GROWTH AND REPRODUCTION OF *STENELLA COERULEOALBA* OFF THE PACIFIC COAST OF JAPAN

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ABSTRACT

This study is based on data from about five thousand specimens of *S. coeruleoalba*. Mean length at birth is 100 cm. Mean lengths at the age of 1 year and 2 years are 166 cm and 180 cm, respectively. The species starts feeding on solid food at the age of 0.25 year (or 135 cm). Mean weaning age is about 1.5 years (or 174 cm). Mean testis weights at the attainment of puberty and sexual maturity of males are 6.8 g and 15.5 g, respectively. Mean ages at the attainment of puberty and sexual maturity of males are 6.7 years (or 210 cm) and 8.7 years (or 219 cm), respectively. Females attain puberty and sexual maturity on the average at 7.1 years (or 209 cm) and 8.8 years (or 216 cm), respectively. There are three mating seasons in a year, from February to May, from July to September, and in December. Mating season may occur at an interval from 4 to 5 months. The overall sex ratio (male/female) is 1.14. Sex ratio changes with age, from near parity at birth, indicating higher mortality rates for males.

INTRODUCTION

The striped dolphin, *Stenella coeruleoalba* are caught annually by the driving fishery or hand harpoons in the Pacific coast of Japan (Ohsumi 1972, Miyazaki *et al.* 1974). According to Ohsumi (1972), Miyazaki *et al.* (1974), and Nishiwaki (1975), the striped dolphins caught in the Pacific coast of Japan are suggested to belong to one population.

The growth and reproduction of the species have been studied by some Japanese scientists (Nishiwaki and Yagi 1953, Hirose *et al.* 1970, Hirose and Nishiwaki 1971, Kasuya 1972, Kasuya and Miyazaki 1976, and Kasuya 1976). Hirose *et al.* (1970), and Hirose and Nishiwaki (1971) made histological examinations of the gonads, but they did not make the age determination. Kasuya (1972) studied growth and reproduction by the age determination by means of dentinal growth layers, and estimated that there are two mating seasons in a year. Kasuya and Miyazaki (1976) reported that the mean calving interval in the population in the coast of Japan is decreasing in accord with a decrease in population level. Recently Kasuya (1976) reconsidered the life history parameter based on cemental layers, and indicated that the analysis of the life history by means of dentinal layers can not be available in the older animals. However, Kasuya (1976) did not analize growth

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and reproduction by detailed examinations of the gonads.

The present study was undertaken to make histological examinations of the testes and detailed observations of the ovaries, in order to reconsider the life history up to the age of 13.5 years based on dentinal layers with abundant specimens, and to estimate the mating season of the species.

TABLE 1. LIST OF MATERIALS USED IN THIS STUDY

School no.	Date of kill	Number of dolphins		Percentage of examination	Researcher
		Caught	Examined		
5	16, 18, 22, Nov. '68	1,700	406	23.9	Kasuya
6	17, Nov. '68	344	318	99.7	Kasuya
8	12, Oct. '70	265	89	33.6	Miyazaki and Kasuya
9	13, Oct. '70	293	64	21.8	Miyazaki
10	21, Oct. '70	324	68	21.0	Miyazaki
11	24, Oct. '70	49	33	67.4	Miyazaki
12	29, Oct. '70	48	34	70.8	Miyazaki
13	22, Nov. '70	1,832	125	6.8	Hirose
15	2, Dec. '70	259	256	98.8	Miyazaki
16	10, Dec. '70	84	84	100	Miyazaki
17	2, Oct. '71	393	176	44.8	Miyazaki
18	4, Oct. '71	101	58	57.4	Miyazaki
19	5, Nov. '71	25	25	100	Miyazaki
20	17, 18, Nov. '71	636	361	56.8	Miyazaki
21	20, Nov. '71	140	100	71.4	Miyazaki
22	15, Dec. '71	903	300	33.2	Miyazaki and Kasuya
23	3, Oct. '72	31	29	93.5	Miyazaki
24	4, Oct. '72	225	96	42.7	Miyazaki
25	7, Oct. '72	120	31	25.8	Miyazaki
26	8, Oct. '72	94	41	43.6	Miyazaki
27	13, 15, 16, Oct. '72	574	211	36.8	Miyazaki
28	14, 18, 19, Oct. '72	305	124	40.7	Miyazaki
29	17, 19, 20, Oct. '72	238	108	45.4	Miyazaki
30	23, Oct. '72	48	29	60.4	Miyazaki
31	26, Oct. '72	54	40	74.1	Miyazaki
32	1, Nov. '72	63	63	100	Miyazaki
33	5, Nov. '72	284	120	42.3	Miyazaki
34	9, Nov. '72	239	104	43.5	Miyazaki
35	10, Nov. '72	45	27	60.0	Miyazaki
36	15, Nov. '72	243	112	46.1	Miyazaki
37	16, Nov. '72	200	71	35.5	Miyazaki
38	17, 20, Nov. '72	372	212	57.0	Miyazaki
39	21, Nov. '72	293	130	44.4	Miyazaki
40	23, 26, Nov. '72	535	137	25.6	Miyazaki
42	7, 9, Dec. '72	912	168	18.4	Miyazaki
43	19, Nov. '73	414	251	60.6	Miyazaki and Kasuya
44	20, 22, Nov. '73	1,724	470	27.3	Miyazaki and Kasuya
—	20 Jan. '73 - 15, Feb. '73	271*	271*	100	Miyazaki
Total**		14,409	5,071		

* animals caught by hand harpoon at Taiji.

** exclude the animals caught at Taiji.

MATERIALS AND METHODS

Biological informations were obtained from 5,071 striped dolphins from 37 schools caught by the driving fisheries at Kawana and Futo on the east coast of Izu Peninsula during the five years from 1968 to 1973, and from 271 dolphins caught by hand harpoon at Taiji on the coast of Kii Peninsula in 1973 (Table 1). Of these specimens the data of the school nos. 5 and 6 were provided by Dr. T. Kasuya, and of the school no. 13 by Dr. K. Hirose.

Body length was measured in 1 cm interval in a straight line from the tip of the upper jaw to the notch of the tail flukes.

Mammary gland was observed in the field and classified into lactating and nonlactating.

The ovaries were collected from most of females and fixed in 10% formalin solution. In the laboratory the ovaries were weighed, the number of corpora albicantia and lutea was counted, and the three diameters of corpora were measured. The mean diameter of the corpora was obtained as the cube root of the value multiplied their diameters.

Usually the testes were collected from most of males, fixed in 10% formalin solution, and then transported to laboratory. Histological samples were taken from the center of cross section at the midlength of the testis, processed into microscopic slide, and stained with haematoxylin and eosin.

Several teeth were collected from the center of tooth row of each dolphin with a pair of gardening scissors and fixed in 10% formalin solution. The teeth were prepared by the method of Kasuya *et al.* (1974). The opaque layers were counted under a binocular microscope (×20–×50) with transmitted light.

The ages of 930 dolphins of the school nos. 5, 6, 22, 28, 43, and 44 were determined by Dr. T. Kasuya. As his age determination of the animals between the age of 1 and 12 years was biased by 0.27 year to the lower side of Miyazaki's reading (Kasuya and Miyazaki 1976), there is no significant difference between their age determinations. Therefore, in this study the age data determined by Dr. T. Kasuya were used together with the same data prepared by Miyazaki.

AGE DETERMINATION

Growth layers in the dentine have been used for age determination of the animals by various authors, for example in *Tursiops truncatus* (Sergeant 1959), *Globicephala melaena* (Sergeant 1962), *Physeter catodon* (Ohsumi *et al.* 1963), *Stenella coeruleoalba* (Kasuya 1972), *Stenella attenuata* (Kasuya *et al.* 1974). Recently cemental layers were employed in the age determination of the animals in *S. coeruleoalba* and *S. attenuata* (Kasuya 1976).

Since the teeth on the anterior parts of the jaws are too small and those on the posterior are too strongly twisted, they were not used for the age determination. The readability of the growth layers in teeth from different positions of the same animal was checked on one individual (Table 2). The number of layers in these

TABLE 2. AGE DETERMINATION BY TEETH COLLECTED FROM VARIOUS POSITIONS OF JAWS IN ONE DOLPHIN

Jaw	Tooth No. from tip of jaw			
	10	20	30	40
Left upper jaw	10.5	12.5	11.5	12.5
Left lower jaw	12.5	12.5	12.5	12.5
Right upper jaw	10.5	11.5	13.5	11.5

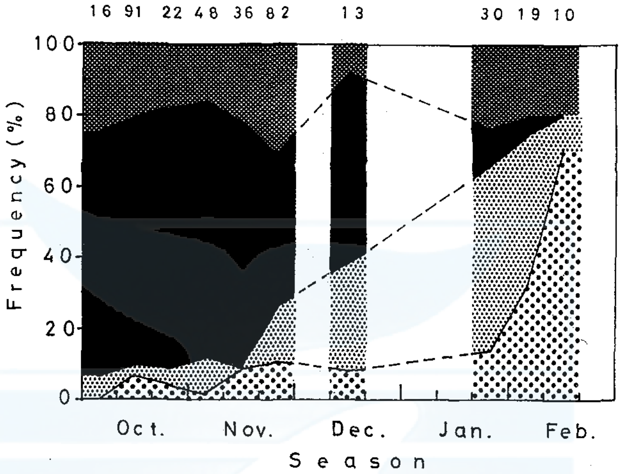

Fig. 1. Seasonal change of the formation of opaque and translucent dentinal layers. The marks indicate thin opaque layer, thick opaque layer, thin translucent layer, and thick translucent layer (from top to bottom). The numbers at the top indicate the sample size. The dates of the kill are grouped into the 1st, 2nd, and 3rd decade of month.

teeth ranges from 10.5 to 13.5 years (average: 12.0 years) indicating no significant variations.

In order to find out the annual accumulation rate of dentinal growth layer, the kind of the last layer and its thickness were examined on the teeth with three or less opaque bands. Fig. 1 shows that the alternation from opaque to translucent layer occurs in the period of December and January. This is slightly later than that estimated by Kasuya (1972). In the present study it is impossible to decide when the alternation from translucent to opaque layer occurs because of the absence of adequate samples. However, above result coincides with that of *S. attenuata* (Kasuya *et al.* 1974) in which the alternations occur in December or January and also in April or May, and each opaque and translucent layer represents about 6 months. Accordingly it will be correct to presume that the alternation from opaque to translucent layer of the dentine of *S. coeruleoalba* may occur in winter and the alternation from translucent to opaque layer in summer, and that each opaque and translucent layer represents approximately 6 months, respectively.

In the present study an approximate age was calculated by the criterion of Kasuya *et al.* (1974) taking into consideration of the kind of the first and the last layers, and of their thickness in the dentine.

Since the dentine above 16 layers is composed of poorly calcified secondary dentine, it is impossible to read precisely the dentine with 16 layers or more. Kasuya (1976) showed that the accumulation of the dentine layers of *S. coeruleoalba* ceases at a large variety of age above 11 dentinal layers and that the accumulation of cemental layers continues longer. The number of dolphins fallen in the range between $x+1$ and $x-1$ cemental layers was calculated at the x dentinal layer on the basis of Fig. 2 of Kasuya (1976). The ratios of this number to the total at 12, 13, 14, and 15 dentinal layers were calculated at 80.9, 72.7, 54.8, and 13.8%, respectively. This indicates that the ratio of the dolphins whose ages are underestimated becomes gradually higher with the increase of the number of dentinal layers during 11 and 15 layers, and this ratio attains about 50% at 14 dentinal layers. Accordingly the age determination of the animals seems to be reliable till 14 dentinal layers with precision of 50% or more. Therefore, this study intends to analize the animals at the age of 13.5 years or less. During 11 and 14 dentinal layers, however, the value of the mean growth curve or age-weight of testis relationship obtained in this study appears to be higher than that expected from cemental layers by Kasuya (1976), and the bias between two values is considered to become larger with increase of the number of dentinal layers.

GROWTH

Mean body length at birth

Since the body lengths of newborn calves do not show distinct sexual dimorphism and available data are scarce, the mean body length at birth was calculated by combining both sexes. The body lengths were grouped at interval of 5 cm. The largest fetus was 108 cm and the smallest calf 98 cm. Then the fetuses and calves from 95 cm to 115 cm groups were used to calculate the mean body length at birth (Table 3). The number of fetuses and calves was equal at 105 cm group. However, the numbers of fetuses and calves between 95 and 115 cm groups were 68 and 20 animals, respectively, and there is a big difference between two numbers. This seems to be caused by the loss of some newborn calves during the driving of animals as already suspected by Kasuya (1972). Then the frequency was corrected to equalize the numbers of fetuses and newborn calves (Table 3). The mean body length at birth was obtained at 100.5 cm as the body length corresponding to the

TABLE 3. BODY LENGTH FREQUENCIES OF FETUSES AND CALVES

Length group (cm)	Fetus (no.)	Calf (no.)	Fetus (%)	Calf (%)	Percent of calf (corrected)
95	33	0	48.53	0	0
100	30	8	44.12	40.00	45.39
105	4	4	5.88	20.00	77.28
110	1	5	1.47	25.00	94.45
115	0	3	0	15.00	100
Total	68	20	100	100	50.00

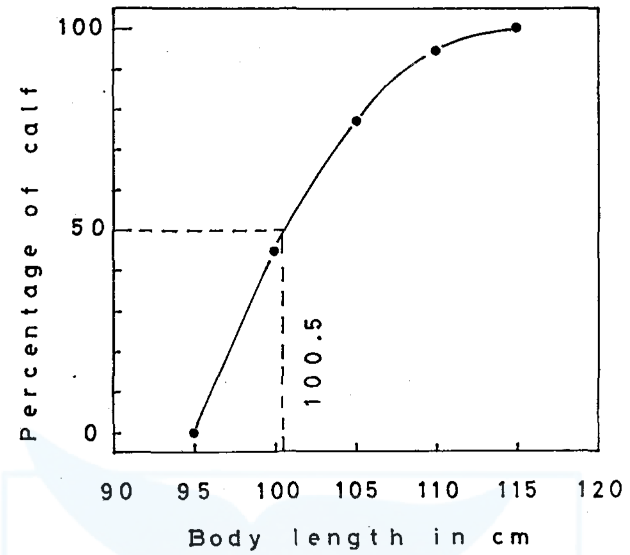

Fig. 2. Mean body length at birth. For explanation see text.

frequency of 50% (Fig. 2). This result coincides with that of Kasuya (1972).

Weaning

The weaning age of the animals was estimated by the following two methods.

First method: The food remains in the first stomach of 45 young animals were examined (Table 4). The smallest animal containing solid food in the stomach was 133 cm and the largest containing milk was 176 cm in body length. The youngest animal containing the solid food in the stomach was 0.25 year old and the oldest containing milk was 1.25 years old. Accordingly it is considered that some individuals start feeding on solid food at 133 cm or 0.25 year, and some may continue to take both milk and solid food until 176 cm in body length or by the age of 1.25 years. However, this age seems to be underestimated, because when an animal contains solid food, it is not easy to detect milk mixed in solid food.

The food items found in the stomachs of these young animals were fishes, squids, and shrimps. This suggests that when the young animals start to feed on solid food, no preference was made among fishes, squids, and shrimps.

Second method: The next method is to compare the number of the young postnatal dolphins and that of the lactating females in the school. In the first place the calves were counted in the order of their ages from the youngest one until the number become equal to that of lactating females. Then the weaning age was determined to be the age of the last calf in this counting in each school. Secondly the dolphins of this age or younger were classified as suckling calves, and the dolphins older than this age as juvenile calves in each school. Finally the ratio of juvenile calves to the total calves from 17 schools was calculated at each age as shown in Fig. 3. The oldest suckling calf was at the age of 2.5 years. As the relation between this ratio and age

TABLE 4. WEANING AND TOOTH ERUPTION

Date of kill	Field no.	Sex	Body length	Age	Milk	Food	No. of erupted teeth	Comments
3, Dec. ’72	155	M	102	0.25	—	—	L: o/o, R: o/o	
23, Nov. ’72	2	M	103	0.25	—	—	L: o/o, R: o/o	
17, Oct. ’72	40	M	110	0.25	—	—	L: +/o, R: +/o	
20, Nov. ’71	41	M	112	—	r	none	L: 30/o, R: 33/o	milk only
20, Nov. ’72	112	F	122	0.25	—	—	L: 35/o, R: 35/o	
17, Oct. ’72	1	M	130	0.25	r	none		milk only
20, Nov. ’72	114	F	132	0.25	—	—	L: 37/28, R: 37/28	
3, Dec. ’72	133	M	132	—	—	—	L: +/o, R: +/o	
20, Nov. ’73	92	M	133	—	r	r		beaks of squids
7, Oct. ’72	7	F	135	0.25	—	r		fish lens
20, Nov. ’73	126	M	142	0.5	r	none		milk only
20, Nov. ’73	182	M	145	0.25	—	r		beaks of squids
20, Nov. ’73	27	M	149	—	r	none		milk only
20, Nov. ’73	28	M	149	—	—	r		beaks of squids
17, Oct. ’72	3	M	150	0.5	—	r		
20, Nov. ’73	12	F	151	—	r	r		beaks of squids
20, Nov. ’73	13	M	152	—	r	none		milk only
20, Nov. ’73	11	M	153	—	r	none		milk only
26, Jan. ’73	20	M	154	0.5	—	r		fish lens
3, Dec. ’72	144	F	154	—	—	—	L: +/+, R: +/+	
20, Nov. ’73	136	F	154	0.5	—	r		beaks of squids
3, Dec. ’72	143	M	157	—	—	—	L: +/+, R: +/+	
20, Nov. ’73	167	F	157	0.5	r	r		beaks of squids
20, Nov. ’73	214	F	158	0.5	—	r		beaks of squids
20, Nov. ’73	127	M	159	1.25	r	r		beaks of squids
20, Nov. ’73	49	F	163	—	—	r		beaks of squids and shrimps
3, Feb. ’73	23	F	163	—	—	r		
17, Oct. ’72	4	F	170	1.25	—	r		
13, Oct. ’72	1	F	172	2.50	—	r		
26, Jan. ’73	11	F	174	2.25	—	rr		fish
3, Feb. ’73	30	M	176	0.75	r	—		
1, Nov. ’72	22	M	182	1.75	—	—		
1, Nov. ’72	2	F	184	1.50	—	r		
30, Jan. ’73	10	F	184	1.75	—	—		
1, Nov. ’72	9	F	184	2.50	—	r		
31, Jan. ’73	3	M	184	2.75	—	—		
31, Jan. ’73	30	M	184	3.00	—	r		
26, Jan. ’73	3	F	185	1.75	—	—		
26, Jan. ’73	7	F	185	3.00	—	—		
31, Jan. ’73	5	F	186	2.75	—	—		
21, Jan. ’73	3	F	187	1.75	—	r		
21, Jan. ’73	4	M	187	1.75	—	rr		
26, Jan. ’73	5	M	188	2.75	—	—		
3, Feb. ’73	29	F	189	3.00	—	—		
26, Jan. ’73	4	M	196	2.25	—	—		

L, left; R, right; M, male; F, female; r, few; rr, abundant; +, erupted can be shown in a straight line during the ages from 0.25 to 2.75 years, this line was calculated by the least squares during this range (Fig. 3). The age at which the ratio shows 50% is calculated to be 1.5 years. This indicates that the mean weaning

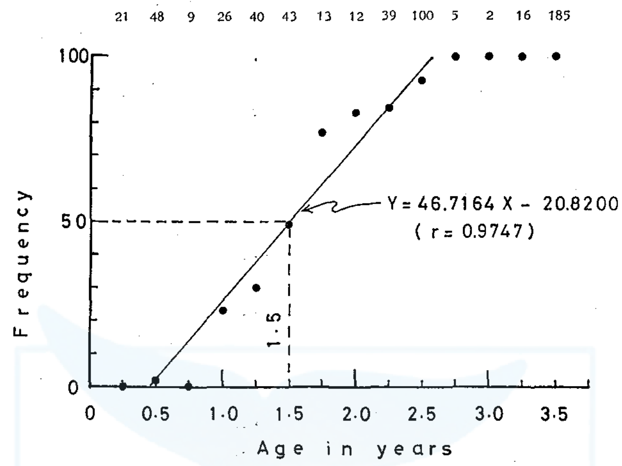

Fig. 3. Age of the weaning in *S. coeruleoalba.* Closed circles indicate the frequency of the juvenile calves. The numbers at the top show the sample size. For explanation see text.

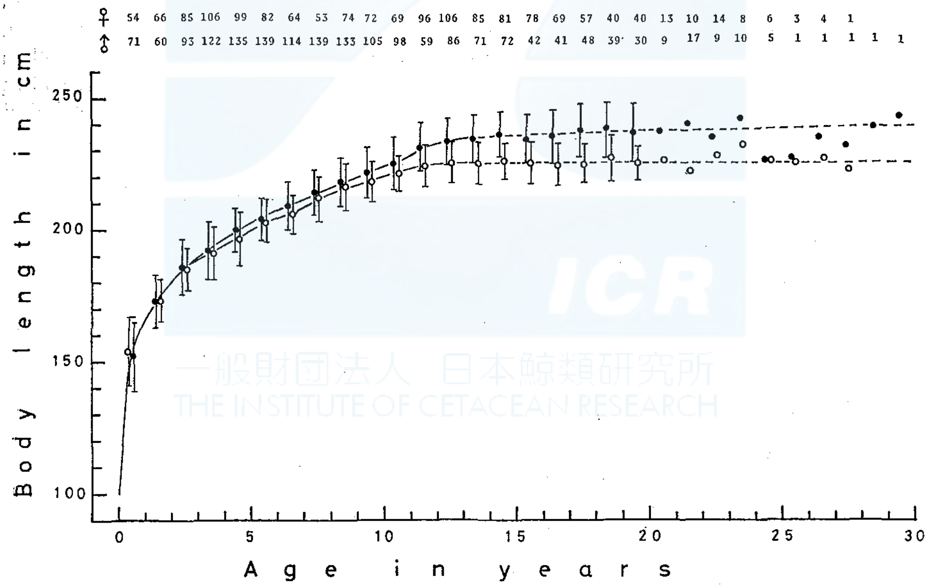

Fig. 4. The mean growth curves of the male and the female. Closed circles indicate the male and open circles the female. The numbers at the top indicate the sample size. For samples greater than 30, ± standard deviations indicated as vertical line. Solid line is drawn for the animals younger than 13.5 years old and the dotted line for the animals older than 13.5 years old.

age is 1.5 years and the body length at this age is 174 cm as indicated by the mean growth curve (Fig. 4). This method is not adequate to estimate the minimum weaning age. However, it is more reliable to estimate the maximum weaning age. Accordingly the mean weaning age is 1.5 years, and some dolphins may continue to suck milk until they become 2 to 3 years old. However, this mean weaning age seems to be overestimated, because the possible loss of newborn calf is expected (see page 25).

From these informations it is concluded that *S. coeruleoalba* starts feeding on solid food at the age of about 0.25 year (or 133 cm), the mean weaning age of the species is approximately 1.5 years (or 174 cm), and some dolphins may continue to take milk till the age of 2 to 3 years.

Tooth eruption

At birth the teeth of young animals have not yet pierced the gums. Teeth begin to erupt at about 110 cm and are almost erupted at approximately 130 to 150 cm in body length, as may be seen from the data shown in Table 4. The order of tooth eruption is: first, the 10-40th tooth of the upper jaw, and then the same numbers of the lower jaw, and finally those close to anterior and posterior ends. The body length in which teeth of both upper and lower jaws almost erupt well agrees with the body length of the animals which start feeding on solid food.

Postnatal growth

As the age determination of *S. coeruleoalba* is reliable till 14 dentinal layers (see page 25), in this section the postnatal growth till 14 dentinal layers was analized in detail with abundant data.

Based on the data of 1,752 males and 1,535 females, the mean body length was plotted against each dentinal layer, and the mean growth curve of *S. coeruleoalba* was drawn by assuming body length at birth is 100 cm (Fig. 4). Fig. 4 shows that *S. coeruleoalba* attains the body length of 166 cm and 180 cm at the age of 1 and 2 years in average, respectively. The sexual dimorphism of the body length appears at the age of about 3 years. The mean body length of the males is larger than that of the females at the ages from 3 to 10 years. The mean growth rate of the females increases at the age from 7 to 8 years. However, the mean body length of the females in this period does not exceed that of the males at the same age. After the age of 9 years, that is close to the mean age of attaining sexual maturity in the females, the mean growth rate of the females becomes slower, and the growth in the mean body length stops at the age of 12 years. On the other hand, the mean growth rate of the males is almost constant during the ages from 5 to 10 years. The mean growth rate of the males increases at the age of 11 years. Then the increase of the mean body length stops at the age of 13 years. The mean body lengths of 284 males older than 14 years, and of 584 females older than 12 years were calculated at 238 cm and 225 cm, respectively. According to Kasuya (1976) the asymptotic ages of *S. coeruleoalba* in the female and the male are 17 and 21 years, respectively. However, the mean body length of females older than 12 dentinal layers is close to the asymptotic length of the female obtained by Kasuya (1976), and that of males older than 14 dentinal layers is larger than the asymptotic length of the male obtained from Kasuya (1976). This indicates that if more abundant data are available, the asymptotic lengths of *S. coeruleoalba* in both sexes would be slightly larger than those expected by Kasuya (1976).

REPRODUCTION IN THE MALE

Testis weight and the maturity

The bilateral difference of testis weight was examined for 30 individuals. The ratio of the heavier testis to the lighter one came between 1.00 and 1.32, and the ratio less than 1.20 was observed in 93% of all the pairs. The ranges of the testis

TABLE 5. T-TEST OF THE SYMMETRY OF THE TESTIS WEIGHT

Weight (left, g.)	Range (L. - R.)	Mean difference	Sample size	Standard error	Probability
<6.8	−1.2 ~ 0.3	−0.2100	10	0.1487	0.80<p>0.90
6.8-15.4	−1.0 ~ 0.9	−0.1700	10	0.1932	0.50<p<0.70
15.5≦	−1.5 ~ 22.0	3.2900	10	2.3091	0.80<p<0.90
Total	−1.5 ~ 22.0	0.9700	30	0.8666	0.70<p<0.80

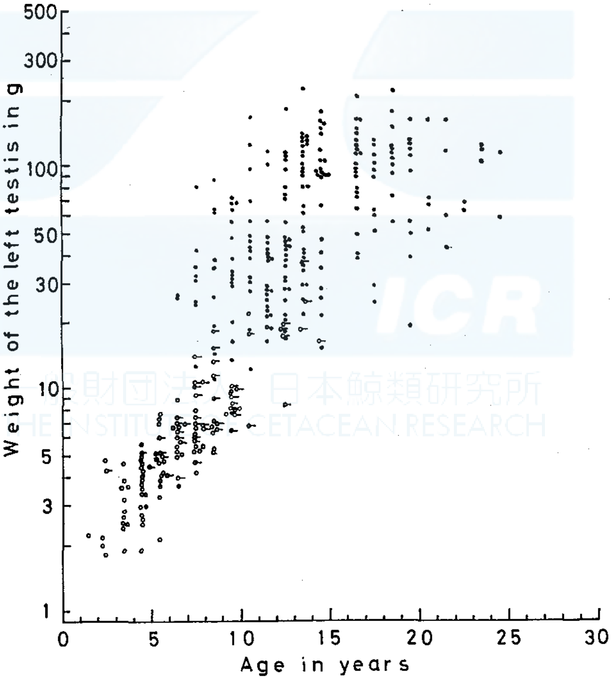

Fig. 5. Relation between age and the weight of the left testis. The weight of the left testis is plotted on logarithmic scale. Closed circles indicate the mature animals, open circles the immature, and open circles with rod the pubertal.

weight of immature, pubertal, and mature males on the average were obtained at less than 6.8 g, from 6.8 to 15.4 g, and at 15.5 g or more, respectively, as indicated in the latter sections of this study. The mean differences of the testis weights in these ranges are small enough to consider that there is no significant asymmetry of the testis weight (Table 5). Therefore, the weight of the left testis was used in the present study.

In order to check the maturity tissues were taken from the center of the cross section at the midlength of the testis and the tissues collected from testes of 350 males were histologically examined. Immature, pubertal, and mature males were defined as the animals having testes containing only spermatogonia, both spermatogonia and spermatocyte, and spermatozoa, respectively.

Fig. 5 shows the relation between age and testis weight. The testis weight rapidly increases at the ages of 2.5 years when pubertal male first appears and of 9 years which is about the mean age attaining sexual maturity. The increase of testis weight stops at about the age of 13.5 years. However, Kasuya (1976) reported that there was no increase related with the age of the animal after 15 years

TABLE 6. MATURITY OF THE MALE AND ACTIVITY OF THE MATURE MALE BY GROUP OF THE LEFT TESTIS WEIGHT

Testis weight (g)	Immature	Puberty	Mature				Total	Maturity (%)
			MI	MII	MIII	Total		
1–	3(100)						3	0
2–	12(100)						12	0
3–	13(100)						13	0
4–	13(65.0)	7(35.0)					20	0
5–	14(73.7)	5(26.3)					19	0
6–	3(20.0)	12(80.0)					15	0
7–	5(35.7)	8(57.1)	1(7.1)			1	14	7.1
8–	4(57.1)	3(42.9)					7	0
9–	1(20.0)	4(80.0)					5	0
10–		8(61.5)	5(38.5)			5	13	38.5
15–		7(43.8)	7(43.8)	2(12.5)		9	16	56.3
20–		1(8.3)	7(58.3)	4(33.3)		11	12	91.7
25–		1(5.3)	15(78.9)	3(15.8)		18	19	94.7
30–		1(10.0)	4(40.0)	5(50.0)		9	10	90.0
35–		1(6.7)	6(40.0)	8(53.3)		14	15	93.3
40–			5(38.5)	6(46.2)	2(15.4)	13	13	100
45–			3(27.3)	6(54.5)	2(18.2)	11	11	100
50–				8(66.7)	4(33.3)	12	12	100
60–			5(31.3)	6(37.5)	5(31.3)	16	16	100
70–			2(22.2)	3(33.3)	4(44.4)	9	9	100
80–			1(10.0)	1(10.0)	8(80.0)	10	10	100
90–					17(100)	17	17	100
100–				5(9.1)	50(90.9)	55	55	100
150–				2(13.3)	13(86.7)	15	15	100
200–					3(100)	3	3	100
Total	68	58	61	59	108	228	354	

Figures in parentheses indicate percentage.

old. This age difference appears to be related with differences in the methods of age determination.

Table 6 shows the ratio of immature males to the total males for each testis weight. The testis weight of the pubertal males ranges from 4.0 to 37.0 g. The relation between this ratio and testis weight in the range from 3.5 to 10.5 g can be shown by a straight line. The following formula was obtained by the least squares method, $y=11.3321x-26.6626$ $r=0.8407$; x: testis weight in g, y: the ratio, r: correlation coefficient. The testis weight that 50% of the animals attain the puberty is 6.8 g.

Table 7 shows the ratio of immature males to the total males at each age. The youngest pubertal male was 2.5 years and the oldest immature was 11.5 years. The relation between this ratio and age in the range from 3.5 to 10.5 years can be shown by a straight line. Calculation by the least squares method gives the formula, $y=15.2060x-51.5292$ $r=0.9652$; x: age in year, y: the ratio, r: correlation coefficient. The age when 50% of the animals attain puberty is 6.7 years and the body length at this age is 210 cm as indicated by the mean growth curve (Fig. 4).

The ratio of mature males to the total males for each testis weight is shown in

TABLE 7. MATURITY OF *S. COERULEOALBA* BY AGE GROUPS

Age	Male*				Female**			
	immat.	pub.	mat.	total	immat.	pub.	mat.	total
0.5	—	—	—	—	4(100)	0(0)	0(0)	4
1.5	1(100)	0(0)	0(0)	1	5(100)	0(0)	0(0)	5
2.5	4(80.0)	1(20.0)	0(0)	5	22(95.7)	1(4.3)	0(0)	23
3.5	11(100)	0(0)	0(0)	11	42(97.7)	1(2.3)	0(0)	43
4.5	17(85.0)	3(15.0)	0(0)	20	32(86.5)	3(8.1)	2(5.4)	37
5.5	15(78.9)	4(21.1)	0(0)	19	20(74.1)	6(22.2)	1(3.7)	27
6.5	9(50.0)	7(38.9)	2(11.1)	18	17(63.0)	8(29.6)	2(7.4)	27
7.5	5(17.9)	15(53.6)	8(28.6)	28	9(36.0)	8(32.0)	8(32.0)	25
8.5	3(14.3)	9(42.9)	9(42.9)	21	6(16.7)	16(44.4)	14(38.9)	36
9.5	4(14.8)	6(22.2)	17(63.0)	27	6(14.3)	7(16.7)	29(69.0)	42
10.5	0(0)	2(10.0)	18(90.0)	20	3(8.3)	5(13.9)	28(77.8)	36
11.5	1(4.8)	0(0)	20(95.2)	21	0(0)	2(3.4)	56(96.6)	58
12.5	0(0)	5(15.6)	27(84.4)	32	1(1.3)	1(1.3)	73(97.3)	75
13.5	0(0)	3(9.4)	29(90.6)	32	0(0)	0(0)	54(100)	54
14.5	0(0)	1(4.2)	23(95.8)	24	0(0)	0(0)	57(100)	57
15.5	—	—	—	—	0(0)	0(0)	46(100)	46
16.5	0(0)	0(0)	21(100)	21	0(0)	0(0)	44(100)	44
17.5	0(0)	0(0)	11(100)	11	0(0)	0(0)	40(100)	40
18.5	0(0)	0(0)	12(100)	12	0(0)	0(0)	27(100)	27
19.5	0(0)	0(0)	10(100)	10	0(0)	0(0)	21(100)	21
20.5~	0(0)	0(0)	15(100)	15	0(0)	0(0)	42(100)	42
Total	70	56	222	348	167	58	544	769

* The testis was histologically examined.

** The ovaries were weighed and the number of corpora albicantia and lutea was counted. Figures in parentheses indicate percentage.

Table 6. The testis weight of the mature males varied from 7.7 to 225.2 g. The relation between this ratio and testis weight can be shown by a straight line in the range from 2.5 to 27.5 g. The following formula was obtained by the least squares method, $y=4.2577x-15.8157$ $r=0.9819$; x: testis weight in g, y: the ratio, r: correlation coefficient. The testis weight that 50% of the animals attain sexual maturity is 15.5 g.

Table 7 shows the ratio of mature males to the total males at each age. The youngest mature male was 6.5 years and the oldest pubertal was 14.5 years. The relation between this ratio and age can be shown by a straight line in the range from 5.5 to 11.5 years. Calculation by the least squares method gives the formula, $y=17.0643x-97.7893$ $r=0.9923$; x: age in year, y: the ratio, r: correlation coefficient. The age when 50% of the animals attain the sexual maturity is 8.7 years and the body length at this age is 219 cm as indicated by the mean growth curve (Fig. 4).

Fig. 6 shows the length frequencies of mature animals and pubertal or immature ones at each age from 6.5 to 10.5 years. This figure clearly shows that the body

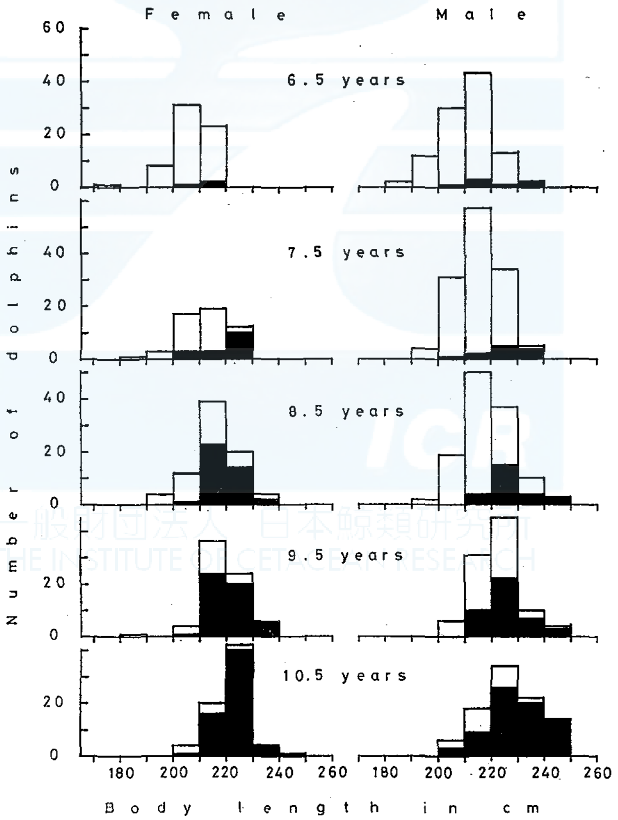

Fig. 6. The body length frequencies of both sexes in each age. White squares indicate immature or pubertal animals, and black mature animals.

length of the mature animals is larger than that of the pubertal or immature ones at the same age, and maturity rate of the older animals is higher than the younger ones at the same body length group. These suggest that the larger animals attain sexual maturity earlier than the smaller in the same age, and the sexual maturity rate of the animals increases with the age in the same body length.

In order to estimate the spermatogenic activity of the testis, 20 seminiferous

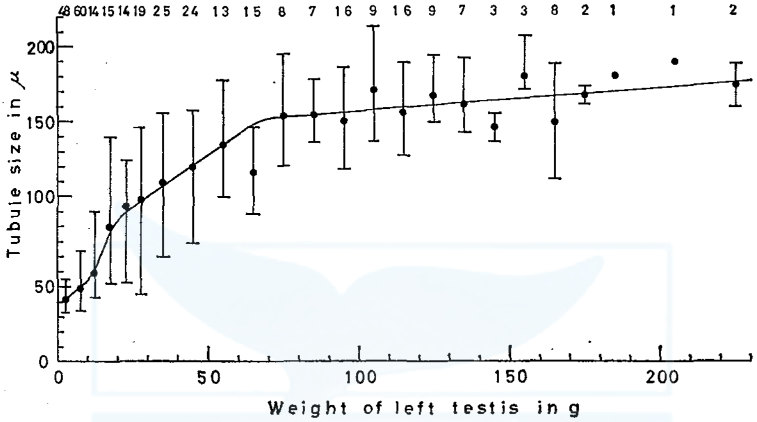

Fig. 7. Relation between the weight of the left testis and the diameter of seminiferous tubules. Closed circles indicate mean and vertical lines range. Solid line is drawn by eyes. The numbers at the top indicate the sample size.

TABLE 8. SEASONAL VARIATIONS OF TESTIS WEIGHT AND SEMINIFEROUS TUBULE

Season		Immature			Pubertal			MI		
		No.	T.W.	S.T.	No.	T.W.	S.T.	No.	T.W.	S.T.
Oct.	E.	6	4.4	40	14	7.5	48	2 (6.3)	66	127
	M.	9	5.1	40	4	15	59	4 (8.0)	50	94
	L.	—	—	—	4	8.5	61	1 (25.0)	35	121
Nov.	E.	2	4.4	46	5	13	63	8 (15.4)	47	109
	M.	5	6.9	48	5	9.5	57	22 (56.4)	29	110
	L.	6	9.6	50	11	15	63	20 (55.6)	29	84
Dec.	E.	—	—	—	—	—	—	—	—	—
	M.	42	3.9	43	15	7.0	47	3 (42.9)	11	59
	L.	—	—	—	—	—	—	—	—	—
Total		70			58			60 (27.3)		
Mean			4.8	44		10	55		33	98

T.W. and S.T. indicate mean left testis weight (g) and mean seminiferous tubule size (μ), respectively.

tubules selected at random from each testis of the sexually mature males were histologically examined. The mature males of type MI and type MIII were defined as the animals having testes containing spermatozoa in only one tubule and in all 20 tubules, respectively. The mature males of type MII was defined as the animals at the intermediate stage of type MI and type MIII. The testis weights of the mature males in type MI, MII, and MIII range from 7.7 to 80.0 g, from 17.2 to 159.7 g, and from 42.2 to 225.2 g, respectively. The ratios of the mature males in type MI, MII, and MIII to the total mature males for each testis weight are shown in Table 6. The relation between the ratio of type MIII and testis weight can be shown by a straight line in the range from 40 to 100 g. Calculation by the least squares method gives the formula, $y=1.5680x-58.1632$ $r=0.9639$; x: testis weight in g, y: the ratio, r: correlation coefficient. The testis weight that the ratio of type MIII shows 50% is 68.9 g. This indicates that the mean testis weight at the attainment of the full sexual maturity is considered to be approximately 70 g. This value well coincides with the weight at the age of 13.5 years (Fig. 5).

Relation between the testis weight and the diameter of seminiferous tubule

The testes of 348 males were histologically examined. The mean of the measurements of 20 seminiferous tubules selected randomly from a testis was used as the diameter of the tubules of the specimen. The diameters of the tubules in 70 immature, 58 pubertal, and 220 mature males range from 33.0 to 65.0 μ (mean: 43.5 μ), from 34.0 to 104.0 μ (mean: 54.6 μ), and from 45.0 to 214.0 μ (mean: 130.8 μ),

IN THE IMMATURE, THE PUBERTAL, AND THREE TYPES OF THE MATURE MALES

Mature								
MII			MIII			Total		
No.	T.W.	S.T.	No.	T.W.	S.T.	No.	T.W.	S.T.
7 (21.9)	97	170	23 (71.9)	119	168	32 (100)	111	166
7 (14.0)	121	158	39 (78.0)	119	155	50 (100)	113	150
3 (75.0)	47	156	—	—	—	4 (100)	44	148
16 (30.8)	49	122	28 (53.8)	98	152	52 (100)	78	136
16 (41.0)	45	119	1 (2.6)	72	169	39 (100)	37	115
12 (33.3)	35	112	4 (12.1)	49	103	36 (100)	33	95
—	—	—	—	—	—	—	—	—
1 (14.3)	17	73	3 (42.9)	55	92	7 (100)	31	75
—	—	—	—	—	—	—	—	—
62 (28.2)			98 (44.5)			220 (100)		
	55	130		108	153		73	131

Figures in parentheses indicate parcentage in the mature.

respectively.

Fig. 7 shows the relation between the seminiferous tubule size and testis weight. The increase of the diameter of the tubule is rapid when the testis weight becomes from 15 to 20 g, that coincides with the mean testis weight at the attainment of sexual maturity. This increase becomes slower at testis weight of 70 g or more where the males attain full maturity. These suggest that the testis grows with the increase of diameter of seminiferous tubule till about 70 g, and then the testis weight and the diameter of seminiferous tubule show no significant correlation.

Seasonal change of reproductive activity in the testis

In order to find out the seasonal change of reproductive activity in the testis, studies were made on the variations of testis weight, of the diameter of seminiferous tubule, and of the ratio of mature males in type MIII to the total mature males. Table 8 shows the variations by ten days period. This Table indicates that there is no seasonal change in both the testis weight and seminiferous tubule size for immature and pubertal males during early October and middle December. As for the mature

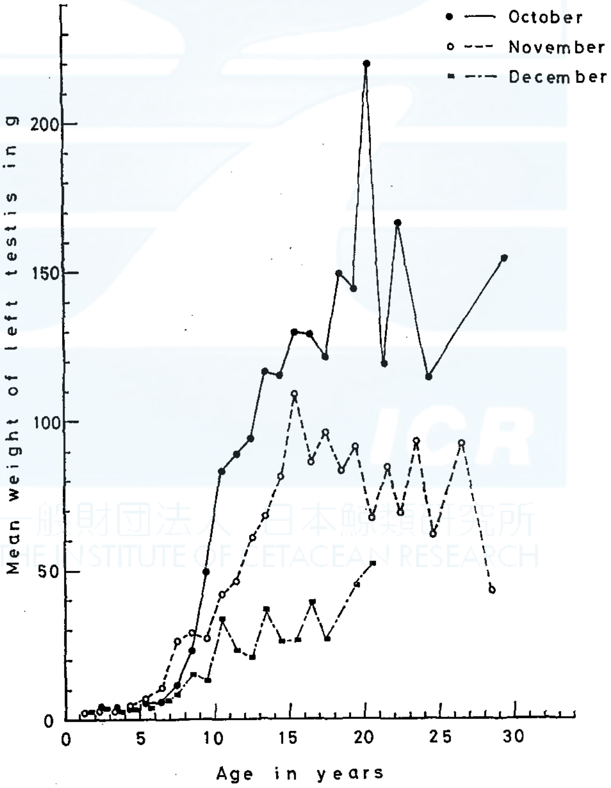

Fig. 8. Relation between age and the mean weight of the left testis. Closed circles (solid line) indicate the males caught in October, open circles (dotted line) the males in November, and closed squares (chain line) the males in December.

males, the seasonal variations of the testis weight, of the seminiferous tubule size, and of the ratio of the mature males in type MIII are also shown in Table 8. This indicates that the testis weight, the tubule size, and the ratio of mature males in type MIII gradually decrease from early October till middle December. As it is expected that such a seasonal change of the reproductive activity in the testis might be affected by the difference of the age composition of the animals, the testis weight of the males at each age was analized by each month from October to December (Fig. 8). This shows that after the mean age at the attainment of sexual maturity (8.7 years), the mean testis weight is heaviest in October and lightest in December.

From these informations, it is suggested that the reproductive activity of the testis is highest in October and then it gradually decreases till December between October and December. This does not well coincide with the main mating seasons estimated from the latter part of this study. Such a seasonal change of reproductive activity of the mature males seems to be affected by the difference of the time in the migration period of mature males into the fishing area, because the sampling period is short.

REPRODUCTION IN THE FEMALE

The maturity

In order to determine the sexual conditions of the females, the ovaries, the mammary gland, and the fetuses were examined in details. Immature animals were identified as those that had the ovaries with no corpus luteum or albicans, pregnant ones as those that had the ovaries with corpus luteum, the lactating ones as those had the

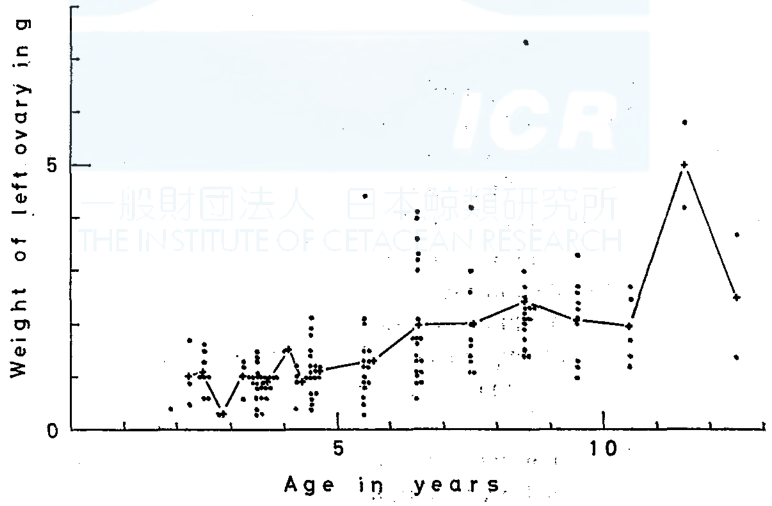

Fig. 9. Relation between age and the left ovary weight. Double crosses indicate the mean weight of the left ovary.

mammary gland secreting milk, and the resting females as those that were matures but neither pregnant nor lactating.

The pubertal females were identified by the following method. As the left ovary of *S. coeruleoalba* becomes mature earlier than the right (Ohsumi 1964), the relation between the weight of the left ovary of the immature and age is shown in Fig. 9. This shows that the weight of the ovary was about 2.0 g or less during 2 and 6 years, and it rapidly increases after the age of 6 years, when the mature female first appears. The weight frequencies of the left ovary with one corpus albicans (251 individuals) and of the left ovary with no corpus albicans or luteum (191 individuals) are shown in Fig. 10. The former had a mode in 3.5 to 4.0 g and the latter also one in 1.0 to 1.5 g. This indicates that the weight frequency of the left ovary can be divided into two groups at the ovary weight of approximately 2.0 g. From these informations the pubertal females were tentatively defined as the immature females who had the left ovary weighing 2.0 g or more. The youngest pubertal female was 2.5 years and the oldest immature female was 12.5 years. The ratio of the pubertal females to the total females at each age is shown in Table 7. The relation between that ratio and age in the range from 3.5 to 11.5 years can be shown by a straight line. Calculation by the least squares method gives the formula, $y=13.1883x-42.9792$ $r=0.9803$; x: age in year, y: the ratio, r: correlation coefficient. The age when 50% of the animals attain the puberty is 7.1 years, and the body length at this age is 209 cm as indicated by the mean growth curve (Fig. 4).

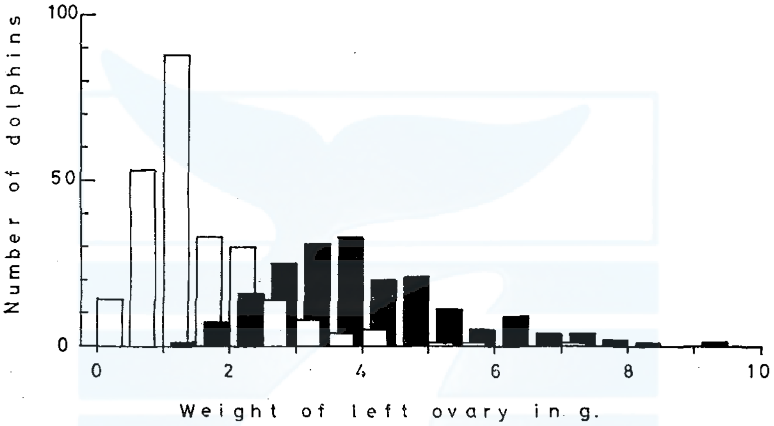

Fig. 10. Frequency of the left ovary weight. White squares indicate the left ovary with no corpus albicans and black the left ovary with one corpus albicans.

Table 7 shows the ratio of mature females to the total females at each age. The youngest mature female was 4.5 years and the oldest pubertal was 12.5 years. The relation between this ratio and age in the range from 5.5 to 12.5 years can be shown by a straight line. The following formula was obtained by the least squares method,

$y=15.1036x-83.0946$ $r=0.9846$; x: age in year, y: the ratio, r: correlation coefficient. The age when 50% of the animals attain sexual maturity is 8.8 years, and the body length at this age is 216 cm as indicated by the mean growth curve (Fig. 4).

Diameter of corpus luteum

Fig. 11 shows the relation between the mean diameters of corpus luteum of 206 pregnant females and the time in months after the start of the last gestation. The date of conception of pregnant female was estimated from the date of kill and the time after conception given by the fetus size on the basis of the mean growth curve (Fig. 15). The pregnant female confirmed no fetus was tentatively considered as the earliest pregnant female. The mean diameter of corpus luteum of these females was 20.7 mm. It may continue the growth until 3 months after the conception and attain the diameter of 29.3 mm. Then the mean diameter of corpus luteum slightly decreases with the lapse of time. If the regression line is calculated by the least squares, it gives the relation: $y=-0.4471x+23.5098$, where y is the mean diameter in mm and x is the proceeding time after conception. The mean diameter at the time of parturition was calculated at 23.5 mm from this formula.

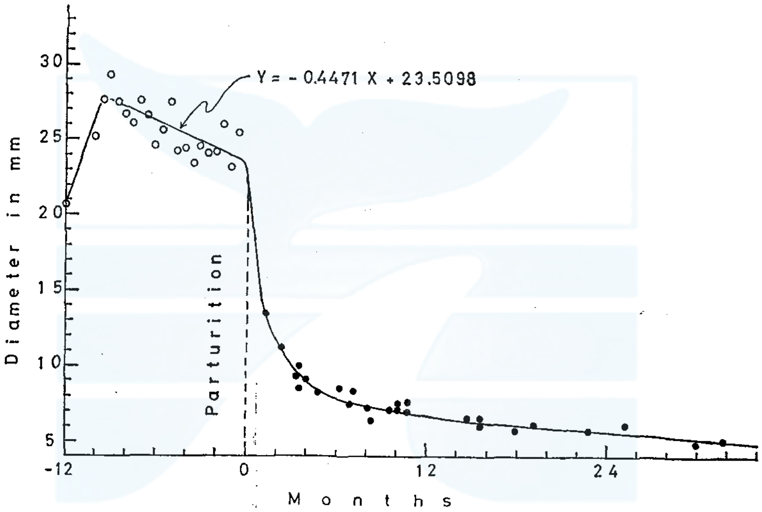

Fig. 11. Change of the diameter of corpora lutea during the period of pregnancy and regression of the diameter of corpora albicantia after parturition. Closed circles indicate the reliable combinations obtained from Fig. 13 and open circles the mean diameter of corpora lutea in the interval of 0.25 month.

Regression of corpus albicans

Fig. 12 shows frequency of diameters of corpora albicantia at each age. The modal diameter gradually decreases with the increase of the age of the animal until

14.5 years. Then the highest peak of the mode stays between 2 and 5 mm in diameter. The minimum size of the corpora albicantia was 2.3 mm. These indicate that the corpora albicantia reaches to final size within several years after the start of regression and may stay in the ovary all the life time.

The regression curve of the diameter of corpora albicantia was estimated by the method of Kasuya *et al.* (1974). As the size frequency of the largest corpora albicantia of lactating females in the same school may represent the frequency of parturition seasons, the length frequencies of calves and size frequencies of the largest corpora albicantia of lactating females in corresponding schools are shown in Fig. 13. The time after parturition was estimated from the mean modal length of calves on the basis of the mean growth curve (Fig. 4).

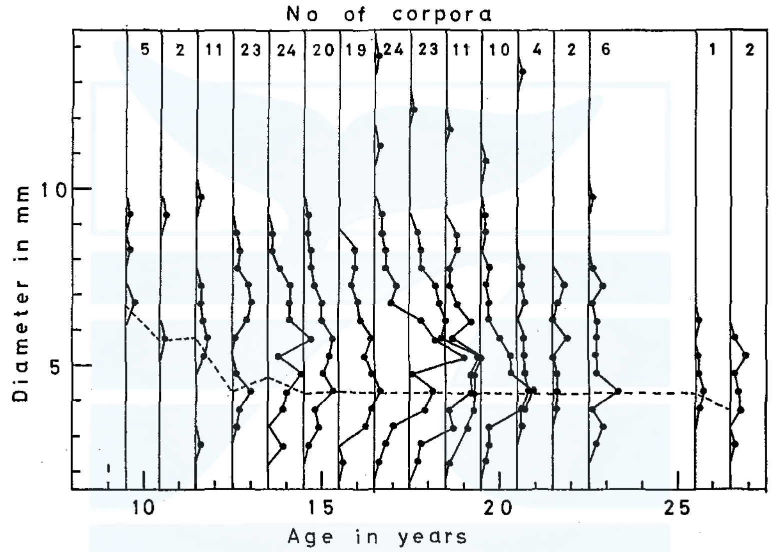

Fig. 12. Distribution of the diameter of corpora albicantia. The dotted line indicates the position of the mode and the numbers at the top show the sample size.

The mean modal diameters of the largest corpora albicantia of lactating females were plotted against the time after parturition in Fig. 11. It shows that the mean diameter of corpora lutea at parturition (23.5 mm) rapidly decreases to 7.0 mm within 4 months. Then the speed of regression gradually slows down and after 18 months the diameter decreases in an almost straight line. However, it is difficult to distinguish between the corpora albicantia of ovulation and those of the last parturition. If a few probable corpora albicantia of ovulation are omitted as in the case of *S. attenuata* (Kasuya *et al.* 1974), the regression curve of the diameter of corpora albicantia seems to become slightly earlier than that expected here.

Ovulation diagram

Of 296 pregnant females, the 26 females on which all the ovulations occured within 12 months before the last conception were picked up in order to make ovula-

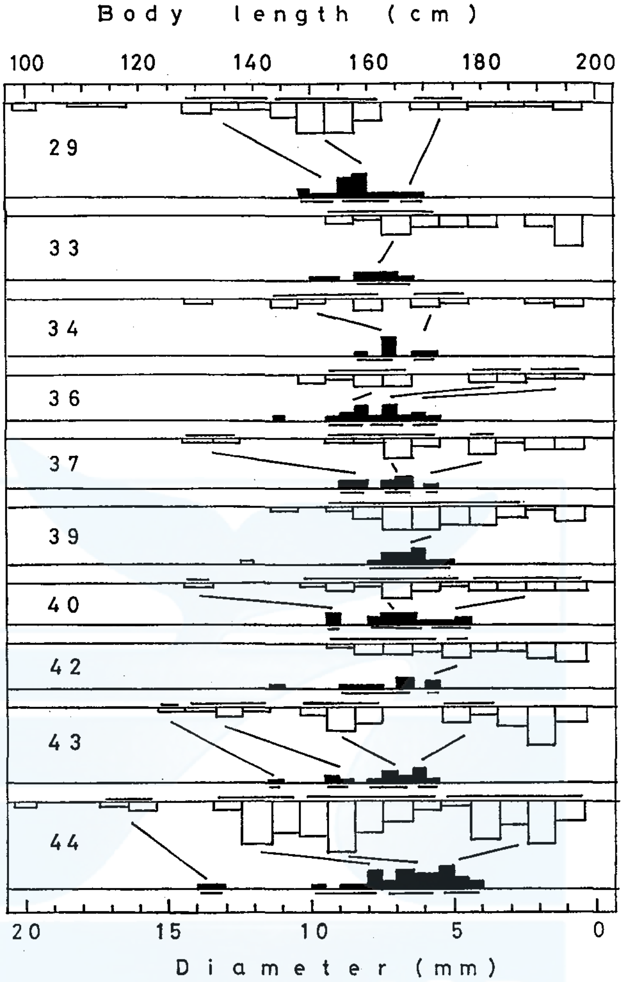

Fig. 13. Comparison of the frequency of the diameter of the largest corpora albicantia of lactating females (black square) and the length frequency of juvenile calves (white square). The numbers at the left indicate the school no.

tion diagram. All corpora albicantia of these pregnant females may be probably corpora albicantia of ovulation, because these pregnant females were not synchronously lactating. This diagram was made by finding out the conception date of the pregnant females from the kill date and fetus size, and the ovulation date of them from the size of corpora albicans and the regression curve of corpora albicans. Fig. 14 shows ovulation diagrams of each pregnant female. This figure shows that all the animals have not regular ovulation rhythm. In the animals of field no. 29 from school no. 15, of no. 13 from school no. 34, and of no. E6 from school no. 42, the ovulation occurs at about 4 months interval and sometimes does at approximately one month or less interval. It also occurs at about 8 months interval in the animals of field no. E1 from school no. 36, of no. 44 from school no. 38, and of no. 344 from school no. 44. These suggests that the ovulation may usually occur at about 4 months or 4 x N months interval (N: integer), and sometimes at approximately one month or less interval. Accordingly the ovulation of the species may occur by combination of several ovulation intervals.

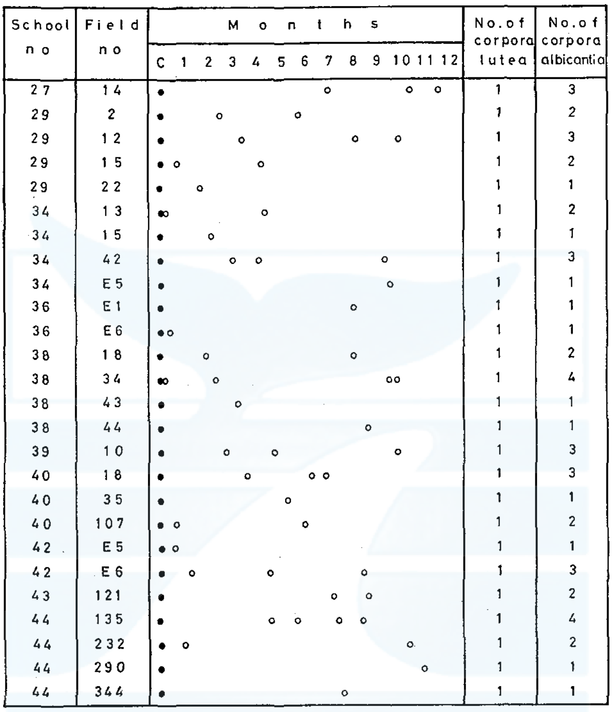

Fig. 14. Ovulation diagrams of 26 pregnant females. Closed circles indicate the corpora albicantia of pregnancy and open circles the corpora albicantia of ovulation. C means conception date. For explanation see text.

Mating season

Since the main sampling period was limited in October to December, it is difficult to define the mating season of *S. coeruleoalba* with precision. In this study the mating season of the species was estimated from the following two methods.

First method: Length frequencies of 603 fetuses and 73 newborn calves by month are shown in Fig. 15. Records of 21 individuals caught in May 1951 were cited from Nishiwaki and Yagi (1953). As they did not report the body length of fetuses smaller than 15 cm but gave the range and the number of fetuses, the middle value of the range was used in this study. Fig. 15 shows that there are three peaks in the body length frequency in October, 10.0, 68.3, and 110 cm and also in November, 5.0, 45.0, and 78.3 cm. Laws (1959) showed that fetal growth in odontoceti can be described by a linear plot of length except for the very early stage of growth. As the gestation length of *S. coeruleoalba* was estimated at 12 months (Kasuya 1972) and the mean body length at birth of the species was about 100 cm (see page 25), if Lt_0 of Laws (1959) is tentatively used as 0.15 x gestation length, the fetal growth rate in the linear plot of length is calculated at 9.8 cm per one month. Taking account of this fetal growth rate and also by using the method of Laws (1959), the mean fetal growth curve can be drawn from the following four points, 8.1 cm in May, 68.0 cm in October, 78.3 cm in November, and 94.0 cm in January (Fig. 15). When this growth curve is moved for 4 months, any mode observed in Fig. 15 well fits to it. On the other hand, from the differences of the mean body lengths between these peaks at each month, the intervals of the mating seasons are estimated as 3.4 to 6.0 months (mean: 4.5 months) on the basis of this fetal growth rate. These suggest that the mating season may occur in the interval of approximately 4 months.

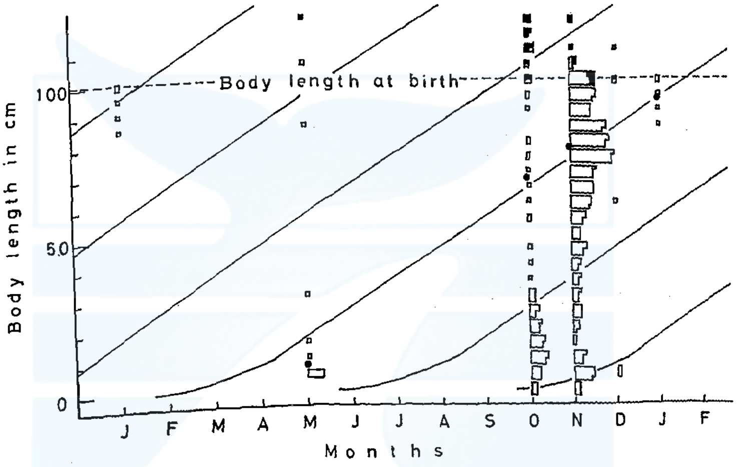

Fig. 15. Body length frequencies of fetuses and newborn calves by month. The fetal growth curve is drawn presuming 12 months of gestation. The specimens in May are cited from Nishiwaki and Yagi (1953). White squares indicate the fetuses, black squares the newborn calves, and closed circles the mean body length in each mode.

Second method: Since the gestation length of *S. coeruleoalba* was 12 months (Kasuya 1972), the mating season was estimated from the parturition season on the basis of the parturition dates of 567 fetuses, 238 newborn calves younger than 1.0 year (or smaller than 166 cm), and 144 juvenile calves from 1 to 2 years of the age (or from 166 cm to 180 cm). The parturition date of the animal was predicted from the kill date and from body length as indicated by the mean fetal and postnatal growth curve. The seasonal fluctuation of the parturition is shown in Fig. 16, with the 949 specimens caught from 1968 to 1972. Fig. 16 shows that there are year-to-year variations in the timing and the number of mating peaks, and when the data for all years are combined it can be said that the mating season is prolonged, with three higher points in Feburary to May, in July to September, and in December. To estimate the interval of the parturition date, the frequency of parturition date

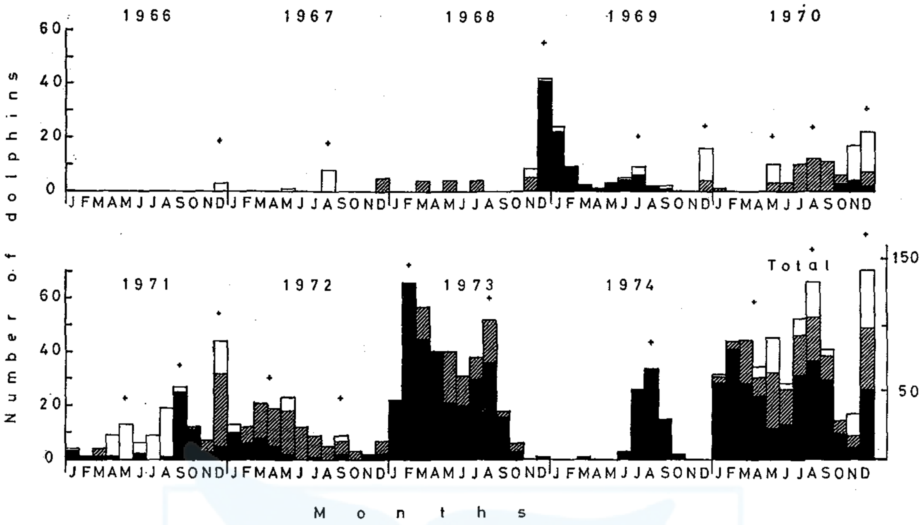

Fig. 16. Frequencies of parturition dates estimated from the body length of fetuses and postnatal calves on the basis of the mean growth curve. Black squares indicate the parturition dates estimated from fetus size, striped squares from the body length of newborns younger than 1 year old, and white from the body length of the calves at the age between 1 and 2 years. Double crosses indicate peak.

TABLE 9. SEX RATIO OF *S. COERULEOALBA* BY AGE GROUPS

Stage or age	No. of males		No. of females		Sex ratio	
fetus	269		247		1.09	
0.5	71	131	54	120	1.31	1.09
1.5	60		66		0.91	
2.5	93	875	85	563	1.09	1.55
3.5	122		106		1.15	
4.5	135		99		1.36	
5.5	139		82		1.70	
6.5	114		64		1.78	
7.5	139		53		2.62	
8.5	133		74		1.80	
9.5	105	419	72	428	1.46	0.98
10.5	98		69		1.42	
11.5	59		96		0.61	
12.5	86		106		0.81	
13.5	71		85		0.84	
14.5	72	327	81	424	0.89	0.77
15.5	42		78		0.54	
16.5	41		69		0.59	
17.5	48		57		0.84	
18.5	39		40		0.98	
19.5	30		40		0.75	
20.5~	55		59		0.93	
Total*	1,752		1,535		1.14	

* exclude the fetuses.

between 1969 and 1972 was available, because the frequency in these years was composed of the data of three stages, which were fetus, newborn calf, and juvenile calf stages. The interval between the nearest peaks ranges from 3 to 7 months (mean 4.7 months). This indicates that the mating season of the species may occur in the interval from 4 to 5 months.

From above informations it is concluded that there are three mating seasons in a year, namely, from Feburary to May, from July to September, and in December, and the mating season may occur in the interval from 4 to 5 months.

Sex ratio

The sex ratio in this study is shown by the number of males per one female. The overall sex ratio was 1.14. Table 9 shows the change of the sex ratio in relation to the age of dolphins. In both the fetuses and newborn animals of the age younger than 2.0 years, the number of males slightly exceeds that of females. The ratio of the males at the age between 2 and 9 years is extraordinary high. This suggests that there is sexual segregation in this period. The number of males is almost equal to that of females in the young mature animals at the age between 9 and 14 years. However, the ratio of the males at the age older than 14 years is too low. This suggests that the mortality of the older mature males higher than that of females at the same age group.

DISCUSSION

It was reported that a pair of opaque (in summer) and translucent (in winter) layer is annually accumulated in the case of *Tursiops truncatus* (Sergeant 1959), *Globicephala melaena* (Sergeant 1962), *Physeter catodon* (Ohsumi *et al.* 1963), and *Stenella attenuata* (Kasuya *et al.* 1974). The seasonal change of the dentinal layers in the present results reveals good agreement with those of the above four species.

On the basis of the comparison of the dentinal and cemental layers of the same tooth on *S. coeruleoalba*, Kasuya (1976) indicated that the accumulation of dentinal growth layers ceases at a large variety of the age above 11 dentinal layers and that the accumulation of cemental layers continues longer. However, the dentinal growth layer is more useful than the cemental layer to determine the age in the younger animals in which the former is more readable than the latter. Thus the present study analized the growth and reproduction of the animals younger than 13.5 years old by means of dentinal growth layers.

Ohsumi (1966) showed an allometric relationship, $B=0.532\, M^{0.916}$, between mean body length at birth (B in m) and that of female at the attainment of sexual maturity (M in m) for *Physeter*, *Berardius* and several species of Delphinidae. If this formula is applied for *S. coeruleoalba* assuming $M=2.16$ (m), 1.08 m is obtained as the mean body length at birth. This figure is too larger than the length obtained in this study. Same tendency is observed in *S. longirostris* (Perrin *et al.* 1975), *S. attenuata* in the Pacific coast of Japan (Kasuya *et al.* 1974), and *S. attenuata* in the offshore eastern tropical Pacific (Perrin *et al.* 1976). On the other hand the ratios of the mean length at birth to the mean length of the females at attainment of sexual maturity were calculated as 0.45, 0.49, 0.46, and 0.46 in *S. longirostris* (Perrin *et al.* 1975), *S. attenuata* in the Pacific coast of Japan (Kasuya *et al.* 1974), *S. attenuata* in the offshore eastern tropical Pacific (Perrin *et al.* 1976), and *S. coeruleoalba* (this study), respectively. The constancy of these values clearly indicates that the mean length at birth well correlates with that of the females at the attainment of sexual maturity in the genus of *Stenella*. Then the relation between the mean length of the females at the attainment of sexual maturity and the mean length at birth in *Stenella* was calculated by the least squares method. This gives the relation $y=0.4758x-1.9152$ ($r=0.9584$), where y is the mean length at birth in cm, x is the mean length of the females at attainment of sexual maturity in cm, and r is correlation coefficient.

According to the observations on *T. truncatus* born and kept in aquallia (Tabolga and Essapian 1957, Nakajima *et al.* 1963) and to the examination of stomach contents on *S. attenuata* (Kasuya *et al.* 1974), these species start feeding on solid food from about 0.5 year old. This coincides with the result obtained on *S. coeruleoalba* in this study. *T. truncatus* continue to take both solid and milk till about 1.5 years. This is similar to the present result on *S. coeruleoalba*. However, Kasuya and Miyazaki (1976) pointed out that the length of lactation in *S. coeruleoalba* became shorter with the decrease of population size. On this problem further study should be done in the future.

According to Kasuya *et al.* (1974) and Perrin *et al.* (1976) the age of *S. attenuata* at attainment of sexual maturity in the female is slightly younger than that in the male. However, the present study indicates that the sexual maturity in *S. coeruleoalba* is attained at about 9 years of the age in both sexes. This result well coincides with that in *S. coeruleoalba* obtained by Kasuya (1972, 1976).

Kasuya (1972) showed that the mating seasons of *S. coeruleoalba* were expected in November and December, and in May and June. The present study, however, shows that there are three mating seasons in a year, namely, from February to May, from July to September, and in December. This is rather similar to result of *S. attenuata* (Kasuya *et al.* 1974). According to Kasuya *et al.* (1974), the species in the colder waters have one mating season in spring or in summer and those in the warmer waters have two or three in a year. The present result seems to support this idea.

The present work shows that the sex ratio at birth is almost parity, indicating coincidence with the case of *S. attenuata* in the offshore eastern tropical Pacific (Perrin *et al.* 1975). However, in the cases of *S. attenuata* in the Pacific coast of Japan (Kasuya *et al.* 1974) and *S. longirostris* (Perrin *et al.* 1975) the number of the males born slightly exceeds that of the females suggesting that the sex ratio at birth appears to be dependant on the population, but not on the species.

For *S. attenuata* (Kasuya *et al.* 1974, Perrin *et al.* 1976) and *S. longirostris* (Perrin *et al.* 1975) it was reported that the mortality rate for the adult male was higher than that for the adult female. The present study that confirms these observations strongly suggests that mortality rate of the adult male is higher than that of the female in the genus *Stenella*.

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