BIOLOGICAL PARAMETERS OF SOUTHERN MINKE WHALES BASED ON MATERIALS COLLECTED BY THE JARPA SURVEY UNDER SPECIAL PERMIT IN 1987/88 TO 1995/96

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ABSTRACT

The present study examines some biological parameters in the southern minke whales. Maturity rate, body length at sexual maturity, age at sexual maturity, annual ovulation rate, apparent pregnancy rate, foetal sex ratio, litter size and growth curve are estimated, based on materials of 1,522 male and 1,240 female samples collected by the JARPA survey in Areas IV and V in 1987/88 to 1995/96. Sexual maturity rate was 82.1% in Area IV and 88.1% in Area V for male, and for female was 58.3% and 74.7% in Areas IV and V, respectively. Body length and age at sexual maturity were estimated using kinds of two estimators : unbiased estimates of body length (*Lm*) and age (*tm*) at sexual maturity and body length (*Lmov*) and age (*tmov*) at first ovulation. The *Lm* value for male was 7.27m and 7.24m in Areas IV and V, respectively. For female was 8.18m in Area IV and 8.01m in Area V. The *Lmov* value was 8.40m and 8.35m in Areas IV and V, respectively. The *tm* value for male was 4.2 and 4.9 years in Areas IV and V, respectively. For female was 7.2 years in Area IV and 8.4 years in Area V. The *tmov* value was 7.2 and 9.1 years in Areas IV and V, respectively. These values are considered to be representative value of age at maturity of the population or much more close to the real value. Annual ovulation rate was 1.03398 in Area IV and 1.05809 in Area V. Apparent pregnancy rate was 90.9% in Area IV and 88.4% in Area V. The male foetal sex ratio was 52.1% and 49.7% and the average litter size was 1.006 and 1.020 in Areas IV and V, respectively. Growth curve formula has firstly obtained at reasonable base using samples from the JARPA survey.

INTRODUCTION

Population study of southern minke whales started by Ohsumi *et al.* (1970) using materials obtained through two preliminary commercial expeditions, carried out by Japan in the Antarctic in 1967/78 and 1968/69. Since then, many authors (Ohsumi and Masaki, 1975; Masaki, 1979; Kato, 1982, 1983, 1985, 1987; Best,1982) examined some biological parameters of southern minke whales in accordance with increasing of its importance as a resource for the commercial whaling in the Antarctic.

The Japanese Whale Research Programme under Special Permit in the Antarctic (JARPA) started in the 1987/88 season as a feasibility survey in Area IV in advance of study full scale of the program and since then it has been carried out every year. One of the major objectives of JARPA is the estimation of biological parameters, especially the natural mortality rate. Although Kato *et al.* (1990, 1991), Fujise and Kishino (1994), Fujise *et al.* (1990, 1991, 1992, 1994), Kishino *et al.* (1991) have examined the

age distribution and segregation of southern minke whales, other basic biological parameters have not been examined using materials derived from JARPA. Therefore, the present study examines some biological parameters such as sexually maturity rate, mean age and body length at sexual maturity, ovulation rate, apparent pregnancy rate, sex ratio of foetus and litter size of southern minke whales using samples and data obtained during nine JARPA surveys.

MATERIALS AND METHODS

Samples

Samples used in the present study were minke whales collected randomly in Areas IV and V under the JARPA surveys in 1987/88 to 1995/96 austral summer seasons. The number of male samples used were 906 in Area IV and 616 in Area V according to the random sampling procedure described by Fujise *et al.* (in prep.). The number of females samples used were 640 and 600 in Areas IV and V, respectively.

Sexual maturity determination

Sexual maturity for females was determined by the presence of at least one corpus luteum or albicans in both ovaries. All of sexual maturity for males was determined by examination to histological status of testis tissues. Males with seminiferous tubules over 100 μm diameter (average of 15-20 measurements) or spermatid in the tubule were determined to be sexually mature (Kato,1986; Kato *et al.*, 1990, 1991).

Age determination

Age of whales was determined by reading growth layers appeared on the bisected surface of the earplug. Growth layers were counted with stereoscopic microscope by Kato for samples collected in 1987/88, 1988/89, 1989/90 and 1992/93 seasons and by Zenitani for 1990/91, 1991/92, 1993/94, 1994/95 and 1995/96 seasons. Furthermore, we sometimes used the baleen plate for age determination of juvenile whales based on the method developed by Kato and Zenitani (1990).

Body length and age at sexual maturity

We estimated body length and age at sexual maturity by following two estimators : unbiased estimates of mean body length and age at sexual maturity were calculated for two halves of the entire periods (first period : 1987/88-1990/91 seasons, second period : 1991/92-1995/96 seasons) and mean body length and age at first ovulation were calculated for each year of sample.

The *Lm* which defined unbiased estimates of mean body length at sexual maturity, we used the following equations from approaches of Kato (1992) which was modified from the approaches of Kasuya (1976) and Cooke (1984) :

$$Lm = l-(s/2)+\{\sum_{l}^{k}(I_a/N_a)\}s \qquad (1)$$

$$\text{var}(Lm) = \{\sum_{l}^{k}\{(M_aI_a)/(N_a^2(N_a-1)\}s \qquad (2)$$

where,

Lm = mean length at sexual maturity
M_a = no. mature animals of sample length a
I_a = no. immature animals of sample length a
$N_a = M_a + I_a$

l = length of smallest mature animal in sample
k = length of largest immature animal in sample
s = interval of each length class in meters

The *tm* which defined estimates of age at sexual maturity, we used the following equations from the approaches of Cooke (1984) :

$$T = j - 0.5 + \sum_{j}^{k} (I_a/N_a) \qquad (3)$$

$$\text{var}(T) = \sum_{j}^{k} (M_a I_a)/(N_a^2(N_a-1)) \qquad (4)$$

where,

T = mean age at sexual maturity
var (T)= variance
M_a = no. of mature animals in the sample aged a
I_a = no. of immature animals in the sample aged a
$N_a = M_a + I_a$ =total no. of animals aged a
j = age of youngest mature animal in sample
k =age of oldest immature animal in sample

Further we used for detecting difference between two estimated values the following a non-parametric significance test from approaches of Cooke (1984) :

$$d = \sum_{j}^{k} (m_{1a}n_{2a} - m_{2a}n_{1a})/N_a \qquad (5)$$

$$s^2 = \sum_{j}^{k} n_{1a}n_{2a}M_a(N_a - M_a)/(N_a^2(N_a-1)) \qquad (6)$$

where,

M_a, I_a N_a, j, k : defines as before, but referring to both samples combined
m_{1a}, m_{2a} : numbers of mature animals aged a in samples 1 and 2, respectively
n_{1a}, n_{2a} : numbers of immature animals aged a in samples 1 and 2, respectively

In a two tailed test of size 5%, deduced as follows:

$d < -2s$: sample 1 has a higher age at maturity than sample 2
$d > +2s$: sample 2 has a higher age at maturity than sample 1
$-2s \leq d \leq +2s$: no significant difference between the samples

The *Lmov* and *tmov* which defined mean body length and age of females soon after attainment of sexual maturity (first ovulation), identified by the presence of a corpus luteum and no corpus albicans in the ovaries.

RESULTS

Sexual maturity rate

Male

Table 1 indicates variation of reproductive status of males and sexual maturity rate (proportion of number of sexually mature animals to total males in the samples), by season and Area. Overall sexual maturity rate in Area IV is 82.1% (range : 78.9-87.0%) and in Area V is 88.1% (range : 82.4-92.8%). Sexual maturity rates of male were reported by Ohsumi and Masaki (1975) and Kato (1982), and the former represented maturity rate was 91.6% and the latter represented monthly changes in maturity rates were 91.0-100.0% and 92.6-97.8% in Areas IV and V. These estimates are slightly higher than present our estimates for sexual maturity rate.

Female

Table 2 indicates variation of reproductive status of females and sexual maturity rate (proportion of number of sexually mature animals to total males in the samples), by season and Area. Overall sexual maturity rates in Area IV is 58.3% (range : 49.6-68.3%) and in Area V is 74.7% (range : 66.9-82.4%). It is noted that the value in Area V is higher than in Area IV. Sexual maturity rates of female were reported by Ohsumi and Masaki (1975) and Kato (1982), and the former represented maturity rate was 78.3% and the latter represented monthly changes in maturity rates were 69.1-80.8% and 70.0-83.3% in Areas IV and V. These estimates are higher than present our estimates for sexual maturity rate.

Body length at sexual maturity

Mean body length at sexual maturity (Lm)

Male

Table 3 indicates the proportion of sexually mature animals and the sexual maturity rate in respective body length class. Sexual mature males appears at 6.7m and 6.6m in Areas IV and V, and the body length of largest sexual immature animals are 8.2m and 7.8m in Areas IV and V, respectively. Almost half of males attain to sexually mature at 7.2-7.3m in Area IV and 7.2-7.4m in Area V.

The resultant estimate of *Lm* for both sexes are given in Table 4. Overall *Lm* values are 7.27m (first period : 7.32m, second period : 7.27m) and 7.24m (first period : 7.14m, second period : 7.23m) in Areas IV and V, respectively. The *Lm* value in the first period are almost similar to in the second period in both Areas. The overall *Lm* value in Area IV is similar to in Area V. Ohsumi and Masaki (1975) and Masaki (1979) estimated body length at which 50% of males are sexually mature (*Lm50%*) and the former represented the *Lm50%* values of 7.2m. The latter represented *Lm50%* values of 7.2m in Area IV and 7.1m in Area V. The present *Lm* values are almost similar to previous *Lm50%* values.

Female

Sexual mature female firstly appears at 7.9m and 7.6m, and the body length of the largest sexual immature females are 8.8m and 8.7m in Areas IV and V, respectively. Almost half of females attain to sexually mature at 8.1-8.2m in Area IV and 8.0-8.1m in Area V (Table 3).

Overall *Lm* value in Area IV is 8.18m (first period : 8.16m, second period : 8.20m) and in Area V is 8.01m (first period : 8.02m, second period : 7.99m) (Table 4). The *Lm* values in first period are almost similar to those in the second period in both Areas. However the *Lm* value of Area IV is slightly larger than those of Area V and difference between the values are statistically significant (non-parametric significance test). In previous study, Ohsumi *et al.* (1970), Ohsumi and Masaki (1975), Masaki (1979) and Kato (1987) estimated the *Lm50%* values. Ohsumi *et al.* (1970) and Ohsumi and

Masaki (1975) represented *Lm50%* values were 7.9m and 8.0m, respectively. Further Masaki (1979) reported *Lm50%* values in over the time period were 8.0m (range in 1971/72-1976/77 : 7.9-8.1m) in Area IV and 8.0m (range in 1974/75-1976/77 : 7.9-8.2m) in Area V. Kato (1987) expressed that *Lm50%* values were approximately at 8.1m in 1971/71 to 1982/83 seasons. Those estimates are almost similar to present our estimates for the *Lm* values.

Mean body length at the first ovulation (*Lmov*)

Mean body length at the first ovulation is given in Table 5. Overall *Lmov* value are 8.40m (range : 8.28-8.63m) and 8.35m (range : 8.18-8.83m) in Areas IV and V, respectively. The *Lmov* value in Area IV is similar to that in Area V. These estimated values are within the *Lmov* values (between 8.2m and 8.5m) that were estimated by Kato (1982) using biological material and data collected by Japanese commercial whaling operations in the Antarctic through 1971/72 to 1979/80.

Age at sexual maturity

Mean age at sexual maturity (tm)

Male

Table 6 indicates proportion of sexually mature animals in relation to age and sexual maturity rate. Sexually mature males appears at 2 years and 3 years and age of the oldest sexual immature males are 8 years and 7 years in Areas IV and V, respectively. Almost half of males attain to sexually mature at about 4 years and about 5 years in Areas IV and V, respectively (Table 6).

Table 7 indicates *tm* for both sexes. Overall *tm* value for entire period are 4.2 years (first period: 3.5 years, second period: 4.8 years) and 4.9 years (first period : 4.6 years, second period : 5.6 years) in Areas IV and V, respectively (Table 7). The *tm* value in the first period is higher than that in the second period in both Areas. Furthermore the *tm* value in Area V is higher than that in Area IV and difference between the values are statistically significant (non-parametric significance test). Kato (1982) represented that the age at which 50% of males are sexually mature (*tm50%*) was estimated to be 2.5 years in Area IV and 2.4 years for all Areas combined, and these estimates are lower than present our estimates for the *Lmov* value.

Female

Sexually mature females appears at 3 years and 5 years in Areas IV and V, respectively, and the age of the oldest sexual immature animals are 13 years in both Areas. Almost half of females attain to sexually mature at about 7 years in Area IV and 8-9 years in Area V (Table 6).

Overall *tm* values for entire period are 7.2 years (first period : 7.6 years, second period : 7.2 years) and 8.4 years (first period : 8.4 years, second period : 8.3 years) in Areas IV and V, respectively (Table 7). The *tm* value in the first period is slightly higher than that in the second period in Area IV, while the *tm* value in the first period is similar to the value in the second period in Area V. The values of *tm* for Area V are always higher than for Area IV in both of periods and difference between the values are statistically significant (non-parametric significance test). Ohsumi *et al.* (1970) reported *tm50%* value of 6-7 years for the 1965/66 to 1968/69. Subsequently this value was modified as 6.3 years by Ohsumi and Masaki (1975). Masaki (1979) estimated *tm50%* value in over the time period of 6.7 years (range in yearly change : 5.0-9.0 years) in Area IV using data of 1967/68 and 1971/72 to 1976/77. And Kato (1982) estimated *tm50%* value of 6.63 years in Area IV and 5.97 years in Area V using data through 1971/72 to 1979/80, since then Kato (1987) examined using data series extended to 1982/83 the *tm50%* values ranged between 6 and 7 years. These estimates are lower than present our estimates for the *tm* value.

Mean age at the first ovulation (*tmov*)

Mean age at the first ovulation is given in Table 5. Overall *tmov* values are 7.2 years (range : 5.4-10.0 years) and 9.1 years(range : 8.0-11.0 years) in Areas IV and V, respectively. The *tmov* values in Area V is higher than those in Area IV and difference between values are statistically significant (t-test). Kato (1987) examined the values of *tmov* have decreased from about 9 years in early 1970s to about 7 years in late 1970s and early 1980s. The *tmov* value estimated in present study in Area IV is similar to the *tmov* value in late 1970s and early 1980s, but the *tmov* value estimated in Area V is higher than its in late 1970s and early 1980s.

Annual ovulation rate

Fig. 1 shows relationship between mean number of corpora and age separately by Areas, in which both of samples collected from the first and second half are combined for the analysis. Because number of corpora increases linearly between 7 years to 30 years, we fitted line regression between age classes 7 years to 30 years, to estimate rate the ovulation. The regression formula of the mean number of ovulations (Y) on age (X) for Areas IV and V data in the 7-30 years age range are :

$$\text{Area IV} : Y = 1.03398X - 5.99917 \quad (r = 0.81908) \qquad (7)$$

$$\text{Area V} : Y = 1.05809X - 7.14237 \quad (r = 0.81304) \qquad (8)$$

Thus, annual ovulation rate are 1.03398 and 1.05809 in Areas IV and V, respectively, and these values are similar in both Areas. Ohsumi and Masaki (1975) and Kato (1982) estimated annual ovulation rate and the former represented the value of 0.866 and the latter of 0.811 in Area IV and 0.883 in all Areas combined. These estimates are lower than present our estimates for annual ovulation rate.

Apparent pregnancy rate

Apparent pregnancy rate is defined as proportion of pregnancy female in total sexually mature females. Table 8 indicates the apparent pregnancy rates by season and Area. Overall apparent pregnancy rates in Area IV is 90.9% (ranges : 85.7-96.6%) and in Area V is 88.4% (ranges : 78.2-98.4%). Ohsumi and Masaki (1975) estimated apparent pregnancy rate of 89.5% and Masaki (1979) estimated yearly change of apparent pregnancy rate and represented that it were estimated 82.8-91.0% (1972/73-1976/77) in Area IV and 86.2-91.2% (1974/75-1976/77) in Area V. And Kato (1982) estimated apparent pregnancy rates of 89.6% and 86.7% in Areas IV and V for the period 1971/72-1979/80. These estimates are similar to present our estimates for apparent pregnancy rate.

Foetal sex ratio

Table 9 indicates the male foetal sex ratio by seasons and Areas. Overall male foetal sex ratio in Area IV is 52.1% (ranges : 44.4-55.7%) and in Area V is 49.7% (ranges : 40.2-53.7%). Except for the 1990/91 season, all the other observed foetal sax ratio are not statistically different from equality (X^2-test). These values are almost same to the previous values (Ohsumi and Masaki ,1975 ; Masaki, 1979 ; Kato, 1982).

Litter size

Table 10 indicates litter size by seasons and Areas. Twins were found in two of 338 pregnant females examined (0.6%) in Area IV, and in eight of 394 pregnant females examined (2.0%) in Area V.

Examined pregnant females didn't have three or more fetuses. Litter size ranges 1.000-1.014 with overall mean of 1.006 and 1.009-1.031 with overall mean of 1.020 in Areas IV and V, respectively. The all of observed values of litter size are not statistically different from 1.000 (X^2-test) in both Areas. Ohsumi and Masaki (1975) and Masaki (1979) reported litter sizes which were estimated about 1.007 and 1.006, respectively. And Kato (1982) estimated that the average value for all Areas combined was 1.006. These estimates are similar to present our estimates litter size in Area IV and are lower than its in Area V.

Growth curve

Male

Fig. 2 shows the relationship between age and mean body length in male minke whales in Areas IV and V. Youngest males are available at age of 1, their mean body length are 5.5m. The mean body length rapidly increase until around five years. Since then, body length of males grow slowly. The body length reach about 8.5m at around 18-20 years and ceased to increase in body length afterlife stage. The fitted Von Bertalanffy growth curve equations for males are as follows:

$$\text{Area IV}: L=8.487(1-e^{-0.2816(x+2.351)}) \quad (9)$$

$$\text{Area V}: L=8.537(1-e^{-0.3076(x+2.022)}) \quad (10)$$

Female

Fig. 3 shows the relationship between age and mean body length in female minke whales in Areas IV and V. Youngest females available at age of one, their mean body length are 5.5m. The mean body length rapidly increase until around five years. Since then body length of males grow slowly. The body length reach about at 9.0m at around 22-23 years and ceased to increase in body length afterlife stage. The fitted Von Bertalanffy growth curve equations for females are as follows:

$$\text{Area IV}: L=9.127(1-e^{-0.2309(x+2.8537)}) \quad (11)$$

$$\text{Area V}: L=8.981(1-e^{-0.2021(x+3.2931)}) \quad (12)$$

The growth curves of the Antarctic minke whale were examined by Ohsumi *et al.* (1970), Ohsumi and Masaki (1975) and Masaki (1979), and these authors noted that the growth curve in younger ages are thought to be insufficient because of the difficulty in collection of five years and younger materials. Since then, some papers tried to draw the growth curve have failed to construct reasonable growth curve due to lack of younger animals in the sample.

DISCCUSION

As described in previous chapters, we have provided new estimates of biological parameters of southern minke whales using data obtained through the JARPA surveys. Through the analyses of parameter value

between the present and previous study, the difference are found in parameter of male's *tm* value and female's *tm* and *tmov* values. As to previous estimate of age at sexual maturity (*tm50%*), there have been concerned that reproductive segregation occurred at the Antarctic whaling ground which mature females dominated there and also catching selectivity which tended to take larger animals give downward bias to the parameter value. However, the present *tm* values of male's (4.2 and 4.9 years in Areas IV and V) and also female's (7.2 and 8.4 years in Areas IV and V) are about 1-2.5 higher than previous estimates by commercial whaling data. As always noted in earlier parts of this paper and fully explained by Fujise *et al.* (in prep.), the JARPA survey has incorporated the random sampling method, in which there is no intentional selection of the animals and also the JARPA survey covers wider latitudes than commercial whaling operation. This might contribute to neglect or minimize biases due to reproductive segregation and catching selectivity. The given evidence are theoretically agree with mechanism to produce the downward bias, thus the parameter value of *tm* are considered to be representative value of the population or at least much more close to real value. Kato (1987) considered *tmov* value provides unbiased values to represent age at sexual maturity of population because these animals are free from biasing factor such as reproductive segregation and catching selectivity. In facts, present study of *tmov* (7.2 and 9.1 years in Areas IV and V) are very close with *tm* (7.2 and 8.4 years in Area IV and V). This must be suggest our both values in Areas IV and V estimated using the JARPA data can be regarded as the representative values for population.

The growth curves of the Antarctic minke whale were examined by Ohsumi *et al.* (1970), Ohsumi and Masaki (1975) and Masaki (1979), and these authors noted that the growth curve in younger ages are thought to be insufficient because of the difficulty in collection of five years and younger materials. Due to limitation of available for small sizes animals under the commercial whaling operation formulation of growth curve for southern minke whales has been extremely insufficient. However the JARPA data provides more reasonable age-length data covers younger animals such as age 1 and 2 which were not caught under the commercial whaling operation. This is also one of products attributable to introducing the random sampling method. Kato (1987) examined the growth curves were constructed for fore year-class groups using each containing 10 years-classes, and found the mean lengths at age in younger cohorts to be statistically larger than that of older cohorts in both sexes and considered that the growth rate had increased with time, however it was not calculated above same method using the JARPA data due to the small sample size and too short time series of data. Therefore it is necessary to continue survey and to accumulate materials and data by the JARPA survey in order to monitor such changes still continue or not.

It is also found that difference some parameter values (such as the female's *Lm* value , the male's *tm* value and the female's *tm* and *tmov* values) between Areas IV and V. These difference of values between Areas IV and V can be produced by both reasons due to separation stock between Areas IV and V or due to reproductive segregation with in same stock. This must be further explored taking account of genetic information.

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Table 1. Reproductive status and maturity rate in male minke whales sampled by the the JARPA surveys, by season and Area.

		Immature	Mature		Unknown	Total	Maturity rate(%)
			Maturing	Mature			
Area IV	87/88	32	7	113	1	153	78.9
	89/90	24	20	140	0	184	87.0
	91/92	30	0	135	0	165	81.8
	93/94	42	9	149	0	200	79.0
	95/96	34	9	161	0	204	83.3
	Combined	162	45	698	1	906	82.1
Area V	88/89	15	15	55	0	85	82.4
	90/91	16	12	136	0	164	90.2
	92/93	12	0	155	0	167	92.8
	94/95	30	5	165	0	200	85.0
	Combined	73	32	511	0	616	88.1
Total		235	77	1209	1	1522	84.5

Table 2. Reproductive status and maturity rate in female minke whales sampled by the JARPA surveys, by season and Area.

		Immature	Mature						Total	Maturity rate (%)
			Ovu.	Rest.	Preg.	Lact.	Preg.&Lact.	Unknown	Total		
Area IV	87/88	60	0	1	57	0	0	1	59	119	49.6
	89/90	57	3	2	77	0	3	0	85	142	59.9
	91/92	39	3	6	70	1	2	2	84	123	68.3
	93/94	61	3	3	57	0	5	1	69	130	53.1
	95/96	50	3	5	68	0	0	0	76	126	60.3
	Combined	267	12	17	329	1	10	4	373	640	58.3
Area V	88/89	44	2	4	98	0	1	2	107	151	70.9
	90/91	28	4	18	108	0	0	1	131	159	82.4
	92/93	37	1	1	120	0	1	0	123	160	76.9
	94/95	43	0	19	66	0	2	0	87	130	66.9
	Combined	152	7	42	392	0	4	3	448	600	74.7
Total		419	19	59	721	1	14	7	821	1240	66.2

Table 3. Relationship between body length and sexual maturity rate in minke whales sampled by the JARPA surveys.

Male

Body length class	Area IV				Area V			
	Immature	Mature	Total	Maturity rate (%)	Immature	Mature	Total	Maturity rate (%)
4.5-4.9	4	0	4	0.0	0	0	0	0.0
5.0-5.4	31	0	31	0.0	13	0	13	0.0
5.5-5.9	46	0	46	0.0	8	0	8	0.0
6.0-6.4	23	0	23	0.0	13	0	13	0.0
6.5	5	0	5	0.0	5	0	5	0.0
6.6	9	0	9	0.0	2	1	3	33.3
6.7	8	1	9	11.1	4	0	4	0.0
6.8	6	0	6	0.0	1	0	1	0.0
6.9	3	0	3	0.0	3	0	3	0.0
7.0	7	2	9	22.2	4	2	6	33.3
7.1	2	1	3	33.3	5	2	7	28.6
7.2	3	1	4	25.0	4	3	7	42.9
7.3	2	7	9	77.8	4	3	7	42.9
7.4	2	8	10	80.0	2	6	8	75.0
7.5	3	4	7	57.1	2	4	6	66.7
7.6	1	14	15	93.3	0	5	5	100.0
7.7	1	10	11	90.9	0	16	16	100.0
7.8	0	17	17	100.0	2	24	26	92.3
7.9	4	28	32	87.5	0	22	22	100.0
8.0	0	34	34	100.0	0	27	27	100.0
8.1	0	54	54	100.0	0	44	44	100.0
8.2	1	67	68	98.5	0	53	53	100.0
8.3	0	81	81	100.0	0	70	70	100.0
8.4	0	84	84	100.0	0	56	56	100.0
8.5	0	74	74	100.0	0	54	54	100.0
8.6	0	78	78	100.0	0	37	37	100.0
8.7	0	61	61	100.0	0	38	38	100.0
8.8	0	42	42	100.0	0	25	25	100.0
8.9	0	30	30	100.0	0	23	23	100.0
9.0-9.4	0	44	44	100.0	0	27	27	100.0
9.5-					0	13	13	100.0

Female

Body length class	Area IV				Area V			
	Immature	Mature	Total	Maturity rate (%)	Immature	Mature	Total	Maturity rate (%)
4.5-4.9	3	0	3	0.0	1	0	1	0.0
5.0-5.4	19	0	19	0.0	10	0	10	0.0
5.5-5.9	49	0	49	0.0	25	0	25	0.0
6.0-6.4	25	0	25	0.0	10	0	10	0.0
6.5	12	0	12	0.0	9	0	9	0.0
6.6	11	0	11	0.0	5	0	5	0.0
6.7	6	0	6	0.0	2	0	2	0.0
6.8	7	0	7	0.0	4	0	4	0.0
6.9	11	0	11	0.0	3	0	3	0.0
7.0	5	0	5	0.0	5	0	5	0.0
7.1	8	0	8	0.0	3	0	3	0.0
7.2	11	0	11	0.0	6	0	6	0.0
7.3	10	0	10	0.0	8	0	8	0.0
7.4	6	0	6	0.0	3	0	3	0.0
7.5	10	0	10	0.0	7	0	7	0.0
7.6	7	0	7	0.0	4	1	5	20.0
7.7	10	0	10	0.0	7	1	8	12.5
7.8	8	0	8	0.0	4	2	6	33.3
7.9	7	2	9	22.2	8	2	10	20.0
8.0	9	4	13	30.8	8	7	15	46.7
8.1	6	5	11	45.5	5	7	12	58.3
8.2	5	11	16	68.8	5	17	22	77.3
8.3	10	8	18	44.4	3	21	24	87.5
8.4	5	21	26	80.8	4	26	30	86.7
8.5	2	18	20	90.0	0	31	31	100.0
8.6	3	22	25	88.0	0	35	35	100.0
8.7	0	32	32	100.0	3	56	59	94.9
8.8	2	38	40	95.0	0	34	34	100.0
8.9	0	27	27	100.0	0	43	43	100.0
9.0-9.4	0	144	144	100.0	0	140	140	100.0
9.5-	0	120	120	100.0	0	109	109	100.0

Table 4. Mean body length at sexual maturity (Lm).

Male

	Area IV			Area V		
	Mean body length	Variance	S.E.	Mean body length	Variance	S.E.
First	7.32	0.0136	0.1164	7.14	0.0477	0.2185
Second	7.27	0.0545	0.2335	7.23	0.0433	0.2082
Total	7.27	0.0304	0.1744	7.24	0.0345	0.1858

Female

	Area IV			Area V		
	Mean body length	Variance	S.E.	Mean body length	Variance	S.E.
First	8.16	0.0427	0.2066	8.02	0.0388	0.1969
Second	8.20	0.0193	0.1388	7.99	0.0394	0.1985
Total	8.18	0.0110	0.1047	8.01	0.0176	0.1325

Table 5. Mean body length and age at the first ovulation (Occurrence of one corpus luteum but no corpora albicantia in the ovaries).

		Body length (m)					Age (year)				
		Mean	S.D.	Min.	Max.	n	Mean	S.D.	Min.	Max.	n
Area IV	87/88	8.28	0.33	8.00	9.01	7	8.9	2.0	6	11	7
	89/90	8.35	0.25	7.93	8.79	11	5.4	1.1	4	8	10
	91/92	8.37	0.38	7.87	8.80	4	7.0	0.0	7	7	3
	93/94	8.58	0.20	8.32	9.00	8	8.0	1.7	6	11	5
	95/96	8.63	0.00	8.63	8.63	1	10.0	0.0	10	10	1
	Combined	8.40	0.30	7.87	9.01	31	7.2	2.1	4	11	26
Area V	88/89	8.27	0.00	8.27	8.27	1	8.0	0.0	8	8	1
	90/91	8.18				1	11.0				1
	92/93	8.31	0.30	7.78	8.72	5	9.2	1.0	8	10	5
	94/95	8.83				1	8.0				1
	Combined	8.35	0.30	7.78	8.83	8	9.1	1.2	8	11	8
Total		8.39	0.30	7.78	9.01	39	7.6	2.1	4	11	34

Table 6. Relationship between age and sexual maturity rate in minke whales sampled by the JARPA surveys.

Male

Age class	Area IV				Area V			
	Immature	Mature	Total	Maturity rate(%)	Immature	Mature	Total	Maturity Mat%
1	29	0	29	0.0	7	0	7	0.0
2	57	2	59	3.4	15	0	15	0.0
3	12	5	17	29.4	9	1	10	10.0
4	16	19	35	54.3	10	4	14	28.6
5	8	18	26	69.2	6	10	16	62.5
6	7	27	34	79.4	6	17	23	73.9
7	2	32	34	94.1	3	22	25	88.0
8	1	40	41	97.6	0	21	21	100.0
9	0	20	20	100.0	0	26	26	100.0
10	0	37	37	100.0	0	29	29	100.0
11	0	27	27	100.0	0	16	16	100.0
12	0	25	25	100.0	0	27	27	100.0
13	0	26	26	100.0	0	13	13	100.0
14	0	22	22	100.0	0	17	17	100.0
15-19	0	102	102	100.0	0	78	78	100.0
20-24	0	84	84	100.0	0	73	73	100.0
25-29	0	76	76	100.0	0	60	60	100.0
30-34	0	49	49	100.0	0	46	46	100.0
35-39	0	28	28	100.0	0	25	25	100.0
40-44	0	9	9	100.0	0	8	8	100.0
45-49	0	8	8	100.0	0	1	1	100.0
50-	0	5	5	100.0				

Female

Age class	Area IV				Area V			
	Immature	Mature	Total	Maturity rate(%)	Immature	Mature	Total	Maturity Mat%
1	24	0	24	0.0	11	0	11	0.0
2	52	0	52	0.0	18	0	18	0.0
3	32	1	33	3.0	17	0	17	0.0
4	26	3	29	10.3	16	0	16	0.0
5	19	5	24	20.8	19	1	20	5.0
6	20	9	29	31.0	11	1	12	8.3
7	11	12	23	52.2	7	5	12	41.7
8	6	14	20	70.0	9	11	20	55.0
9	3	14	17	82.4	7	9	16	56.3
10	4	24	28	85.7	5	13	18	72.2
11	2	17	19	89.5	2	17	19	89.5
12	0	13	13	100.0	1	23	24	95.8
13	1	8	9	88.9	3	24	27	88.9
14	0	10	10	100.0	0	21	21	100.0
15-19	0	65	65	100.0	0	97	97	100.0
20-24	0	49	49	100.0	0	76	76	100.0
25-29	0	37	37	100.0	0	55	55	100.0
30-34	0	25	25	100.0	0	25	25	100.0
35-39	0	13	13	100.0	0	17	17	100.0
40-44	0	5	5	100.0	0	6	6	100.0
45-49	0	6	6	100.0	0	3	3	100.0
50-	0	2	2	100.0	0	1	1	100.0

Table 7. Mean age at sexual maturity (tm).

Male

	Area IV			Area V		
	Mean age	Variance	S.E.	Mean age	Variance	S.E.
First	3.5	0.0653	0.2556	4.6	0.1075	0.3278
Second	4.8	0.0514	0.2267	5.6	0.0619	0.2489
Total	4.2	0.0366	0.1913	4.9	0.0545	0.2334

Female

	Area IV			Area V		
	Mean age	Variance	S.E.	Mean age	Variance	S.E.
First	7.6	0.3478	0.5897	8.4	0.1857	0.4310
Second	7.2	0.0666	0.2580	8.3	0.2127	0.4612
Total	7.2	0.0726	0.2695	8.4	0.0835	0.2890

Table 8. Apparent pregnancy rates in minke whales sampled by JARPA surveys, by season and Area.

		Mature		Pregnancy
		Preg.	Total	rate (%)
Area IV	87/88	57	59	96.6
	89/90	80	85	94.1
	91/92	72	84	85.7
	93/94	62	69	89.9
	95/96	68	76	89.5
	Combined	339	373	90.9
Area V	88/89	99	107	92.5
	90/91	108	131	82.4
	92/93	121	123	98.4
	94/95	68	87	78.2
	Combined	396	448	88.4
Total		735	821	89.5

Table 9. Male foetal sex ratio in minke whales sampled by the JARPA surveys, by season and Area.

		Male	Female	Unknown	Total	Male%	χ^2_{cal}
Area IV	87/88	24	30	3	57	44.4	0.667
	89/90	40	32	9	81	55.6	0.889
	91/92	29	32	12	73	47.5	0.148
	93/94	34	27	1	62	55.7	0.803
	95/96	34	31	2	67	52.3	0.138
	Combined	163	150	27	340	52.1	0.540
Area V	88/89	49	47	5	101	51.0	0.042
	90/91	43	64	2	109	40.2	4.121*
	92/93	50	58	14	122	46.3	0.593
	94/95	36	31	3	70	53.7	0.373
	Combined	178	180	24	382	49.7	0.011
Total		341	330	51	722	50.8	0.180

*:The hypothesis of 1:1 sex ratio is significant at the 5% level.

Table 10. Litter size of minke whales sampled by the JARPA surveys, by season and Area.

		Number of female	Number of foetus 1	2	Litter size	χ^2_{cal}
Area IV	87/88	57	57	0	1.000	0.000
	89/90	80	79	1	1.013	0.025
	91/92	72	71	1	1.014	0.028
	93/94	62	62	0	1.000	0.000
	95/96	67	67	0	1.000	0.000
	Combined	338	336	2	1.006	0.024
Area V	88/89	98	95	3	1.031	0.184
	90/91	108	107	1	1.009	0.016
	92/93	120	118	2	1.017	0.067
	94/95	68	66	2	1.029	0.118
	Combined	394	386	8	1.020	0.325
Total		732	722	10	1.014	0.273

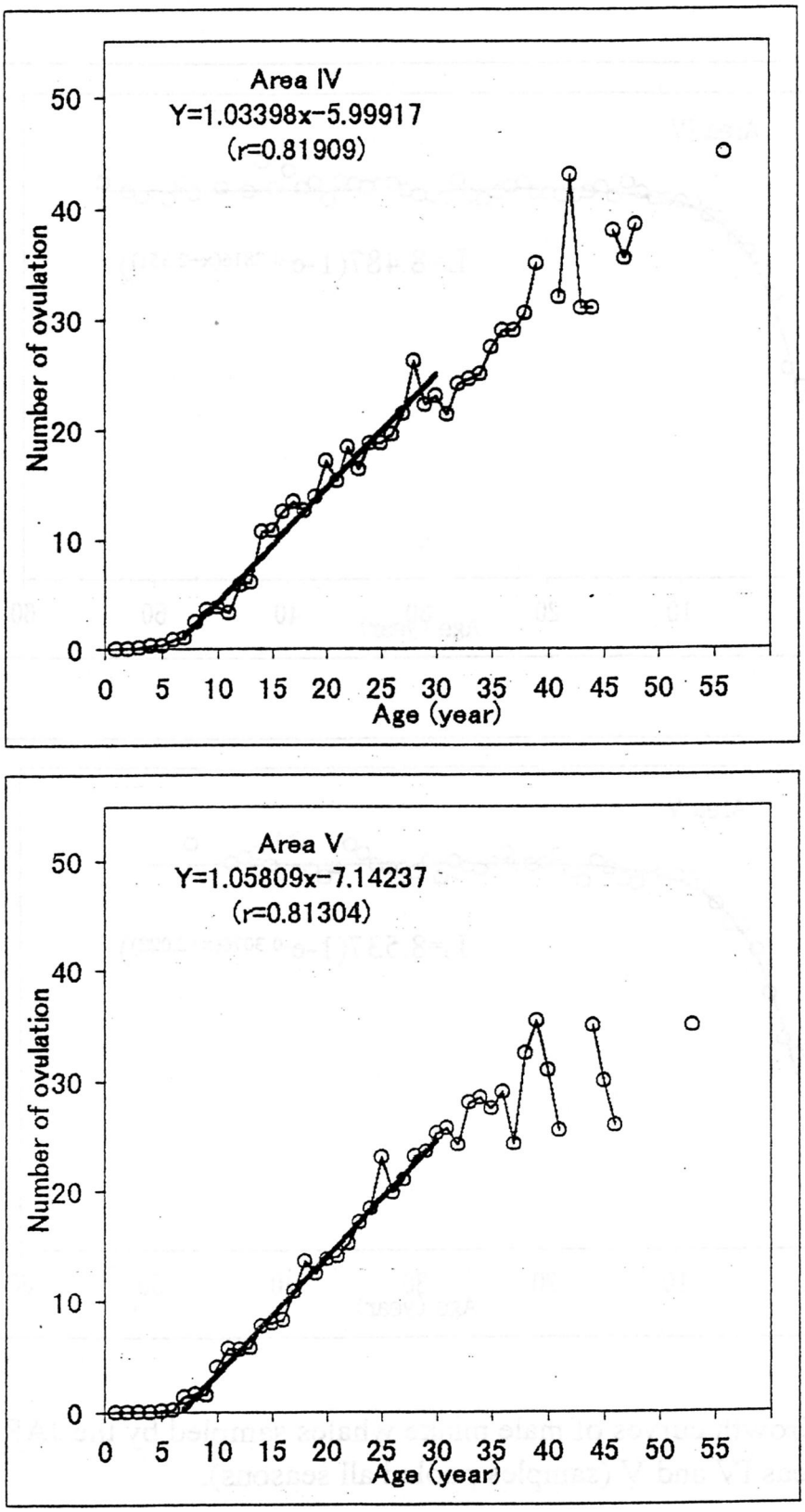


Fig 1. Relationship between mean number of corpora and age minke whales sampled by the JARPA surveys in Areas IV and V (samples pooled all seasons).

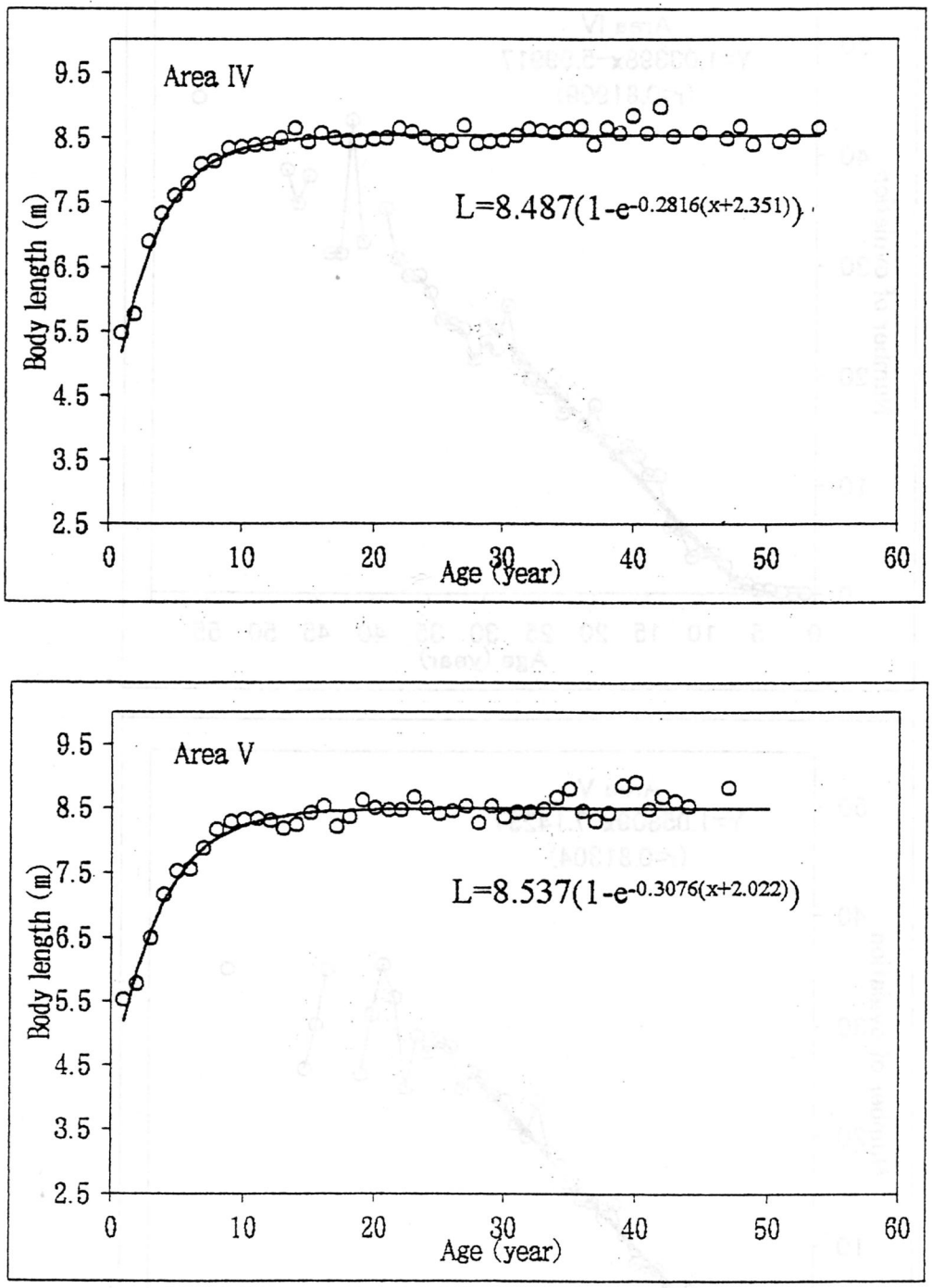
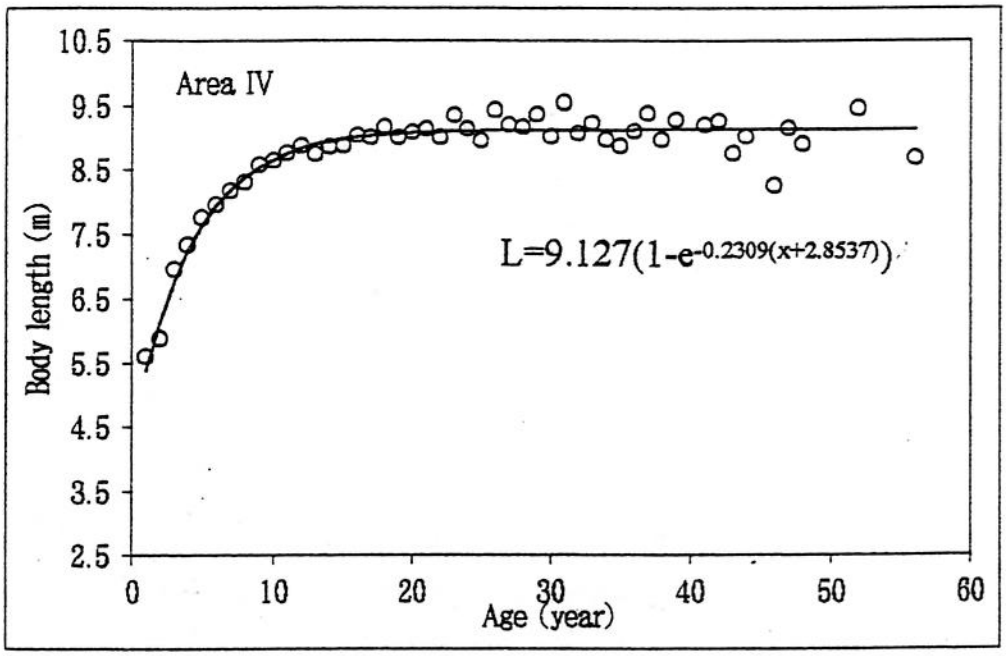


Fig. 2 Growth curves of male minke whales sampled by the JARPA surveys in Areas IV and V (samples pooled all seasons).



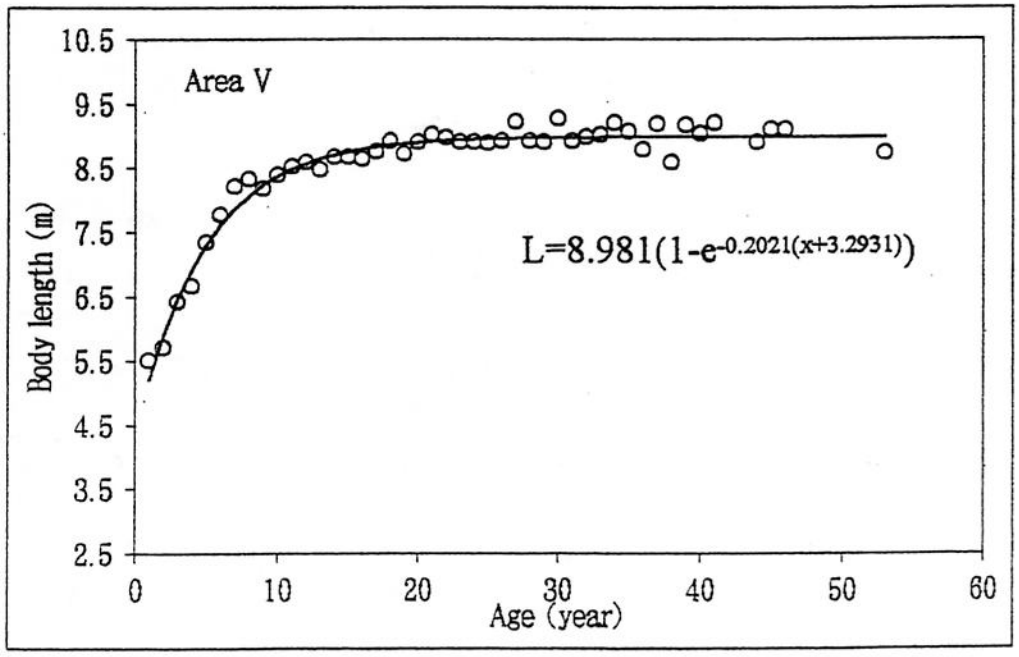


Fig. 3 Growth curves of female minke whales sampled by the JARPA surveys in Areas IV and V (samples pooled all seasons).