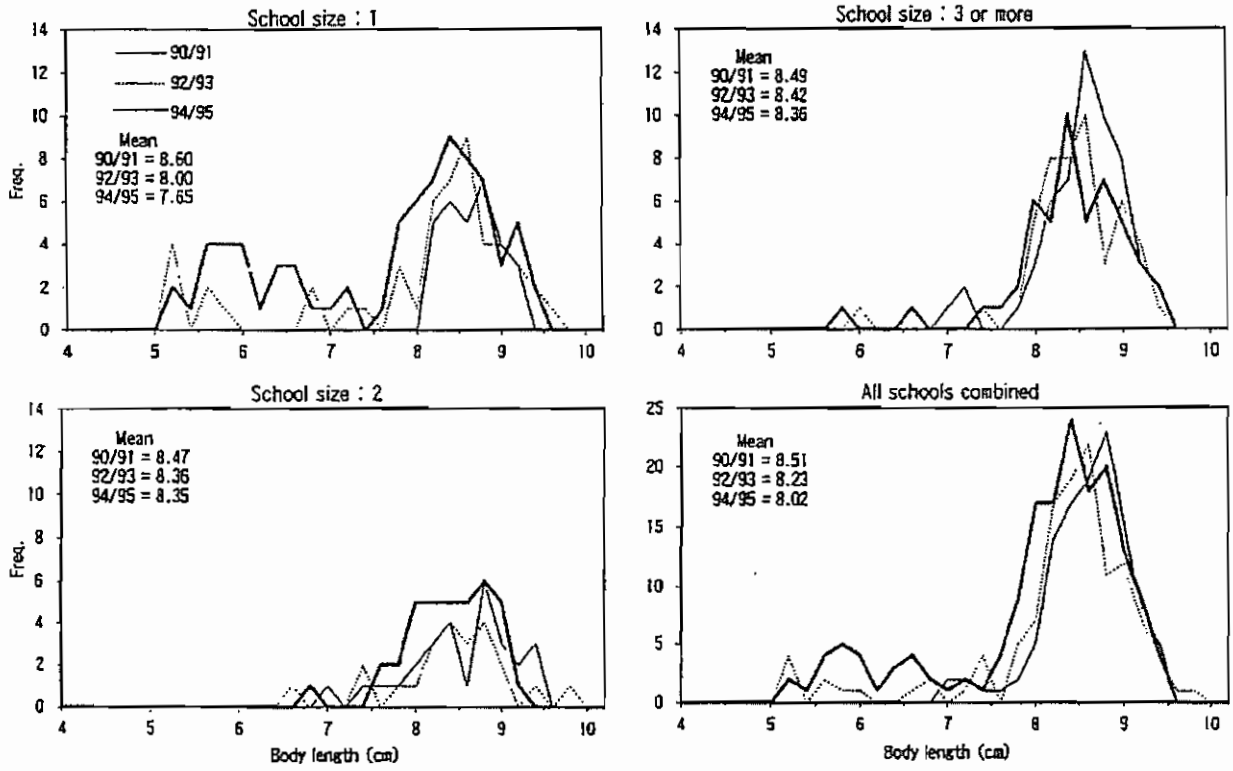

Fig. 7. Comparison of body length frequencies of minke whales in the eastern sector of Area V, by thier school size.