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CONTENTS OF NUMBER 29

目　次

AGE DETERMINATION AND GROWTH OF THE BAIRD'S BEAKED WHALE WITH A COMMENT ON THE FETAL GROWTH RATE

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ABSTRACT

Two kinds of cycles exist in the alternation of the stainability of dentine and cementum of the species. The longer is of annual, and the stainable layer is deposited from August to January and the unstainable in the rest of the year. The shorter cycle ranges from 27 to 31 days with possible individual variations. The deposition of dentine ceases within several years after birth, and the short cycle is distinguishable in the first few annual layers. In cementum, on the other hand, the annual layer is possibly formed for all the life time, and the short cycle on the anterior tooth until 40 to 60 years of age. The length of life time is 70 years. The gestation will last for about 17 months, one of the longest among the cetaceans.

INTRODUCTION

The morphology and life history of the Baird's beaked whale, *Berardius bairdii* Stejneger, 1883 in the western North Pacific and adjacent seas were studied by Omura *et al.* (1955) based on the catch statistics of the Japanese commercial whaling in the period from 1948 to 1952 and on many specimens investigated by them. Later Nishimura (1970) discussed the distribution of the species in the Sea of Japan based on several stranded animals. Nishiwaki and Oguro (1971) analysed the statistics of Japanese catch of the species in the years from 1965 to 1969. In recent years, the catch of *B. bairdii* is mostly restricted, by the economical factors, to the coastal waters of the Boso Penninsula on the Pacific coast of central Japan, and the annual catch seems to be less than 30 whales (Dr. Y. Naito, person. comm.).

In spite of the effort of these authers, very little is known about the life history of the species. The main obstacle in the study exist in the difficulty in obtaining the adequate number of samples and in the absence of the age determination technique. Though, Omura *et al.* (1955), studying the anatomy of the tooth of *B. bairdii*, indicated the presence of the annual layers in cementum and suggested the possibility of the age determination, they did not show the reason for the conclusion nor try to estimate the age of the whales. The present study was made in order to reconsider their study and provide some clue of the age determination of the species.

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MATERIALS AND METHOD

Nineteen samples, in the twenty used in this study, were collected from the catch of coastal whaling off the Boso Penninsula (35°N, 140°E), of which 18 animals by Omura in 1957 through the cooperation of the Tokai Gyogyo Co., Ltd, and another sample WD-9 by Dr. Y. Naito. Whale no. 20 was collected at an whaling station at Ayukawa (38° 20'N, 141° 30'E) on the Pacific coast of Japan through the field investigation of the Whales Research Institute.

TABLE 1. LIST OF MATERIALS

Whale no.	Date of catch	Body length	Sex	Gonad[10] (kg)	Tooth		
					position[1]	thickness	height
4	—, — , '57	—	—	— , —	Post.	16 mm	48 mm
20	13, Oct., '59	9.8 m	♂	6.4 , 5.8	Ant.	26 mm	73 mm
36[6]	5, Aug., '57	10.8 m	♀	0.44 , 1.55	Ant.	35 mm	81 mm
36					Post.	15 mm	49 mm
37[7]	6, Aug., '57	10.6 m	♂	4.10 , 4.10	Ant.	—	76 mm
37					Post.	13 mm	—
38	8, Aug., '57	11.1 m	♂	5.20 , 5.30	Post.	21 mm	52 mm
40	15, Aug., '57	10.6 m	♂	4.80 , 4.90	Ant.	28 mm	73 mm
40					Post.	16 mm	48 mm
41	16, Aug., '57	10.9 m	♂	4.70 , 5.80	Ant.	34 mm	89 mm
41					Post.	18 mm	90 mm
44	18, Aug., '57	11.4 m	♀	0.205, 0.245	Ant.	32 mm	84 mm
49	27, Aug., '57	10.7 m	♂	4.10 , 3.90	Ant.	34 mm	80 mm
49					Post.	14 mm	51 mm
50	28, Aug., '57	10.7 m	♂	8.20 , 8.20	Ant.	34 mm	56 mm
50					Post.	15 mm	47 mm
51	30, Aug., '57	10.7 m	♂	5.60 , 5.80	Ant.	43 mm	68 mm
52	30, Aug., '57	10.8 m	♂	7.00 , 6.90	Ant.	36 mm	79 mm
52					Post.	18 mm	64 mm
53	1, Sept., '57	7.8 m	♂	0.40 , 0.36	Ant.	33 mm	86 mm
53					Post.	16 mm	51 mm
54	1, Sept., '57	10.4 m	♀	0.320, 0.275	Post.	18 mm	62 mm
55	15, Sept., '57	6.4 m	♀	0.062, 0.060	Ant.	32 mm	66 mm
57	14, Oct., '57	10.1 m	♂	5.50 , 5.50	Ant.	35 mm	74 mm
57					Post.	20 mm	50 mm
58	15, Oct., '57	10.8 m	♂	7.00 , 9.80	Ant.	41 mm	84 mm
58					Post.	18 mm	57 mm
60	6, Nov., '57	11.0 m	♀	0.235, 0.245	Ant.	35 mm	85 mm
60					Post.	18 mm	59 mm
61	14, Nov., '57	10.7 m	♂	1.20 , 1.15	Ant.	39 mm	90 mm
61					Post.	18 mm	60 mm
WD-9	4, Aug., '76	10.5 m	♂	3.62 , 4.94	Ant.	32 mm	67 mm

[1] Ant.: Anterior tooth, Post.: Posterior tooth. [2] —: Not erupted, +: Erupted and osteodentine
covered, [4] In parentheses: Pulp cavity filled with osteodentine, Italics: No. of annual layers (long
Pregnant with 12 mm fetus (Omura, 1958), physically mature. [7] Physically immature. [8] 30 short
All the testes, except for the whale no. 20, were weighed by the Tokai Gyogyo Co., Ltd., and the ovaries

The body length recorded by foot (0.305 m) or shyaku (0.303 m) was converted into metric system. The records of sex and weight of gonad were obtained directly by the biologist or by the whaling company as in the case of the body length.

Teeth of 19 whales, other than that of WD-9, were preserved in dry condition after cleaning by boiling. Each tooth was cut on a lingua-buccal medial plane, and one 2 to 3 mm section was taken with a saw. Then, usually, either lingua or buccal half of the section was polished with whet stones and glued on a clear plastic plate. The other side was polished with the same way to a thickness between

USED IN THIS STUDY

		No. of long cycles[4]		Age with complete short cycle	Last long cemental cycle[5]
attrition[2]	root[3]	in dentine	in cementum		
–	closed	[5]	38, *44*, 46	—	Unstainable (wide, -)
+	closed	[7]	40, *41*, 42	≧41	Stainable (thin, 2)
++	closed	—	35, *36*, 38	≧36	Unstainable (wide, 7)
+	closed	[4]	30, 33, 35	—	
+	closed	[5]	16, *17*, 17	≧17	Unstainable (wide, 7)
–	closed	[6]	17, 17, 17	—	
++	closed	—	25, *26*, 27	—	Unstainable (wide, -)
++	closed	—	56, *57*, 61	≒57	Stainable (thin, 2)
+	closed	[4]	56, 58, 63	—	
+	closed	[7]	40, *47*, 51	≧47	Stainable (thin, 1)
+	closed	[5]	37, 40, 40	—	
+	closed	[5]	22, *25*, 29	≧25	Stainable (wide, 3)
+	closed	[4]	20, *21*, 22	≧21	Stainable (thin, 2)
–	closed	[5]	23, 23, 24	—	
++	closed	—	66, *67*, 71	≦52	Unstainable (wide, -)
+	closed	[5]	54, 67, 68	—	
++	closed	—	68, *71*, 72	≦42	Unstainable (wide, -)
+	closed	[5]	29, *30*, 31	≧30	Stainable (thin, 1)
+	closed	[6]	30, 30, 32	—	
–	open	3	3, *3*[8], 3	≧ 3	Stainable (wide, 3)
–	open	3	3, 3, 3	—	
+	closed	[7]	35, *36*, 37	—	Stainable (thin, -)
–	open	2	2, *2*[9], 2	≧ 2	Stainable (thin, 2)
++	closed	—	51, *58*, 59	≦57	
+	closed	[6]	49, 51, 56	—	
++	closed	—	50, *50*, 52	≧50	Stainable (wide, 3)
+	closed	[6]	46, 47, 48	—	
++	closed	—	37, *39*, 40	≧39	Stainable (wide, 3)
+	closed	[5]	44, 46, 51	—	
+	closed	[5]	40, *40*, 41	≧40	Stainable (wide, 4)
+	closed	[6]	37, 39, 41	—	
++	closed	—	64, *65*, 66	≦56	Stainable (thin, -)

not exposed, ++ : Osteodentine exposed, [3] Closed : Root covered with cementum, Open : Root not
cycle) used in other part of this study. [5] In parentheses number of short cycles if observable. [6]
cycles in cementum and 31 in postnatal dentine. [9] 22 short cycles in dentine and cementum. [10]
by Dr. H. Omura after the fixation in 10% formalin.

40 μm to 70 μm. The thin ground section was decalcified in 5% formic acid for several hours, stained with Mayer's haematoxylin solution for 30 minutes and mounted with permanent mounting medium. In case of the tooth of WD-9, which was fixed in 10% formalin, the section was at first step embedded in polyester resin, and then processed with the same method to a thinner decalcified and stained preparation. Its thickness was about 25 μm. This method did not give different result except for the technical convenience to produce thinner section. Many other ancillary thin preparations (10 to 15 μm) were made from small pieces of cementum, and used for limited observations.

The observation of the growth layers was made with a microscope (×40 and ×100) under transmitted light, and counting was always made on the stainable layers.

Though, the same process was made, if available, on both anterior larger tooth and posterior smaller tooth, the latter was used for restricted purpose. If it is not specified, in the latter part of this study, the analysis are for anterior tooth.

RESULT

Growth of the tooth

About 80% of individuals of *B. bairdii* have two pairs of mandibular tooth, and the rest of animals more (Kirino 1956). The tooth is shaped of a bilaterally compressed cone, and the fundamental structure is same for both the anterior and posterior tooth (Pl. I). In case of the unerupted tooth, the cusp is covered with thin enamel layer, as already indicated by Omura *et al.* (1955) on a fetal tooth. The enamel layer of the postnatal individuals is often covered with cementum (Fig. 1).

Beneath the enamel layer there are dentinal layers and large pulp cavity. This pulp cavity is later filled with osteodentine and only narrow root canal, which is connected to the outside of the tooth through the thick cemental layer, is often left

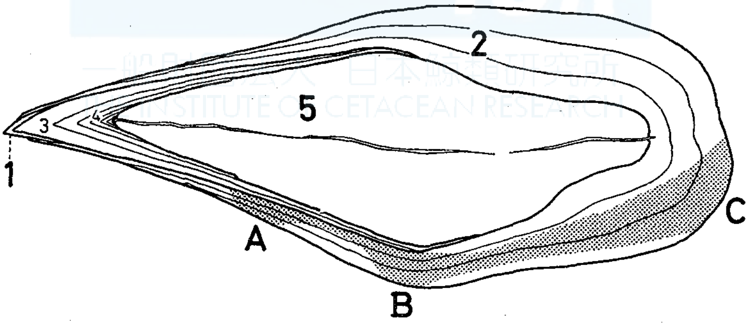

Fig. 1. Schematic figure of the lingua-buccal section of the tooth of *B. bairdii*. 1 : Enamel. 2 : Cementum, only three layers are indicated. 3 : Fetal dentine. 4 : Postnatal dentine. 5 : Osteodentine. Alphabets indicate the positions for counting the layers used in Figs. 2 and 3.

in case of the older animals.

The cementum covers almost the entire length of the lateral surface of the tooth of postnatal animals. In young individuals such as nos. 53 and 55, of which ages are estimated in the later part of this study to be about 30 months, and 21 months respectively, the osteodentine is exposed on the base of the tooth, however, in the older animals, the root is covered with cemental layers. This stage is classified into the " closed " state in Table 1. This definition is different from that of Omura *et al.* (1955), where the root was considered to be closed if the osteodentine fills the pulp cavity. The closure of the root seems to occur at the age between 3 and 17 years.

The eruption of tooth was recorded at the whaling station and it was confirmed in the laboratory using, if necessary, a microscope. The eruption is considered to occur in relation to the attainment of sexual maturity (Omura *et al.* 1955). The present scanty materials suggest that the eruption of anterior tooth occurs at an age between 3 and 17 years, and the posterior smaller tooth between 21 and 30. The sexual difference of the eruption was not detected in this study. Matsuura (1942) considered that the posterior tooth of the female does not erupt, however, the present data, whale nos. 36 and 60, indicate that the posterior tooth of female also erupt at some age as already indicated by Kirino (1956).

Dentinal growth layers

As shown in Fig. 1 and Plate I, the outermost layer of the dentine is the fetal layer. This is the largest in the thickness, and the length of the contour is longest next to the first postnatal dentinal layer. There are observed obscured layered structures in the fetal dentine both in the thin ground section and in decalcified and stained section. Though most of the layers in the prenatal dentine are obscure, several contiguous layers are clear in most of the individuals (Pl. II). These clear layers are formed at the various stage of the deposition of the prenatal dentine, and the number of the clear layers is usually from 3 to 7 with 2 exceptional cases of 0 and 12 layers (13 individuals examined). The condition is same in the anterior and posterior tooth of the same individual. The total number of the layers in the prenatal dentine has a mode at 14 layers (Table 2).

The postnatal dentine is separated from the fetal dentine by a thin clear unstainable layer, and distinguished from the latter by the good stainability and clearer fine layers in it. Though the postnatal dentinal layers are irregular and

TABLE 2. FREQUENCY DISTRIBUTION OF FINE LAYERS IN PRENATAL DENTINE

No. of layers	Frequency	
	anterior tooth	posterior tooth
12	—	1
13	1	1
14	3	3
15	—	2

the counting is difficult, there are observed two kinds of accumulation cycles. The one is of long interval, which possibly corresponds to the annual growth layers of the dolphins and sperm whales studied by Ohsumi *et al.* (1963) and Kasuya (1976). These layers decrease in length and thickness in accordance with the progress of deposition, and the last layer is observed only near the apex of the pulp cavity. The number of these long cycle layers is between 4 and 7 layers on either anterior or posterior tooth where the pulp cavity is completely filled with osteodentine, clearly showing the end of the deposition at those ages (Table 1).

In the postnatal dentine, there are observed many alternation of stainability possibly reflecting the physiological changes of the shorter cycle. These layers are most conspicuous in the dentine deposited in the younger stages, and are almost indistinguishable in the 5th to 7th layers of long cycle described above. It is notable that in the anterior tooth of the whale no. 53 there are observed 31 small layers in the 3 long cycle layers, and 22 small layers in the 2 long cycle layers of the anterior tooth of whale no. 55 (Pl. II).

Cemental growth layers

There are observed two kinds of cycles in the alternation of the stainability of cemental groundsubstance, as in the case of dentinal layers. The one is of longer interval and the other the shorter. In other words, the stainable and unstainable layers of the long cycle are, usually, composed of several short cycles, and the cyclic change of the stainbility of these short cycle layers constitutes the long cycle (Pls. II and III). The cementocytes are diffusedly distributed at all the part of the cementum, and there is detected no relationship between its arrangement and the stainability of the cemental groundsubstance.

As the deposition of the cementum is restricted, after the eruption, to the proximal part of the tooth, the count of the cemental layers must be made for the correct age determination on the area connecting the lateral margin of the fetal den-

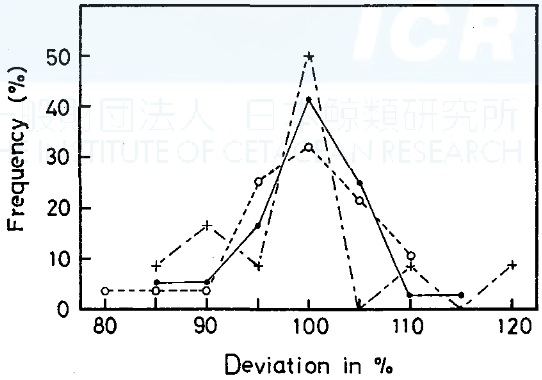

Fig. 2. The variation of the counts of long cycle cemental layers. Closed circle and solid line indicate the anterior tooth, open circle and dotted line the posterior tooth, and cross mark and chain the ratio of the number of layers in posterior tooth to that in anterior tooth of the same animal.

tine and the external margin where the layer of cementoblasts is present. In the present study, the cementoblasts were still observable on the section prepared from the tooth preserved for many years in dry condition.

The number of the long cycle cemental layers shown in Table 1 was counted on the area corresponding to " C " in Fig. 1, where the cemental deposition is most rapid and the two kinds of cycles are most clearly recorded. Usually three counts were made independently and a value at their middle was taken as the number of the cycles. The fluctuation of other two counts expressed by the percentage of the central value are shown in Fig. 2. It is usually within the range of 15% in either case of anterior or posterior tooth. The diversity between the anterior and posterior teeth of a same whale was expressed by the ratio of the two central values. Most of the difference is also found within the range of 15%. However, as the reading of the layers in the posterior tooth is difficult, its data is used only when the anterior tooth is not available.

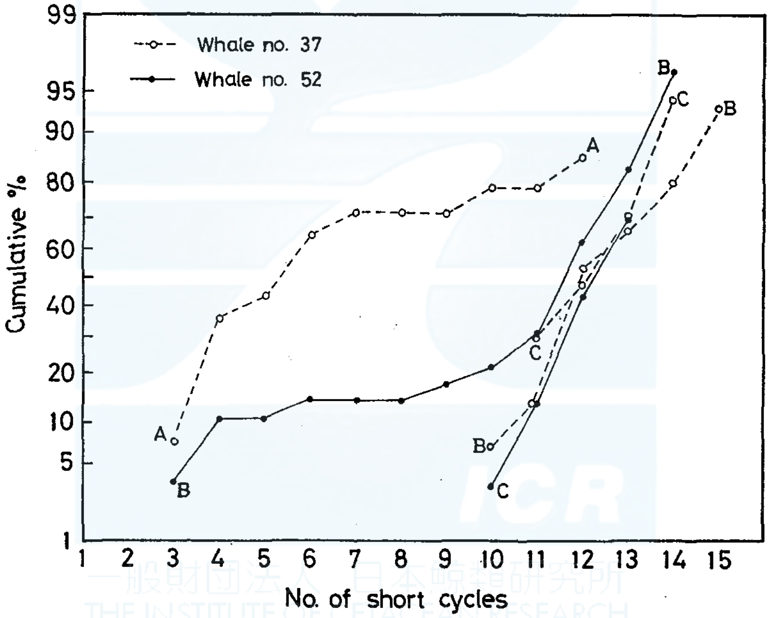

Fig. 3. Probability plot of the frequency distribution of the number of short cycles in a long cycle cemental layer. Alphabets indicate the position shown in Fig. 1.

The short cycle alternation of the stainability of cementum of the anterior tooth is analysed below. Fig. 3 shows the probability plot of the frequency of the number of fine layers in one long cemental cycle. If the number of the fine layers is normally distributed, the cumulative frequencies plotted in this way lie on a straight line. It seems that the points corresponding to 10 or more short cycles come on a straight line and considered to be normally distributed. However, the frequency of the long cycle layers which contain 9 or less fine layers is not normally distributed and the abundance of such long cycle layers decreases from the distal portion to the base of the tooth. This may suggest the next two possibilities, one is that the short cycle is not fully recorded nor distinguished on the distal part of the tooth where the deposition of the cementum becomes slower at earlier age, the second is that the distinction of long and short cycles is not correctly done at the distal part of the tooth.

Fig. 4 will solve the above question. In this figure, the numbers of short cycles in one long cycle are arranged in the order of their deposition. As the first and

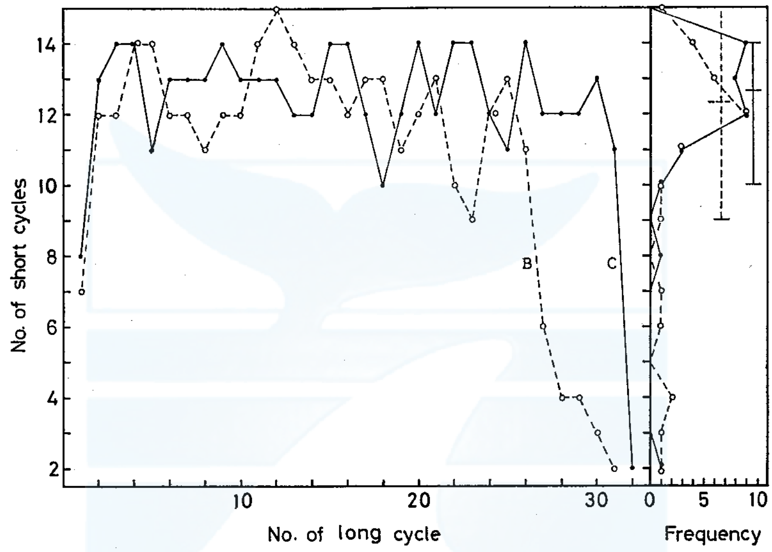

Fig. 4. Age and locality difference of the number of short cycles in a long cycle cemental layer, whale no. 52. Alphabets indicate the position shown in Fig. 1.

TABLE 3. FREQUENCY DISTRIBUTION OF NUMBER OF

Whale no.		55	53	37	49	52	60
Sex		♀	♂	♂	♂	♂	♀
No. long cycles present		1.8	2.4	17	21	30	37
No. long cycles checked		1	2	16	19	30	16
No. short cycles	9	—	—	—	—	—	—
	10	—	—	—	1	1	—
	11	—	1	4	—	3	3
	12	1	—	3	8	9	4
	13	—	1	4	5	8	7
	14	—	—	4	2	9	—
	15	—	—	1	2	—	2
	16	—	—	—	—	—	—
	17	—	—	—	1	—	—
	mean	12.0	12.0	12.7	13.0	12.7	12.6
Mean days in a short cycle[2]		30.4	30.4	28.8	28.2	28.7	28.9

[1] Mean of the 13 mean values. [2] 365 days are assumed for long cycle.

the last layers are incomplete, they are not adequate for the present discussion. The disagreement of one layer between the number of long cycles distinguished at distal area (B) and proximal area (C) is within the reasonable range of the error. Then Fig. 4 indicates that in the proximal portion of the tooth, about 10 to 14 short cycles are distinguished in every long cycle cemental layers, and that the same number of cycles are present in the distal portion only up to the age of 22 long cemental cycles. After this age the number of short cycles observed in the distal portion rapidly decreases. This was confirmed by the direct tracing of some long cycle layers, in which higher number of short cycles are observed in the proximal portion but only lower number in the distal portion. The thinner section, about 20 μm, of the latter part could not increase the number of observable short cycles. Accordingly, it will be safe to conclude that, after a certain age, the deposition of cementum becomes slower at the distal area of the tooth and the alternation of the stainability of short cycle is not fully recorded. This change will progress towards the proximal portion in accordance with the progress of the eruption of tooth. This is supported also by the fact that the number of long cycle layers where the complete number of short cycles are clearly recorded is very few on the posterior tooth. As the cemental layers are thin on the posterior tooth, the growth must be slower than the anterior tooth.

In order to estimate the relative length of the accumulation cycles of long and short cycle layers, the number of short cycles was counted on several contiguous long cycle layers at the selected position of 13 anterior teeth. As shown in Table 3, the fluctuation of the number of short cycles in one long cycle layer is wide. This is partially because the alternation of the stainability of long cycle is gradual and the distinction of each long cycle layer is not very definite. Accordingly, if one long cycle layer contains a relatively small number of short cycles the next long cycle layer often gives the higher count, and the reliability of the mean value in Table 3 might be higher than that expected from the fluctuation. The range of

SHORT CYCLES IN A LONG CEMENTAL CYCLE OF *B. BAIRDII*

20	41	58	40	57	50	51	Total	
♂	♂	♂	♂	♂	♂	♂	—	—
41	47	50	57	58	67	71	—	—
7	7	21	11	13	15	11	169	100%
—	—	—	—	—	—	—	—	—
1	1	4	—	—	—	—	8	4.7
1	1	3	5	3	4	—	28	16.6
1	2	4	3	3	7	2	47	27.8
—	3	6	2	5	3	4	43	25.4
4	—	4	1	2	1	4	31	18.7
—	—	—	—	—	—	1	6	3.5
—	—	—	—	—	—	—	—	0.0
—	—	—	—	—	—	—	1	0.6
12.7	12.0	12.1	11.9	12.5	12.1	13.4	12.1	12.4[1]
28.7	30.4	30.1	30.6	29.3	30.2	27.3	30.1	29.4[1]

the mean values is between 11.9 and 13.4 short cycles per one long cycle, and there is detected a significant difference of the mean values between some of the individuals as indicated in Fig. 5 and dealt with in the next section. The mean for the 13 whales is 12.4 short cycles per a long cemental cycle.

The number of short cycles constituting one stainable layer of long cycle was counted in 15 anterior teeth with from 5 to 10 long cycle layers each, and shown in Fig. 6. The mean counts per long cycle layer of each individual lie between 5.0 and 6.9 cycles, and the mean number of the short cycles calculated for all of the 86 data is 5.86 cycles. This result indicates that the stainable and unstainable layer of the long cycle represent approximately the same length of time, but only if each layer of short cycle represents equal time periods.

The age when the deposition of full number of short cycle layers (≧10 layers) ceases in the cementum of anterior teeth is estimated from the direct observation of

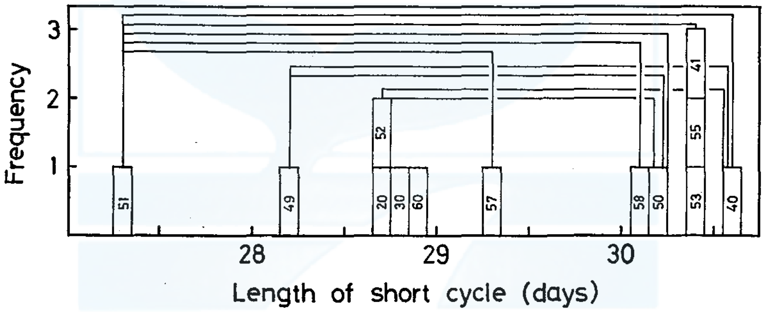

Fig. 5. Individual variation of the mean length of short cemental cycles. Numerals in the squares indicate the whale number, and the line the combination where the difference is statistically significant ($p<0.05$).

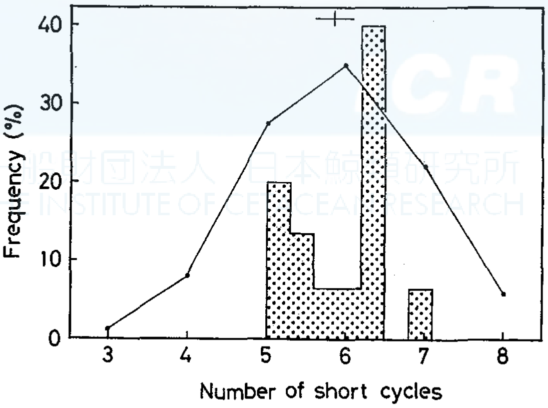

Fig. 6. Variation of the number of short cycles in a long cycle stainable layer in the cementum. Solid line and closed circle indicate the frequency, and dotted area the distribution of the mean values of each animal. Mean and the range of 2 standard errors are indicated at the top.

the teeth (Table 1). The youngest age when the short cycle layers deposition ceases is 39 long cycle layers, and the cumulative frequency of such animals increases with the age. The oldest animal found to be still forming the full number of the short cycle cemental layers is 57 long cycle layers and the cumulative frequency increases in the younger age. The two cumulative frequencies become equal at the age of 49.5 long cycle layers, which is the mean age at the cessation of the deposition of complete number of short cycle cemental layers.

Seasonal alternation of the layers

The condition of the last cemental layer, concerning the long cycle, was analysed in relation to the date of the catch. As shown in Tables 1 and 4, there are observed two kinds of layer states at equal abundance in August. One is in the process of forming the unstainable layer on the outer margin and the other stainable layer. The thickness of the former layer is large and the number of short cycles in it is 7 cycles in 2 countable cases. Whereas the thickness of the latter layer is thin and the number of short cycles in it is only 1 to 3 cycles in August. All the

TABLE 4. SEASONAL CHANGE OF THE CONDITION OF THE LAST CEMENTAL LAYER[1]

Month	Unstainable wide	Stainable		Total
		thin	wide	
Aug.	5	5	1	11
Sep.	—	2	1	3
Oct.	—	1	1	2
Nov.	—	—	2	2

[1] concerning the long cycle

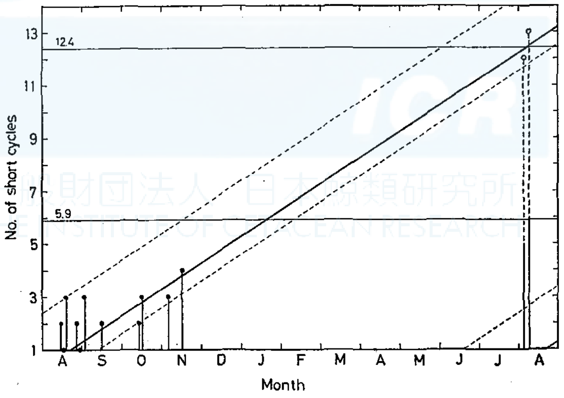

Fig. 7. Seasonal variation of the number of short cycles in the last incomplete long cycle cemental layer. Closed circle and solid line indicate the stainable long cycle layer, and open circle and dotted line the unstainable. Mean number of short cycles in one long cycle and that in one long cycle stainable layer are indicated. For further explanations see text.

seven whales killed after August were depositing the staniable layer of long cycle, and the thickness seems to increase with the progress of the season. It is safely concluded, from these informations, that the alternation of the layer from the unstainable to the stainable, occurrs, in the average, in August.

As the present sample is restricted to 4 months, it is impossible to detect the season when the deposition of the stainable layer of the long cycle ceases and that of unstainable layer starts. However, the analysis of the seasonal increment of the short cycle layer gives a suggestion for it. In Fig. 7, the number of short cycle layers in the last incomplete long cycle layer is plotted against the date of death. The two whales, nos. 36 and 37, which were accumulating the unstainable long cycle layer in August, are extended forward by 12 months and the number of short cycles in the preceding stainable long cycle layer was added. Then the linear regression was calculated by the least squares for the 8 whales, excluding the 5 whales killed in August, that had recently started the deposition of the stainable layer. The inclusion of these whales will cause a bias toward the higher number of short cycles, because half of the whales are still accumulating the unstainable long cycle layer in August. The regression is shown by

$$y = 0.03184x + 0.58$$

where x indicates the days from the first of August and y the number of short cycles accumulated since the start of the last stainable long cycle layer. It is, in a strict sense, incorrect to project the two whales for 12 months, because the accumulation rate of the long cycle is not proved to be 12 months. However the annual accumulation of the long cycle is considered to be correct based on the following reasons.

1. The gradient of the regression fits to the data of September and November, and other gradients assumed for the cycles shorter than one year do not.
2. If the length of the cycle longer than 1 year is assumed, there must be observed more varieties in the condition of cemental layers being accumulated in August and September.

Above regression indicates the accumulation of one short cycle in 31.4 days, and 12.4 short cycles, the mean number in one long cycle, in 389 days. This is sufficiently within the range of error for the conclusion of the annual formation of the long cycle cemental layers. The alternation from the stainable long cycle layer to the unstainable seems to occur in January. In other words, the long cycle stainable layer is formed in the season when the length of the daytime decreases, and the unstainable in the opposite season. This seasonal alternation is similar to that of the spotted dolphin studied by Kasuya (1976) except for the slightly earlier change in *B. bairdii*.

When the annual cycle is assumed for the long cemental cycle, the mean lengths of short cemental cycle of 13 whales come in the range of 27.3 to 30.6 days (Table 2). As shown in Fig. 5, the difference of the mean length of the cycle is significant between some animals ($p<0.05$), and there are expected the presence of 4 modes at 27, 28, 29, and 30 or 31 days. However it will be safe to retain the definite conclusion on this problem until the study is made on more animals, because the individual variation in the readability of the short cycle layer may influence the result.

In the natural environment, such a cycles which may cause the 29 or 30 days cycle of the cemental deposition seems to be the lunar cycle. For the check of this problem, the comparison between the state of the outermost cementum and the lunar cycle of the day of catch was made on selected 13 animals using the thinly prepared section (10 to 15 μm). However it gave a negative result. The stainable or unstainable layer of short cycle is considered to be formed at any period of a lunar cycle. Though more study is needed on this problem, it is probable that the short cycle is not a direct reflection of the environmental change, but a cycle hereditarily decided individual specific cycle just as the menstrual cycle of some of the female primates. This hypothesis can support the presence of the individual variation in the length of short cycle.

DISCUSSION AND CONCLUSION

In the present study no tooth of fetus or of newborn calf was studied. This obstructed the conclusion on the start of the deposition of cementum and on the relative rate of the formation of layers in dentine and cementum. However, Omura *et al.* (1955) studied the anatomy of the tooth of 9 feet, 2.7 m, fetus which had no cemental layer on it. The observation on the cementum of postnatal individuals showed that there is no clear layer such as neonatal line observed in dentine, and that the numbers of short and long cycles in cementum and postnatal dentine are almost same in the anterior tooth of young whales, nos. 53 and 55. In case of the dolphins, *Stenella attenuata* and *S. coeruleoalba*, the cementum is lacking on the tooth of fetal or newborn animals on which no postnatal dentine is deposited (Kasuya 1976, Kasuya unpublished), and it was considered that the cementum is laid down soon after the birth (Kasuya 1976). Accordingly I conclude that the deposition of cemental layer will start in *B. bairdii* soon after the birth as in the case of other odontoceti, and that the accumulation cycle of dentinal layers is fundamentally the same as that of cemental layers except for the earlier cessation of the accumulation in the former tissue. In order to estimate the age of the young animals of the species, it will be accurate to count both the long cycle layers (annual) and the short cycle layers (about 29.4 days) in dentine and cementum. However it is practical, in case of animals older than 3 years of age, to count the annual cemental layers. The age of the oldest animal thus estimated is 71 years, and seems to be reasonable compared with the same figure of the female sperm whale 64 years (Ohsumi *et al.* 1963).

The present study suggests that the short cycle layering in the postnatal dentine and cementum is probably caused by a genetic physiological cycle of about 29.4 days in the average. However, the effect of the lunar cycle is still left to be studied. The long cycle layer is formed by the enhancement of some of the short cycle layers, which seems to be caused by the annual cycle of the physiological condition possibly relating to some environmental changes. As the cause of the formation of the layers in the prenatal dentine, both the genetic physiological cycle (29.4 days in the average) of the fetus and of the mother can be expected. If the both factors work at the same intensity and the length of the cycle of the mother and of the fetus is equal, all the prenatal dentinal layers can be obscure by the complete masking of the opposite phases or can be clear by the complete or partial overlapping of the same phase. However, if the lengths of the cycle is not equal, the complete coincidence occurs once in the 27 to 31 cycles and the nearby several layers will be seen clear. Among the present materials, the prenatal dentinal layers of the whale no. 4 are almost completely obscure, in the whale no. 40 so many as 12 layers are clear, and other 11 individuals had 3 to 7 clear layers in the prenatal dentine. These facts can be explained by the above hypothesis, if the length of the gestation of the species is about 17 months as suspected from the fetal growth rate in later part of this section. However, it is also possible to explain the presence of the clear and obscure layers in the prenatal dentine solely by the strong effect of the mothers physiological changes of the short and long cycles, because the layers in the prenatal dentine formed in the season when the unstainable long cycle layer is deposited in the mother can be faint. Though the conclusion on the above problem must be left for the future study and the counting is not fully reliable at present, it will be possible to expect that the length of the cycle of the prenatal dentinal layering is nearly same with that of the short cycle layers in the postnatal dentine and cementum.

Omura *et al.* (1955) estimated the body length of the species at birth 15 feet (4.6 m) and the mean body length at the attainment of sexual maturity between 32 and 33 feet (7.8 and 10.1 m) for males and between 33 and 34 feet (10.1 and 10.4 m) for females. The length at the attainment of physical maturity was not estimated by them. However, there are, in the odontoceti, usually observed the coincidence of the body length and one of the modal length—if there are multiple modes that of the largest body length (for the bottlenose whale see Christensen 1973 and 1975, for the sperm whales see Clarke 1956 and Gambell 1972, and for the sppotted and striped dolphins see Kasuya 1972 and 1976 and Kasuya *et al.* 1974), and this is expected also for *B. bairdii*. The length frequencies of *B. bairdii* shown in Fig. 3 of Omura *et al.* (1955) indicates the mean length of the females at the attainment of physical maturity about 36 feet (11.0 m), and that of the males 35 feet (10.7 m). These values fit well to the age-length data in Fig. 8, and physical maturity of the species seems to be attained at an age over 20 years.

The growth curves in Fig. 8 are the von Bertalanffy growth equations calculated from the length at birth 4.6 m, asymptotic length 11.0 m (females) and 10.7 m (males), and 7.1 m the mean length of the two juvenile whales nos. 53 and 55 at the mean age of 2.1 years. The equations are shown by the following formulae

$$\text{male: } y = 10.7\ (1-e^{-0.5620-0.2511x})$$
$$\text{female: } y = 11.0\ (1-e^{-0.5416-0.2358x})$$

where y indicates the body length in m, and x the age in years. There is, at present, no reason to believe that the mean growth of *B. bairdii* can be exactly expressed by the von Bertallanffy equation and most of the known examples are opposite cases

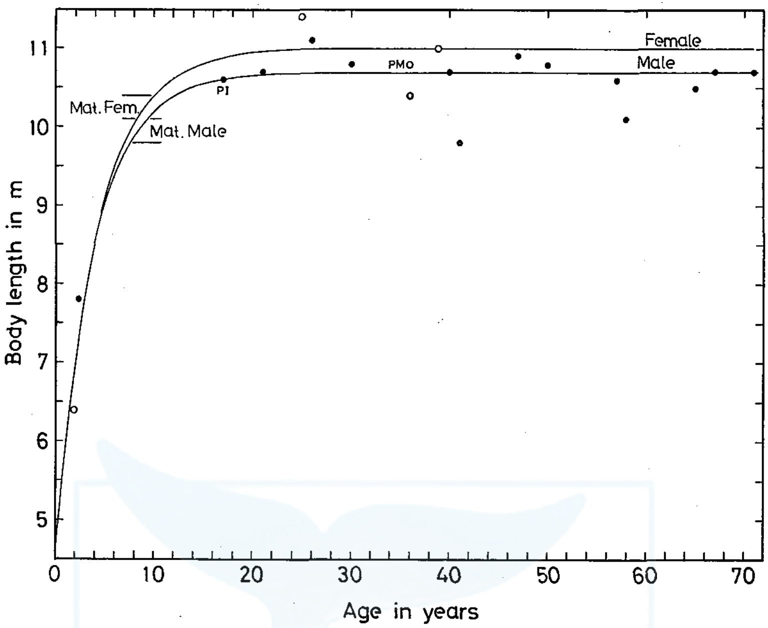

Fig. 8. Relationship between body length and the age of *B. bairdii*. Closed circle indicates male, open circle female, PM a physically mature female, and PI physically immature male. The ranges of the mean body length at the attainment of sexual maturity are cited from Omura *et al.* (1955). For the growth curves see text.

as seen in both sexes of the sperm whale (Nishiwaki *et al.* 1958), of the bottlenose whale (Christensen 1973), of the pilot whale (Sergeant 1962), of the white whale (Sergeant 1973), and of the striped and spotted dolphins (Kasuya 1976). One of the peculiar features of the growth curves of these species is the presence of a long prepubertal period when the growth is rather linear. Accordingly, if the above three points are given correctly, the von Bertalanffy growth equation gives slightly higher body length at pubertal stage. However, *B. bairdii* does not seem to have a post-pubertal growth spurt of the male often observed in polygynous marine mammals (Bryden 1972) because the asymptotic length of the male is smaller than that of the female and possible difference of social behavior is expected (Omura *et al.* 1955). Accordingly it is considered, at the present status of knowledge on this species, that the above growth equation will roughly indicate the mean growth of the species. These growth curves and the mean body length at sexual maturity presented by Omura *et al.* (1955) suggest that the species attains the sexual maturity at about 8 to 10 years of age (Fig. 8), which is close to that of the female bottlenose whale (Christensen 1973).

Omura *et al.* (1955) estimated 10 months for the length of gestation of *B. bairdii* based on the seasonal change of the fetal length. However, if the accumulation cycle of 29.4 days is assumed for the fine layers in the prenatal dentine as in the case of short cycles in postnatal dentine and cementum, the fetal period of the species after the start of deposition of fetal dentine is 29.4×14=412 days or 13.5 months.

Laws (1959) indicated that the fetal growth of odontoceti in body length is expressed by a earlier curvilinear growth and later linear growth, and that the period from the start of gestation to the x-intercept of the extended growth curve of the latter, t_0, varies between 7% and 15% of the total length of gestation (t_g) in accordance with the length of t_g. There are indicated large between species variation of the length of gestation and the fetal growth rate at the period of the linear growth (Laws 1959, Frazer and Huggett 1973), and there is observed a general tendency that the odontoceti species with large neonatal length has longer gestation period and faster fetal growth rate. In Fig. 9 the daily increment of the body length at the linear stage of the fetal growth is plotted against the mean length at birth cited from various authors. For *Tursiops truncatus* the neonatal length 90 cm and gestation length 12 months are cited from Tavolga and Essapian (1957), and t_0 was estimated as 0.135 × (gestation time)=49 days. This indicates the daily increment 90/(365−49)=0.285 cm/day. There is observed a linear relationship between the two parameters of the delphinoidea as shown below (thin solid line in Fig. 9).

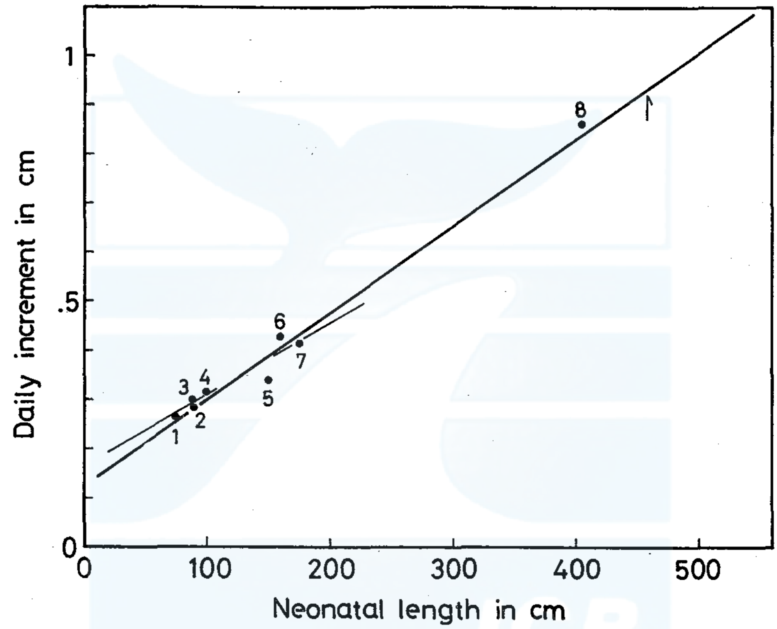

Fig. 9. Relationship between the neonatal length and the fetal growth rate in odontoceti. 1 : *Phocoena phocoena*, Laws 1959. 2 : *Tursiops truncatus*, Tabolga and Essapian 1957. 3 : *Stenella attenuata*, Kasuya *et al.* 1974. 4 : *S. coeruleoalba*, Kasuya *et al.* 1974. 5 : *Delphinapterus leucas*, Hudson Bay, Sergeant 1973. 6 : *D. leucas*, Kara and Barents Sea, Sergeant 1973. 7 : *Globicephala melaena*, Sergeant 1962. 8 : *Physeter catodon*, Ohsumi 1965. Arrow : neonatal length of *B. bairdii*, Omura *et al.* 1955. For further explanations see text.

$$y = 0.001462x+0.1622$$

Where y indicates the daily increment in body length (cm) and x the mean neonatal length (cm). A set of parameters for the sperm whale seems to be slightly above the regression. If all the 8 data are dealt together, the least square regression is expressed by the following equation (thick solid line in Fig. 9).

$$y = 0.001802x+0.1234$$

Though the former may fit better for smaller odontoceti, the latter seems to be suitable for the relationship in the general odontoceti. Using the latter equation, the length of the linear growth period, t_g-t_0, is expressed as follows, when x indicates the mean neonatal length in cm.

$$t_g-t_0 = x \,/\, (0.001802x+0.1234)$$

As the neonatal length of *B. bairdii* is 15 feet or 458 cm (Omura *et al.* 1955), (t_g-t_0) and the growth rate of the period for the species is estimated from the above equations to be 483 days and 0.949 cm/day respectively. Accordingly, the days from the start of gestation to the x-intercept of the linear growth curve, t_0, is $(0.07\times483) / 0.93=36$ days, and the total gestation time is $36+483=519$ days or 17.0 months for *B. bairdii.*

The approximate age of the fetus of *B. bairdii* at the start of the deposition of the first dentinal layer is $519-412=107$ days of gestation. The body length at the time is $(483-412)\times0.949=67$ cm. In case of *Globicephala macrorhynchus*, the fetal dentine starts to be laid down at about 40 cm in body length (Kasuya unpublished), the above figure is reasonable and the correctness of the estimation of the gestation length of *B. bairdii* is suggested. This fetal growth curve and the fetal length frequency reported by Omura *et al.* (1955) and Omura (1958) indicate that the mating peak of this species exists in October and November and the birth occurs from November to July with a peak in March and April. This feature is the reverse of that of the northern sperm whale (Ohsumi 1965).

The above equation indicates that the (t_g-t_0) of odontoceti has an asymptote of $1 / 0.001802=555$ days or 18.2 months. For the total asymptotic gestation time, t_0 or about 1 month shall be added to this value. Then it is considered that the gestation period of any recent odontoceti will not exceed 19 months, and that the fetal growth of the sperm whale or of the Baird's beaked whale is one of the most specialized. This specialization seems to have started from the fetal growth pattern of the small delphinids, which are less migratory staying usually in one water mass and have the mating and parturition in a same season in connection with the gestation of about one year, and attained the modification to have the mating and parturition in the opposite season of a year. This may have a relationship with the attainment of the augmentation of the body and that of the migration habit of longer distance, both of which are observed in the sperm whale and the Baird's beaked whale.

ACKNOWLEDGMENTS

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EXPLANATION OF PLATES

PLATE I

Lingua-buccal medial ground sections of the teeth of *B. bairdii.* Photographed under transmitted light and the contrast is reversed. The outermost structure is the artefact of the resin, actual size. 1 : Fetal dentine, 2 : Postnatal dentine, 3 : Osteodentine, 4 : Cementum, 5 : Resin.

Fig. 1. Anterior tooth of the whale no. 55, 6.4 m, female, about 1.8 years old.
Fig. 2. Anterior tooth of the whale no. 53, 7.8 m, male about 2.4 years old.
Fig. 3. Anterior tooth of the whale no. 41, 10.9 m, male, 47 years old.
Fig. 4. Posterior tooth of the whale no. 53. For the explanations see Fig. 2.

PLATE II

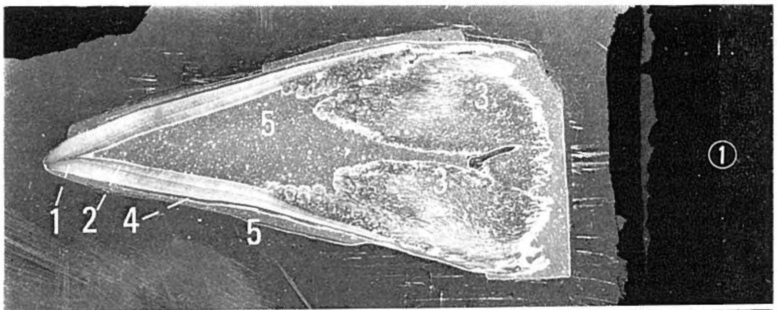
Decalcified and stained sections of the teeth of *B. bairdii.* Scale indicates 0.1 mm.

Fig. 1. 1 : Cementum, 2 : Fetal dentine, 3 : Postnatal dentine. Bar indicates the long cycle stainable layer, and circle the short cycle stainable layer. Anterior tooth of the whale no. 55, 1.8 years old.
Fig. 2. Cementum of the same tooth. Circle indicates the short cycle stainable layer.
Fig. 3. Fetal dentine of the anterior tooth of the whale no. 53. Circle indicates short cycle stainable layer.
Fig. 4. Cemental layers of the whale no. 37, anterior tooth. Pulp side at the top. For the marks see Fig. 1.
Fig. 5. Cemental layers of the whale no. 51, anterior tooth. Pulp side at the top. For the marks see Fig. 1.

PLATE III

Decalcified and stained section of the anterior tooth of *B. bairdii*, whale no. 49. Scale indicates 0.1 mm.

Fig. 1. Lower magnification, pulp side at the bottom, dentine is lost. Closed circle indicates the stainable layer of the long cycle.
Fig. 2. Higher magnification of the upper left part of Fig. 1.



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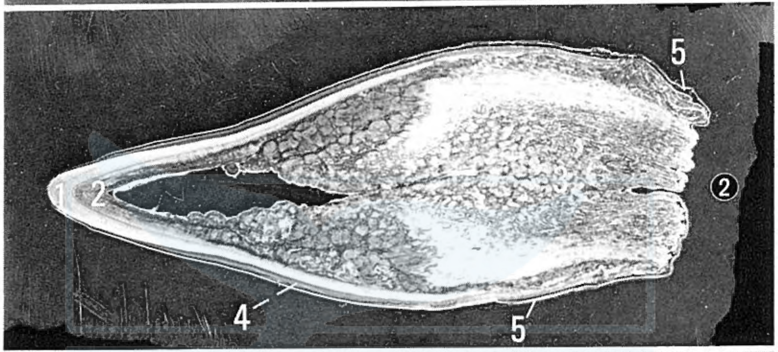

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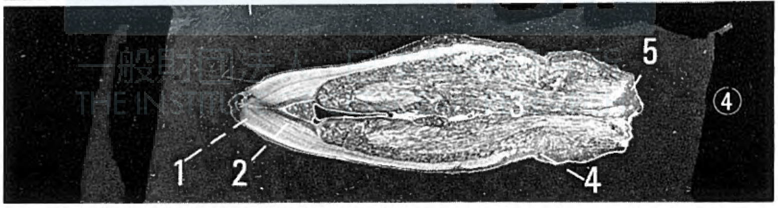

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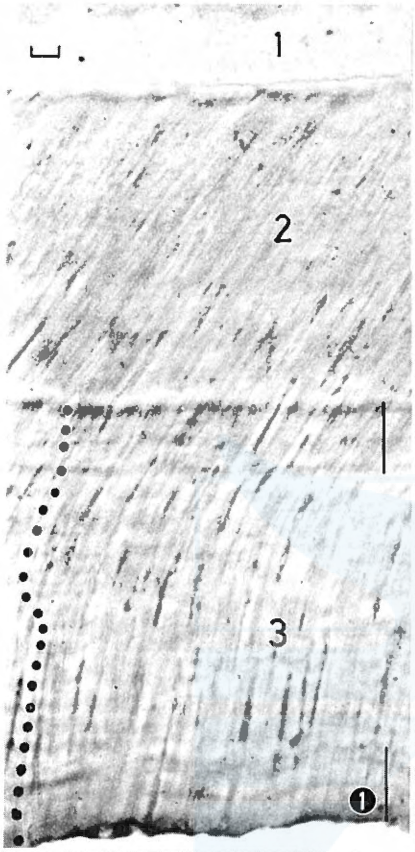
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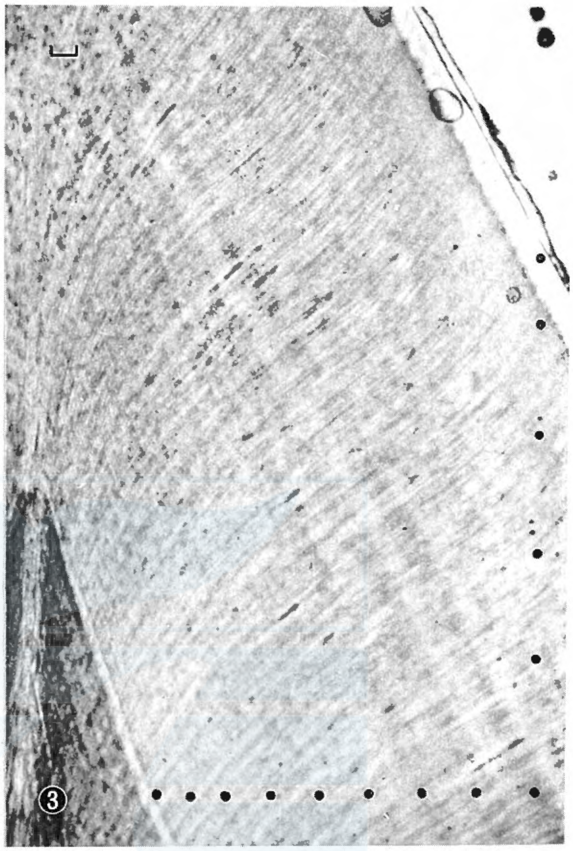
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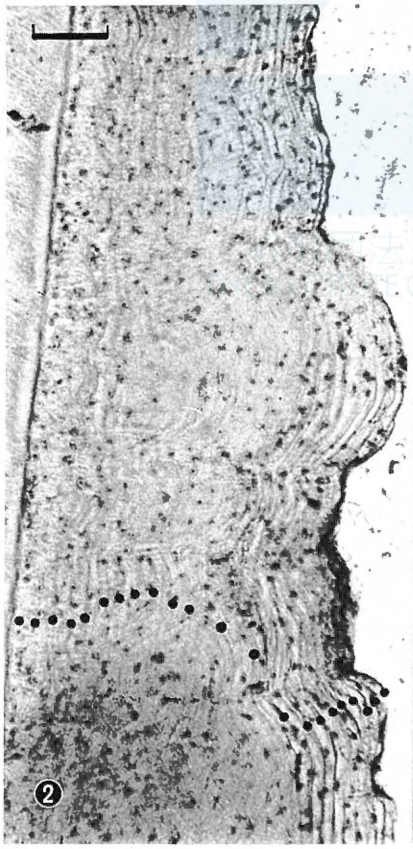
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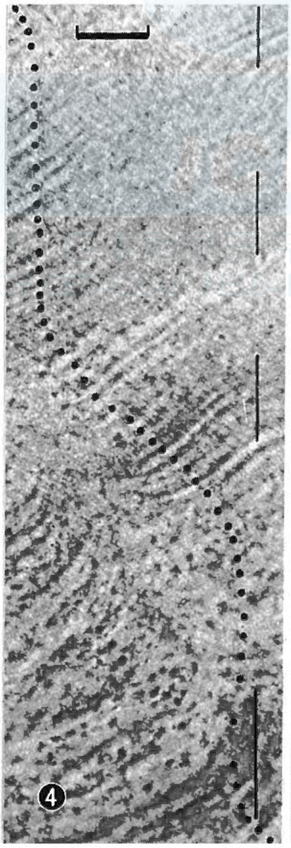
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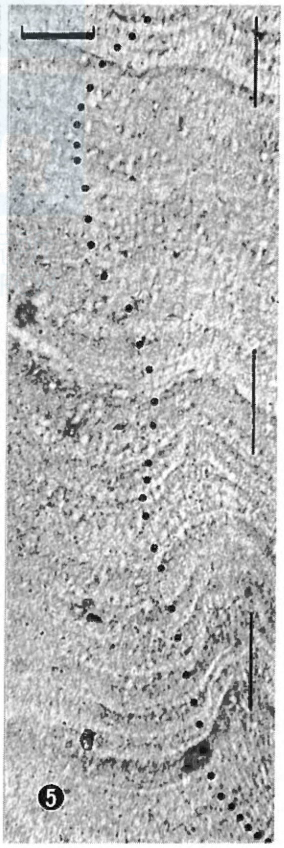
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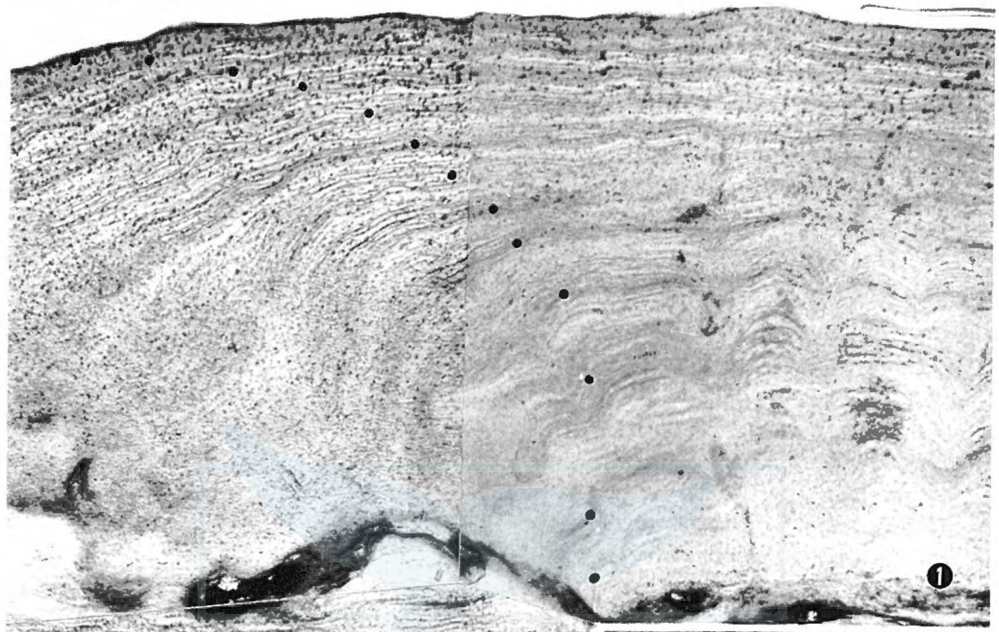

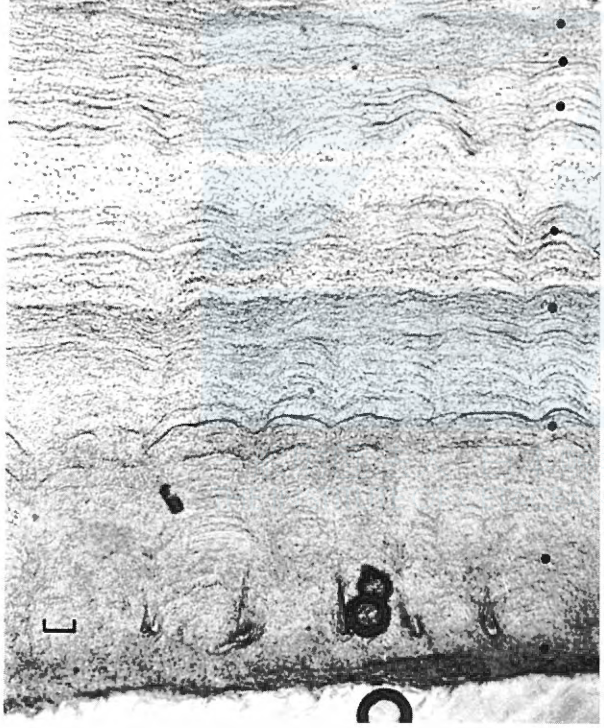

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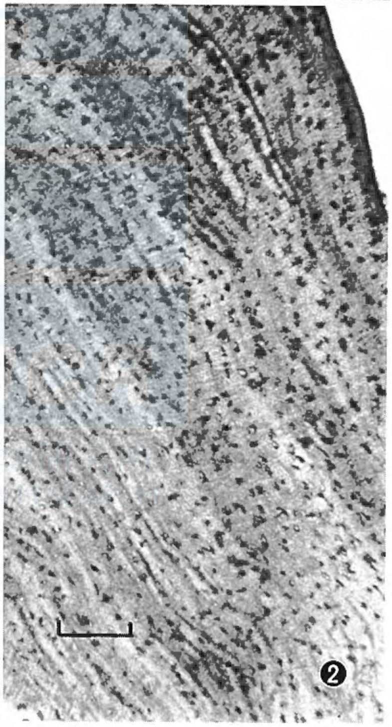

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GROWTH AND REPRODUCTION OF *STENELLA COERULEOALBA* OFF THE PACIFIC COAST OF JAPAN

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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

Sci. Rep. Whales Res. Inst.,
No. 29, 1977, 21–48

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

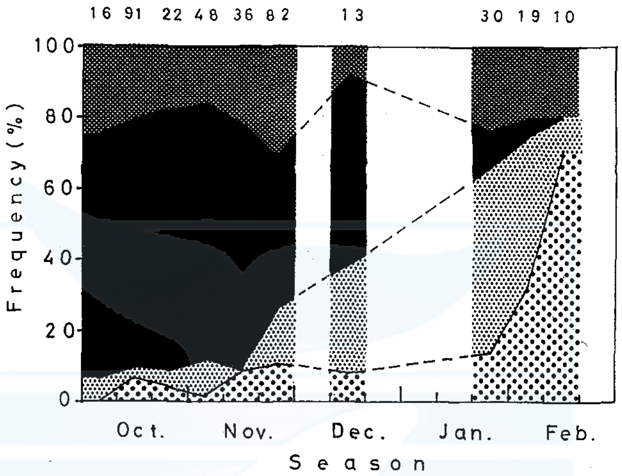

Fig. 1. Seasonal change of the formation of opaque and translucent dentinal layers. The marks indicate thin opaque layer, thick opaque layer, thin translucent layer, and thick translucent layer (from top to bottom). The numbers at the top indicate the sample size. The dates of the kill are grouped into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

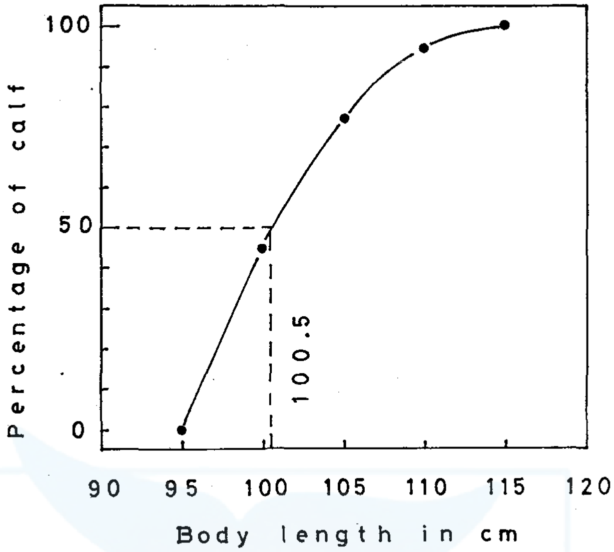

Fig. 2. Mean body length at birth. For explanation see text.

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

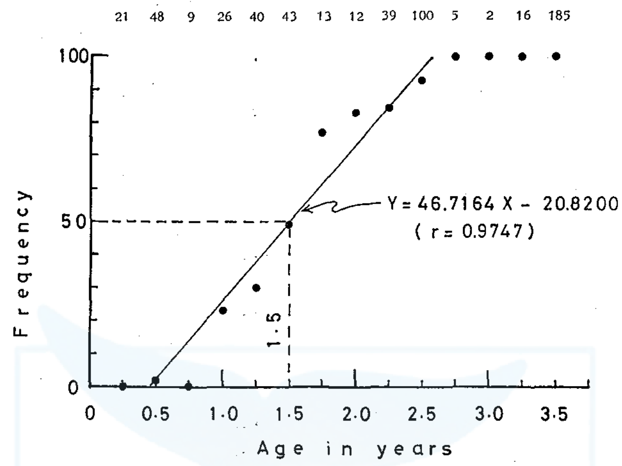

Fig. 3. Age of the weaning in *S. coeruleoalba*. Closed circles indicate the frequency of the juvenile calves. The numbers at the top show the sample size. For explanation see text.

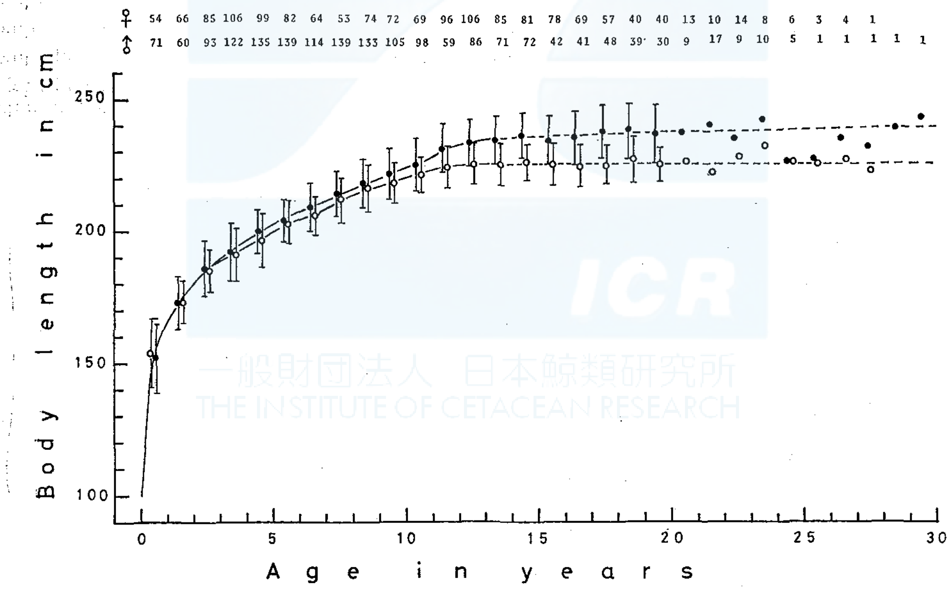

Fig. 4. The mean growth curves of the male and the female. Closed circles indicate the male and open circles the female. The numbers at the top indicate the sample size. For samples greater than 30, ± standard deviations indicated as vertical line. Solid line is drawn for the animals younger than 13.5 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	$0.70<p<0.80$

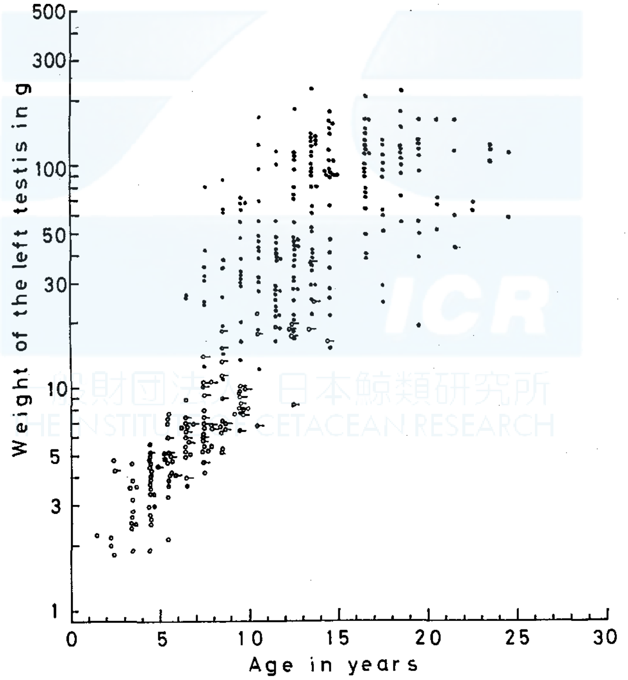

Fig. 5. Relation between age and the weight of the left testis. The weight of the left testis is plotted on logarithmic scale. Closed circles indicate the mature animals, open circles the immature, and open circles with rod the pubertal.

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

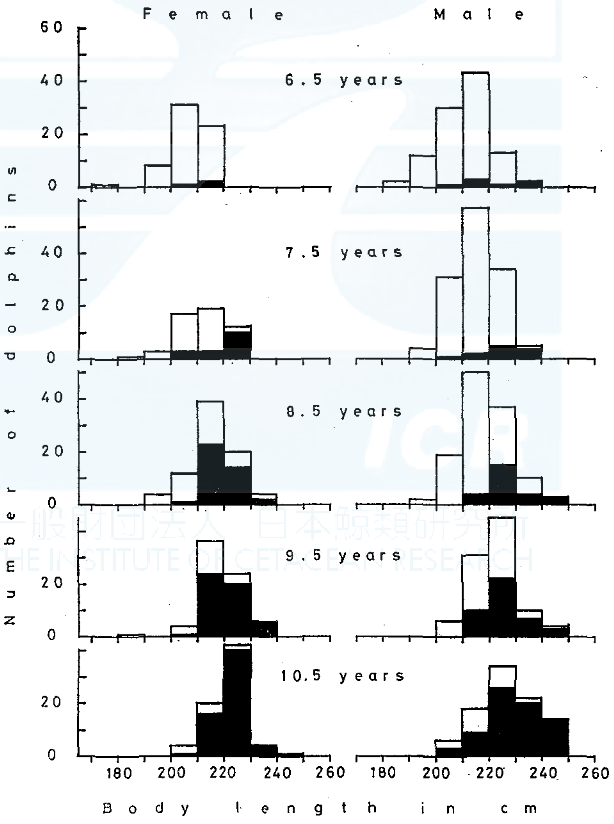

Fig. 6. The body length frequencies of both sexes in each age. White squares indicate immature or pubertal animals, and black mature animals.

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

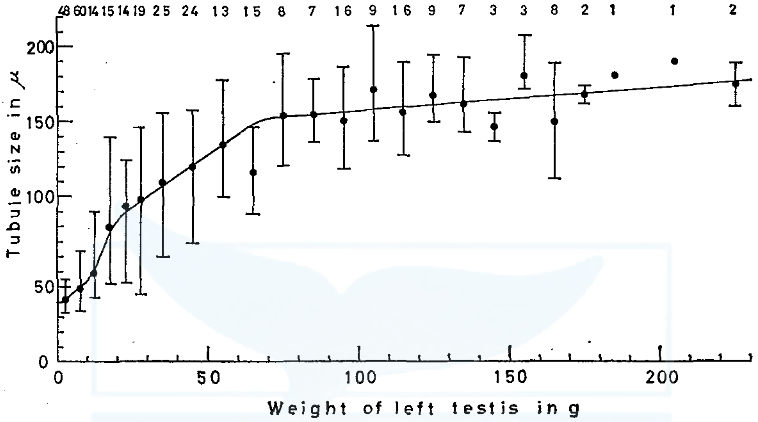

Fig. 7. Relation between the weight of the left testis and the diameter of seminiferous tubules. Closed circles indicate mean and vertical lines range. Solid line is drawn by eyes. The numbers at the top indicate the sample size.

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)	55	130	98 (44.5)	108	153	220 (100)	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

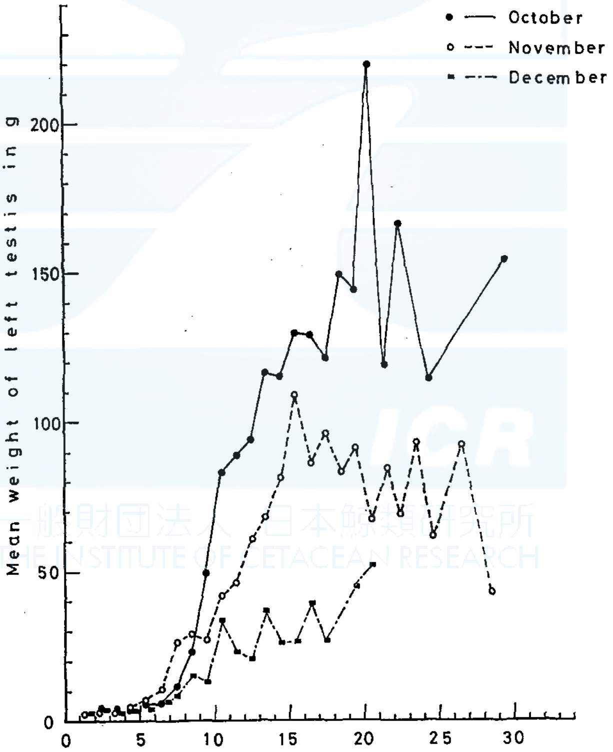

Fig. 8. Relation between age and the mean weight of the left testis. Closed circles (solid line) indicate the males caught in October, open circles (dotted line) the males in November, and closed squares (chain line) the males in December.

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

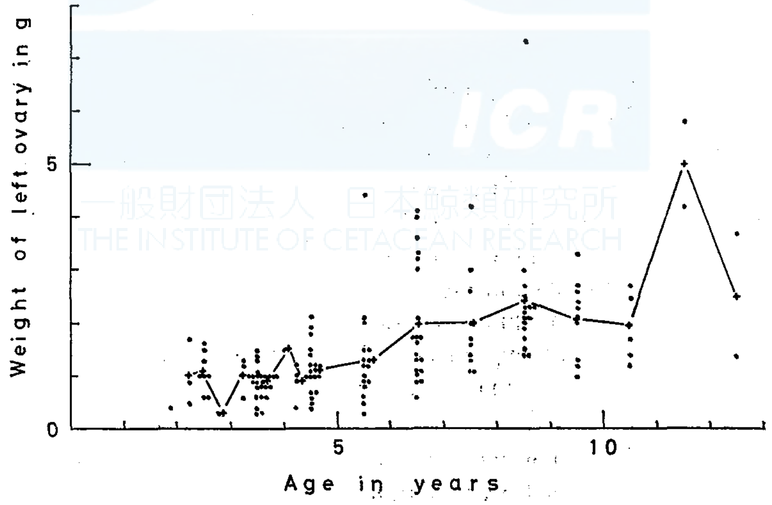

Fig. 9. Relation between age and the left ovary weight. Double crosses indicate the mean weight of the left ovary.

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).

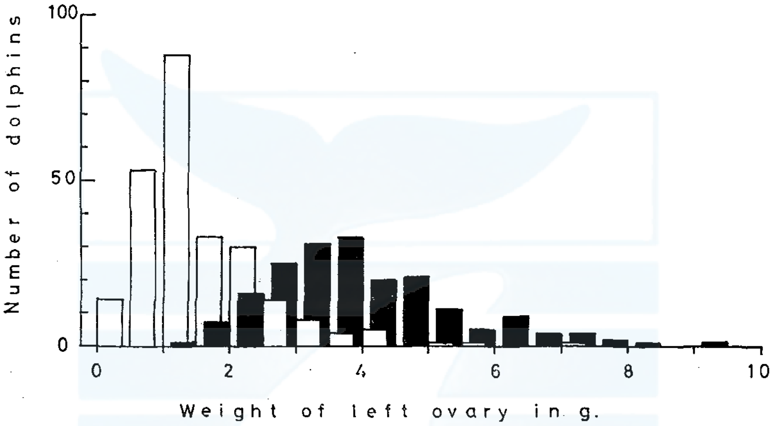

Fig. 10. Frequency of the left ovary weight. White squares indicate the left ovary with no corpus albicans and black the left ovary with one corpus albicans.

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.

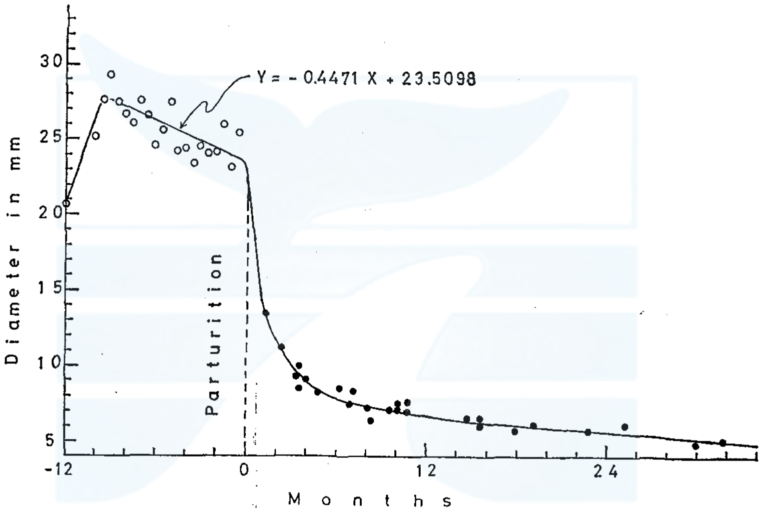

Fig. 11. Change of the diameter of corpora lutea during the period of pregnancy and regression of the diameter of corpora albicantia after parturition. Closed circles indicate the reliable combinations obtained from Fig. 13 and open circles the mean diameter of corpora lutea in the interval of 0.25 month.

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).

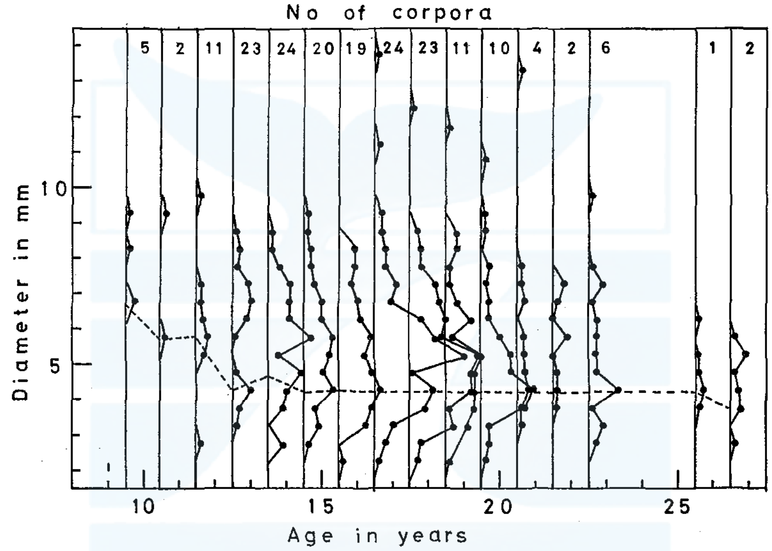

Fig. 12. Distribution of the diameter of corpora albicantia. The dotted line indicates the position of the mode and the numbers at the top show the sample size.

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-

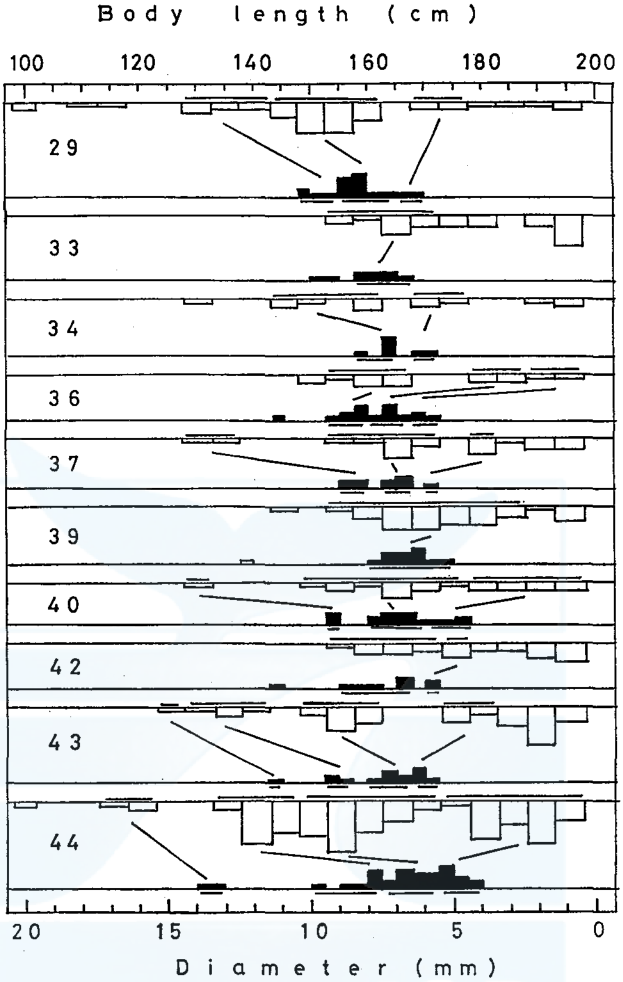

Fig. 13. Comparison of the frequency of the diameter of the largest corpora albicantia of lactating females (black square) and the length frequency of juvenile calves (white square). The numbers at the left indicate the school no.

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.

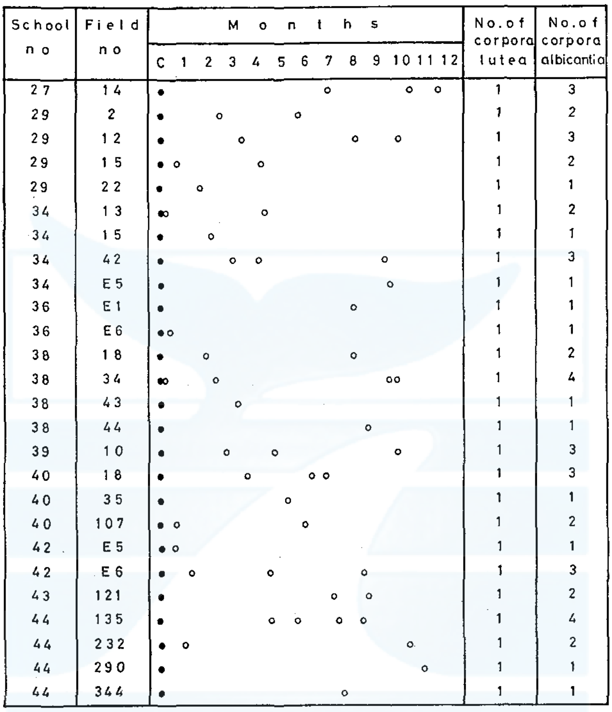

Fig. 14. Ovulation diagrams of 26 pregnant females. Closed circles indicate the corpora albicantia of pregnancy and open circles the corpora albicantia of ovulation. C means conception date. For explanation see text.

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.

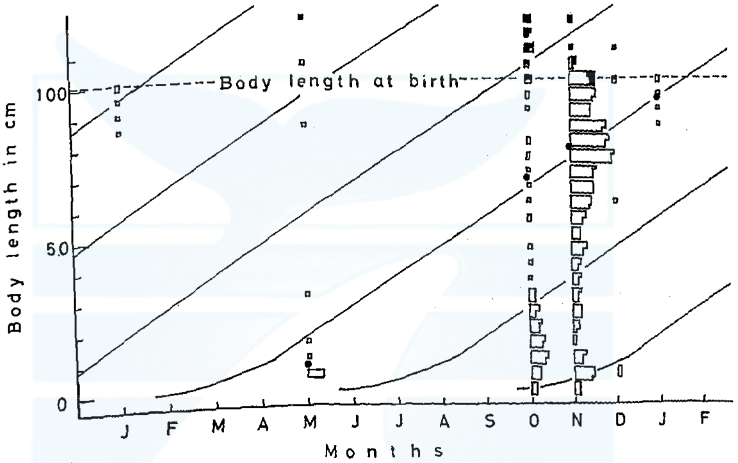

Fig. 15. Body length frequencies of fetuses and newborn calves by month. The fetal growth curve is drawn presuming 12 months of gestation. The specimens in May are cited from Nishiwaki and Yagi (1953). White squares indicate the fetuses, black squares the newborn calves, and closed circles the mean body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

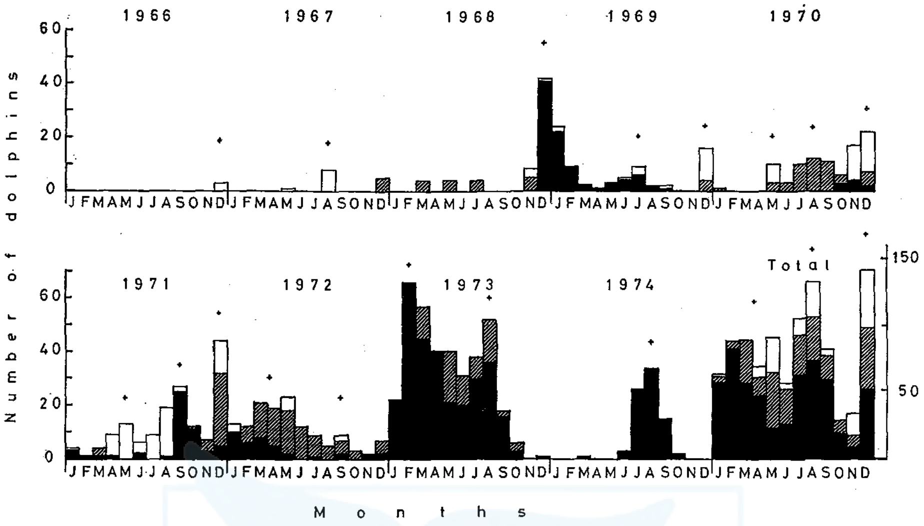

Fig. 16. Frequencies of parturition dates estimated from the body length of fetuses and postnatal calves on the basis of the mean growth curve. Black squares indicate the parturition dates estimated from fetus size, striped squares from the body length of newborns younger than 1 year old, and white from 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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ON THE FOOD OF BRYDE'S WHALES CAUGHT IN THE SOUTH PACIFIC AND INDIAN OCEANS

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ABSTRACT

A total of 225 Bryde's whales was caught in the Coral Sea, South Pacific and southwestern Indian Oceans during the 1976/77 Antarctic season under the scheme of special permission (Figs. 1A-B), and their stomach contents along with feeding conditions in terms of the state of repletion were examined. In the South Pacific regions 75% of animals was found to be repleted with under various state whereas it was 46.7% in the animals caught in the temperate Indian Ocean. (Tables 1A-B). The occurrence of fully repleted animal during the daytime suggests that there seems to exist a considerable availability of whales food even in the pelagic waters over the tropics (Tables 2A-B). The stomach contents were solely comprised of three species of euphausiids: *Euphausia diomedeae*, *Euphausia recurva* and *Thysanoessa gregaria*. There found to exist a possible differences in the fashion of geographical distributions among those euphausiid species as whales food (Table 3). Both *E. diomedeae* and *E. recurva* occurred dominantly over the whaling regions in question with monospecific or mingled composition whereas *Th. gregaria* alone was completely absent from the Indian Ocean animals.

INTRODUCTION

During 1976/77 Antarctic season two Japanese whaling fleets, Tonan Maru No. 2 and Nisshin Maru No. 3, caught a total of 225 southern Bryde's whales in the Coral Sea, tropical South Pacific and southwestern Indian Oceans under the scheme of special permission for the scientific purpose.

The report on the general topics and some biological observations performed on those Bryde's whales was preliminarily documented by Ohsumi (IWC/SC/38/1977). This report deals with the food habits of the Bryde's whales which are identical to that above mentioned but very briefly since the examination on the stomach contents collected by each factory ship are still halfway of microscopic observations at present. Therefore, the argument was focussed on discussing the marine biological purport for taking the whales under special permission rather than describing the result in detail. However, the article as a whole hopefully be regarded as a supplement to the document by Ohsumi.

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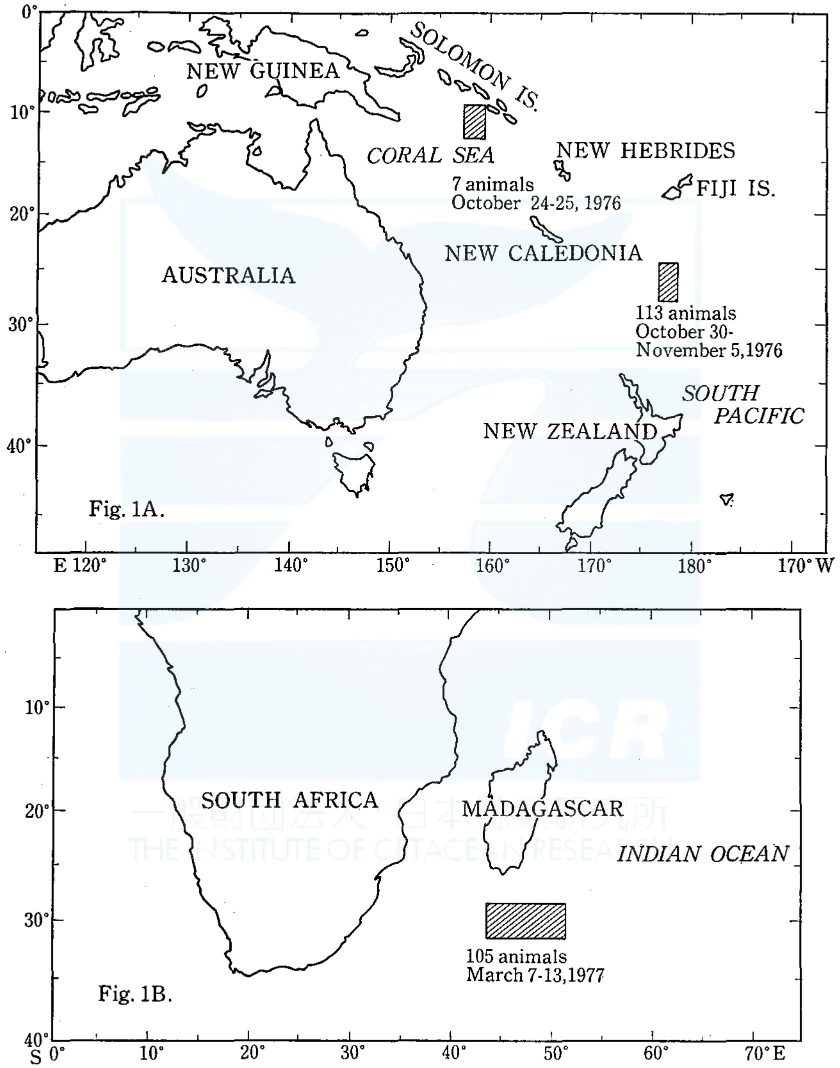
MATERIAL

Seven Bryde's whales out of 225 animals were caught in the Coral Sea during October 24–25, 1976, and 113 were caught in the tropical South Pacific between Fiji Islands and New Zealand during October 30-November 5, 1976. The rest 105 animals came from the catch in the waters off Madagascar, southwestern Indian Ocean. The approximate locality where the catches took place is demonstrated by the hatched squares in Figs. 1A and 1B.



Figs. 1A-B. Whaling ground for the Bryde's whales caught by Japanese whaling fleets, (1A) Tonan Maru No. 2 and (1B) Nisshin Maru No. 3, under the special permission for the season of 1976/77. Location of catch is indicated by the hatched squares framed by the farthest extremes of catch positions.

A total of 121 stomach contents was collected from the identical number of animals, of which 69 samples were obtained from the South Pacific and Coral Sea regions, and 52 were from the southwestern Indian Ocean.

The collected stomach contents were preserved in 10% formalin solution. Although a considerable amount of the stomach contents was heavily digested leaving a very small fraction of the appendages of prey organisms, it was rather easy to identify euphausiid species by the remains of male copulatory organ on the 1 st–2 nd swimming legs and spermatophore in female since there was quite clear biasing in sex composition by each euphausiid species.

Apart from sampling the stomach contents, eye observations on the stomach of each carcass were made by a personnel on board, and the results were recorded by the kind of food organisms on all animals. By examining this results, there found no descriptions of food items other than euphausiids.

RESULT

Stomach condition in general

The overall state concerning the amount of stomach contents was based on eye observations by classifing it into five quantitative categories. One of summed up figures was given in Tables 1A and 1B by the whaling ground. In the animals caught in the Coral Sea and tropical South Pacific waters, 75% of animals were found to be repleted with food to some extent under varying quantity. Although the majority of those repleted animals showed few in the quantity of stomach contents, say, 57.5% of animals were repleted less than half of the stomach volume, it is noteworthy or even amazing that there occurred 17.5% of animals which were repleted almost fully (' Rich ' plus ' Full ' in the table-A) in those pelagic waters of the tropics where the quantitative distribution of planktonic organisms is very scarce in general.

TABLES 1A-B. THE OVERALL STATE OF THE STOMACH CONDITION IN BRYDE'S WHALES CAUGHT IN THE CORAL SEA AND SOUTH PACIFIC OCEAN DURING OCTOBER 24—NOVEMBER 5, 1976 (A), AND IN THE SOUTHWESTERN INDIAN OCEAN DURING MARCH 7-13, 1977 (B).

(A)*

Amount of stomach contents	Empty	Few	Moderate	Rich	Full	
No. of animal	30	49	20	13	8	(=120)
% to total	25.0	40.8	16.7	10.8	6.7	(=100)

* catch by the Tonan Maru No. 2 fleet

(B)**

Amount of stomach contents	Empty	Few	Moderate	Rich	Full	
No. of animal	56	21	10	1	17	(=105)
% to total	53.3	20.0	9.6	0.9	16.2	(=100)

** catch by the Nisshin Maru No. 3 fleet

In contrast to the animals in the South Pacific regions, there occurred considerably large number of poorly fed animals in the southwestern Indian Ocean. The number of whales with empty stomach roughly doubled in this whaling ground. However, there still exists about 50% of animals of being well repleted stomach, and the percentage figures combined both ' Rich ' and ' Full ' are very similar to that found in the South Pacific animals.

The stomach conditions in southern blue and fin whales, for instance, show very frequent occurrence in the number of animals with empty stomach in the Ross Sea region, and its percentage figures usually vary between 40% and 57% (Kawamura, 1977). By comparing these figures with those found in the southern Bryde's whales, it may be considered that the relatively frequent occurrence of well fed animals both in the South Pacific and southwestern Indian Oceans is significant evidence in connection with dealing the ecosystem through food webs in the pelagic waters of the tropics.

Occurrence of stomach contents by the local time

In the animals caught in the South Pacific and Coral Sea regions, there seems to be no clear trends in the stomach condition by the local time of catch. The animal caught in October showed somewhat large number in the frequency of empty stomach (44.4%) while it was reduced to 13.3% in November (Av. 25.0%), but there was a slight difference in the Indian Ocean. (Tables 2A and 2B).

The number of animals of being repleted stomach in terms of the percentage figures is very large throughout every time series of catch. Both upper and lower most extremes of the percentage in the South Pacific animals repleted with some amount of food for given time series was 87.5% for 0900 hour and 60.0% for 0800 hour respectively, while they were 66.7% and 16.7% in the Indian Ocean animals. The very high percentage occurrence of animals of repleted stomach through a series of daily catch time (0500–1800 hours) suggests that there must be considerably rich availability of food organisms for baleen whales, and that possibly for many other key members involved in the tropical food webs. No animal with repleted stomach was found in 0500, 1000 and 1100 hours, but perhaps it was due to poor catch number during those time zones. One of important facts in Tables 2A and 2B should be found in the occurrence of ' Rich ' and ' Full ' stomachs during the daytime (1200–1400 hours). These animals undoubtedly preyed upon euphausiids within the past several hours prior to their capture. This indicates that there exists an abundant food organisms even during the daytime and that *E. diomedeae*, *E. recurva* and *Th. gregaria* occur with large biomass by forming the mono-specific surface swarms instead of remaining in deep waters.

Species of food organisms

From a total of 121 stomach samples following three species of euphausiid were indentified:

Euphausia diomedeae Ortmann
Euphausia recurva Hansen

TABLES 2A-B. FREQUENCY DISTRIBUTION OF THE NUMBER OF ANIMALS BY THE LOCAL TIME OF CATCH AND THE STATE OF STOMACH CONTENTS, (A) OCTOBER—NOVEMBER, 1976 IN THE SOUTH PACIFIC AND CORAL SEA, AND (B) MARCH, 1977 IN THE SOUTHWESTERN INDIAN OCEAN.

(A) Tonan Maru No. 2 fleet

Period	October 24-30, 1976						November 1-5, 1976							
Amount of stomach contents	Empty	Few	Moderate	Rich	Full	Total	Empty	Few	Moderate	Rich	Full	Total	Grand total	% animal with food
05	1	—	—	—	—	1	—	—	—	—	—	—	1	—
06	3	—	—	—	—	3	1	6	2	—	—	9	12	66.7
07	3	2	—	—	—	5	2	8	4	3	1	18	23	78.3
08	—	1	—	—	—	1	4	3	1	—	1	9	10	60.0
09	1	3	1	—	—	5	—	—	—	—	—	3	8	87.5
10	1	—	—	—	—	1	1	—	—	—	—	1	2	—
11	1	—	—	—	—	1	—	3	1	—	—	4	5	80.0
12	1	—	—	2	1	4	1	—	1	1	2	5	9	77.8
13	1	—	—	1	1	3	—	1	3	—	—	4	7	85.7
14	2	1	—	1	—	4	—	4	2	—	—	6	10	80.0
15	1	4	—	—	—	5	1	—	1	3	—	5	10	80.0
16	4	—	—	1	1	6	—	4	2	1	1	8	14	71.4
17	1	2	—	—	—	3	—	1	1	—	—	2	5	80.0
18	—	2	1	—	—	3	—	1	—	—	—	1	4	80.0
Total	20	15	2	5	3	45	10	34	18	8	5	75	120	
%	44.4	33.3	4.4	11.2	6.7	100.0	13.3	45.3	24.0	10.7	6.7	100.0		

(B) Nisshin Maru No. 3 fleet

Period	March 7-13, 1977						
Amount of stomach contents	Empty	Few	Moderate	Rich	Full	Total	% animal with food
06	1	1	1	—	—	3	66.7
07	7	5	1	—	1	14	50.0
08	16	3	1	1	7	28	42.9
09	6	6	3	—	3	18	66.7
10	9	—	—	—	2	11	18.2
11	2	1	1	—	1	5	60.0
12	7	2	2	—	2	13	46.2
13	3	2	1	—	—	6	50.0
14	5	—	—	—	1	6	16.7
15	—	1	—	—	—	1	100.0
Total	56	21	10	1	17	105	
%	53.3	20.0	9.5	1.0	16.2	100.0	

Thysanoessa gregaria G.O. Sars

The population of *Euphausia diomedeae* occurred in the Coral Sea during October was comprised of adult of both sexes except an instance which was solely comprised of female, and there found a single spermatophore attached to the thelycum in female or to the external genital aperture in male in some individuals. In the South Pacific and Indian Ocean population of *E. diomedeae*, however, male individual was complete absent to result complete mono-sexual composition. The stomach contents of Bryde's whales caught in the Coral Sea were represented solely by *E. diomedeae* without exception.

In contrast to the case in *E. diomedeae*, *Euphausia recurva* population was comprised of adult male. Female did not occur completely in this species. *E. recurva* occurred both in the South Pacific and southwestern Indian Ocean, but not in the Coral Sea. There were no individuals carrying spermatophores in the specimen came from the tropical Pacific whereas some few individuals from the Indian Ocean carried a single spermatophore on the genital aperture although the majority was not.

Thysanoessa gregaria was comprised of both adult male and female. Both *E. diomedeae* and *E. recurva* distributed widely over the whaling grounds in question,

TABLE 3. COMPOSITION OF THE FOOD OF BRYDE'S WHALES CAUGHT IN THE CORAL SEA, SOUTH PACIFIC AND SOUTHWESTERN INDIAN OCEANS FOR THE 1976/77 ANTARCTIC SEASON. FIGURES IN THE TABLE INDICATE THE NUMBER OF ANIMALS.

Sea area	S. Pacific & Coral Sea	S. W. Indian Ocean
Fleet	Tonan Maru No. 2	Nisshin Maru No. 3
No. of animals caught	120	105
No. of stomach contents examined	69	52
Euphausia diomedeae	17[5]	4
E diomedeae/E. recurva[1]	12	17
E. diomedeae/Th. gregaria	1	—
Euphausia recurva	—	2
E. recurva≒E. diomedeae[2]	9	15
E. recurva/E. diomedeae	2	8[6]
E. recurva+E. diomedeae[3]	3	5
E. recurva≤E. diomedeae/Th. gregaria	3	—
Euphausia sp.[4]	7	1
Thysanoessa gregaria	10	—
Th. gregaria/E. diomedeae	1	—
Th. gregaria/E. recurva	1	—
Th. gregaria/E. diomedeae+E. recurva	3	—

[1] by the order of dominancy

[2] mixture of closely equal quantity

[3] mixture of two species but quantitative share among them is unknown due to heavy digestion

[4] the fraction of appendages and spermatophore strongly suggest that the species may possibly be composed of *E. diomedeae* and/or *E. recurva*

[5] of which five animals out of seven in all caught in the Coral Sea are included

[6] including one stomach contained a single specimen of hatchetfish

but *Th. gregaria* tended to show a sporadic occurrence which suggests the presence of possible five different local groups. There were however, no noticeable indications in the environmental condition which may explain their characteristic occurrence. The occurrence of *Th. gregaria* was fairly restricted in the whaling ground of the South Pacific regions.

The Bryde's whales caught in the Coral Sea, South Pacific and southwestern Indian Ocean preyed upon these three euphausiid species with some local differences in the species composition. As it is shown in Table 3 the food of Bryde's whales which distributes in the pelagic waters of the tropics was found to be comprised of monospecific or mixtured swarms of euphausiids. Comparing this with the stomach contents having been known throughout the so-called boreal and antiboreal feeding grounds, the revealed composition of prey organisms in terms of the variety of species in the tropical waters is considered to be rather monotonous. To see Table 3 there may be found differences but slight between South Pacific and Indian Oceans: One of clear differences was complete absence of *Th. gregaria* from the stomachs in the Indian Ocean, instead, *Euphausia recurva* was possibly dominant in this locality. The result shows in general that both *E. diomedeae* and *E. recurva* are considered to be very important food items among all in a scope of studying the energy flow through marine food webs in the tropical seas where micronektonic organisms other than euphausiids have been considered likely to be the key biotic group in the ecosystem of those waters.

DISCUSSION

It is well known fact in general that the abundance of zooplankton in the waters over the tropics is very poor. The stomach contents of surface dwelling fishes such as albacore, yellowfin and skipjack suggest that micronektonic fishes and squids may possibly be the key members in the pelagic food webs in those warmer waters (e.g. Roger and Grandperrin, 1976). Analysing the stomach contents of above mentioned tunas in the tropical Pacific, Roger and Grandperrin (1976) reported that 60% of the diet of tunas was comprised of micronektonic fishes, and euphausiids accounted only about 12% of the food of preyed fishes or may account only 7% of the food of tunas through the predation by their prey fishes.

The Bryde's whales have been considered to be the inhabitant of warm waters of the surface temperature higher than 20°C (Omura and Nemoto, 1955). They possibly share an identical ecosystem with tunas, surface dwelling fishes and other many micronektons in those tropical waters. The baleen whales undoubtedly feed to some extent on some organisms while they are in warmer waters. An example suggesting their active feeding may be found in the behaviour of excreting reddish faeces by blue whales in the Indian Ocean (Gambell *et al.*, 1974), and the similar one was observed in Bryde's whales during the marking cruise of Miwa Maru to the equatorial western Pacific (Far Seas Fish. Res. Lab., 1975; Wada, 1975). By considering those facts along with some speculations, it may be considered quite naturally that the Bryde's whales are likely to feed mainly on small gregarious fishes, larvae or juvenile of larger fishes and/or micronektonic organisms. However, one of the evidences revealed in the present study on the feeding of Bryde's whales that inhabit in the tropical South Pacific and southwestern Indian Oceans suggested somewhat different from that have been considered previously. The Bryde's whales under consideration preyed exclusively upon euphausiids. There occurred no other kind of food organisms. Although the importance of euphausiids as food of Bryde's whales in the tropical seas is still obscure since the material did not cover over the sufficient period and amounts. However, the fact that euphausiids occurred significantly over the different time and space suggests their importance as the stable foodstuff not only for Bryde's whale but also perhaps for all other baleen whale species occurring in those warm waters regardless the origin of whales whether the animals were endemic or migrants. In this respect the Bryde's whales in the tropics are by no means at higher trophic level than any other migrating baleen whale species, and the ecological niche for those Bryde's whales is considered very similar to that known throughout balaenopterid whales.

The euphausiids species, *E. diomedeae*, *E. recurva* and *Th. gregaria* are very common over the waters from tropics toward the warm temperate regions. Usually these euphausiids migrate vertically for a considerable distance of about several hundred meters and are considered seldom to occur in the near surface during the daytime (e.g. Boden *et al.*, 1955; Ponomareva, 1963; Mauchline and Fisher, 1969). According to Roger and Grandperrin (1976), only *Stylocheiron* species may become available for its predators during daytime in the tropical Pacific. *Euphausia* species, on the other hand, may become more important at night (Roger, 1973a, b). However, the occurrence of *E. diomedeae*, *E. recurva* and *Th. gregaria* largely in the stomach contents of Bryde's whales even in the daytime suggests the primary importance of these food species at some restricted time and space over the pelagic waters of the tropics. Apart from the diurnal behaviour pattern, the formation of swarms at this time of the season in these euphausiid species might relate to their reproduction, which is indicated by an extremely biased sexual composition occurring only male for *E. recurva* and female for *E. diomedeae* of the South Pacific populations, and several other characteristics such as that the spermatophore frequents in *E. diomedeae*.

The mass occurrence of euphausiids in the tropical seas so abundant as to be utilized by the predators is again significant phenomenon in considering the energy budget of baleen whales. Through the calculation of energetic budget in the southern baleen whales, Kawamura (1975) suggested that the overall estimations may fulfill the energetic requirements by migrating animals, but at the sametime there exists very ill fed animals with thin blubber, and these animals perhaps must to feed on the way to and from the so-called breeding ground in the warmer waters. One of questions arose from the discussion was whether there were any possibility to come across suitable feeding place for those stenophagous filter feeders in the tropical seas, and the failure in this may suggests a critical situation for the mulnutritioned animals. Although the mass occurrence of euphausiids in the austral spring as was suggested through this study did not coincide with a possible seasons of appearing the migrating whales, it can be said that the swarms of euphausiids may occur over the whole warmer season at least in some restricted localities. The occurrence of euphausiids both in October-November and March with considerable availability may support this, and there have been reported a considerable amount of half-grown to adult specimens of *E. diomedeae* occurred during the austral winter in Siboga-Expedition (Hansen, 1910).

In concluding with the discussion, the occurrence of euphausiid swarms in the tropical South Pacific and in the southwestern Indian Ocean strongly suggests its importance in considering the pelagic ecosystem through the food webs in the tropics as well as the identical subject taking place in the feeding ground of the mid- to higher latitudes. The consumption of planktonic crustaceans by baleen whales may amount significantly among many other predators even if the whale does not feed so much as to fulfill its nutritional daily ration. Although the role of euphausiids in the tropical marine ecosystem does not seem such magnitude as to noticeable extent in the overall energetic flows, the swarming of these crustaceans may be one of the phenomena that can not be overlooked from the ecological aspects. The swarms of euphausiids possibly be utilized largely by many kind of predators in addition to the Bryde's whales, and the latter undoubtedly accounts an indispensable role as the biotic members in the tropical marine ecosystem. More accumulation of this kind of knowledge is therefore needed to fulfill the biased knowledge both the biology of whales and biological oceanography since many similar evidences for the latter topics have been known solely by studying on the food of baleen whales (e.g. Nemoto, 1962; Omori *et al.*, 1972; Kawamura, 1974).

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Note: According to Best (1974) there exist clear difference in the dietary habit of Bryde's whales in the South African waters : his ' inshore form ' feeds mainly on fish (*Engraulis capensis, Trachurus trachurus, Sardinops ocellata*) whereas ' offshore form ' does euphausiids (*Euphausia lucens, E. recurva, Nyctiphanes capensis, Thysanoessa gregaria*). As far as this result is concerned, the animals caught in the Coral Sea, tropical South Pacific, and Indian Ocean seem to represent his ' offshore form '. Although Best's result provides very important knowledge on the southern Bryde's whales, there was no other way but exclude his result throughout my discussion since the document (Best, P. B., 1974 : IWC/SC/SP/74/DOC4) has not been published yet at the moment of publishing this article.

HUMPBACK WHALES IN THE HAWAIIAN BREEDING WATERS: POPULATION AND POD CHARACTERISTICS

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ABSTRACT

Aerial, shipboard, and underwater observations were made during Spring 1976 of the population of humpback whales, *Megaptera novaeangliae*, breeding in Hawaiian waters. Animals were found around all of the major islands, almost always within the 100 fathom contour, with the bulk of the population concentrated in regions having the greatest contiguous extent of such water. Breeding and calf rearing were not confined to any given area. Survey results yielded estimates of from 200 to 250 animals. The birth rate was estimated as less than 10%, a low figure of some concern. Coloration characteristics of the Hawaii population differed considerably from the eastern North Pacific population of humpback whales, suggesting little genetic exchange with that group. Differences from the western North Pacific group were less clear, in part because of sparsity of data. Approximately 18% of the animals were alone when observed; the remainder were in pods of 2 to 9 animals. Overall there were considerably fewer singletons and considerably larger-sized pods than has been observed in feeding ground aggregations. A calf was typically found in a multiple-animal pod, consisting of the mother and, most frequently, one other adult " escort " whale. The escort seemed to serve a protective function. The large majority of the pods were swimming in fairly regular formations in apparent local migratory movements. Milling pods, with animals contacting one another, or engaging in other behaviors seemingly consistent with sexual courtship or advertisement, was observed in 16% of the cases. The possibly adverse effects of increasing public and commercial on-water and in-water whale-watching activites on the reproductive success of the whales was noted.

INTRODUCTION

Each year, during the winter breeding/calving season, a population of hump-whales (*Megaptera novaeangliae*) migrates into waters adjoining the major Hawaiian islands. The first arrivals may appear as early as November; peak numbers occur during February and March, and the last stragglers depart as late as May or June. From Hawaii, the animals return to summer feeding grounds along the Alaskan peninsula or elsewhere in the high-latitude regions of the North Pacific. This report focuses on the description of this population while in Hawaiian waters, based principally on observations carried out during the Spring of 1976. The study goals included the determination of areas of principal aggregation and their function, the estimation of population abundance and of the rate at which calves

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were recruited into the population, the description of some of the principal demographic and phenotypical characteristics of the population, the analysis of the organization of pods of whales, and the documentation of behaviors of the animals. The study was carried out using aerial, shipboard, and underwater visual observations, and included extensive photographic documentation. The analysis of behaviors is reserved for a separate paper.

The humpback whale is part of the family of Balaenopterid whales, or rorquals, which principally include the blue (*Balaenoptera musculus*), fin (*B. physalus*), sei (*B. borealis*), Bryde's whale (*B. edeni*), and piked whale (*B. acutorostrata*). Rorquals are cosmopolitan species, generally found in all oceans of the world. They are distinguished from other mysticete whales by multiple longitudinal ventral grooves extending from the throat to as far as the navel. These grooves can distend greatly, like the lower jaw of a pelican, when feeding on the small marine crustacea or small, schooling fish that are their main diet. Additional rorqual characteristics are a small, posteriorly-placed dorsal fin, and a generally slim, tapered body well adapted for rapid swimming. Unlike the other rorquals, *Megaptera* has extremely long (e.g., 3.5 to 4.5 m), highly mobile, pectoral fins; rounded knobby tubercles on the upper jaw and portions of the lower jaw, possibly sensory in function; irregular protruberances along the leading edges of the pectoral fins; moderately fine serrations or scalloping along the trailing edge of the caudal fin (tail flukes); and an irregularly shaped dorsal fin. It has been described as stouter of body than other rorquals, but those seen in Hawaiian waters seem generally slim and graceful in form. The slender form apparently reflects the reduced or even absent food intake, characterizing breeding migrations of humpback whales and other rorquals (Dawbin, 1966; Tomilin, 1967). We occasionally observed some Hawaiian humpback whales engaging in what appeared to be feeding behaviors.

According to Rice's (1963) data on eastern North Pacific stocks, physically mature female *Megaptera* average slightly longer in body length (14.8 m) than do males (13.6 m), though Tomilin (1967) reports somewhat smaller differences. Sexual maturity occurs when the animals are 2–3 m shorter. Newborn calves may range from 4 to 5 m in length (Nishiwaki, 1972), but in Hawaii some appear to be smaller than the minimum stated. Following sexual maturity at 6–12 years, females calve generally only every other year, giving birth almost always to a single young. The gestation period is close to 12 months and the lactation period lasts from 10 to 11 months. Some additional aspects of reproductive biology of humpback whales are discussed later in this paper. More detailed discussions of general and reproductive biology of *Megaptera* are available in a number of sources (e.g., Chittleborough, 1959, 1965; Mackintosh, 1972; Matthews, 1937; Nishiwaki, 1959; Omura, 1953; Rice, 1963; Symons & Weston, 1958; Tomilin, 1967; Wolman, 1972).

Megaptera, like most other rorquals, engages in long-distance annual migrations between higher-latitude summer feeding grounds and lower-latitude winter breeding grounds. Dawbin (1966) described sexual and maturational temporal segregation during migration and discussed some of the physical and ecological conditions possibly triggering and guiding migration of Southern Hemisphere humpback whales (also see Chittleborough, 1965; Nishiwaki, 1959, 1960). Unlike other rorquals, *Megaptera* prefers breeding grounds in the nearshore, shallow waters around continents or islands at approximately 10° to 20° latitude. In many cases, near-shore preference increased the vulnerability of *Megaptera* to whaling.

DISTRIBUTION AND ABUNDANCE OF THE NORTH PACIFIC STOCK

The Hawaiian population is part of the highly-exploited stock of North Pacific humpback whales. The distribution of this stock has been discussed, directly or indirectly, in a number of sources (e.g., Kellogg, 1929; Mackintosh, 1947; Nishiwaki, 1966; Omura, 1955; Rice, 1974; Tomilin, 1967; Townsend, 1935). Charts prepared by Omura (1955) and Nishiwaki (1966) and material provided by Tomilin (1967) reveal the orginal feeding range as extending from the Sea of Okhotsk on the far western rim of the upper North Pacific to the Gulf of Alaska on the eastern rim. Within this broad range, the whales were concentrated along the Kuril Islands and on both sides of Kamchatka Peninsula in the western North Pacific, within the Bering Sea and northward to the Bering Straits and the Chukchi Sea, and along the northern and southern shores of the Aleutian chain and the Alaska Peninsula down through S.E. Alaska.

Three breeding populations are generally recognized according to their separate migration loci each winter in the tropical zones of the North Pacific. An eastern Pacific, or American group, migrates southward past the west coasts of Canada and the United States to calving/breeding grounds in the bays and outlying islands along the west coasts of Baja California and the Mexican mainland (Kellogg, 1929; Rice, 1974). A western Pacific, or Asiatic group, seemingly follows a southwesterly route along the east coasts of Japan to calving/breeding areas near Taiwan, or further east in the Bonin Islands, the Mariana Islands, and reportedly, the Marshall Islands. According to Kellogg (1929) and Tomilin (1967) some whales may penetrate into the Sea of Japan on their way to the Yellow Sea. Finally, the central Pacific, or Hawaiian group, migrates into the Hawaiian waters by a route which is still unknown. Also unknown is the degree to which the three populations disperse and comingle in their summer feeding grounds, and whether there is any significant genetic exchange across breeding populations. Ivashin and Rovnin (1967) believe that dispersed groups return to their original breeding grounds and that genetic exchange is negligible. Coloration data for the different groups, discussed in a later section of this paper, tends to support this contention.

Historically, the humpback whale was hunted in the North Pacific as early as the 17th century by Japanese shore whalers using spears and arrows and, later, nets (Omura *et al.*, 1953). However, major exploitation did not occur until the 19th and 20th centuries when the stock of North Pacific humpback whales was extensively hunted throughout its summer feeding grounds by Japanese and Russian pelagic whalers (20th century); along its migratory routes in the eastern and western North Pacific by American and Japanese shore whaling stations; and in many of its tropical calving/breeding areas, principally by American and

Japanese whalers (Omura, 1955; Tomilin, 1967; Townsend, 1935). Its hunting was finally banned in 1966. At that time there may have been 200–300 animals remaining in the American population, based on extensive surveys in 1965 of the winter breeding grounds of this population (Rice, 1974). There were probably similar numbers remaining in the Hawaiian population, judging from the recent survey reported in this paper. There appear to have been no formal surveys of the Asiatic population since 1966. However, the rarity of sightings even before 1966, as noted by Tomilin (1967) and the fact that western North Pacific concentrations were always smaller than eastern North Pacific concentrations (Omura, 1955, Appendix 17) suggests that very few animals remained in the Asiatic population by 1966. Optimistically, it would seem that the North Pacific stock in 1966 numbered at most 1000 animals. Stock assessments by Wada (1972) suggested only 1200 animals. Thus, there are no indications of any substantial recovery of the North Pacific stock since 1966.

Wolman's (1972) brief review of humpback whales included an estimate of original abundance of the North Pacific stock as 4000 animals and Nishiwaki (1959) suggested 5000–6000 animals. These estimates seem low given the 3037 humpback whales caught in the North Pacific in the three-year period 1925–27 (International Whaling Statistics, 1931) and the 3455 caught by Russian pelagic whalers in the two-year period 1962–63 (International Whaling Statistics, 1966). Also, the catch statistics for 1925–27 apparently did not include the take off Kamchatka Peninsula in the western North Pacific (Omura, 1955). If we assume the estimates of Wolman and Nishiwaki are reasonable, then current abundance may be no more than 15–25% of the original stock. Worldwide figures for humpback whale populations are correspondingly low. The original abundance of the Antarctic stock may have been as much as 90,000–100,000 animals, but census data between 1965–70 revealed, on the average, a maximum of 2800 animals, or roughly 3% of the original stock (Chapman, 1974). The Antarctic stock has been protected since 1964. The eastern North Atlantic stock was decimated before the end of the 19th century and is extremely rare today (Tomilin, 1967). The western North Atlantic group currently numbers roughly 1200 animals (Winn *et al.*, 1975). It has been protected since 1955, and according to Winn et al. (1975) may not be much below its numbers at the end of the nineteenth century just before major exploitation began. Based on the slow recovery rates in other areas (Myers, 1975) and the small catch in the North Atlantic of only 22 whales in 1969/70 under a special permit to take 40, as compared with the total catch of 729 humpback whales in that area in 1903/04/05 (Mitchell, 1974), it seems more likely that full recovery of the Atlantic group lies considerably in the future. Chittleborough (1965), for example, estimated that recovery of portions of the Antarctic stock to original levels could take more than 65 years, while increases of world stocks to " significant " levels could take 50 years (Anon., 1975). The worldwide protection currently given the humpback whale by member nations of the International Whaling Commission hopefully will someday enable its reclassification upwards from an endangered species.

BACKGROUND OF THE HAWAIIAN POPULATION

The Hawaiian Island region nicely meets the preferred ecological requisites for breeding grounds of *Megaptera*. The eight main Hawaiian Islands (Fig. 1), around which the whales predominately aggregate, comprise the southeastern portion (Leeward chain) of a linearly arranged archipelago extending some 1300 nm from Kure atoll in the northwest (178° 30' W, 28° 25' N) to the island of Hawaii in the southeast. Figure 1 shows some extensive areas surrounding the main islands in which the water depth is 100 fathoms or less, especially within the four-island region of Molokai, Lanai, Maui, and Kahoolawe, and within Penguin Bank extending some 25 nm southwest of Molokai. Between November and March, surface water temperatures remain close to 25° C (77° F), with a near-isothermal layer extending downward to 50–80 m (Gosline, 1965). Zooplankton is fairly uniformly distributed throughout the coastal waters, though in markedly lesser concentrations than in equatorial waters or in waters further to the north and northeast of the islands (King and Demond, 1954; King and Hida, 1954). The relatively low zooplankton abundance and that runoffs from land have little permanent effect on the nearshore environment make for clear waters. The water clarity and the concentration of the whales near shore make for ideal surface and underwater study conditions. Strong northeast trade winds or southern storms occasionally restrict viewing opportunities, but the majority of the time the whales may be readily observed

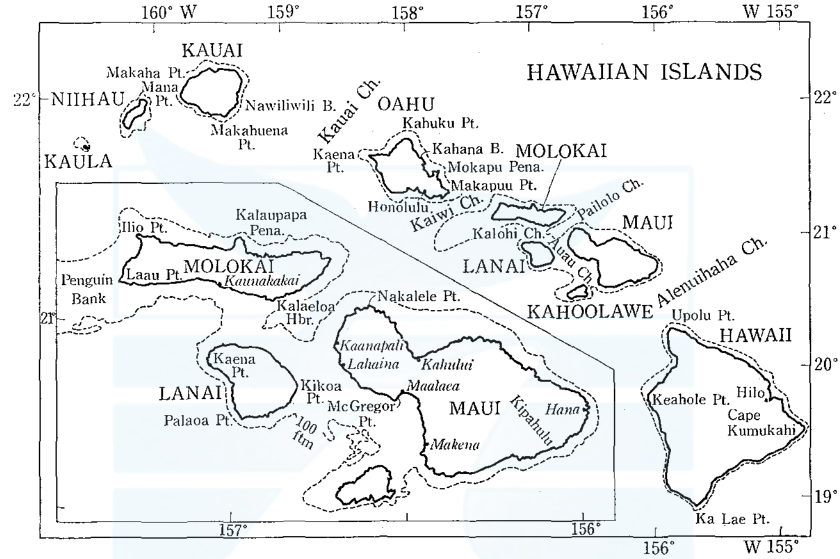


Fig. 1. The main islands of the Hawaiian Archipelago. The inset expands the four-island region of Molokai, Lanai, Maui and Kahoolawe. The dotted lines are the 100-fathom contours. Penguin Bank is the entire region within the 100-fathom contour extending southwesterly from Laau and Ilio Points, Molokai.

from a number of key shore points or easily accessed by ship or light aircraft.

Prior to the 1976 season, the Hawaiian population had not been studied in any detail. In fact, it seems to have gone almost unnoticed in the scientific literature until relatively recently, as illustrated by a number of compendia on the zoogeography of cetacea that failed to record the population (e.g., Marcuzzi and Pilleri, 1971; Tomilin, 1967). Bryan (1915), in his review of Hawaiian ethnology, geology, and natural history, seems to be the first to give mention of the population, but as noted by Tomich (1969) Bryan's documentation is sparse. Unfortunately, the situation improved little thereafter, being limited mainly to occasional newspaper reports of sightings (see summary in Tomich, 1969). This historical neglect seem paradoxical given that Hawaii was the commercial hub of North Pacific whaling in the early and mid-nineteenth century, offering rest, recuperation and reprovisioning to the hundreds of vessels hunting sperm whales in equatorial waters or in the seas adjacent to Japan, or else searching for right whales in the Bering Sea, the Sea of Okhotsk, and in adjacent waters. Apparently, the whalers had little interest in catching or even logging the presence of the seasonally resident humpback whales in Hawaii, which were of lesser economic importance at the time than were sperm or right whales. Minor exploitation of the Hawaiian humpback whale population (and of a few sperm whales) did occur from the late 1840's through to the late 1860's by shore whaling stations operating mainly from the island of Maui (Anon. 1848, 1856, 1866; Baldwin, 1958; also see Jones, 1938), but the records seem too fragmentary to allow for any estimates of nineteenth century abundance of the humpback whale in Hawaii. The 19th century exploitation by shore stations appears to have begun just about the time when whales, in general, were diminishing in economic importance worldwide. Combined with the apparent difficulty encountered by the Hawaiian shore stations in capturing the animals, each operation seems to have petered out only a few years after it began. Exploitation of the at-large North Pacific humpback whale stock in its higher latitude summer feeding grounds, which certainly must have included portions of the Hawaiian population was, as noted, a continuing process from the latter part of the nineteenth century, when Japanese and, apparently, Russian pelagic whaling began (H. Omura, personal communication), through to the end of 1965.

There is no evidence of any exploitation of the humpback whale by native Hawaiians prior to the nineteenth century. The antiquities of the Hawaiians, including their petroglyphs, contain no record of humpback whales, or indeed of whales of any type, and there are no Hawaiian whale legends other than a very few obviously imported from the South Pacific, where native whaling did occur (Beckwith, 1970; Kirtley, 1971; Malo, 1951). The Hawaiian language seems to contain no special word for humpback whale, though a general word for whale, *kohola*, exists, as does a special term, *palaoa*, for sperm whale teeth or products derived from the teeth, such as whale-tooth pendants (Malo, 1951; Pukui and Elbert, 1971). Sperm whales and other toothed whales were apparently washed ashore on occasion, and their teeth became the valued property of the royalty. No similar names for derivatives from baleen whales (such as baleen plates) appear in recorded Hawaiian history or in the language. The sum of the evidence thus suggests that the humpback whale was either of little interest to the pre-nineteenth century Hawaiian natives, or else that the whales were inhabiting different breeding grounds than those used today, grounds which were not observable from the island shores or the nearby waters. The resolution of those two hypotheses poses an interesting challenge to marine mammalogists and archaeologists.

CURRENT OBSERVATIONS: FIELD METHODS

We began the study at the end of February 1976, while the migratory season was in progress, and concentrated our efforts principally in the regions of suspected highest whale density, the waters within the four-island region and on Penguin Bank (Fig. 1). Other areas were also surveyed, but in less detail. Table 1 summarizes dates, times, and whale spotting conditions for the various aerial and ship surveys. Aircraft surveys used a high-winged Cessna 172, flying at 152-m (500 ft.) altitude at air speeds of approximately 100–120 knots. During an aerial survey, a predetermined transect over an area of interest was flown untill sighting of a whale or pod of whales. The aircraft then diverted from its path and orbited the pod at 152-m altitude for close-range visual observation and photography. We used

TABLE 1. AERIAL AND SHIPBOARD SURVEYS OF HUMPBACK WHALE POPULATION IN HAWAII (1976)

Date	Time	Region	Method[a]	Spotting Conditions[b]
29 Feb.	1130–1454	Hnl to W. Maui	A	E
29 Feb.	1617–1833	W. Maui to Hnl	A	E (F after 1745)
1 Mar.	0926–1222	Hnl to W. Maui	A	G
1 Mar.	1456–1737	W. Maui to Hnl	A	G
13 Mar.	0840–1801	Hnl to Molokai	S	E
14 Mar.	0910–1810	Kalohi Channel	S	E
14 Mar.	1110–1420	Hnl, Lanai, to W. Maui	A	E
14 Mar.	1600–1735	W. Maui to Hnl	A	G to F
15 Mar.	0800–1640	Kalohi Channel	S	G
16 Mar.	0730–1615	Molokai to Hnl	S	G (P after 1000)
19 Mar.	1000–1056	S. coast Oahu to W. Kauai	A	E
19 Mar.	1231–1627	Circle Kauai, Niihau, Oahu	A	G to F
9 Apr.	0853–1137	Hnl to W. Maui	A	F
9 Apr.	1333–1651	N. & E. Maui, circle Hawaii	A	F
9 Apr.	1745–1840	N. Hawaii to E. Maui	A	F
15 Apr.	1353–1517	Circle Oahu	A	E to G

[a] A = aircraft. S = ship

[b] E = Excellent; weather fair and seas calm to slight; no whitecapping (Beaufort Scale No. 0–2).
G = Good; weather fair or cloudy and seas moderate with minor whitecapping (Beaufort Scale No. 3).
F = Fair; weather fair or cloudy and seas moderate with more frequent whitecapping (Beaufort Scale No. 4); or reduced visibility due to poor light but sea state 3 or less.
P = Poor; reduced visibility and sea state 4 or more; or greatly reduced visibility in any sea state; or sea state 6 or greater.

Nikon F2 and Canon FTB cameras equipped with 105, 200, and 300 mm lenses. Visual observations were recorded in real-time on audio cassettes. The position of the aircraft over whales was obtained by reference to land-based VORTAC radio stations, if in range, or to landmarks using USCG navigational charts. The swimming direction of the whales was determined through use of the aircraft's onboard compass. Three personnel in addition to the pilot accompanied each flight.

Shipboard surveys between Oahu and Molokai were made on March 13th and 16th. The boat followed approximately the same path as the aircraft within a surveyed region, but did not divert from its path following a spotting. Three observers were positioned along the port side, and another three along the starboard side. Whales observed beyond the stern of the boat were not counted unless obviously not a previously-seen spot. The swimming direction of the whales was estimated by handheld compass and their distance from the boat gauged by visual estimation. The position of the boat was determined by reference to visibly charted landmarks or by dead-reckoning using time and distance data.

The ship remained in the Kalohi Channel area between Molokai and Lanai on March 14th and 15th for close-range observation of the whales and for launching of underwater observations. Divers equipped with Nikonos II 35-mm underwater cameras dropped off the stern of the moving ship at positions which hopefully would intercept the path of whales observed swimming astern. Scuba gear was not used because it was felt that bubble emissions might prove aversive to the whales. A surfboard was thrown into the water for the diver's use immediately after his departure, while the ship continued on its path. The diver was recovered by the ship after completing observations or on failing to contact the whales. Divers made tape recorded notes of their visual observations immediately after returning to the vessel.

The aerial, shipboard, and underwater photographs obtained, in conjunction with notes on visual observations, were used to refine the numerical counts of pod size, to describe pod composition and organization, to identify morphometric characteristics of individual animals and to categorize behaviors.

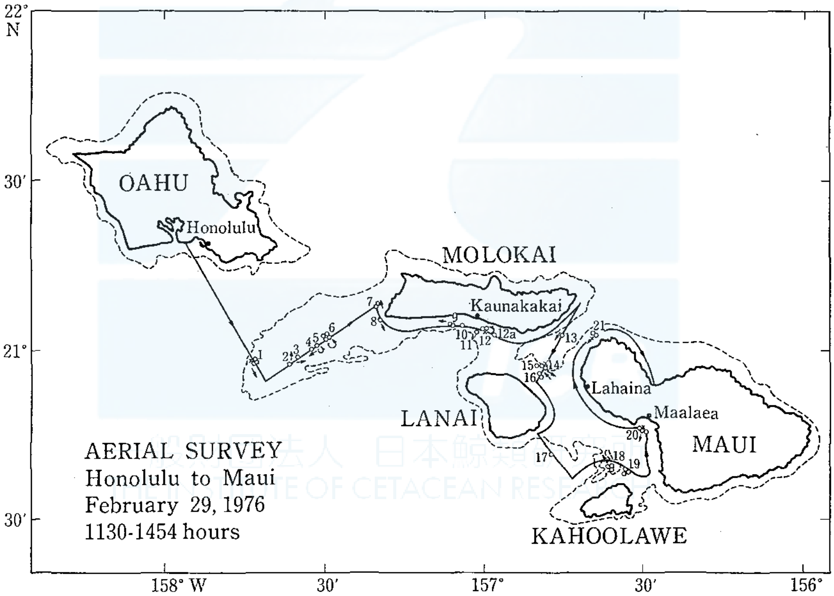
RESULTS AND DISCUSSION

Population Parameters

Distribution and Concentrations: *Four Island Region.* Figures 2–4 show representative data, giving the locations of pods and numbers of whales per pod during aerial surveys between Honolulu and W. Maui on February 29th and March 14th and during a ship survey between Honolulu and Molokai on March 13th. Each pod is numbered serially, in the order seen, and the movement characteristics of the pod, if obtainable, are shown. Calves are noted as cross symbols. The remaining animals were almost always classified as adults, though a few of seemingly juvenile status were also seen, but are not identified separately in this report. Table 2 summarizes pod and whale counts for all surveys within the four-island region. Figures 2–4 show that whales were principally found within the 100-fathom contour. Air-

TABLE 2. FOUR-ISLAND REGION: NUMBERS OF PODS, WHALES PLUS CALVES, AND CALVES OBSERVED DURING AIRCRAFT AND SHIP SURVEYS

	Region	Pods	All Whales	Calves	Whales/Pod
Aircraft					
Feb. 29	Hnl-Maui	22	43	4	1.96
	Maui-Hnl	20	52	5	2.60
Mar. 1	Hnl-Maui	23	56	0	2.43
	Maui-Hnl	22	54	4	2.45
Mar. 14	Hnl-Maui	22	55	5	2.50
	Maui-Hnl	15	27	1	1.80
Apr. 9	Hnl-Maui	6	15	3	2.50
	Totals:	130	302	22	2.32
Ship					
Mar. 13	Hnl-Mlk	38	48	0	1.25
Mar. 14	Kalohi Ch.	10	31	3	3.10
Mar. 15	Kalohi Ch.	18	30	3	1.67
Mar. 16	Mlk-Hnl	16	18	0	1.13
	Totals:	84	127	6	1.51



AERIAL SURVEY
Honolulu to Maui
February 29, 1976
1130-1454 hours

Fig. 2. Aerial survey results, showing path of aircraft (solid line), pod numbers in the order seen, and the number of whales per pod. Adults are shown as open circles and calves as cross symbols. Straight arrows show movement direction of swimming pods; arrows with a cross-hatch indicate a resting pod oriented in the direction shown; curved arrows indicate milling pods. Not all pods were classifiable because of observation difficulty. The 100-fathom contour is shown as a dashed line.

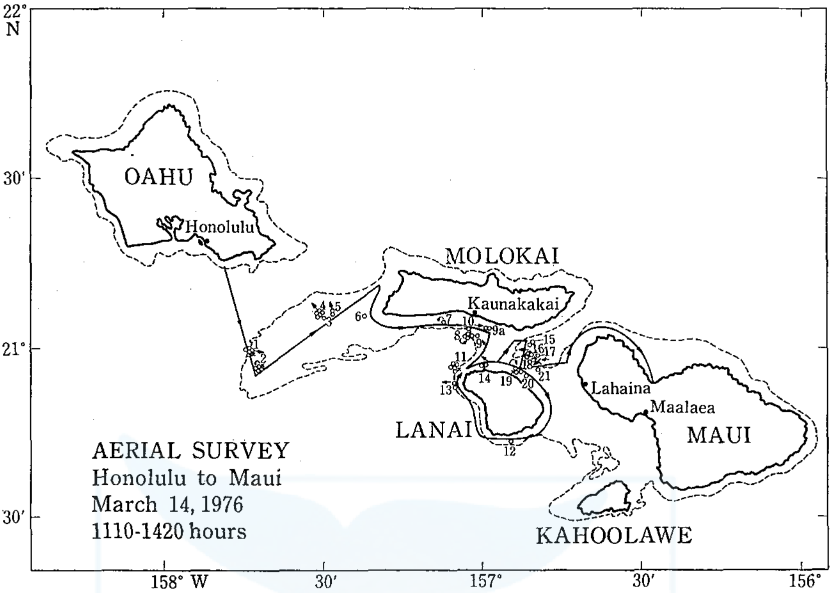


Fig. 3. Aerial survey results keyed as in Figure 2.

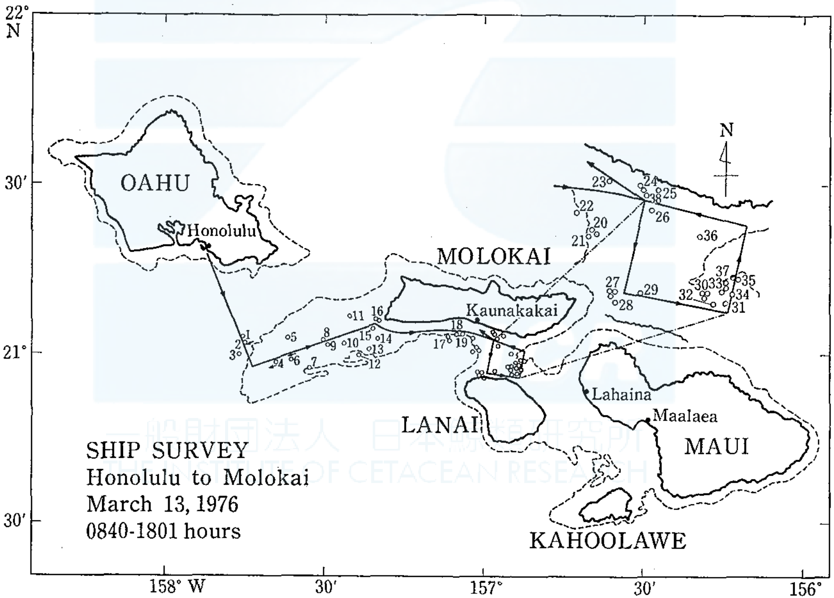


Fig. 4. Ship survey results keyed as in Figure 2. The Kalohi Channel area is expanded in the upper right of the chart to show details of the pods.

craft data gave the relatively greatest numbers of whales, on the average, in Kalohi Channel (13.7 whales/flight). This was followed by Penguin Bank (11.7 whales/flight), the Auau channel area southeast of Kalohi Channel (9.6 whales/flight) and the south coast of Molokai from Laau Point to Kaunakakai (6.3 whales/flight).

Other regions yielded much smaller numbers. The relative numbers of whales seen in the various regions remained reasonably consistent across successive flights, although some anomalies were evident. On the flight of February 29th from Maui to Honolulu, especially heavy concentrations were seen along the south coast of Molokai, and on April 9th no whales at all were seen in Kalohi Channel. Though spotting conditions were only fair on April 9th (Table 1), possibly accounting for some reduction in the counts, as on the return flight of March 14th from Maui to Honolulu, it is more likely that by this date many whales had already left on their return migration to the summer feeding grounds. Kalohi Channel, especially the south and southeast portions, seems to be an important breeding area and as these activities diminish over the season it would be one of the earliest areas expected to show a population decline. With respect to the south coast of Molokai, ten of the twenty-two whales seen on February 29th were actually located near the beginning of Penguin Bank. Though moving towards southwest Molokai, a survey perhaps an hour earlier might have placed them within the usually more densely populated Penguin Bank.

The ship survey of March 13th verified the aircraft data showing large concentrations of whales in Penguin Bank and Kalohi Channel. The fewer numbers of whales per pod, as compared with aircraft data reflects the difficulty in estimating the numbers of whales without approaching pods closely. On March 13th (and on March 16), with but one exception, the ship did not divert from the planned transect to inspect pods. In contrast, on March 14th in Kalohi Channel, the ship frequently diverted from its transect for the close-range inspection of pods, yielding an elevated count of 3.1 whales per pod (as compared with the overall estimate of 2.7 whales per pod from aircraft data in Kalohi Channel). It is significant that calves were seen from the ship only during close-range inspection. On March 15th, less time was spent on close-range inspection from the ship than on the 14th and more on general survey, resulting in an elevated pod count, but less whales per pod. Three of the pods approached on the 15th had calves, as was the case on the 14th. In general, it seems that pods with calves are easier to approach than those without, in part because the latter are capable of more rapid locomotion and prolonged diving.

On March 16th, during the ship survey, large swells and considerable white-capping were encountered in the Penguin Bank region. Nevertheless, the pod count in that area (9 pods) was not much reduced over that found on March 13th (13 pods) under better weather conditions. Spotting of the pods on March 16th was almost entirely through seeing the large splash resulting from the breaching of an animal, whereas on the 13th blows and the animals themselves could be spotted in the absence of breaching. It may be, as has been suggested by others, that breaching is more common in rough water, perhaps serving to maintain acoustic and/or visual contact between whales.

Distributions and Concentrations: Other Regions and Islands. We cannot draw strong conclusions about concentrations of whales in the areas outside of the four-island complex or Penguin Bank, since the outlying areas were surveyed less frequently and sometimes beyond the peak of the migratory period. Nevertheless, it seems apparent from the available data that outlying concentrations in no way approached those observed within the four-island region and Penguin Bank. Table 3 shows that on March 19th, presumably still at or near the peak period of concentration of whales in the four-island complex and Penguin Bank, a total of only ten whales (four pods) was seen around the entire island of Oahu, along the north and northeast coasts; six whales (three pods) around the entire island of Kauai, between Nawiliwili Bay and Makaha Point; and no whales at all around the island of Niihau or nearby Kaula Rock. The island of Hawaii was not surveyed until April 9th, and judging from our results on that same date in the four-island region (Table 2), this was already past the peak migratory period. The two pods of whales seen near Hawaii on April 9th were at or just south of Upolu Point. The pod of six whales seen in Alenuihaha Channel was approximately 8–10 nm NW of Upolu Point heading north-northeasterly. It was one of the few pods found considerably outside of the 100-fathom contour and possibly was on the beginning of a return migration to higher latitudes.

TABLE 3. OUTLYING REGIONS: NUMBERS OF PODS (P), WHALES PLUS CALVES (W), AND CALVES (C) OBSERVED DURING AIRCRAFT SURVEYS

	Mar. 19			Apr. 9			Apr. 15		
	P	W	C	P	W	C	P	W	C
Oahu	4	10	0	—	—	—	1	3	1
Kauai Ch.[a]	0	0	0	—	—	—	—	—	—
Kauai	3	6	0	—	—	—	—	—	—
Niihau	0	0	0	—	—	—	—	—	—
Kaula Rock	0	0	0	—	—	—	—	—	—
E. Maui	—	—	—	1	1	0			
Alenuihaha Ch.[b]	—	—	—	1	6	0			
Hawaii	—	—	—	2	4	0			

[a] Survey path was a straight line between Kaena Pt. Oahu and Nawiliwili Bay, Kauai.

[b] Survey path was a straight line between Kipahulu Gulch, Maui and Upolu Pt., Hawaii.

The survey around the island of Oahu on April 15th revealed only a single pod of three whales, including a calf. No further surveys were conducted after that date, though as late as mid-May the authors observed several pods from peaks overlooking the south coast of Oahu. Also, reports were received of a few whales lingering around the island of Oahu in June.

The last departures on the northward migration seemingly would tend to be pods with calves, judging by the relatively high proportion of such pods (three of six) seen on April 9th and 15th. The delayed departure of calves would allow for attainment of sufficient growth and blubber deposit before encountering the rigors of migration and the colder waters of the higher latitudes, and typifies migratory characteristics of Southern Hemisphere populations of humpback whales (Dawbin, 1966).

Our data showing that concentrations of whales outside of the four-island region and Penguin Bank are relatively small are consistent with sighting reports from commercial hydrofoil craft during the 1976 season (Shallenberger, 1976).

Population Estimates. The combined data from the ship and aircraft surveys can be used to estimate population numbers in selected areas. Gulland (1972) suggested that counting all whales for two miles on each side of a ship's path through an area yields accurate estimates of whale density (whales/nm^2) in the four-mile wide strip covered, which may then be extrapolated to the entire region of interest. Gulland's model assumes that nearly all whales in the strip will be seen. Our data suggest, however, that it is simpler to estimate pod density (pod/nm^2) than whale density by ship survey. Our ship, transecting an area at ten knots, probably missed very few of the pods actually present within the 4-nm wide sighting strip. But, our aircraft surveys over the same region revealed that the number of whales per pod was underestimated, unless the ship approached the pods closely. Aircraft, from their favorable vantage point, count whales per pod with great accuracy, but unless surveying a region in fine detail, miss some proportion of the pods actually present. It would seem, then, that nearly all whales present in a region could be accounted for by using ship data to estimate pod density in the region, and aircraft data to estimate mean whales per pod. Multiplying the two estimates should yield highly accurate population counts. This simple model was used to estimate the number of whales present in the three main regions surveyed by ship on March 13th. The results were 63 whales for Penguin Bank (.22 whales/nm^2), 9 for the south coast of west Molokai within the 100-fathom contour (.2 whales/nm^2), and 47 for Kalohi Channel (.57 whales/nm^2), for a total of 119 whales. To this we can add seven more in the small region just north of the NW tip of Penguin Bank, where the ship encountered three pods, and aircraft data yielded an average of 2.5 whales per pod. Other than this small region, the number of whales in the area between Honolulu and Penguin Bank appears negligible. The estimates given suggest that aircraft surveys sampled from one-third to two-thirds of the population present. The larger sample size was obtained when the region was well covered by the aircraft, such as the restricted coast-line areas of Molokai.

The remaining major concentration of whales present on March 13th in the four-island region would have been in the Auau Channel region east of Kalohi Channel between Maui, Lanai, and Kahoolawe, and within the 100-fathom contour. This region was not surveyed by ship. If we assume the whale distribution on March 14th was not significantly different from that on the 13th, we can use the aircraft flights of the 14th to add to our population estimates. Five pods were spotted by the aircraft in the Auau Channel region on March 14th, but all dove before they could be approached closely. We can, however, use the mean value of 2.0 whales per pod, based on all aircraft flights over that region, to estimate the number of whales in those pods as ten. Applying the sampling ratio for aircraft, previously discussed, of from one-third to two-thirds of the population, gives a final estimate of from 15 to 30 whales actually present in Auau Channel. The assumptions made in these calculations should be treated with caution but appear reasonable in view of our overall data.

In summary, the overall estimate of population size on March 13th in the four-island region, and including Penguin Bank and the area immediately adjacent to its NW tip is thus 141–156 whales (119+7+15 to 30). There were undoubtedly whales in other regions, but likely in considerably smaller numbers than in the four-island region and Penguin Bank. On March 14th, for example, only six whales were seen along the northeast coast of Molokai and the south and west coasts of Lanai, and on March 19th, only 16 whales were found around all of Oahu, Kauai, Niihau and Kaula Rock (Table 3). East Maui and the island of Hawaii, surveyed on April 9th, yielded only 11 whales (Table 3). Concentrations in these latter two regions were likely greater three weeks earlier, and our uncertainty in estimates for the period near March 13th is, accordingly, greatest for these regions. For the present, it seems best to bracket our estimates for all combined outlying regions and islands as perhaps 50 animals as a lower bound and 100 as an upper bound. The total population on or about March 13th might then have numbered from close to 200 animals to as many as 250 animals. The March 13th period was apparently within the peak of the migratory cycle, judging by our aircraft data (Table 2). However, we do not know how long individual whales remain in the islands, and it is possible that some animals might have already departed the Hawaiian waters and that others were still in-migrating, which would add to our population counts somewhat. It would be desirable to extend the census work in the future, so that all major areas within the islands could be surveyed in parallel on given dates, and in- and out-migration studied in detail.

Nursery Grounds and Numbers of Calves. Tables 2 and 3 gave data for the number of calves seen during each aerial survey. Calves were typically accompanied by more than one adult, as discussed more fully in a later section, but in no case was there more than one calf in a pod. With the one exception of a pod of two adults and calf observed off north Oahu on April 15th, all pods with calves were found within the four-island region and on Penguin Bank. For all flights combined, the areas of greatest concentration were Kalohi Channel (9 calves), especially along the north coast of Lanai, and Penguin Bank (8 calves). Additionally, two calves were seen south and southwesterly of Lahaina, Maui. No other area yielded more than a single calf. Though the north coast of Lanai is clearly the most densely concentrated nursery region and should be protected, there is considerable dispersion of nursery areas throughout the regions surveyed.

The numbers of calves seen relative to total whales provides a basis for estimating gross recruitment rate (Seber, 1973). As a first approximation we can assume that the Hawaiian population is similar demographically to populations of humpback whales elsewhere having characteristics known through whaling operations. Normal sexual maturity for humpback whales, as for some other baleen whales, occurs from 6–12 years (Anon, 1975) for both males and females. Earlier average onset may be recorded in highly exploited stocks due to the more rapid growth rates in such cases, or the selective depletion of larger (older) animals (Chittleborough, 1965). Mackintosh (1972) states that given the two-year reproductive cycle of female baleen whales, and that 99% of the births are single calves with the sex ratio approximately equal, the expected birth rate would be 50% of the sexually mature female population. Rice (1963) calculated a pregnancy rate of 43% based on examination of 168 humpback whales caught by shore stations near San Francisco. The number of females was not specified. Nishiwaki's (1959) data on humpback whales caught in Ryukyuan waters in the western North Pacific gives the annual percentage of ovulating females as 60% and pregnancy rates as 40%. Chittleborough (1965), using catch-effort statistics from the whaling station of Albany in southwest Australia, estimated that 37% of the female humpback whales were pregnant. Of a small sample of 13 female humpback whales collected in the northwest Atlantic in 1969 and 1970, 7 (54%) were pregnant (Mitchell, 1974). The collective data from these sources suggest that the normal birth rate could be somewhat lower than 50% of the mature females; 43% may be a reasonable best estimate.

According to Nishiwaki (1959) approximately half of a normal humpback whale population are sexually mature animals, with half of these males and half females. This places the normal limit on calf recruitment rate as $.5\times.5\times.43=.108$ or 10.8% of the entire population. Applying this recruitment rate to the Hawaii population, conservatively estimated as 200 animals, would yield an expected calf population of 22.

Across all of our aerial surveys, there were some obvious vagaries in our calf counts (Table 2). Low counts can generally be attributed to unfavorable spotting conditions or to the abbreviated nature of a survey, though in the case of the morning flight of March 1st, the reasons for the zero count were unclear. The largest number of calves seen on any flight was five, on the second flight of February 29th and then again on the first flight of March 14th. In each case, spotting conditions were excellent for all or nearly all of the survey. The most optimistic estimates of recruitment rates are obtained by considering the calf to adult ratios on these two flights. (Calf to adult ratios obtained after the peak migratory period, such as that of April 9th, are biased because mothers with calves remain longest in the breeding grounds, cf. Dawbin, 1966). On the second flight of February 29th, 9.6% of the total of 52 whales seen were calves, and on the first flight of March 14th 9.1% of the 55 whales were calves. These percentages can be considered the upper limits of the current calf recruitment rate for the Hawaiian population, but both are somewhat below the discussed expected rate of 10.8%. More importantly, since the four-island region and Penguin Bank appear to contain the major nursery grounds, birth rate samples from these areas may not be representaative of other areas, and would overestimate rates for the population at large. Hence, the rates of 9.1% and 9.6% should be regarded as optimistic.

The apparent low birth rate is disturbing and calls for additional assessment. The reasons for the apparent low rate are unclear. In a small unexploited population, presumably below the carrying capacity of the environment, one would, in fact, expect higher than normal rates of birth (Wilson, 1975). It seems doubtful that our sampling of the calves was disproportionately low, since pods with calves are typically slow moving or even resting, seldom diving deep or for long periods, and hence are relatively easy to spot from aircraft. It may be that a demographic analysis of the Hawaiian population would show, for reasons unknown, a smaller than usual number of mature whales, explaining the low recruitment rate. Or, it may be that the low rate reflects unfavorable biological or ecological conditions, or a response to continued harassment from the ships, aircraft, and divers passing close to the whales, intentionally or otherwise. Whatever the cause, the apparent low recruitment rate underscores the potential fragility of the population and the pressing need for its careful protection and management.

Pod Characteristics

Pod Size. Table 4 summarizes the findings on sizes of pods for all aerial surveys combined. There is generally an orderly decrease in the frequency of occurence of successively larger pod sizes, though the majority (59%) of the pods were comprised of two or more animals. The largest pod size, nine, was observed on February 29th in Kalohi Channel and on March 1st near Laau Point, Molokai. The percentage of singletons is very probably an overestimate, since we conservatively estimated one whale for all spots for which a single blow, breach, or body part was seen at a distance but the animal could not be relocated on closer approach. There were 23 such cases out of the total of 59 singletons.

TABLE 4. SIZE COMPOSITION OF PODS FOR ALL AERIAL SURVEYS

	Pod Size									
	1	2	3	4	5	6	7	8	9	Totals
No. of Pods	59	37	18	11	8	6	1	0	2	142
% Total	41.5	26.1	12.7	7.8	5.6	4.2	0.7	0.0	1.4	100.0

Note: Pod size includes both adults and calves.

The data of Table 4 may be contrasted with that of Nemoto (1964) who reported on pod sizes for the humpback whales in their summer feeding grounds in the upper North Pacific. Of 92 pods encountered by Nemoto, 50% were singletons, 43% pairs, 3% threesomes, 2% foursomes, and 1% fivesomes. There was also a single group of seven (1%). The largest difference between our data and that of Nemoto occurs for groups of three or more: 32% of our groups were three or more animals but only 7% of Nemoto's. Dispersal in the feeding ground and clustering in the breeding ground appear obviously adaptive. Grouping in baleen whales may stimulate and facilitate reproductive activities as it does for other species (Wilson, 1975) and is consistent with the presumed promiscuous mating behaviors of female baleen whales in which multiple males appear to attend a single female (e.g., see Payne, 1976). Apparent polyandrous mating bouts were observed in a number of our aerial surveys, but we cannot be sure of the sex of the participants. The counts by Winn *et al.* (1975) of the humpback whales in the West Indies breeding grounds seem discrepant in that only 23% of their sightings were groups of two or more as compared with 49% for Nemoto and 59% for our data. The Winn *et al.* counts were based on shipboard transects which apparently did not approach the whales closely. Their data may thus underestimate whales per pod, as did similar ship surveys we conducted on March 13th and 16th. The data of Nemoto (1964), though based on shipboard observation, relied on catch statistics in which boats necessarily pursued and approached whales very closely, allowing for highly accurate counts of pod size.

Pods With Calves. Table 5 shows that calves are typically found in pods with multiple adults, most often two adults, the mother and an " escort " whale. This is in contrast to other Balaenopterid whales in which the mother and calf often travel unescorted (Nemoto, 1964). The Southern Hemisphere mother-calf humpback whale pairs, like the Hawaiian group, do tend to school with other whales.

TABLE 5. NUMBER OF PODS WITH CALF (C) AND THE NUMBER OF ACCOMPANYING ADULTS (A)

Flight	1A-1C	2A-1C	3A-1C	4A-1C	5A-1C	Totals
Feb. 29 (1)		2	2			4
Feb. 29 (2)		5				5
Mar. 1 (1)						0
Mar. 1 (2)	3	1				4
Mar. 14 (1)		1		2	2	5
Mar. 14 (2)				1		1
Mar. 19						0
Apr. 9	1	1		1		3
Apr. 15		1				1
Totals	4	11	2	4	2	23

Chittleborough (1953) reported that all nine mother-calf humpback whale pairs seen in Antarctic waters were accompanied by other whales. Four of the nine were accompanied by a single additional whale. In some contrast only two of nine mother-calf humpback whale pairs seen in North Pacific waters by Nemoto (1964) were accompanied by other whales. It may be that schooling with other whales occurs principally in the terminal breeding and feeding areas rather than enroute. Thus, Chittleborough (1953), observing migrating Southern Hemisphere humpback whales near the western Australia coast, reported that the calf was usually accompanied only by the mother. Also, in Exmouth Gulf, on the Australian west coast, all seventeen calves seen by Chittleborough were accompanied only by the mother. Exmouth Gulf does not seem to be a terminal point, since migrations north and south of the Gulf were observed. Since mother-calf pairs do depart the breeding grounds last, there are few other whales for them to school with on the return migration, except for other cow-calf pairs. But, as noted for the Hawaiian population, multiple calves in a pod were never seen, and may indicate a self-imposed segregation of mothers from calves which are not their own.

The escort whale or whales may serve a protective function, as discussed in a later section. Here we may note that Southern Hemisphere humpback whale trios with calf have been observed defending themselves against killer whales. In one case cited by Chittleborough (1953), one adult of the two present kept the calf very close while the second charged the pack of 4–5 killer whales, successfully beating them off with its flukes.

Gross Activity of Pods. The gross activity of a pod was classified as swimming, milling, or resting (Table 6). Swimming behavior was defined as movement in a fixed direction during the aircraft's approach. Milling was defined as spatially undirected activity occurring within a small area. Milling animals might be lolling about, rolling on their backs, or contacting one another in the case of multiple animal pods. For singletons, the animal was classified as milling using a similar criterion of area-restricted activity, though contactual behavior was of course absent. Resting animals were lying quietly in the water, dorsal surface up, barely moving at best, usually stationary. Gross activity data was available for 97 (68.3%) of the total of 142 pods seen on all flights. The remaining pods either dove when closely approached and before they could be classified or else we could not locate the animal on close approach.

TABLE 6. GROSS ACTIVITIES OF PODS CLASSIFIED BY TYPE AND SIZE

Activity /Size	Singleton	Multiple-Adult Pods					Pods with Calf[a]						Totals
	1	2	3	4	5+	All	1	2	3	4	5+	All	
Swimming	20(83.3)	19	5	4	10	38(76.0)	1	6	2	2	2	13(56.5)	71(73.2)
Milling	4(16.7)	3	0	4	1	8(16.0)	0	2	0	2	0	4(17.4)	16(16.5)
Resting	0(0.0)	2	1	1	0	4(8.0)	3	3	0	0	0	6(26.1)	10(10.3)
(Subtotal)	24	24	6	9	11	50	4	11	2	4	2	23	97
No Data	35	9	1	0	0	10	0	0	0	0	0	0	45
(Total)	59	33	7	9	11	60	4	11	2	4	2	23	142

Note: Percentages, given in parentheses, are based on subtotals.

[a] pod size refers to number of adults accompanying calf.

It is clear from Table 6 that for multiple-adult pods, and for single adults as well, active swimming was the most common gross activity, with milling considerably less common but still more frequent than resting. It is the milling multiple-adult pods that are engaging in mating behaviors. There are no obvious relations between pod size and pod activity.

For pods with calves, swimming was relatively less frequent though still the most common behavior, while resting was more common than milling. It is probable that the young calf tires easily and tends to require that the mother be stationary while nursing. Whalers in the past have taken advantage of the lesser stamina of the calf to catch and kill the mother who remains nearby the tiring calf throughout the pursuit.

The breakdown of activity by size of pod having calves reveals a tendency for swimming and milling activities to be associated with larger-sized pods, while resting seems common when the calf is accompanied only by the mother. The data base is very small so these trends must be interpreted with caution. If they are indicative of the population at large, it may be that calves accompanied only by the mother are quite young, and that as they mature the pair either joins other whales, who tend to be active, or else are attractive to other whales who join them.

Spatial Organization of Pods. The spatial formation of swimming pods, when observable, was classified into eight different categories as described in Table 7: line astern (file); diagonal; line abreast (rank); wedge-shaped with animals spread out symmetrically behind a leading animal or animals (simplified echelon); vee-shaped with multiple leading animals abreast and one or more additional animals centered and behind; T-shaped; diamond shaped; and x-shaped. In many cases, the formation was clean-cut, as in the case of a pod of five whales observed line astern, each animal nearly touching the flukes of the one ahead, or the neatly staggered diagonal array of a pod of four whales observed on another occasion. More often, the formation was broken by one or two animals, so that three might be tightly astern while a fourth swam off to one side. In such cases, the formation of the majority of the animals was used to categorize the pod's organization. Only formations actually seen are listed. There are obviously other possibilities.

TABLE 7. SPATIAL ORGANIZATION OF SWIMMING PODS GROUPED BY POD SIZE

Formation /Pod Size	All-Adult Pods					Pods With Calves[a]					Totals
	2	3	4	5+	All	2	3	4	5+	All	
Astern	2	1	5	2	10(38.5)	2	1	0	0	3(27.3)	13(35.1)
Diagonal	2	0	2	1	5(19.2)	3	0	0	1	4(36.4)	9(24.3)
Abreast	5	0	0	0	5(19.2)	1	0	0	1	2(18.2)	7(18.9)
Wedge	—	0	2	0	2 (7.7)	—	1	0	0	1(18.2)	4(10.8)
Vee	—	2	0	0	2 (7.7)	—	0	0	0	0 (0.0)	2 (5.4)
Tee	—	—	0	1	1 (3.8)	—	—	0	0	0 (0.0)	1 (2.7)
Diamond	—	—	0	0	0 (0.0)	—	—	0	1	1 (2.7)	1 (2.7)
X	—	—	—	1	1 (3.8)	—	—	—	0	0 (0.0)	1 (2.7)
(Subtotal)	9	3	9	5	26	6	2	0	3	11	37
No information	9	3	0	0	12	0	0	0	1	1	13
(Total)	18	6	9	5	38	6	2	0	4	12	50

Note: Dashes in columns mean that spatial organization of the type specified is not possible for the given number of animals. Numbers in parentheses are percentages of subtotals.

[a] Organization based on adults in pods only. One swimming pod of the total of 13 in Table 6 was a single adult with calf and hence is not classified here.

Among the all-adult pods, the line abreast formation was observed only for paired animals, swimming side by side. For larger pods, the adults arranged themselves most commonly in the line astern formation or what may be simply its variant, the diagonal. The function of these " follow-the-leader " formations is not apparent, nor is it clear whether specific animals maintain leadership positions in the swimming pod. More protracted observations are necessary to answer these questions.

For pods with calf, only the spatial organization of the adults was classified, since the calf typically remained close to a given adult, presumably the mother. The number of swimming pods having calves was small, so generalizations are difficult. In pods with a single escort whale, the escort tended to remain behind the mother-calf pair. If multiple escorts were present, one or more might remain ahead of the mother-calf pair while the others remained behind or abreast. Invariably, we noted that when a pod with calf shifted its formation in response to the orbiting aircraft, it was to tighten the formation and move the calf to a more central position between the adults, a clearly protective behavior. In contrast, for all-adult pods, shifts of formation occurring in response to overhead aircraft were predominantly dispersals of the pod, the animals moving further apart or temporarily going in different directions. Another defensive response of a pod to the aircraft was deep diving (sounding). This tended to occur more commonly for singletons and for pods of two but rarely for larger groups.

Underwater observations of milling or stationary pods revealed that vertical dispersion was often greater than horizontal dispersion. In pods with calf, the escort would typically appear from well beneath the near-surface mother-calf pair, presumably in response to the presence of the diver. The pod would then depart from the area of the diver.

Coloration: A Clue to Population Identification

Most humpback whales are predominantly black on their dorsal surface, excluding the pectoral fins and tail flukes which may have extensive white coloration. White coloration is common on the ventral surface of the pectoral fins, flukes, and portions of the body from the throat region to the navel. In earlier whaling days when humpback carcasses could be examined, investigators studying coloration focused on the description of ventral surfaces as these seemed to show the most variability. Lillie (1915), working with carcasses of Southern Hemisphere humpback whales, devised a seven category classification scheme for ventral surface coloration, ranging from extensive white to all or nearly-all black. Later invesigators generally continued to use Lillie's categories (Chittleborough, 1965; Matthews, 1937; Omura, 1953; Nishiwaki, 1959; Symons and Weston, 1958). The major interest was in whether coloration differences could predict demographic characteristics of the population, in particular sex and body length (age). No stable, clear-cut relationships were found within or across studies, but a by-product of the research was the observation that geographically isolated groups often demonstrated different coloration characteristics. In the Southern Hemisphere, Matthews (1937) found that humpbacks from the South Georgia and South Africa regions were on the average darker in color (84.8% of 53 animals fell in the darkest two of Lillie's categories and 1.8% in the lightest two) than humpbacks from the New Zealand area (26% of 30 animals were in the darkest two categories and 26.7% in the lightest two). Symons and Weston (1958) reported that 24.1% of 58 animals captured in the Bellinghausen Sea adjoining Antarctica fell in the darkest two color categories while 36.2% were in the lightest two. Omura (1953) provides an excellent summary of differences among all five Antarctic groups and Chittleborough (1965) gives additional data on coloration differences between east and west coast Australian populations.

In the North Pacific, Pike's (1953) data for 184 British Columbia humpback whales reveal that all fell into the darkest two coloration categories. Nishiwaki (1959), examining 237 western North Pacific whales captured in Ryukyuan waters, classified 92.2% as being black or mostly black and none as being predominantly white. These results were very similar to another 164 animals subsequently captured in the same waters (Nishiwaki, 1962), leading Nishiwaki (1965) to conclude that North Pacific humpback whales are darker in coloration, having only a few small white areas, than Southern Hemisphere humpback whales, which often have large white areas.

Our coloration data for the Hawaiian population, based principally on aerial observations, must rely on coloration of dorsal, not ventral surfaces. We have found considerable variation in dorsal surface coloration of the pectoral fins. Past literature on humpback whale coloration has in a few cases reported dorsal surface coloration of the pectoral fins. These data suggest considerable color variation in the dorsal surfaces of the pectoral fins between geographically isolated breeding groups.

In Table 8 dorsal surface coloration of the pectoral fins for the Hawaii population is classified into four categories: all black; slight white (leading or trailing edges white, or a few small spots of white seen elsewhere on the surface); moderate white (mottled, piebald, speckled, or patchy areas of white); and extensive white (solid white or mostly white). Classification was based on detailed examination of aerial photographs and on supplemental notes made while circling a pod. Coloration data were available for 189 of the total of 332 whales spotted during the various aerial transects. Many of these whales were undoubtedly the same animal seen on different occasions, but assuming that whales are sampled on a random basis (with replacement in the population) the percentages should estimate population parameters closely. Table 8 shows that 37% of the whales were classified in the extensive white category and 35% in the all black category. The data reveal very close correspondence in percentages for mothers, calves, and adults, suggesting that phenotypical color characteristics are stable in the population.

TABLE 8. COLORATION OF DORSAL SURFACE OF PECTORAL FINS: COMBINED AERIAL TRANSECTS

Coloration	Mother		Calf		Adult[a]		Total	
	N	%	N	%	N	%	N	%
All Black	7	33.3	6	31.6	53	35.6	66	34.9
Slight White	3	14.3	3	15.8	27	18.1	33	17.5
Moderate White	3	14.3	3	15.8	14	9.4	20	10.6
Extensive White	8	38.1	7	36.8	55	36.9	70	37.0
Subtotal	21	100.0	19	100.0	149	100.0	189	100.0
Undetermined	2		4		137		143	
Grand Total	23		23		286		332	

[a] Includes six animals classified as juveniles, two with all black coloration, one with slight white coloration and three undetermined.

These characteristics could prove useful in identification of the Hawaiian population in its summer feeding grounds, if dispersal and intermingling of populations is minimal.

From the limited data available on Southern Hemisphere stocks, it appears that white coloration on the dorsal surface of the pectoral fins was rare. Lillie (1915) made no mention of all-white pectoral fins; neither did Omura (1953) or Symons and Weston (1958). Matthews (1937) stated that of the groups in the darkest two categories, 7% had white pectoral fins. Unfortunately, data for other coloration categories was not given. In the eastern North Pacific, Pike (1953) reported that only 14.7% of the British Columbia whales had predominantly white coloration on the dorsal surface of the pectorals. This is considerably below the 37.0% value we find for the Hawaiian group. Scammon (1874) described the eastern North Pacific population as all black above, or nearly so. Very recent observations of humpback whales in the southeast Alaska region describe them as having all black pectoral fins above and as numbering 60–61 animals (M. Tillman, personal communication). From these combined data, we can infer that the Hawaiian population is reproductively isolated from the eastern North Pacific stock and that it does not summer in the feeding grounds of that region.

Tomilin (1957) provided only qualitative data on coloration of the western North Pacific stock, presumably in the area of the Kamchatka Peninsula. He described the dorsal surface of the pectorals as ranging from black to piebald or even completely white. He also described a group from the Chukchi Sea and the Bering Sea as having dusky flippers with an exceptionally white border. This was not a characteristic observed in the Hawaiian group, suggesting reproductive isolation of the Hawaiian group from at least portions of the Asiatic population. It is difficult to say whether significant intermingling of the populations occurs in common feeding grounds in the Aleutian Island regions or further to the west and north.

Chittleborough (1953), using aerial surveys to study the New Zealand humpback whale population, reported that calves were born light and darken rapidly with age. How rapidly was not specified. All of the calves we saw in Hawaii were dark above, except for pectoral fin coloration as noted and, occasionally, some white coloration on the dorsal surface of the tail flukes. We cannot say whether the calves we saw had already darkened, or whether the light color of the newborn does not occur in the Hawaiian population. Other than Chittleborough's observations on newborns, investigators seem to agree that coloration and age are not related.

The extensive color variation among individuals within the Hawaiian population, and here we include ventral as well as dorsal surfaces, may function in individual recognition among conspecifics. Color patterns may also serve as signals communicating movement intention or direction, as in the exposure underwater of the white surface of a raised pectoral or caudal fin to a school-mate swimming nearby. Additionally, light ventral surfaces and darker dorsal surfaces provide for cryptic coloration important for predators, such as *Mageptera*, which at least in part feed on schooling fish (A.V. Yablokov, in Sokolov, 1971).

SUMMARY AND CONCLUSIONS

The Hawaiian population of humpback whales may number between 200 and 250 animals, though more detailed surveys of outlying islands and study of migratory patterns is necessary to refine the bounds of these estimates. Our estimates concur with Shallenberger's (1976) data on peak population size, peak population periods, and that the population numbers are much reduced by or after the first to second week of April. A ship survey from Kauai to Hawaii from 23 February to 7 March 1976 by the National Marine Fisheries Service counted 373 whales (M. Tillman, personal communication). The bases for this somewhat larger count have not yet been clarified.

Almost all of the whales were found within the 100-fathom contour surrounding the islands, a trait noted also for other breeding groups of humpback whales (Chittleborough, 1953; Winn *et al.*, 1975). The principal areas of aggregation were within the four-island region of Molokai, Lanai, Maui, and Kahoolawe, and within Penguin Bank extending 25-nm southwesterly from Molokai.

No unique nursery area was found, though the greatest numbers of calves were in two areas: Kalohi Channel between Molokai and Lanai, particularly on the Lanai side, and on Penguin Bank. Since these two areas are also regions of maximum whale density, it is not clear whether the greater number of calves simply reflects that fact. The number of calves recruited into the population was numerically small, and the recruitment rate, at its most optimistic, appeared to be somewhat below normal expectations. Given the small population size, this seems an unusual occurrence and leads to concern for the recovery of the stock. High priorities should be given to further investigations of recruitment rate.

Calves were typically found with multiple adults, most usually two (including the mother). The additional adults seemed to serve a protective function as noted from the tightening of calf groups versus the dispersal of all-adult groups on approach of aircraft. Over the entire population, pod size was on the average larger than that noted by investigators of humpback whale populations in other waters, either in breeding or feeding areas. Accurate determination of pod size seems heavily dependent on close approach by ship or aircraft, and unless this is done the number of animals in a pod may be underestimated. Also, calves are often difficult to detect without close approach. Our data were in most cases based on close-range observations.

The amount of migration between subregions within the island waters is unclear, though the 76% of the all-adult pods seen swimming on " determined " courses suggested considerable local migration, but without any obvious pattern. The remainder of the all-adult pods were milling about within some small area often in great activity (16%), or else simply stationary or nearly so (8%). Milling pods appeared to be engaged in courtship and mating activities, though actual mating was not seen. Pods with calves were more frequently resting (26%) than were all-adult pods, possibly reflecting the lesser stamina of the calf (or mother) and/or a requirement for nursing.

The most common formation for swimming pods was line astern (file), noted in 38% of the cases. Diagonal arrays and line abreast (rank) each typified 19% of the swimming pods. The functions of the various formations were not clear.

Most of our data were obtained within the peak period of the migratory cycle, from the end of February through to the third week of March. Therefore, we have no information on changes in local aggregations over time. Data collected by E. Shallenberger (1976), particularly those based on daily observations made by the crews of hydrofoil craft transiting between the various islands of Hawaii, suggest that the earliest immigrants may arrive in the four-island region. As the season progresses, the population appears to extend itself easterly and westerly, in comparatively small numbers, from the four-island region.

The routes by which the whales arrive at or leave the islands are unknown, as is their migratory loci in northern waters. A survey we made in November 1976 of the Northwest Hawaiian Islands, the small atolls and islands extending 1,200 nm northwesterly to Midway and Kure from the main Hawaiian Islands, revealed no whales. Coast Guard flights over this region by others in November 1975 and March 1976 (Shallenberger, 1976) also found no whales. However, in late December 1976, a report was received of two pods of whales in the eastern portion of the Northwest chain, moving southeasterly. It may be that the Northwest Hawaiian Islands are used as a migratory route by only a few whales, or only during portions of a season. Further studies of this area are necessary. Currently, there seems to be no evidence that any humpback whales breed in this chain. Our discussions with personnel based on the Midway Islands indicate that no humpback whales are ever seen there, nor heard there by underwater listening stations. Nishiwaki's (1972) statement that humpback whales are frequently seen around the Midway Islands in winter is therefore puzzling.

Based on their early arrivals in the four-island area, it may be that the principal migratory route to the main Hawaiian Islands is due south, south-southeasterly, or south-southwesterly from the higher-latitude feeding grounds along the northern rim of the North Pacific. The major return migration may simply be in the reverse direction, as suggested for example, by the northerly heading of a pod of six adult whales we observed in deep water on April 9th 10 nm off the west coast of Hawaii. Direct observations of these possible migratory routes needs to be implemented.

Coloration characteristics of the dorsal surfaces of the pectoral fins of the Hawaiian whales strongly suggest that the population is not that observed in the feeding areas near southeast Alaska. The coloration also appears to differ from some subpopulations observed near Kamchatka in the upper western Pacific, though this is less certain. The degree to which there may be dispersal of the Hawaiian population in the feeding grounds should be studied, and its degree of intermingling with other populations ascertained. If the three North Pacific populations are like the Southern Hemispere humpback whales, little migration between populations would be expected (Ivashin and Rovnin, 1967; Mackintosh, 1947). However, ecological conditions vary widely in the higher latitudes of the two hemispheres. In particular, feeding areas are more restricted in the North Pacific, so generalizations are difficult to make.

It was also noted that color variations within the Hawaiian population and displays of coloration could function in individual identification among conspecifics and as signals for movement intention and direction. Additionally the ventral-dorsal variations provide cryptic camouflage.

Finally, the potential fragility of the Hawaiian population, given its small numbers and apparent low recruitment rate, should be stressed. The annual migration of the population into Hawaii has been receiving increasing popular attention, and the number of people observing or wanting to observe the whales seems to be increasing annually at an exponential rate. The generally good weather in Hawaii and the nearshore clear-water regions favored by the whales makes their observation easy. While this is a scientific boon, and vitally important to the description and understanding of the natural behaviors and dynamics of a breeding population of mysticete whales, the rare spectacle of the whales is an attraction to all. Increasingly, commercial and pleasure ships and small boats are launched to watch the whales, divers enter the water to observe, photograph, and perhaps touch the animals, planes and helicopters on tourist runs circle the animals. All of this unregulated activity constitutes a potential source of major harrassment to the whales, and some controls on this activity are needed which will, first, protect and conserve the whales and, secondly, allow the expression of their benefit to humans as an educational and aesthetic experience.

Harmer (1928) long ago warned that whales may abandon their preferred grounds under harrassment, a warning that has been realized too often in whaling history. When driven from a given locality, whales rarely return to it, selecting instead secondary and likely less favorable grounds. Harmer's warning should be well heeded in the case of the Hawaiian humpback whale.

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OBSERVATIONS ON THE BEHAVIOUR AND OTHER BIOLOGICAL ASPECTS OF THE GANGES SUSU, *PLATANISTA GANGETICA*

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ABSTRACT

Observations on the behaviour of the Ganges susu, *Platanista gangetica* (Roxburgh, 1801), indicated that these animals frequent the confluence of a smaller stream with the main river, even with over-flooded banks, for food fishes. The most satisfactory method so far tried for capture of these animals was the use of ‘jagatberh’. With a little care these could be easily transported over long distances. Though they are known to be side-swimming, the Ganges susu cruised in normal fish-like movement with the body in normal, upright position. Rate of breathing showed individual and diurnal variations, the rate being more for younger specimens, and again during day-time. One susu was seen chasing a big fish at a tremendous speed, another attacked a goose, and a third one attacked a fish caught in the hook and thereby itself got caught in a locked-jaw condition. Two others reportedly were seen in the act of mating about an hour after sunset in August 1959. Parturition in these animals appears to occur around May, with another peak possibly around December.

INTRODUCTION

Thirteen live specimens of the Ganges susu, *Platanista gangetica* (Roxburgh, 1801), collected at different times from the Brahmaputra-Jamuna-Meghna river-systems during the period from January 1970 to May 1973 were each maintained for a time in ornamental pool, civil-work ponds, and/or in portable swimming pool in the Agricultural University Campus at Mymensingh, Bangladesh. These were among a total of 44 specimens collected and studied during investigations on the

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biology of the Ganges susu. Various aspects of their behaviour during captivity in these small, artificial waterbodies as well as on land and in the river were studied.

METHOD OF CAPTURE

The Ganges susu were found to avoid fast-moving boats, and seemed to be able to sense the presence of nets set in the vicinity. Various methods were tried for capture of these animals. The most satisfactory method was, however, found to be the use of a special type of seine-net, locally called 'jagatberh' used for catching bigger carps and other fishes in the river when the water-level was low. A row of such nets mounted on specially constructed rafts is placed across the river at two points each usually several kilometers apart. Dolphins are found to frequent the confluence of a smaller stream with the main river evidently for food-fishes (Kasuya and Aminul Haque, 1972). This was true even with over-flooded bank of the river. If the two components of the jagatberh were placed in the river enclosing such confluences, chances are that several specimens of dolphin would be rounded up towards the end of the jagatberh operation. Care has to be taken to remove the dolphins from the net as quickly as possible, as otherwise the dolphins may get entangled in the net, and get drowned.

Harpooning may be possible at the confluence of two streams frequented by dolphins, but this was not tried.

HANDLING

On land the dolphins were relatively calm, showing not much of visible distress. When picked up, they would struggle, within manageable limits, trying to wriggle out of hands. An interesting thing noted in a number of cases was that supported on one hand placed just below the throat-region, the dolphins became calm and still, stopping all strugglings. This was most pronounced in a calf about three weeks old (No. 33, 76 cm, ♀) that had been held in the swimming pool for 30 days since 8 June 1970.

TRANSPORTATION

Transportation on land from the place of capture to Mymensingh was easily done on a stretcher by two men, or on the lap by one man—longer distances being covered by rickshaws or trains with the animal left on the footboard or on the floor of the train compartment, as the case may be. The animal was loosely wrapped up with a length of rug leaving the blow-hole uncovered, the rug being kept wet by occasional sprinkling of water so as to keep the skin moist and cool. When released in artificial waterbodies, like ponds, the animals recovered in no time, without any apparent ill-effects. The breathing rate stabilised slowly from little under 500 times per hour on land to about 65 times per hour in water.

For really long distances covering several thousand kilometers (Mymensingh-Dacca, 200 km by truck; Dacca-Bangkok-Manila-Tokyo, 5,000 km by plane; and in some cases, Tokyo-Kamogawa, 100 km by truck again) the animals, duly wrapped up with wet rug, were placed in wooden crates of suitable size lined with polyethylene sheets and with 7–10 cm of water added. The animals stood the long journeys, in some cases, of about 21 continuous hours, surprisingly well, and recovered from the shock of the unusual journey fairly quickly.

SWIMMING

In confined, shallow waters—for example, in ornamental pool (865×360×45 cm deep, with a fountain-base, 65×65 cm, in the middle), small pond (960×725×80 cm deep), or swimming pool (450 cm dia. ×105 cm deep)—the dolphins swam on one side nodding the head continuously in ' yes ' motion. One remarkable thing noted is that, of the thirteen specimens observed in shallow waters, all except one swam in anti-clockwise direction, that is, on the right side, while only one swam in clockwise direction or on the left side. This ' right- or ' left-handedness ' may well be controlled genetically, so that occasional individuals with left side-swimming may not be unexpected.

The Indus susu, *P. minor* Owen, 1853, has also been reported to be a side-swimming cetacean with individuals moving either clockwise or anti-clockwise (Herald *et al.*, 1969). We are, however, inclined to believe that side-swimming in the Ganges susu is only one aspect of its swimming behaviour under specific environmental conditions—like small, confined area and depth of the waterbody. Further, contrary to popular explanation for side-swimming, this may not have anything to do with food-seeking or food-catching.

On one occasion, as described elsewhere in this paper (*vide infra*), a specimen of the Ganges susu was seen chasing a big fish in the river at a tremendous speed. This was a normal, fish-like swimming movement, with the body in normal, upright position.

TERRITORY FORMING

Ganges susu are non-gregarious creatures (Kasuya and Aminul Haque, 1972), although occasional two—most probably mother and calf as suggested by size-difference—have been seen swimming up or down the river.

Two specimens (No. 31, 138 cm, ♀; and No. 32, 123 cm, ♂) maintained in a pond during the period from 17 May to 21 August 1970, established themselves in two mutually exclusive areas in the pond, never crossing—as far as could be ascertained from their surfacings—into each other's territory. Also, they were observed never fighting with, or chasing, each other in the pond. These observations were true of two other specimens (No. 22, 188 cm, ♂; No. 24, 166 cm, ♂) similarly maintained in another pond.

BREATHING RATE

The ' blowing ' of the Ganges susu is a composite act—exhalation, quickly followed by inhalation—both done so quickly within a fraction of a second that the two sounds appear to be of one single action. It is interesting to note, however, that on one occasion on 15 May 1973 a specimen (No. 38, 91 cm, ♂) placed on a table in the Laboratory was found to have missed inhalation in one blowing, which was followed after only two seconds by another blowing, this time only inhalation taking place, so that for all practical purposes there were two separate blowings for exhalation and inhalation with a two-second interval between the two.

There were individual and diurnal variations in the rates of breathing of these animals. Record of breathing as kept for different specimens maintained in artificial waterbodies as well as on land has been summarised in Table 1 below. It may be noted from the Table that the minimum breathing rates for any individuals

TABLE 1. RATES OF BREATHING OF SEVEN SPECIMENS OF *PLATANISTA GANGETICA* UNDER DIFFERENT CONDITIONS

(Unless otherwise stated, breathing rate was recorded for 60 continuous minutes each time within the hours mentioned.)

Specimen No.	Sex	Size (cm)	Date	Rate of breathing per hour						
				On land			In water			
				0600 to 1000 hrs.	1200 to 1600 hrs.	1900 to 1830 hrs.	0600 to 1000 hrs.	1200 to 1600 hrs.	1700 to 1830 hrs.	0000 to 0100 hrs.
22	♂	188	27-4-'70	—	—	—	53	52	58	—
			8-5-'70	—	—	—	43	42	—	—
24	♂	166	8-5-'70	—	—	—	58	54	—	—
31	♀	138	15-5-'70	—	—	—	121/2[a]	129/2[a]	—	—
			16-5-'70	—	—	—	127/2[a]	—	—	—
			17-5-'70	—	492[b]	348[b]	—	—	—	—
			26-5-'70	—	—	—	—	64	—	—
			21-8-'70	—	—	—	40	—	—	—
32	♂	123	15-5-'70	—	—	—	121/2[a]	129/2[a]	—	—
			16-5-'70	—	—	—	127/2[a]	—	—	—
			17-5-'70	—	444[b]	204[b]	—	—	—	—
			26-5-'70	—	—	—	—	67	—	—
			21-8-'70	—	—	—	88	—	—	—
33	♀	76	9/10-6-'70	—	—	—	—	—	—	106[c]
			24-6-'70	—	—	—	88	68	—	40
36	♀	130.5	30-9-'70	—	—	—	96	92	—	58
38	♂	91.0	15-5-'73	156[d]	—	—	—	—	—	—

[a] Combined data for two specimens (Nos. 31 & 32.)

[b] Breathing recorded for 15 minutes (and multiplied by 4) while being transported in a railway compartment.

[c] Breathing recorded one day after capture.

[d] Breathing recorded for 10 minutes (and multiplied by 6) in the laboratory half an hour after arrival by road.

were recorded for two specimens (Nos. 33 and 36) at nights, and the same could indicate their hours of sleeping. Two other specimens (Nos. 31 and 32) also recorded low breathing rates (on 21 August 1970) when they had in fact become very much emaciated due apparently to starvation. One of these latter two specimens (No. 31) died some 10 hours after the minimum breathing rate of 40 per hour had been recorded, and the other specimen was sacrificed the next day.

During transportation, the breathing rate of these animals was, for obvious reasons, significantly higher than under acclimatised state in water.

FEEDING HABITS

(a) *Acceptance or rejection of food:* While specimens of the Ganges susu readily accepted food (small fishes) from the handler in the ornamental pool and in the oceanarium, those kept in the pond did not accept food offered to them, nor did they seem to take any food from the pond which had previously been stocked with an assortment of fishes of various sizes. Specimens left in ponds seemed to have slowly starved to death as the general emaciated state of health and post-mortem examination of the stomach would indicate.

(b) *Attack on a goose:* Specimen No. 22, while in a pond, once bit the neck of a domestic goose, *Anser cygnopsis cygnoides*, while the latter was, in its characteristic manner, probing the pond-bottom for food. The dolphin, however, loosened its grip and the goose managed to come out of the water. The injured goose was then slaughtered, and on examination the neck and part of head were found to have rows of tooth-marks on both the sides, establishing that the goose had really been bitten by the dolphin (Plate I, Fig. 1).

(c) *Dolphin caught in a hook:* An unusual case of a dolphin getting caught in a hook was brought to light on 28 September 1970. On the preceding night two anglers had placed a series of hooks each hanging from a bamboo rod, and fixed near the bank of the river. There were live baits (small fish or frog) hooked to the line, the hooks just touching the surface of water. This was a common local method of catching such predatory fishes as freshwater shark (*Wallago attu*, a kind of Teleostomi), featherback (*Notopterus chitala*) and snakeheads (*Channa striatus* and *C. marulius*).

At about 0200 hours, local time, the anglers were attracted by violent splashing sounds from the direction of one of the hooks. They took this to be caused by an extra-large freshwater shark, and hauled it up with a push-net. They were, however, shocked to see a Ganges susu instead, and decided to present the curious specimen to the Faculty of Fisheries across the river. When the specimen was brought to us early in the morning, we were bewildered to understand the circumstances under which the dolphin got caught in the hook. As stated above, the hook had a live bait of a frog or small fish, which lured to the hook a 36 cm freshwater shark, which, in its turn, attracted the dolphin. On examination the hook at the end of a length of string, was found deep into the oesophagus of the fish, which, in its turn got caught in the jaws of the mammal, the hook nowhere even touching the jaws of the latter. Apparently, the dolphin found itself in a ‘ locked-jaw ’ condition, in which condition it was still fixed to the fish in the latter’s abdomen and tail region that bore on the dorsal side distinct tooth-marks of the dolphin (Plate I, Figs. 2–4). The 130.5 cm dolphin (No. 36) was still alive, and after being maintained for 9 days in a swimming pool, was transferred to Kamogawa Sea World in Japan to start a new life in the oceanarium there.

CHASING A BIG FISH

On 17 October 1969, when the river old Brahmaputra was in half spate, a big (approximately 45 cm) carp, *Labeo rohita*, was seen being chased by a Ganges susu close to the surface of the water, to almost where one of the present authors with several friends had been standing near the edge of the water. Both the fish and the mammal were cruising at tremendous speeds, the latter continuing to chase the former to some 10 meters beyond the amazed on-lookers after which they both swam deeper down in water beyond sight.

MATING

Judging by the date of capture of very young, untoothed and teething calves, it appears safe to say that parturition in the Ganges susu in the river-system in Bangladesh takes place around May. According to Anderson (1878) parturition in

TABLE 2. PARTICULARS OF 13 YOUNG SPECIMENS OF GANGES SUSU, *PLATANISTA GANGETICA*, ALL LESS THAN 120 CM IN LENGTH

Specimen No.		Sex	Size (cm)	Date of collection or capture	River*	Remarks
at BAU	at ORI					
—	14	♀	27	28- 8-67	M	Foetus
33	21	♀	67.4	8- 6-70	B	Hair follicles very prominent;
			76	8- 7-70**		Teeth not erupted
38	—	♂	91	15- 5-73	B	Hair follicles prominent; Only 10 or 11 teeth on each side of the jaws erupted; Curdy substance found in mouth
3	2	♂	100.5	?- 6-69	B	
2	1	♂	105	?- 6-69	B	
7	5	♀	110	20-10-69	B	
11	7	♂	113	6- 1-70	B	
15	11	♀	113	26- 1-70	J	
4	3	♂	115	23- 8-69	B	
16	13	♂	115	26- 1-70	J	
9	6	♂	117	20-12-69	B	
17	15	♀	118	26- 1-70	J	
—	KS-76-5	♂	118	13- 9-76	B	

* River-names: M—Meghna ; B—Brahmaputra ; J—Jamuna

** Date of taking second measurement.

the Ganges susu may occur in two seasons—between April and July, and November and December. Harrison (1972), however, believes that parturition in this animal probably occurs in April, and he gives the length of neonates as 70–75 cm. From details of 13 young specimens, all measuring less than 120 cm (Table 2), it may reasonably be concluded that parturition in the Ganges susu takes place around May. Whether a second season for parturition exists for this animal cannot be confirmed from available data. The capture of 5 of the 13 specimens listed in the Table, all belonging to the same size-group (113–118 cm), in December-January, indicates that these were all born about the same time of the year. Since the age of these individuals was estimated with dentinal growth layers as 1.0 year (Kasuya 1972), it seems possible to expect another parturition peak around December.

There is no reliable information to estimate the period of gestation in the Ganges susu. Assuming that the period of gestation in these animals is 9 months (Anderson, *op. cit.*), mating would appear to take place around July/August. The collection of a 27 cm foetus on 28 August 1967 at Chandpur (R. Meghna) would lend support to this assumption.*

One first-hand report from a Professor, an M.A. in Bengali language, and having no biological background, describes an incident involving two dolphins (Prof. M.A. Nawaz, BAU; pers. comm.). It was about an hour after sunset on 14 August 1959. The gentleman, while crossing the river Burhiganga at Dacca on board a small country-boat, was alarmed at violent splashings in the water of two huge struggling creatures, locked in embrace, and rolling and almost shooting out of water. Both the Professor and the boatman watched in horror this ‘ struggle ’ that was apparently an act of mating of two dolphins. The boatman was, however, categorical that it was actually so.

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The authors wish to thank the authorities at the Bangladesh Agricultural University, Mymensingh, Bangladesh, at the Ocean Research Institute, University of Tokyo, Japan, and at the Kamogawa Sea World, Chiba, Japan, for the generous help and co-operation received at different times during the period of study reported in the present paper.

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* Since the paper was sent to the press, a second foetus, 30 cm, has been collected on 13 October 1977 from the river Meghna.

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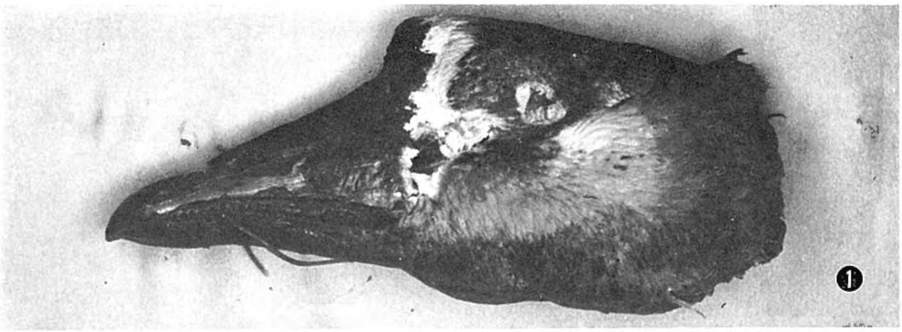
EXPLANATION OF PLATE

PLATE I

Fig. 1. Head of a goose with rows of tooth-marks of a Ganges susu.

Figs. 2–4. Specimen of a freshwater shark (*Wallago attu*) with tooth-marks of a Ganges susu on its body.



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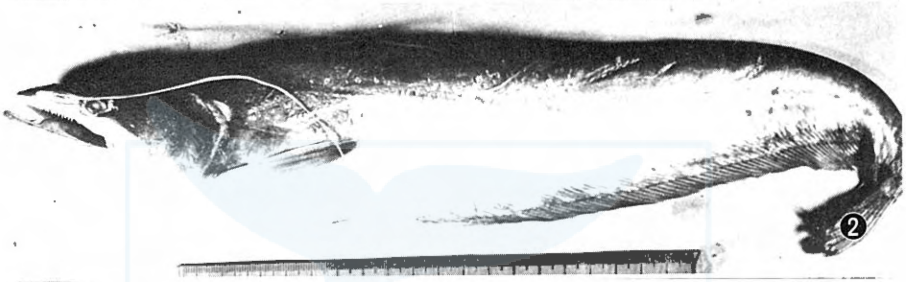

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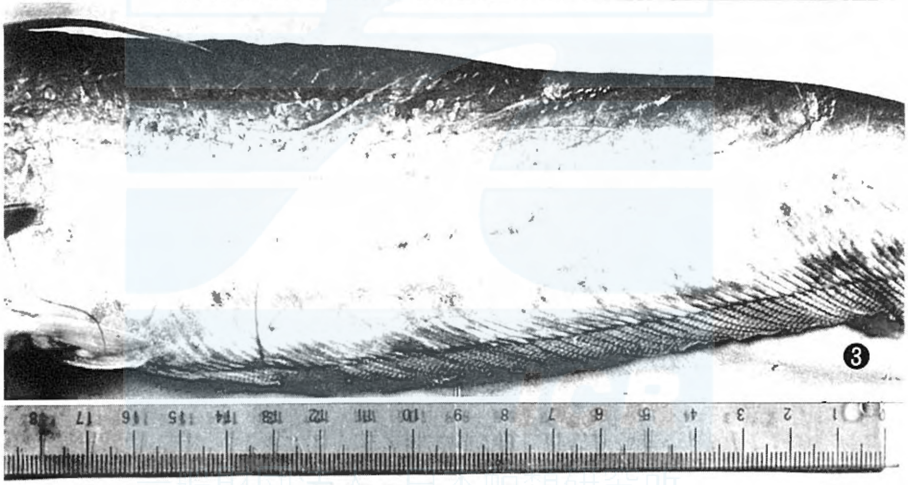

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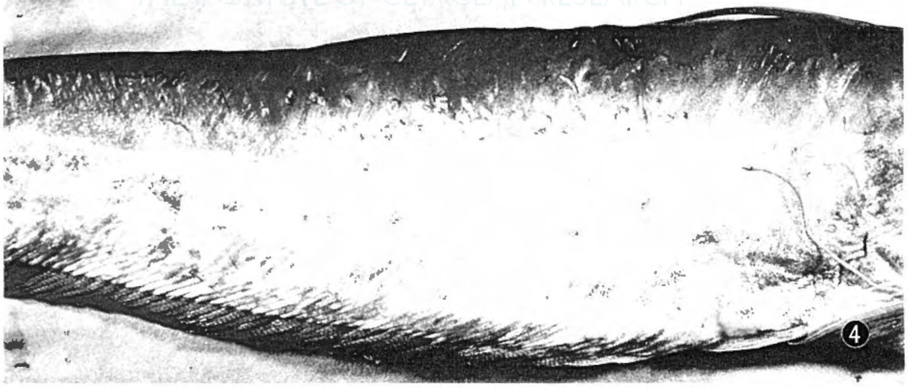

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A COMPARATIVE MORPHOLOGY OF ANAL TONSILS IN PLATANISTIDAE

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ABSTRACT

Anal tonsils, complex lymphoepithelial structures in the anal canal, were found in *Platanista gangetica*, and morphological observations were made macro- and light microscopically. In *Platanista*, the anal tonsils are mainly present and scattered on the oral half of the anal canal, however, they are relatively poorly developed and small in number. The formation of the anal tonsils cannot be found in *Inia geoffrensis*, although accumulations of lymphoid tissue are observed as far as the posterior part of the anal canal. In *Pontoporia blainvillei*, even such accumulations are absent from all parts of the anal canal. Comparative considerations of the anal tonsils are mentioned in Platanistidae and in some other cetaceans.

INTRODUCTION

Ortmann (1960) reviewed the lymphatic apparata and so-called " anal tonsil " in the anal region in many mammals, however, in his description no mention was made of those in Cetacea. Uys and Best (1966) made a pathological observation on Cetacea in which they described the anal tonsil in sperm whales. This structure is present externally around the anal opening. Cowan and Brownell (1974) reported the anal tonsil in the anal canal of gray whales and made comparative and functional considerations on this subject. We made an anatomical observation on the digestive tract of the Ganges susu in 1972, however, we overlooked the anal tonsils at that time. Recently, we have reexamined the previous materials and observed other specimens of this dolphin, and similar structures to that in gray whale were found in the anal canal. No reports on this subject in Cetacea, except for the abovementioned two reports, have been published to date and there still remain many problems of ambiguity in the biological meanings of the anal tonsil. Therefore, a brief morphological description of the anal tonsil in the Ganges susu will be added to the knowledge of that of Cetacea. In addition, comparative observations were done on two other kinds of Platanistidae, Franciscana and Boutu, and also on the striped dolphin.

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MATERIALS AND METHODS

Six specimens of Ganges susu, *Platanista gangetica* (body length; 76.0, 105.5, 106.5, 113.0, 118.0, 127.0 cm) were used in this study. For comparison four Franciscana, *Pontoporia blainvillei* (98.5, 113.5, 121.0, 171.0 cm) and a Boutu, *Inia geoffrensis* (204 cm) were examined. The *Platanista* and the *Pontoporia* were collected by the Cetacean Research Expedition of the University of Tokyo. Specimens of 76.0, 113.0, 118.0 and 127.0 cm in the *Platanista* were collected in the Brahmaputra River (Bangladesh) from 1969 to 1970 and the other in the Indus River (Pakistan) in 1974. The *Pontoporia* were caught off the Uruguayan coast from 1972 to 1973. The *Inia* was offered to us by the Kamogawa Sea World Aquarium in Chiba, Japan. Six striped dolphins, *Stenella coeruleoalba*, collected off the Pacific coast of Izu peninsula, Japan, were also examined as one example of marine dolphins.

Materials were fixed in 10% formalin solution at the site of capture and sent to our laboratory. After macroscopical observations from the interior of the anal canal, the whole length of which was cut serially in about 5 mm thicknesses, detailed examinations were done. Histological pieces were embedded in paraffin and celloidin, and then sectioned and stained with hematoxylin and eosin.

OBSERVATIONS AND COMPARATIVE CONSIDERATIONS

The anal canal, from the posterior end of the rectum to the anal orifice, varies in length with individual body length and is about 4 to 7 cm long in the *Platanista* observed. The epithelium shows an abrupt change at a point between the rectum and anal canal from intestinal glandular mucosa to stratified squamous epithelium in all species of dolphins observed. We have labelled this point the recto-anal epithelial transition (Takahashi and Yamasaki, 1972). Cowan and Brownell, in the gray whale, labelled it as the muco-squamous junction. The oral half of the inner surface of the anal canal in *Platanista* is somewhat irregular and uneven in appearance and several longitudinal folds are present on the posterior half (Fig. 1). The epithelium of the anal canal becomes pigmented towards the anal orifice and continues to the external skin.

Complex lympho-epithelial structures in the anal canal, anal tonsils, are found in *Platanista*, with the exception of one 76 cm specimen. A well developed structure (Fig. 2) similar to that of the gray whale observed by Cowan and Brownell was found. This structure may correspond to the ‘ first type ’ described by them, however, the development and the number of the tonsils in *Platanista* is rather poor and less, respectively, than that of the gray whale. There seems to be no sexual difference. In *Platanista* the anal tonsils are present but scattered in the oral three-fifths of the anal canal, except for the zone adjacent to the recto-anal transition, approximately 2 to 3 mm in width.* The tonsils are rather well developed in the

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* In our previous paper on the intestinal tract of *Platanista* (1972) there was no mention of this structure because we had observed only the part adjacent to the recto-anal transition where no tonsils were present.

oral half of the anal canal and they decrease in size and number towards the posterior. There are a few structures which form an independent elevation and these are usually found grouped in the irregular or longitudinal folds of the anal canal, forming oval masses 2 to 3 mm thick, 4 to 5 mm wide and 5 to 6 mm long. In the gray whale, distinct openings of the tonsilar crypts are abundant in Figure 1 of Cowan and Brownell's article. In *Platanista* they are very small, usually pinhole in size, and few distinct ones are found on the inner surface of the anal canal. Although it is fairly difficult to distinguish the existence of the tonsilar crypt with the naked eye, especially in younger animals, when viewed through a stereomicroscope small openings can be recognized on the surface. When viewed on a cross-cut surface of the anal canal masses of lymphatic nodules, being yellowish gray in color, are rather easily distinguishable.

Anal tonsils in the gray whale, of which the anal canal is 30 to 40 cm long, are found on the posterior part of the muco-squamous junction extending over about 10 cm in width (Cowan and Brownell). In sperm whales, they are present as numerous lumps and exist externally around the anal opening (Uys and Best). The location and the distribution of the tonsils may vary considerably among different species of some cetaceans which may have anal tonsils.

The sample shown in Figure 2 is of a well developed, independent tonsil in *Platanista* (113 cm) which we observed. It shows a distinct epithelial elevation, about 5 mm across and 3 mm high. The tonsil is composed of a mass of lymphatic nodules with a few germinal centers. The mass is about 4 mm in diameter. Its capsulation of connective tissue which is continuous with that of the submucosa is poorly developed. The tonsilar surface is covered with stratified squamous epithelium, invaginated into the subjacent lymphoid tissue to form a central crypt, which ramifies into a small number of subdivisions. Invaginated epithelium from the free surface becomes thinner and almost disappears at the mid-portion of the crypt. In cases of younger specimens (105.5, 106.5 cm), tonsils are small in size, 1 to 3 mm across, and they are grouped in places in the submucosa (Fig. 3). The crypts, some of which are slightly tortuous in course, ramify near the surface to the adjacent tonsils which are separated by connective tissue, or the crypts of two or three tonsils open onto the surface by a common opening. Lymphatic nodules without crypts are often present next to the tonsils. In the deeper portions of the crypts in younger specimens secondary papillae of their epithelia are poorly developed and the limit between the epithelium and lymphoid tissue is obscured by an infiltration of the epithelium with lymphocytes. Small numbers of mucous glands are present at the bottom of the structure. In younger cases, glands are seen near the masses of lymphatic nodules. In the case of the 76 cm specimen, there can be seen a very few small aggregations of lymphocytes without the formation of lymphatic nodules in the submucosa.

Thus, *Platanista* has anal tonsils, which are mainly present in the oral half of the anal canal, although relatively poorly developed and small in number. Since the anal tonsils were not formed in the 76 cm specimen and in younger stage they are small in size, it seems that the anal tonsils develop with age in *Platanista* as far as we have been able to observe.

Cowan and Brownell referred to the relation of the anal tonsils in Cetacea with the avian bursa of Fabricius. They described the morphologic homology and suggested the functional homology between the two structures. Assuming that the anal tonsils of *Platanista* develop with age, the relationship between the anal tonsils and the bursa, which may degenerate with age, may be converse, and this problem should be discussed based on further observations of the anal tonsils in other cetaceans.

On the other hand, in *Inia*, although we observed only a single case of a specimen of 204 cm in body length, diffuse accumulations of lymphoid tissue are observed in the submucosa to the posterior region of the anal canal. Crypt-like epithelial invaginations can often be observed, but they are not always associated with accumulations of lymphoid tissue. Germinal centers are poorly developed. In the *Inia* observed, well outlined organs of lymphoid tissue such as in *Platanista* could not be observed (Fig. 4).

In contrast, in *Pontoporia* no accumulations of lymphoid tissue can be observed in any part of the anal canal and only a very few aggregations of lymphocytes can be seen in all animals examined, as we briefly pointed out in a previous paper (Yamasaki *et al.*, 1975). The submucosa is highly vasculized (Fig. 5).

In *Stenella coeruleoalba*, well outlined anal tonsils with distinct germinal centers are present on the oral over about three-fourths of the anal canal. Many openings of the tonsilar crypts are clearly visible to the naked eye at the region corresponding to the tonsils on the inner surface of the anal canal. Anal tonsils in this species of *Stenella* are far more well developed compared with those in *Platanista*.

There is a remarkable difference in the lymphoid tissue in the anal canal in Platanistidae as mentioned above. It is interesting as to whether anal tonsils are present in other kinds of *Stenella* or not. Ortmann (1960) has already reviewed the considerable variations in the presence of anal tonsils in all the species of mammals he observed, although no mention was made of those in cetaceans.

There seems to be a close relationship between the existence of the anal tonsils and the distribution of the lymphoid tissues in the entire intestinal tract. Therefore, observation of the anal tonsils should be done along with that of the whole intestinal tract in each species.

There are so few descriptions on this subject that further comparative observations on other cetaceans should be done and are needed to clarify biological meanings from immunological, ecological and phylogenetical standpoints.

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EXPLANATION OF PLATE

PLATE I

Fig. 1. Inner surface of the oral three-fourths of the anal canal of a *Platanista gangetica* (body length, 105.5 cm). The oral half of the surface is uneven in appearance and longitudinal folds are present on the posterior half. Anal tonsils in *Platanista* are mainly present in the oral half of the anal canal. An arrow shows one of the tonsilar crypts which are usually fairly difficult to distinguish with the naked eye. A recto-anal epithelial transition is clearly visible at the top of the photograph. Hollows seen in the longitudinal folds at the bottom of the figure are not tonsilar crypts. ×3.3

Fig. 2. A photomicrograph of a well developed anal tonsil of a *Platanista* (113 cm). Although no opening of the crypt is seen in this section, the surface epithelium invaginates into the subjacent lymphoid tissue to form a central crypt, which ramifies into subdivisions. Germinal centers can be seen in places within the lymphoid tissue. ×15

Fig. 3. A cross section of the anal canal of the *Platanista* in Figure 1. In younger specimens anal tonsils are rather small in size compared with the larger animals. A tonsilar crypt shown by the arrow corresponds to the arrow in Figure 1. Anal tonsils are grouped in places within the submucosa. Small glands are visible near the anal tonsils. ×9

Fig. 4. A cross section of the oral part of the anal canal of an *Inia geoffrensis* (body length, 204 cm). Accumulations of lymphoid tissue are present but formation of the anal tonsil cannot be seen in the *Inia*. Germinal centers are poorly developed. ×9

Fig. 5. A cross section of the oral part of the anal canal of a *Pontoporia blainvillei* (body length, 171 cm). No lymphoid tissue can be seen in any part of the anal canal. Submucosa is highly vasculized. ×9


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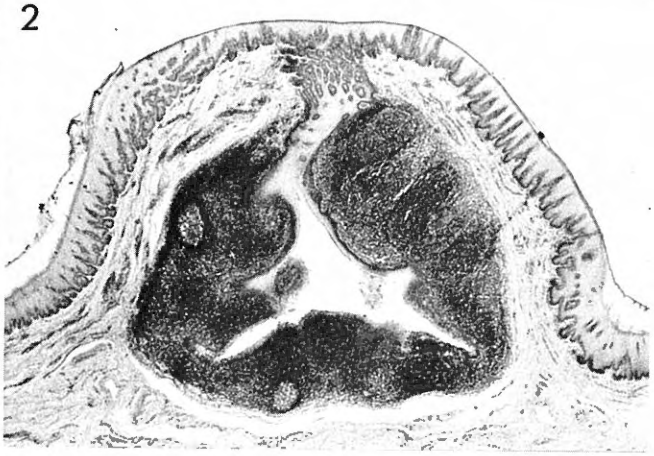
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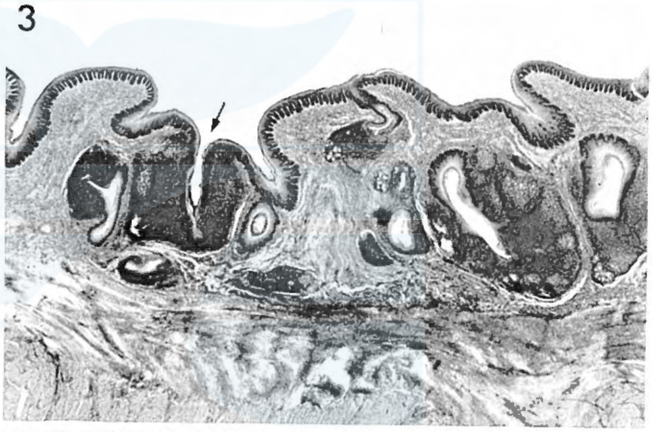
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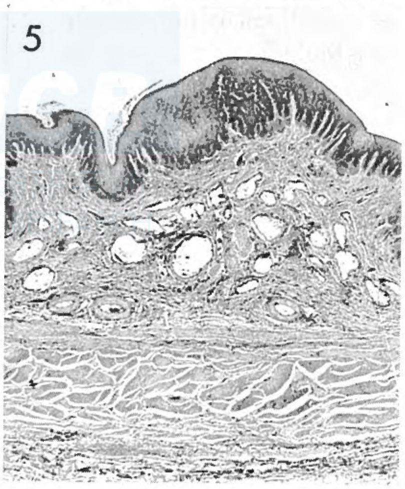
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COCCONEIS DIATOM ON THE SKIN OF FRANCISCANA

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ABSTRACT

Two species of diatoms are described from the skin films of Franciscana caught in the adjacent waters to Urguay. *Cocconeis ceticola* is common diatom on skin films, and one other naviculoid species is also found on this dolphin.

INTRODUCTION

Many diatoms have been reported from skin films of larger baleen whales and sperm whales both in the North Pacific and in the Antarctic (Hart, 1935; Nemoto, 1956). Species of diatoms are various, but *Cocconneis ceticola* is found generally on whales examined. Those parasitic diatoms are common on all larger whales in the polar waters and include many species which have not generally found in pelagic plankton (Nemoto, 1956). *Cocconeis ceticola* and its varieties and forms are common on *Balaenoptera* species and sperm whales, and some peculiar naviculoid diatoms, *Stauroneis* species are also found on sperm whales, which have not been described as a pelagic form.

Although many descriptions on parasitic diatoms have been made on larger whales including killer (*Orcinus orca*) and Baired beaked (*Berardius bairdii*) whales, few observations on diatom films on the skin of small cetaceans have been reported. Only a few descriptions have been made by Harrison and Thurley (1974) and Brownell (1975) recently.

Among many Franciscana studied in Urguay, some specimens had green-brown films of diatoms on the body surface. We studied these diatoms with reference to diatoms found on other whales.

DESCRIPTIONS

The Franciscana (*Pontoporia blainvillei*) has been studied from 1971 to 1973 in Punta

Sci. Rep. Whales Res. Inst.,
No. 29, 1977, 101–105.

del Diablo, Urguay by one of us Brownell. The progress report on the biology of those Franciscana studied is already given by Brownell (1975). Diatom films were mainly observed on the dorsal and lateral surface of the most fresh dolphins examined (Brownell, 1975). This observation suggests that more Franciscana may have had diatom films on the skin surface if they were examined in more fresh and un-rubbed conditon. The catch of those dolphins is done by gillnets by fishermen (Brownell, 1975), which possibly have removed diatom films with epidermis of the skin of dolphins.

TABLE 1. OBSERVATIONS OF DIATOM FILMS ON SKIN FILMS OF FRANCISCANA IN URUGUYAN WATERS

Field No.	Sex	Body length (cm)	Weight (kg)	Date caught	Remarks
717	M	119	19.5	9 Aug. 1971	Diatom film collected from left side of dorsal fin.
721	F	104	16.4	11 Aug. 1971	Diatom film collected.
753	M	131	—	25 Aug. 1972	Diatoms present on dorsal side and lateral tail stock, flippers and side of head. Sample collected from tail stock.
762	M	110	19.0	13 Sept. 1972	Diatom film around base of dorsal fin.
771	M	111	—	24 Sept. 1972	Diatom film present.
774	M	115	—	25 Sept. 1972	Diatom film covering all of the animal-areas of heaviest concentration were around the gape and tail stock-areas of next heaviest concentration were flukes (dorsal and ventral), the flippers (dorsal and ventral) and the dorsal fin.
869	F	130.5	27.3	5 Jan. 1973	Diatom film collected.
872	M	142	31.4	11 Jan. 1973	Heavy diatom film on dorsal and lateral surfaces.
889	F	136.5	29.1	23 Jan. 1973	Some diatoms on dorsal surface of flippers, dorsal fin, and tail stock.
895	F	112.5	17.3	28 Jan. 1973	Heavy diatom film on tail stock.

Diatom films are observed at least 10 dolphins in the studies carried out since 1971, in which three diatom specimens have been collected from three dolphins. The data of observations are given in Table 1. Generally diatom films are found on the side of dorsal fin and the dorsal surface of flippers and tail stocks. It is considered also that diatom films are common on the surface of dorsal fins and flukes. The seasons of catch of dolphins are both in winter (January) and summer (August) of the southern ocean, and dolphins which have been caught in both seasons were infected with diatoms.

The collected samples are examined by scanning electron and ordinary microscopes. Among all samples, *Cocconeis ceticola* specimens are found. On one porpoise (RLB-717), naviculoid diatoms are also found.

Cocconeis diatoms found on the skin films of Franciscana are considered all *ceticola* type and the variety form such as *constricta* form has not been found in samples. Although the shape of *ceticola* is somewhat oval but it is similar to those found on sperm whales. Sizes of diatoms are all within the general distribution of size which are reported up to date (Nemoto, 1958). Another naviculoid diatom is also found in specimens collected from No. 721 dolphin. This naviculoid diatom is considered to be one of the definite records from the skin films of whales like the report by Harrison and Thurley (1974), although there was some description of *Navicula* sp. from fin whales (Amemiya, 1916), which is considered as *Stauroneis* species.

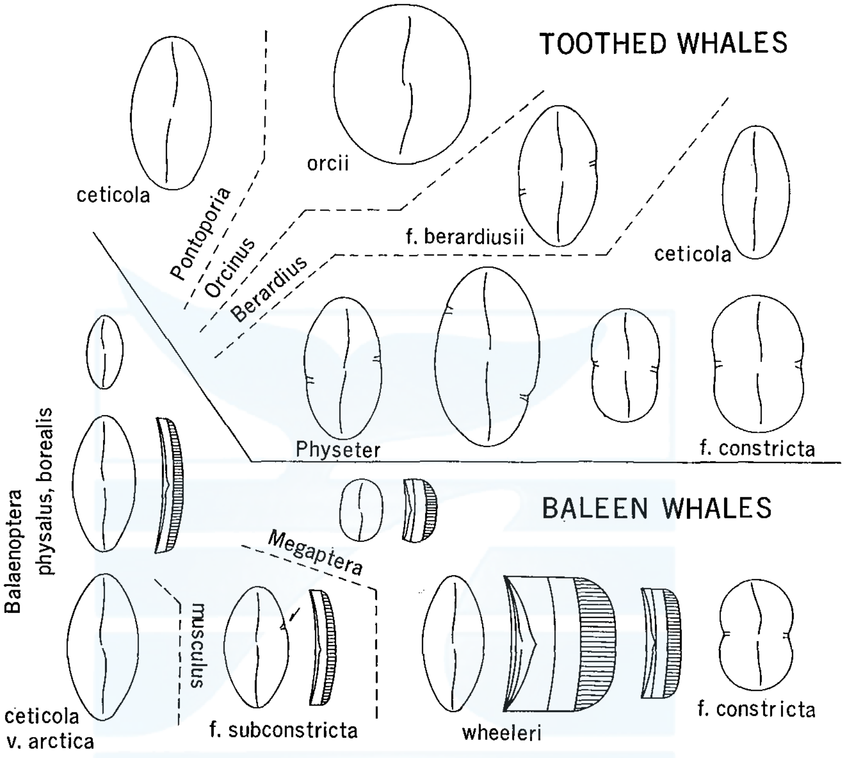

Fig. 1. Variety and deformation of *Cocconeis* diatoms on whales.

DISCUSSION

Many descriptions and discussions have been reported on diatom infection on the skin films of larger cetaceans. On the other hand, rather small numbers of observation have been reported on smaller cetaceans including dolphins. In the Antarctic and both in the Atlantic and the Pacific, many diatom films have been observed from blue, fin, humpback and sei whales even from sperm whales (Hart, 1935; Nemoto, 1956). Diatom films have also been observed in moderate sized whales of bottle-nose (*Hyperoodon ampullatus*) and the killer whales (*Orcinus orca*) (Bennett, 1920) in the Antarctic. Although diatom films have been observed on dolphins in other occasions, few precise descriptions have been reported after 1920.

The notice of diatom films on dolphins, *Lagenorhynchus cruciger* and *Cephalorhynchus commersonii* was reported at South Georgia by Hart (1935), however no taxonomical observation was made on those diatoms. Harrison and Thurley (1974) described two species of diatoms on the surface of one young *Phocoena* stranded alive in the British coast. Species are *Synedra tabulata* (Ag.) Cleve and *Navicula ramosissima* (Ag.) Cleve, the latter species is closely related to our specimen.

Diatoms found on Franciscana here are mainly common parasitic diatom *Cocconeis ceticola* Nelson. This species is found on many whales and dolphins, but it also shows many variety forms according to host whale species. As shown in Fig. 1, typical *ceticola* form is found on *Balaenoptera* species namely fin, and sei whales. It is also found on blue whales and *subconstricta* form which has constriction in one side is reported (Nemoto, 1958). *C. ceticola* group found on other whales sometimes shows different forms and variations. *Cocconeis wheeleri* found on humpback whales is large and thick as compared with typical *C. ceticola*. *Cocconeis ceticola* found on toothed whales also shows the variation of shape mostly in the outline. Generally *ceticola* found on sperm whales bears more oval outline. Some specimens of *C. ceticola* from sperm whales have the constinction in both sides in oval shape and called *C. ceticola* f. *constricta*. The size of oval *C. ceticola* including *constricta* form on sperm whales is larger than those found on fin and sei whales.

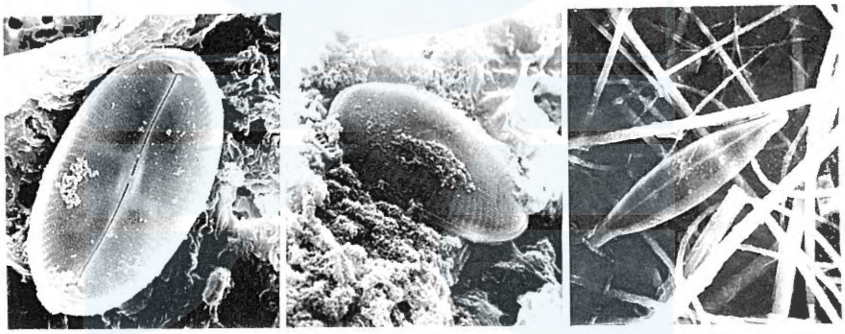

Fig. 2. Diatoms found on Franciscana caught in Urguay waters. Left and middle: *Cocconeis ceticola*, Right: *Navicula* sp.

Kliashtorin (1962) found constricta form from *Berardius bairdii*. He named this *Cocconeis ceticola* f. *berardii*, but this is the similar type from sperm whales illustrated by Nemoto (1958, Fig. 3-M; 11–15 in plate II). Another round type is described from *Orcinus orca* as a new species *Cocconeis orcii* by Kliashtorin (1962). This species is also considered as one variety of *Cocconeis ceticola* on killer whales.

We do not find any variation of forms of *Cocconeis ceticola* on Franciscana but oval *ceticola* type. Size of *C. ceticola* found on Franciscana are also ranging within the usual range of *Cocconeis ceticola* of normal and oval types and its varieties. The size is generally less than 40 μ.

The future study of diatom films of dolphins is thus needed for more diversed species among cetaceans especially for dolphins. Perhaps *constricta* forms of *Cocconeis ceticola* will be found on smaller toothed whales and dolphins too. Among organisms attached to cetaceans from diatoms to lampreys and whalesucker (Dailey and Brownell, 1972), some ectoparasites are considered to be indicative of whales' migration. The most of records of parasitic diatoms have been recorded from the waters colder than 20°C. Especially *Cocconeis ceticola* has only been reported in the polar waters.

The water temperature around the fishing ground of Franciscana are ranging between 13° and 23°. The seasonal difference of water temperature is not so great as to show clear decline or decrease of infection of diatoms on the skin. Perhaps more extensive research on dolphins and whales reveals the infection of *Cocconeis* diatoms on whales are common in Urguay waters throughout the year.

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FOOD OF A KILLER WHALE: EAGLE STING-RAY, *MYLIOBATIS* FOUND IN THE STOMACH OF A STRANDED *ORCINUS ORCA**

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ABSTRACT

The killer whale, *Orcinus orca* feed on a variety of foods including sea mammals, sea birds, fishes and squids. Among fishes, teleosts seem to be more frequently found in the stomach content than elasmobranchs. There are some records where electric ray, skates and sharks are mentioned as preyed by killer whales.

Eagle sting-ray, *Myliobatis* teeth plates were the only remain found in the stomach of a killer whale stranded on the beach of Rio Grande do Sul, Brazil. As in the case of sharks that prey on sting-rays, six broken stings were found embedded on the jaw and snout tegument. By comparison of the teeth plates, the total length of the *Myliobatis* rays was estimated in a range of 65 to 81 cms.

INTRODUCTION

During the first week of November 1976 a killer whale, *Orcinus orca* was stranded 3 km South of Lagoa dos Peixes bar and 120 km North of Rio Grande (R.S., Brasil). During the last week of December two trips were made by the staff of the Museu Oceanografico to the stranding place. During the first trip color slides were obtained and the possibility of retrieving a part of the skeleton was considered. On the second trip, the complete head and the left flipper (M.O.R.G. Cetacean coll. n° 37) were collected, some measurements were taken and the stomach content was preserved and identified.

The 5.60 m long male killer whale was almost dried and partially burried in sand above the high tide line. Through a left lateral cut the liver was reached and under it the stomach was found. Numerous ray teeth, one cartilage, a broken shell and sand were retrieved.

STOMACH CONTENT

The teeth were identified as belonging to the eagle sting-ray, *Myliobatis*, a common venomous ray of the SW Atlantic waters and abundant during the summer along Rio Grande do Sul coasts.

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* Contribution of the Base Oceanografica Atlantica n° 1

Sci. Rep. Whales Res. Inst.,
No. 29, 1977, 107–111.

Teeth plates and venomous spines of the Whip rays, *Dasyatis;* Butterfly rays, *Gymnura;* Cow-nosed rays, *Rhinoptera* and Eagle rays, *Myliobatis* were dissected for comparison with those obtained from the stomach content.

Two kind of *Myliobatis* teeth could easily be recognized, long rectangular ones with slightly curved edges placed at the middle of the teeth plate and small polygonal ones on both sides of the middle series.

VENOMOUS STINGS

The killer whale was carefully inspected. The tegument had been loosing oil and was partially dried. All injuries and scars were opened with scalpels and 6 pieces of broken venomous stings were easily seen and extracted from inside the tegument at the following places:

sting A: 3.5 cm long at 10.5 cm distance, sligthly to the left of the tip of snout, upper jaw
sting B: 1.9 cm long at 4.0 cm distance below the 3rd upper right tooth, lower jaw
sting C: 4.3 cm long at 8.0 cm distance below the 8th lower tooth, lower jaw
sting D: 1.0 cm long at 4.5 cm distance below the 4th lower tooth, lower jaw
sting E: 2.0 cm long at 9.0 cm distance below the 5th upper tooth, upper jaw
sting F: 2.0 cm long at 13.0 cm distamce from the tip of snout, lower jaw

KILLER WHALE FOOD HABITS

The killer whale of the West coast of North America feed on a variety of foods, including four main kinds: sea mammals (whales, dolphins, seals and sea otters); sea birds; fishes (ling cod, *Ophiodon;* salmon, *Oncorhynchus*) and squids (Scheffer and Slipp, 1948).

The different preys of *Orcinus orca* had been carefully listed, including 10 species of cetaceans, 8 pinnipeds, 11 teleosts, 6 other vertebrates and 3 varieties of elasmobranchs (Martinez and Klinghammer, 1969).

It has been reported that a killer whale was observed to be feeding on an electric ray, *Torpedo californica* (Norris and Prescott, 1961) while unidentified skates and sharks are also mentioned among their diet (Tomilin, 1967).

The killer whales from the coastal waters of Japan feed mostly on fishes and cephalopods, but also feed on large numbers of cetaceans and pinnipeds (Nishiwaki and Handa, 1958).

The stomach content of 10 killer whales studied in the Eastern North Pacific contained the remains of at least three California sea lions (*Zalophus californianus;* four Steller sea lions (*Eumetopias jubatus*)*;* seven Elephant seals (*Mirounga angustirostris;* two harbor porpoises (*Phocoena phocoena*)*;* two Dall porpoises (*Phocoenoides dalli*)*;* one minke whale (*Balaenoptera acutorostrata*); two Opah fishes (*Lampris regius*)*;* one Pacific halibut (*Hippoglossus stenolepus*)*;* two carcharinid sharks and one squid

(Rice, 1968).

The leatherback sea turtle, *Dermochelys coriacea*, has been added to the known prey of the killer whale from the St. Vincent Island (Lesser Antilles) (Caldwell and Caldwell, 1969).

DISCUSSION

Orcinus orca has been recently included on the list of Rio Grande do Sul cetaceans on the base of eight stranding records (Castello and Gianuca, in press).

The stranding of November 1976 (8th. record) took place along one of the longest sandy beaches of the SW Atlantic coast (from Chui to Torres), where sea lions *Otaria flavescens* and fur seals, *Arctocephalus australis* are seldom seen.

The La Plata dolphin or " Franciscana ", *Pontoporia blainvillei* has been considered as a possible prey of killer whales at Punta del Diablo (Dto. de Rocha, Uruguay) waters (Brownell, 1975), but until now this has not been documented.

It is also known that sharks frequently prey upon sting-rays. Dr Perry Gilbert (1977) from Mote Marine Laboratory, Florida, USA. recalled removing 96 sting ray spines from the mouth and lips of a 4.20 m long Hammerhead shark, *Sphyrna mokarran*. The spines were from the common sting ray, *Dasyatis americana* and the little round sting ray, *Urolophus jamaicensis*. Also from the jaws and neck region of a Hammerhead shark, *Sphyrna zygaena* (3.70 m long) caught in Beaufort North Carolina, USA., 58 stings were dissected. In a second specimen, there were remnants of 17 caudal spines in the stomach and at least 24 spines were in the gums. Stings can also be observed embedded in the tissues covering the jaw of *Carcharinus limbatus* (13 stings) and of the Sharp-nosed shark, *Scoliodon terra-novae* (one sting) (Gudger, 1946).

A Black-tip shark, *Carcharinus limbatus* from North Carolina waters (3.0 m long and 192 kg of weight) contained pieces of the Small Devil-fish, *Mobula* and in three Tiger sharks, *Galeocerdo tigrinus* pieces of *Mobula* and Whip ray (*Dasyatidae*) were found (Bell and Nichols, 1921). A Whip ray spine was imbedded in the muscle at the corner of the mouth of a 1.8 m long *Carcharhinus commersonni* collected at the Bay of Forida (Nichols, 1917).

From the size and number of teeth plates recovered from the stomach content and the size and number of the stings embedded on the jaw and snout of the killer whale, six eagle sting rays, in a range of 65–81 cm of total lenght, were eaten.

Two species of eagle sting rays are mentioned for Rio Grande do Sul waters, *Myliobatis freminvillei* and *M. goodei* (Bigelow and Schroeder, 1953). Unfortunately I am not able by the moment to distinguish both species on the basis of teeth or stings.

A broken shell of the bivalve, *Pitar rostratus* (Koch, 1844) also found in the stomach content was probably eaten by one of the eagle rays.

When caught in the killer whale's mouth each ray had in defense lashed out with its long tail and at least 6 of them had left with the killer whale mementos of their fights. Apparently no vital organ was injured by any of the stings.

ACKNOWLEDGMENTS

To my friend, Prof. Norton M. Gianuca, Director of the Base Oceanografica Atlantica who identified the killer whale carcass and also to Miss Rosangela Lessa and Mr. Lauro Barcellos and Mr. Rodney Nascimento who collaborated in taking measurements, color slides and helped to collect the head and flipper on the beach. To Dr. Eliezer Rios, Director of the Museu Oceanografico who determined the bivalve shell and to Dr. Perry Gilbert; Dr. George Y. Harry, Director of the Marine Mammal Division, N.O.A.A., Seattle, Washington and Dr. James W. Atz from The American Museum of Natural History, New York, USA. who kindly helped me with bibliography and information.

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EXPLANATION OF PLATE

PLATE I

Fig. 1. Left middle series teeth of the upper plate (n° 1) of an eagle sting-ray, *Myliobatis* estimated to be 81.5 cm long, eaten by the killer whale. Right-Lower plate of the same specimen.

Fig. 2. Eagle ray teeth in different positions, three first rows are middle teeth, fourth row are lateral ones.

PLATE II

Fig. 1. Dorsal aspect of the lower teeth plate (n° 3) of an eagle sting-ray eaten by the killer whale.

Fig. 2. Ventral aspect.

PLATE III

Fig. 1. Labial cartilage of an eagle-sting ray found in the stomach content.

Fig. 2. Rests of a *Pitar rostratus* bivalve shell, probably eaten by one of the sting rays.

PLATE IV

Six pieces of eagle ray stings that were embedded on the jaw and snout of the killer whale.

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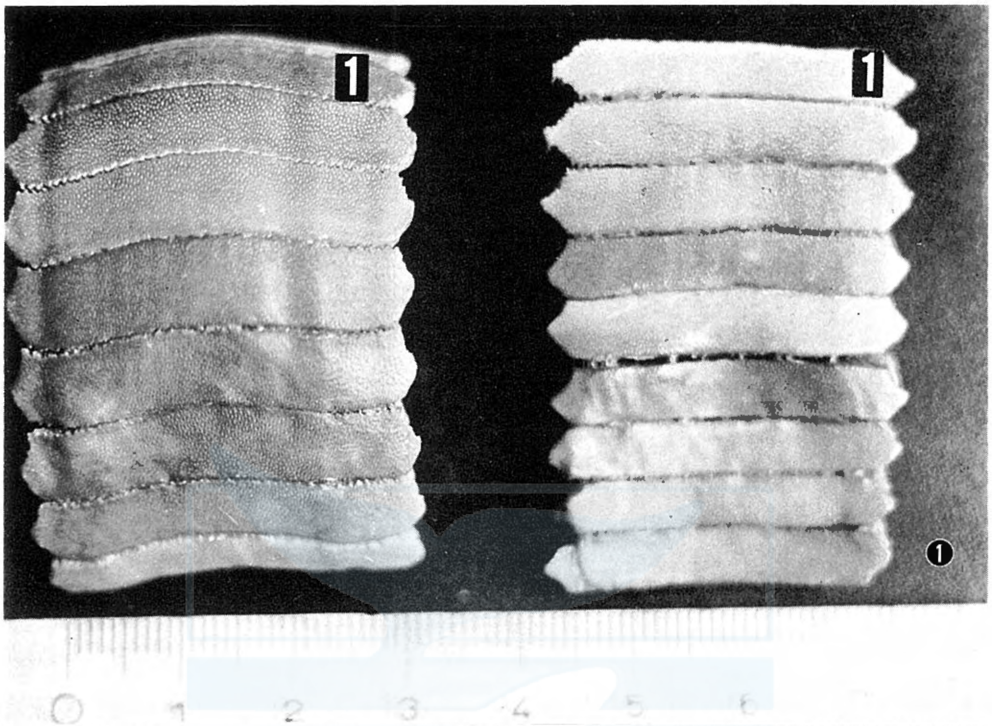

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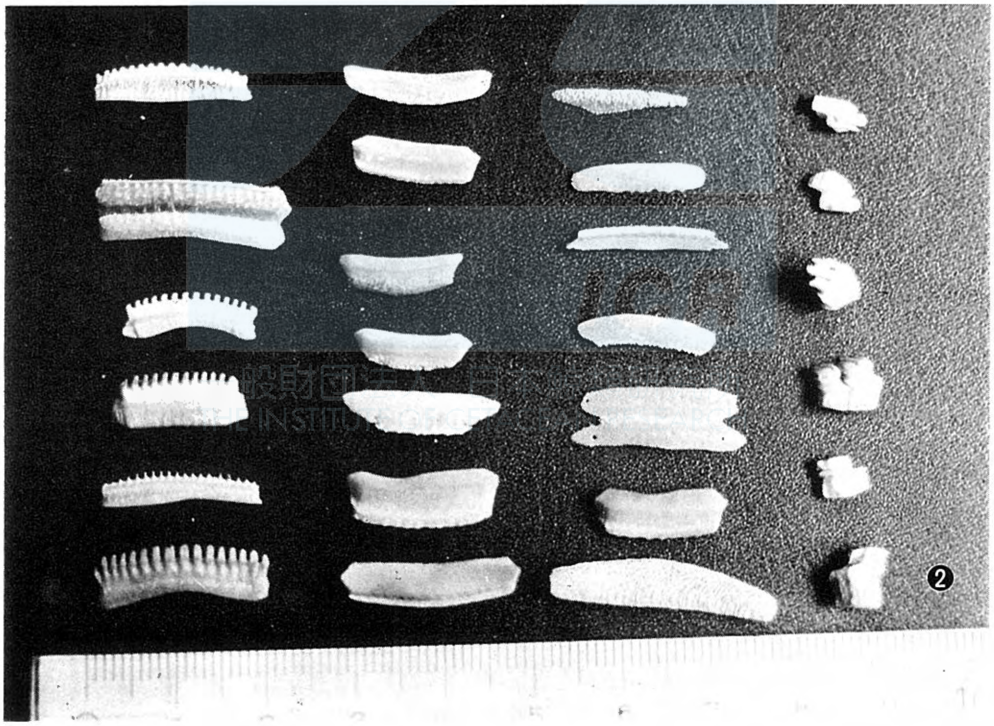

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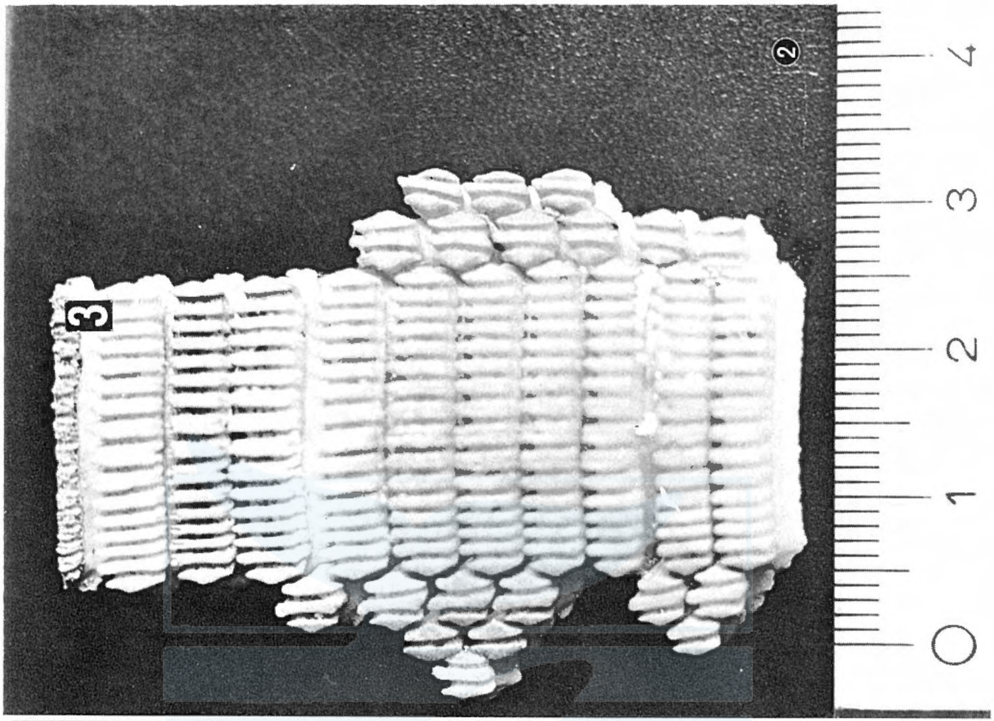
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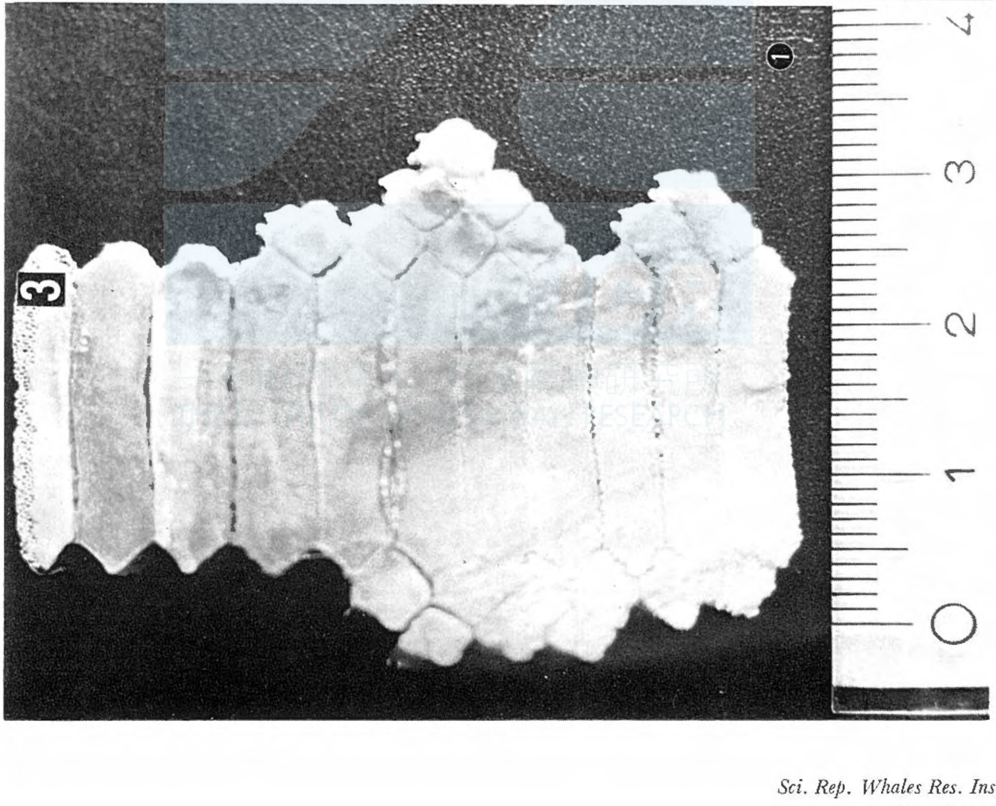
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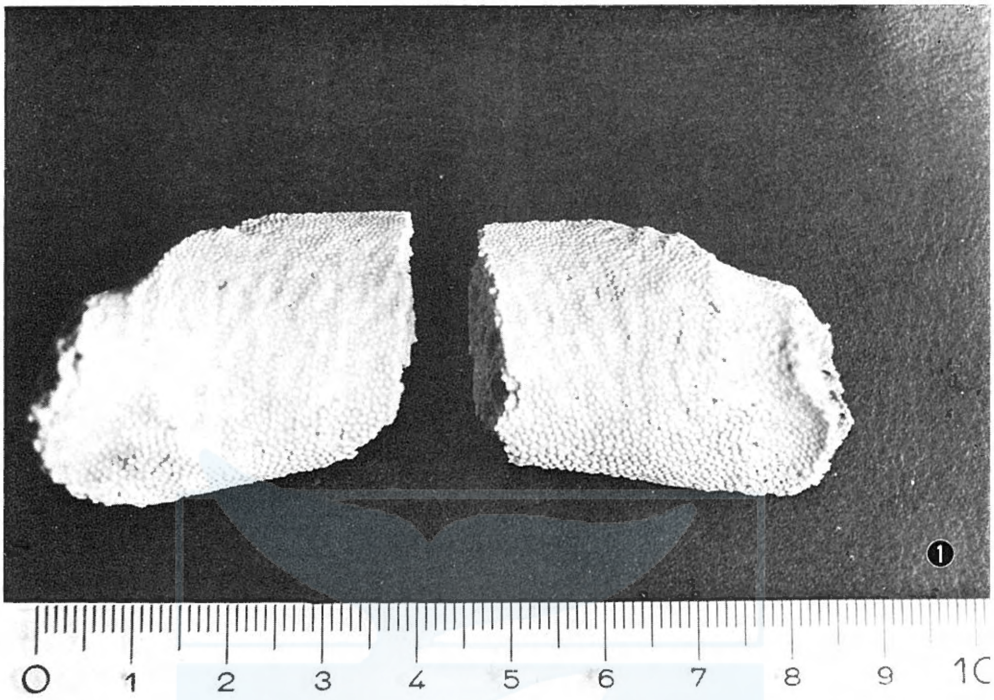
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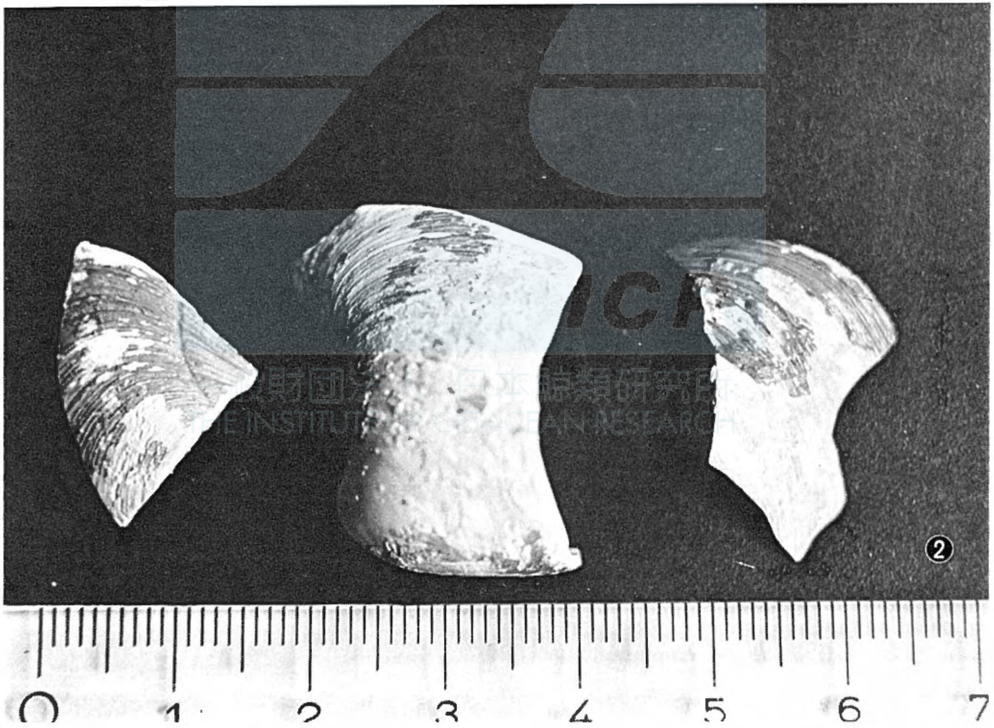
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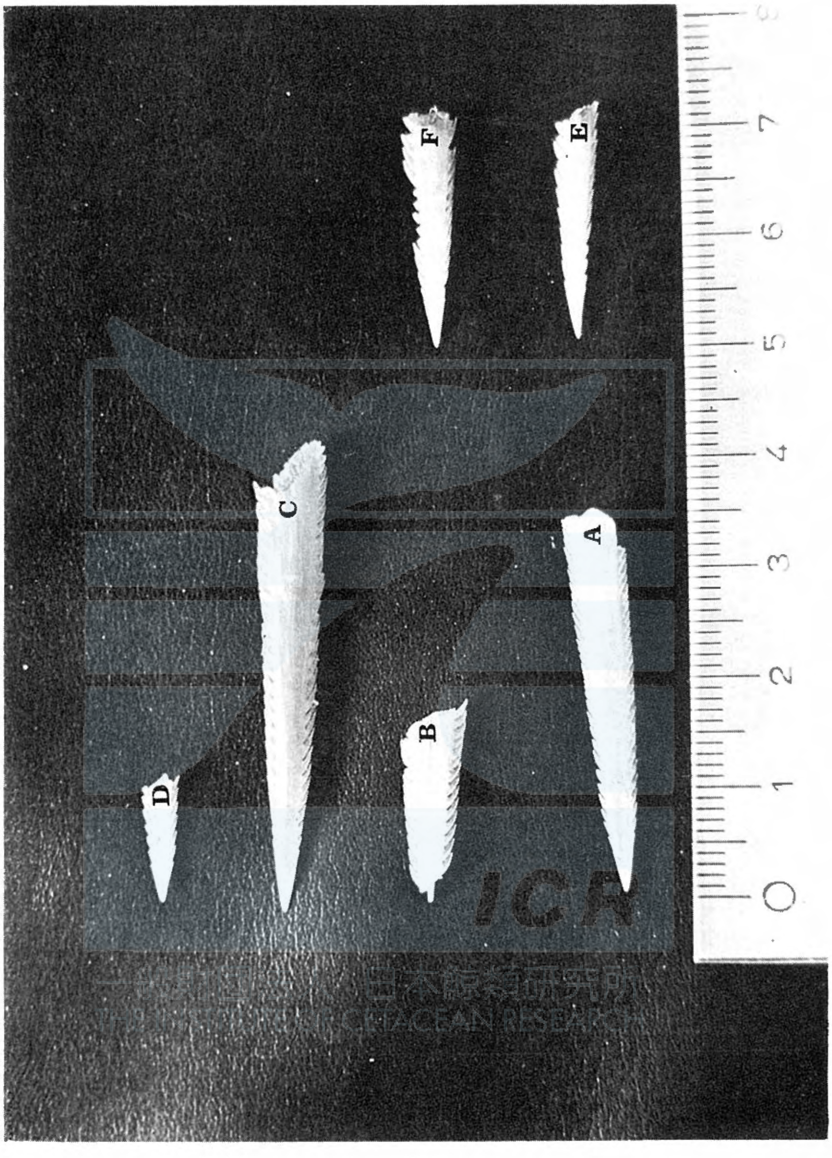
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HUMAN ACTIVITIES DISTURBING NATURAL MIGRATION ROUTES OF WHALES*

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ABSTRACT

Trying to prove human activities which disturbed natural migration routes of whales, two populations of whales were investigated.

In Tokyo Bay area, annual catch numbers of the Baird's beaked whale (*Berardius bairdii*) in Boso whaling ground are between 50–300. Although the whales have shown no sign of average body length decrease, (Nishiwaki and Oguro 1971), apparent decrease of whales caught inspite of increasing Catch Per Unit Effort makes us no other way, accept the fact that the maritime transportation disturbed the migration routes of whales of this stock.

Same is true in the northern coast of Kyushyu. Reason of catch decrine in the present investigation can not be considered as damage to the minke whale (*Balaenoptera acutorostrata*) stock caused by whaling. Catch Per Unit Effort is, as a whole, in an up surging, but the number of whales caught is decreasing without average body length decrease.

Great number of vessels are coming into and going out of the both areas and the number is still increasing. Not only those whales, but also various species of marine mammals may be troubled by the busy traffic. The result of this investigation would be a warning to the countless activities by men, which disturb or expel wild animals from their natural inhabiting ground and migration routes everywhere in our environment.

INTRODUCTION

Handreds of years ago, when human population was moderate and people did not try to catch whales, many species of big whales which by nature favored to breed in temperate or warmer waters, may have entered into lagoons and inlets of Japan. Evidences of half fossilized whale skeletons have been found at many places along the coast of the Inland Sea, in the western Kyushyu Island and even on the coast of Tokyo Bay. At present, however, there are very few sighting reports of big

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Sci. Rep. Whales Res. Inst.,
No. 29, 1977, 113–120.

whales in those areas.

In 1969, a stray calf of the bowhead whale came into Osaka Bay and was accidentally caught by local fishermen (Nishiwaki and Kasuya 1970). The incident was a proof of the natural preference of this species which had favored the temperate waters of the Inland Sea.

At Scammon's Lagoon, Baja California, gray whales had come abundantly to breed in former days. However, when the rumour of this phenomenon spread among people, not only scientists but also a large number of general people gathered to see the whales. Disturbed by the sightseers, it was reported, that the number of whales coming to the lagoon had apparently decreased. The incident was one of disturbances, not by whaling activities, but by another human action affected the whales.

Trying to prove human activities which disturbed natural migration routes of whales, we investigated the two populations of whales, the Baird's beaked whale (*Berardius bairdii*) in Boso whaling ground and the minke whale (*Balaenoptera acutorostrata*) in Yobiko whaling ground, both of which did not receive a serious damage by whaling, but affected by the increasing number of ships and boats coming in and out or passing near by the whaling grounds (there are very few whale population which have received no harm from whaling).

INFLUENCES OF VESSELS OVER THE BAIRD'S BEAKED WHALES IN BOSO WHALING GROUND

Baird's beaked whale catch has been operated from land stations in certain limited areas of Japan. One of such whaling grounds is Boso ground in Chiba Pref. The ground is only 20 miles distant from the mouth of Tokyo Bay. Coast of Tokyo Bay is dotted with commercial, naval and fisheries' ports. As shown in Fig. 1, there

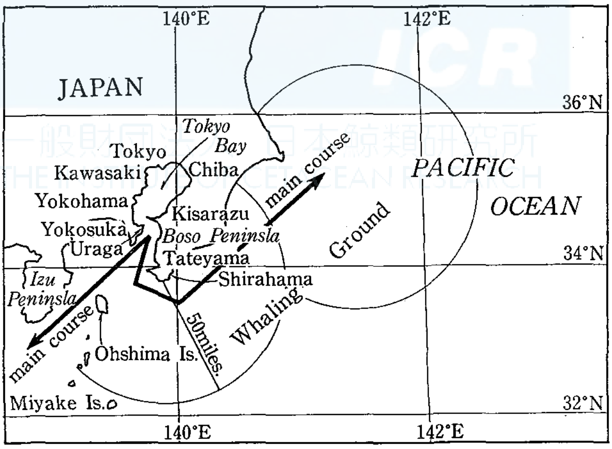

Fig. 1. Boso whaling ground and the main course of vessels in and out of Tokyo Bay.

TABLE 1. ANNUAL NUMBER OF VESSELS ENTERED THE PORTS

Year	Tokyo Bay Area				Northern coast of Kyushyu			
	Tokyo	Yokohama	Yokosuka	Chiba	Dokai Area	Kokura	Moji	Shimonoseki
1948	11941	—	—	—	41756	15330	17738	5199
1949	11301	5870	3521	—	37132	14108	34839	11478
1950	13797	12507	1768	—	58467	12849	33884	90886
1951	13913	14723	3228	—	47441	30427	13156	113332
1952	12625	16262	3806	—	42926	29211	40612	90239
1953	13957	21093	6220	—	49788	28211	47807	96694
1954	15038	20009	7182	—	72641	28192	44655	100046
1955	15116	17118	8337	—	10391	18858	43447	56812
1956	12066	22953	8101	3744	72450	29398	27857	42382
1957	20649	26737	9156	6306	75743	27165	27564	47460
1958	22813	28384	10063	4155	63310	27394	43600	80323
1959	27360	30573	12408	6708	65657	29265	42820	77185
1960	31776	37120	14690	9479	70136	28117	45100	78151
1961	32767	45121	16085	11198	71648	28354	77778	75664
1962	31358	45644	16206	9942	69944	29952	66141	77257
1963	33936	50649	16114	18513	67224	28792	65720	77317
1964	45886	60078	16223	31237	76418	30013	62430	75909
1965	53381	71087	19136	32241	76544	26424	55807	74237
1966	57356	76039	24719	33500	68172	23450	65530	72665
1967	64502	88238	27880	39480	64064	25034	84363	71059
1968	68894	99691	26404	35336	58037	25994	62448	73913
1969	70158	106721	24556	60065				65317
1970	78816	108427	27549	73713				64124
1971	76586	104742	28243	72098				65993
1972	79763	101537	28632	77347				71576
1973	81689	102946	26225	87185				69319
1974	72222	93987	27673	80827				66845

are Tokyo, Kawasaki, Yokohama, Yokosuka, Chiba, Kisarazu, Uraga and Kurihama Ports. Various ships and boats which are coming into those ports, must enter the mouth of Tokyo Bay. A list of a great number of vessels of over 5 tons is shown by the year in Table 1. Moreover, all boats which once enter into the Bay, must inevitably go out. So, the number of boats must be considered as twice as much to become an amazingly big number. Although it was difficult to get data from every port of Tokyo Bay area, general circumstances of maritime transportation around the Bay might be understood with this table. Actual number of the boats was, of course, much more than the indicated number. In the year when 100 whales were caught, the number of boats coming into Tokyo Bay was about 250,000. That is, one boat per minute was passing through the mouth of the Bay.

In Fig. 2, annual number of vessels entered into Tokyo Bay is compared with that of Baird's beaked whales caught at Boso whaling ground since 1948 till 1974. These numbers are averages of every three years. This method makes the curves smoother and the curves show the tendencies more clearly.

As it is also indicated in Fig. 2, CPUE (Catch Per Unit Effort) has been increasing in the years. The reason of the remarkable increase of CPUE between

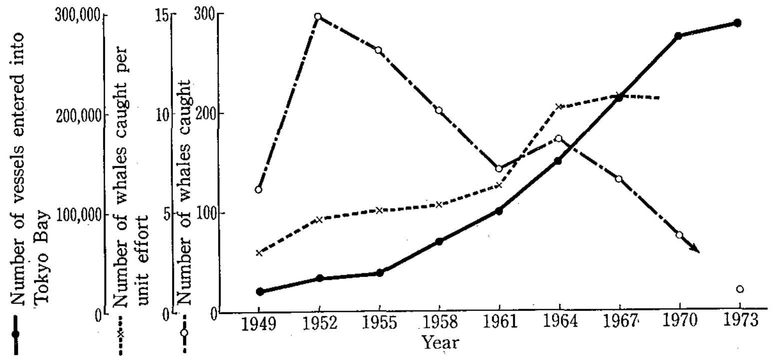

Fig. 2. Annual number of vessels entered into Tokyo Bay compared with that of Baird's beaked whales caught from Boso whaling ground.

1961 and 1964 was that, small tonnaged (15–20 tons) catchers were abolished and bigger (30–50 tons) catchers were taken up for operation. Accordingly, number of catchers decreased, instead, capability per boat increased. Nevertheless, the population seems to have shown no sign of receiving damages during the 25 years, although biological examination on those whales caught has not been done every years. Annual catch numbers are between 50–300. The numbers are rather small, but the whales have shown no sign of average body length decrease (Nishiwaki and Oguro 1971). Considered the increasing CPUE and apparent decrease of whales caught without population damage, we have no other way, accept this phenomenon as a fact that the maritime transportations have disturbed the migration routes of the Baird's beaked whale.

MINKE WHALES IN YOBIKO WHALING GROUND AND MARITIME TRAFFIC ON THE NORTHERN COAST OF KYUSHYU

In the northern part of Kyushyu Island, local people have had a habit of eating whale meat since more than four hundred years ago. Among the species of whales coming near to the coast, minke whales are relatively fearless and even coming into set net to be an easy harvest for fishermen. The meat of minke whale was a very important protein resources at the time of devastation just after World War II: minke whale meat was a necessary food in northern Kyushyu and consumed abundantly. Whaling on minke whale is usually done by small boats of 15–20 tons with 35–50 mm harpoon guns. The whaling ground is naturally limited within 30 miles from the shore (Fig. 3).

Fortunately, the record of the body length of minke whales caught in this area since 1948 has been kept to date, and was very important reference to our investigation. It was very difficult to grasp a number of vessels coming in and out of all the ports in Northern Kyushyu. As main transportations of this area, number of vessels coming into Dokai district (Yahata, Wakamatsu and Tobata), Kokura, Moji and Shimonoseki Ports, were investigated. Fig. 4 shows a relation between

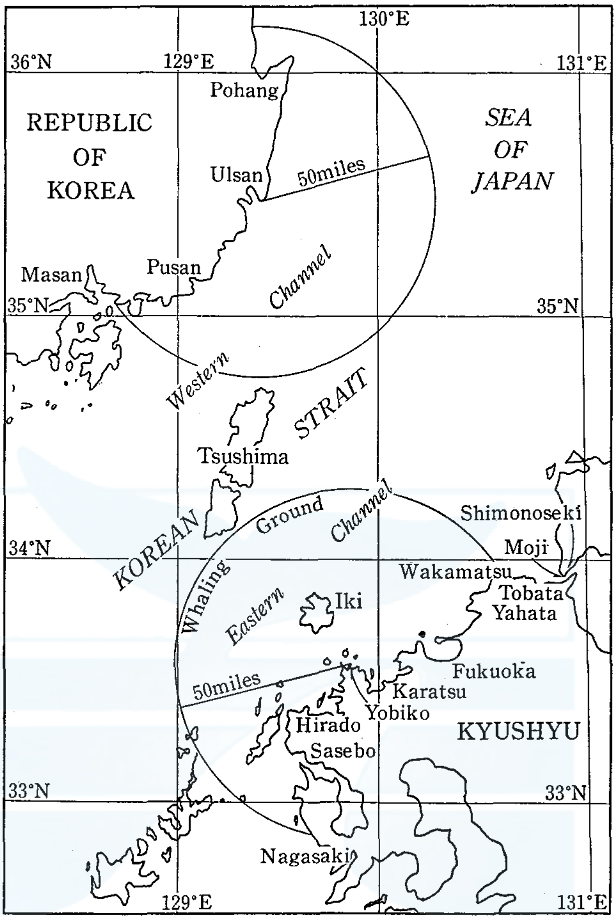

Fig. 3. Yobiko whaling ground and ports of Northern Kyushyu on the coast of Korean Strait.

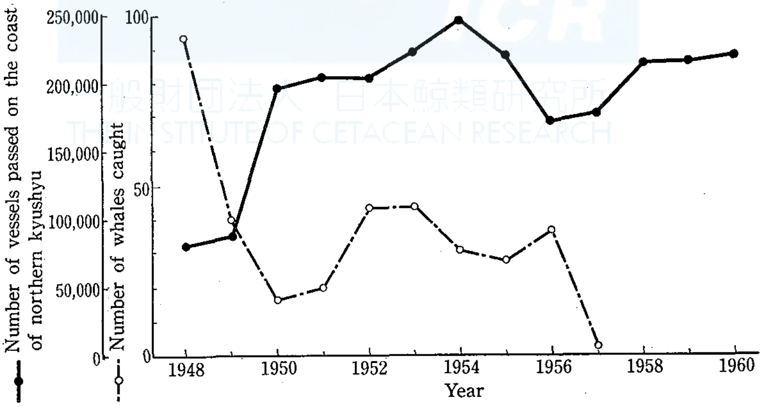

Fig. 4. Relation between the incresing number of vessels and that of the decreasing whales caught in Yobiko whaling ground since 1948 till 1957.

the increasing number of vessels and the decreasing number of minke whales caught in Yobiko whaling ground. Similar number to that in Tokyo Bay, 250,000 vessels came to those ports in the most prosperous years. In Fig. 4, actual numbers of whales caught are used, not averages of every three years. So, the curves are not so smooth as those in Fig. 2, but the tendency of traffic and catch number might be recognized.

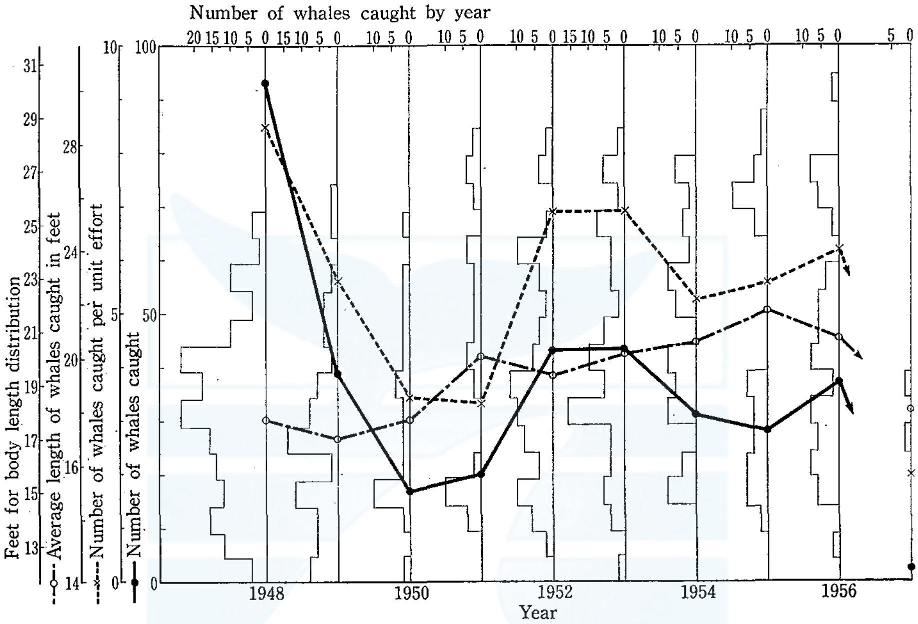

Fig. 5. Annual number of whales caught, its body length distribution and average body length with CPUE in Yobiko landstation during the period 1948–1957.

We would like to discuss at this point whether that decline of catch in Yobiko was caused by whaling damage on the minke whale stock. Fig. 5 shows the annual size distribution, average body length and number of whales caught with CPUE since 1948 till 1957. The data of whales caught were exclusively body length without physiological records such as maturity or pregnancy. The number of whales caught were rather small in most years, especially in 1957. Very little can be presumed only from size distribution of each year. However, if the size distribution of all whales caught during the ten years period is observed collectively, whales can be divided into groups. Each peaks of size distribution appears at the body lengths 15, 18–20 and 23–24 feet respectively. These peaks are considered to be groups of yearings, the one to two years old and the older than three years. At that time, minke whale whaling in Japan was not restricted by regulations. So, females and calves were caught together. But in later years of the period, number of yearings became smaller: disturbed frequently by increasing maritime transportations, mothers with calves must have detoured the coast of northern Kyushyu.

Record in 1947 is unknown. In 1948, 93 individuals were caught. Then Korean War broke out in 1950. Number of vessels coming to Northern Kyushyu in 1950 was triple times as much as the number in 1949. The least catch in 1950 was not because exclusively of disturbing maritime traffic, but also of various industrial reasons, including munitional boom. In other words, wages from such industries became more profittable than those from whaling, so whalers switched to other employments in those years. Conditions were similar in 1951 and 1952. In 1953, the war stopped and the munitional boom gradually ceased. However, number of vessels showed little decrease. Whalers of the ground saw unstable status of their whaling desperately and wanted to move to some other district. One catcher boat moved to Ushizu, Ishikawa Pref. in 1950 and caught five minke whales (average body length of them was 20 feet), then other two followed in 1951 and caught 25 individuals (average body length of them was 23.3 feet). In 1956, one whaling boat of Yobiko made an expedition to southern islands of Kyushyu as far as Naze, Amami-Oshima and caught 19 individuals (average body length of them was 25.0 feet). Finally whalers of Yobiko whaling ground gave up the entire ground and all except one moved to the far northern district, Wakasa Bay, Fukui Pref. And though remained one worked, caught only two individuals in the following year. Then Yobiko whaling was ceased at all.

TABLE 2. ANNUAL NUMBER OF CATCHER-BOATS, WHALES CAUGHT WITH AVERAGE BODY LENGTH AND CPUE IN YOBIKO WHALING GROUND

Year	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957
Number of catchers	10	7	5	5	6	6	6	5	6	1
Number of whales caught	93	39	17	20	43	43	31	28	37	2
Average body length in feet	17.8	17.0	17.7	20.0	19.3	20.1	20.5	21.7	20.7	18.0
CPUE	8.5	5.6	3.4	4.0	7.2	7.2	5.2	5.6	6.2	2.0

Again, reason of the catch decline can not be considered as damages caused by whaling to the whale stock. As it can be understood from Fig. 5, though CPUE has been flactuated by the years, as a whole, it was in an up surging, but average body length of the population showed no sign of decrease, or even showed increase. We would like to introduce here a letter from Mr. S. L. Bowen addressed to the senior auther written on 18th April, 1972. He was then an army soldier dispatched to Korea. He had had interest in the gray whale and its status and conditions. He told Nishiwaki that in 1970, total number of whales caught from the whaling ground adjacent to Ulsan was 740, among them, 715 were minke whales. It may be safe to presume that the stock of minke whales there was identical population to the Yobiko stock. Distance between the two grounds is little more than 100 miles. If the number which Mr. Bowen indicated, is right, cause of Yobiko whaling decline (they caught, at most, 100 a year since 1948 till 1957) was not by damages on the minke whale stock by whaling activities. At present, minke whale whaling can not be operated in the Yobiko whaling ground, eastern channel of the Korean Strait, but is still prosperous in the Ulsan whaling ground, the western channel of the Korean Strait. Considered the experience in Yobiko whaling ground, one can hardly deny influences of maritime traffic to the minke whales. As great number of vessels which belonged or connected to the Northern Kyushyu Industrial Zone, in which Moji, Tobata, Yahata, Karatsu, Sasebo and Nagasaki, biggest ports of Japan, are included, are coming in and going out and the number is still increasing, various other species of marine mammals may be troubled similarly by the busy traffic.

CONCLUSION

Naturally, there might have been other additional factors of influences which affected the whale populations to some extent. But, at least, result of the present investigation shows apparent disturbances by ships and boats to the migration routes of Baird's beaked whales in Boso whaling ground and minke whales in Yobiko whaling ground.

The result of this investigation would be a warning to the countless activities by men, which disturb or expel wild animals from natural inhabiting grounds and migration routes everywhere in our environment. As well as aerial and land transportations, maritime traffic is another environmental problem. Damages by whaling has been so controvercial in recent years, but those by maritime traffic tends to be overlooked. From the view point of ecosystem, maritime influences to animals are not small, but little countermeasures to those have been taken up till now.

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ON THE FORMATION AND REGRESSION OF CORPUS LUTEUM IN THE NORTHERN FUR SEAL OVARIES

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ABSTRACT

Corpus luteum and the process of its formation in fur seal ovary, collected around the Robben Island in the Okhotsk Sea, were studied. The regressive phases of follicle and courpus luteum were examined histologically. There are two kinds of corpus luteum, one is formed inside the vesicular follicle after ovulation, the other is formed outside the follicle without ovulation. The former is the true corpus luteum and the latter is the accessory corpus luteum or corpus atreticum. The function of corpus luteum graviditatis degenerates in the last stage of pregnancy. Corpus albicans originated from the true corpus luteum is distinguished from the corpus atreticum clearly. The former exists for about two years in the ovary and then disappears, but the latter vanishes shortly.

INTRODUCTION

There are many informations about the mammalian ovaries including human race. Since the fur seal is a kind of marine mammal but goes ashore during some months once a year for reproduction, its sexual cycle, age and growth were made clear by various authors. But microanatomical studies of the reproductive tracts are still rather scanty. Craig (1964), Enders *et al.* (1946), and Pearson and Enders (1951) report ovarian cycle for seals taken in the eastern Pacific and on the Pribilof Islands respectively. However, there is no report on the microanalisis of reproductive organs on the Robben and Commander fur seals.

In the field observation of fur seals for the purpose of the stock assessment, numbers of corpus luteum and corpus albicans are counted, but the disappearing process of corpus luteum and corpus albicans can not be followed sufficiently by this method and further the corpus albicans can not be identified from corpus atreticum by macroscopical observation. The disappearing processes of corpus luteum and corpus albicans were not treated sufficiently in the aforesaid reports.

We report in this paper on the corporal cycle in the fur seal ovaries taken in the seas around Robben Island between July and October 1975.

Sci. Rep. Whales Res. Inst.,
No. 29, 1977, 121–128.

MATERIAL AND METHOD

The Fur Seal Section of the Far Seas Fisheries Research Laboratory, Japanese Fisheries Agency, took fur seals in the seas around Robben Island in 1975 for the purpose of stock assessment and their reproductive tracts were preserved in 10% formalin after field biological investigation. We have sampled randomly 117 pairs of ovaries from these, which consisted of ovaries from 11 immature females, 11 ovulated females for the first time this year, 29 nonpregnant females but ovulated in preceding breeding season, 23 ovulated females this year but non-ovulated in preceding breeding season, and 43 pregnant females. These ovaries were weighed their weight, then sliced to the thickness of about 2 mm, and measured the diameter of corpus luteum in three dimensions, counted the number of corpus albicans, and measured the diameter of the largest Graafian folicle. And then all ovaries were further sliced into thin sections, embedded in paraffin, and these sections were stained by compound stain method of Mayer's haematoxylin and eosin, and then observed. Age of these fur seals was determined by annual rings in the upper and lower cuspids.

OBSERVATION AND RESULT

(1) *Regression of follicle*

Section of the pup ovary of about three months after birth is indicated in Plate I-1 which contains many small follicles. Very few follicles among them develop to large size and finally ovulated, but many other follicles would be regressed, because it can be seen that there are many corpora atretica and follicles in process of degeneration and contraction. Plate I-2 shows ovary of 2 years of age, immature female, which contains many large follicles and this specimen was collected in the middle of October. In this investigation mature females had no large follicle in the ovaries at this time of the season, owing to their functional corpus luteum, but in the ovaries of immature females, a number of comparatively large follicles are present, due to the fact that they have no functional corpus. Plate I-3 shows matured ovary of 14 years of age. A functional corpus luteum caused by ovulation of this reproductive season exist in this section. Since this specimen was collected towards the end of July, it is not clear whether this is corpus luteum graviditatis or corpus luteum of without gravidity. (Craig, 1964; Enders *et al.*, 1946; Pearson and Enders, 1951). In addition there are corpus albicans and corpora atretica resulted from Graafian follicles in this figure.

Enlarged follicle figure in the process of regression existed in pup ovary of Plate I-1 is shown in Plate I-4. Oocyte is actualized in this figure but stratum granulosum begins to degenerate, and in antrum folliculi, a sort of phagocyte which is usefull for exhaustion are observed in abundance, and the basement membrane transformed to glassy membrane by distortion and increase of thickness. The former term of vesicular follicle in the progress of development which is similar to that of the other mammals is shown in Plate II-1. Contraction of the vesicular follicle, the stratum granulosum degeneration in the first place, and then in oocyte are shown in Plate II-2. In corpus atreticum distortion has occurred and thickened glassy membrane, and in Plate II-3, there are no oocyte and stratum granulosum. This corpus atreticum existed abundantly in ovary and it can be distinguished from corpus albicans resulted from corpus luteum distinctly and it seems that these corpora atretica vanishes rapidly.

The figure of large vesicular follicle which contracted already is shown in Plate II-4. The glassy membrane in this figure thicken increasingly than the former, but it is the same in fundamental structure as corpus atreticum.

(2) *Corpus luteum and its degeneration*

The aspect just ruptured to release an ovum from a ripened vesicular follicle is shown in Plate III-1. In this figure, liquor folliculi and blood are still exist in antrum folliculi, stratum granulosum along interna of theca folliculi increases the thickness exceedingly and follicular epithelial cells formed stratum granulosum begin to expand and change to lutein cell in the enlarged figure. It is thought that fur seal corpus luteum is originated mainly from the cells of stratum granulosum and not from theca interna of folliculi.

TABLE 1. CORPUS LUTEUM DIAMETERS IN mm
AFTER OVULATION BY MONTHS

	Vertical diameter	Lateral diameter	Height
July	8.0	7.4	8.5
August	10.0	8.7	9.7
September	11.3	10.4	10.5
October	14.0	12.7	13.5

The corpus luteum resulted from an ovulation about two months before is shown in Plate III-2, a specimen from mid September. In the fur seal corpus luteum is contained within the ovary like in many other mammals, though in whales it is usually protruded from the ovary. Other corpus luteum constituted around the outside of vesicular follicle, beside formal corpus luteum, is observed in Plate III-2. Such corpus luteum is not rare in fur seal ovary, like in ovaries of whales (Harrison *et al.* 1972). It seems that the lutein cells of such corpus luteum are originated from theca follicular cells and perform the same function as formal one besides suppressing the development of its inside follicle. The lutein cells in formal corpus luteum resulted from an ovulation of about three months before are enlarged in Plate III-3, a specimen from mid October. This figure shows the most active appearance of lutein cells and there are many secretions in the protoplasm of these cells and around them. The lutein cells in corpus luteum formed around vesicular follicle show the same histological appearance in this season too.

In Table 1 corpus luteum measurements in three dimensions are arranged in the order from July to October. The corpus luteum which was formed in early

July by ovulation increases its size during the progress of month and increases its function gradually, as shown in Table 1 clearly. And no difference in the size of corpus luteum by ages, from three to twenty years, is noted.

After fur seals went ashore for reproduction and delivered a calf, the ovulation is taken place within one week. Consequently it might be necessary that the regression of the lutein cells should begin towards the latter of the pregnancy. Craig (1964) describes that the corpus luteum graviditatis of the fur seal in the eastern Pacific is functional until February and begins to degenerate after that. His description agrees with ours. The histological figure of corpus luteum graviditatis of pregnant animal prior to delivery caught on 10 July is indicated in Plate III-4. In this figure lutein cells are almost degraded or fallen off and remains are small and not in complete phase. It is distinct that the aspect of this corpus luteum graviditatis does not perform the secretion, unlikely from the lutein cells in Plate III-3, and has the connective tissue penetrating into the structure of corpus luteum arborescently. As we have only specimens for four months, from July to October, we can not conclude definitly about the cycle of corpus luteum, but it is thought that the same pattern of corporal cycle of Robben seal, as reported by Craig (1964), would be followed by the eastern Pacific stock of the fur seal.

Table 2 shows the process of regression of the corpus luteum graviditatis, in diameters in three dimensions, from just before delivery to after birth. In spite of the unfunctional lutein cells, the size of this corpus luteum is larger than that shown in Table 1, so it is concluded that the corpus luteum enlarges continuously since ovulation. Fur seal fertilized ovum remains free in the lumen of uterine horns and does not implant for about four months and placentation is established after implantation (Craig, 1964; Enders *et al.*, 1946; Pearson and Enders, 1951). It seems possible that this phenomenon occurs not only in fur seal but also in all Pinniped animals (Matthews and Harrison, 1949). The corpus luteum without pregnancy, or in the case of unfertilization or unimplantation it does not contract rapidly, unlikely to whales, because it has enough time for contraction until next reproductive season and contractive process is thought to be same to that of corpus luteum graviditatis. Pearson and Enders (1951) describes that the fur seal corpus luteum which has not accompanied by a pregnancy follows even in the latter part of March same phase of corpus luteum graviditatis and this is similar to our result. The corpus albicans originated from corpus luteum without pregnancy in the

TABLE 2. THE AVERAGE DIAMETER OF CORPUS LUTEUM IN mm BEFORE AND AFTER PARTURITION

		Vertical diameter	Lateral diameter	Height
Corpus luteum just before parturition		18.9	14.2	15.5
Corpus luteum after parturition	July	11.2	10.4	13.0
(corpus albicans)	August	10.6	8.7	10.9
	September	8.7	8.5	8.9
	October	8.6	7.3	8.5

preceding breeding season, and from an animal caught in 6 August, is shown in Plate IV-2. The size and the stage of degeneration of this corpus albicans is same to that of Plate IV-1. From Table 2, the corpus luteum graviditatis contracts rapidly just after whelping, but the pace of contraction become slow after that.

The corpus albicans two months later from the parturition is indicated in Plate IV-1, in which no lutein cell is observed naturally. And this is a typical corpus albicans originated from the true corpus luteum and it shows quite different phase, compared with the accessory corpus luteum or corpus atreticum originated from vesicular follicle. Laws (1958) discusses about the differences between the corpus albicans resulted from corpus luteum graviditatis and that without pregnancy in whales, but in the fur seal, there is no difference between both corpora albicantia from the starting points of ovulations.

(3) *Corpus albicans and its degeneration*

The corpus albicans disappears within a comparatively short span of time in most mammals, but in whales the corpus albicans persists in the ovaries throughout the life. This is thought to be based on the fact that their ovaries are large enough for admiting the persistence of all corpora albicantia, but in the fur seal, the ovary is small and has no core in the center of corpus albicans, unlikely to whales. Accordingly, the disappearing period of corpus albicans is not short in the fur seal, compared with other mammals. It does not remain, however, in the ovary throughout the life.

A contracted figure of corpus albicans after one year since parturition is shown in Plate IV-3. Its surrounding parts are torn to pieces and has disappeared and became smaller. There are many ovaries in our specimens which have such a corpus albicans, collected from animals one year after parturition, in which twenty percent have vanished within one year, and this rate is higher in younger animals than older. Plate IV-4 shows corpus albicans of an animal taken two years after parturition. Such an old corpus albicans which existed such long time is very seldom in the fur seal. According to our investigations, it is concluded that in the fur seal corpus albicans vanishes within three years after ovulation, though there are some individual variations. That is different from the finding of Pearson and Enders (1951) who describe that it disappears before the next ovulation from the same ovary, which means that the corpus albicans disappears within one year after parturition.

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EXPLANATION OF PLATES

PLATE I

Fig. 1. ×11.4, Histological section of fur seal pup ovary after three months from birth. Caught 11 October, 1975.

Fig. 2. ×5.7, Histological section of immature fur seal ovary, two years old. Caught 13 October, 1975.

Fig. 3. ×5.7, Histological section of mature fur seal ovary, 14 years old. Caught 31 July, 1975. It contains one functional corpus luteum resulted from this ovulation, one corpus albicans originated from corpus luteum and eight corpora atretica originated from vesicular follicle.

Fig. 4. ×380, Histological figure of small follicle in the progress of degeneration. The same ovary of Fig. 1.

PLATE II

Fig. 1. ×380, Early stage of vesicular follicle in the process of development, three years old. Caught 3 September, 1975.

Fig. 2. ×155, Degrading vesicular follicle, five years old. Caught 15 July, 1975. There is no stratum granulosum already and oocyte is degenerating.

Fig. 3. ×155, Corpus atreticum originated from vesicular follicle, from the same specimen shown in Fig. 2.

Fig. 4. ×51, Corpus atreticum originated from large vesicular follicle, eighteen years old. Caught 6 August, 1975.

PLATE III

Fig. 1. ×11.4, Ovulated follicle, four years old. Caught 29 July, 1975.

Fig. 2. ×5.7, Mature ovary, nineteen years old. Caught 14 September, 1975. In this section there are two kinds of corpus luteum, one is the formal by ovulation, the other is formed around the outside of vesicular follicle.

Fig. 3. ×760, Functional lutein cells, fourteen years old. Caught 11 October, 1975.

Fig. 4. ×155, Histological figure of corpus luteum graviditatis just before delivery. Fourteen years old. Caught 10 July, 1975. It is in the process of degeneration.

PLATE IV

Fig. 1. ×51, Corpus albicans after about two months from parturition. Seven years old. Caught 13 September, 1975.

Fig. 2. ×51, Corpus albicans not accompanied by pregnancy passed about thirteen months after ovulation. Eighteen years old. Caught 6 August, 1975.

Fig. 3. ×51, Corpus albicans originated from corpus luteum graviditatis of about fourteen months after parturition. Six years old. Caught 28 September, 1975.

Fig. 4. ×51, Corpus albicans of about two years after parturition. Fifteen years old. Caught 3 July, 1975.

EXPLANATION OF SYMBOLS IN PLATES

AF	Antrum folliculi
BM	Basement membrane
CA	Corpus albicans
CAT	Corpus atreticum
CLF	Corpus luteum formed around the follicle
CO	Cumulus oophorus
FC	Functional corpus luteum
GM	Glassy membrane
LC	Lutein cell
LF	Liquor folliculi
N	Nucleus
O	Oocyte
P	Protoplasm
PH	Phagocyte
S	Secretion
SG	Stratum granulosum
TA	Tunica albuginea
TF	Theca folliculi
VF	Vesicular follicle
ZP	Zona pellucida

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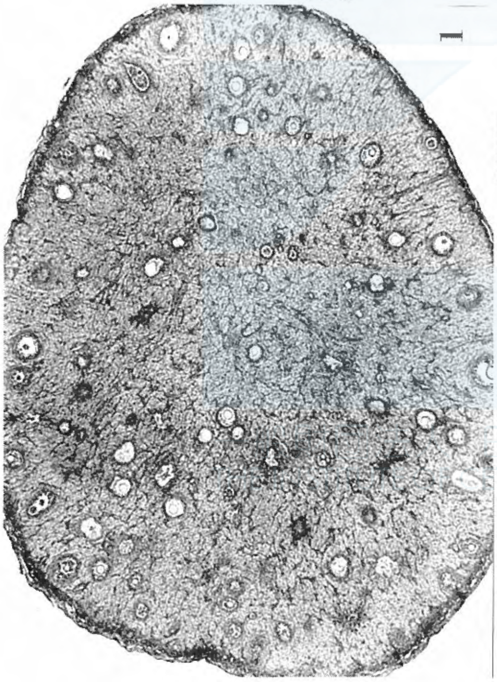

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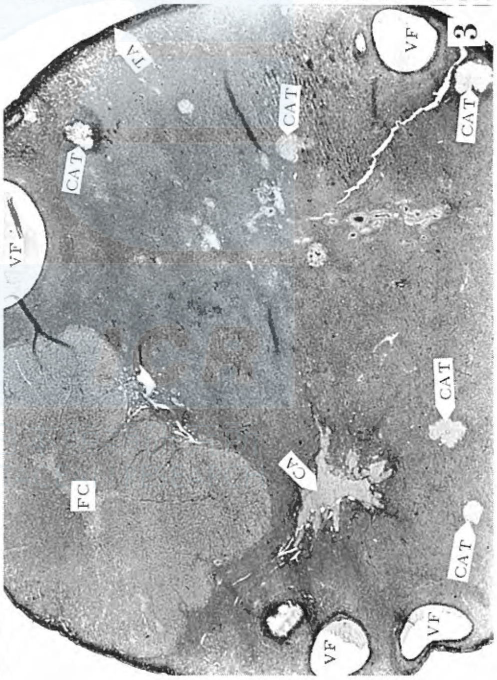

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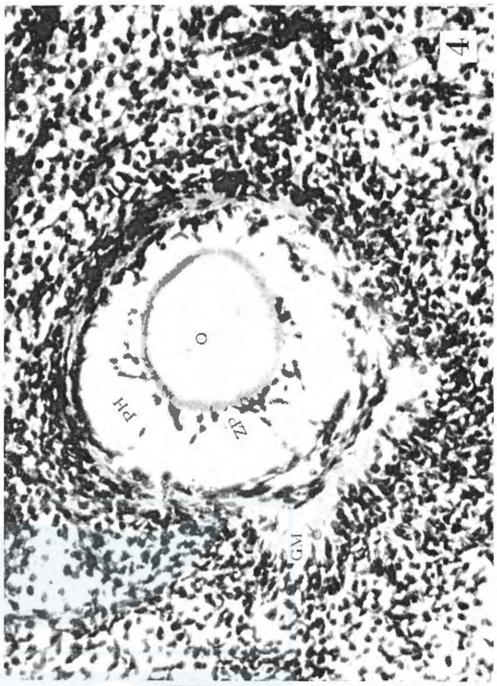

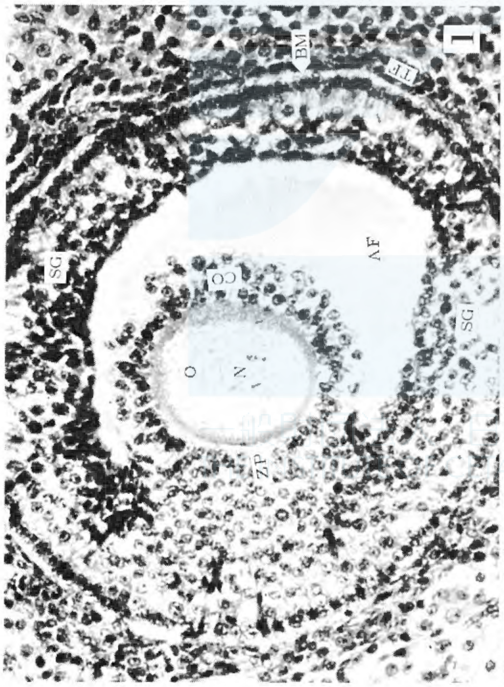
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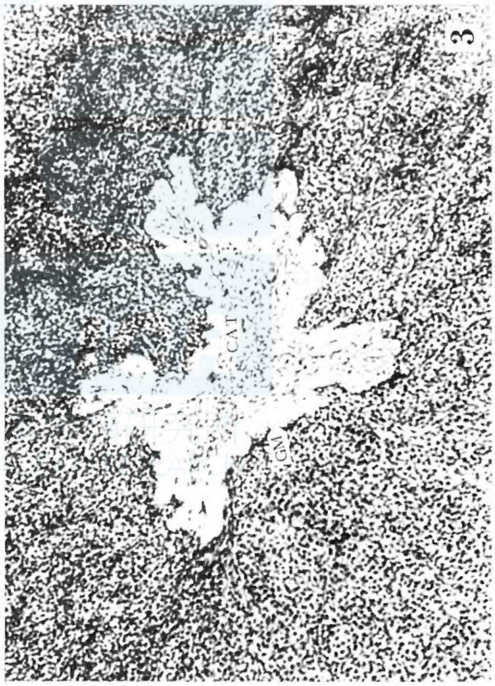
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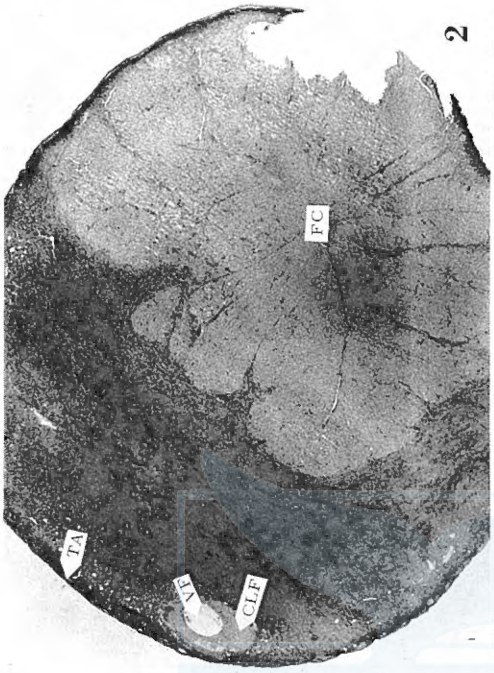

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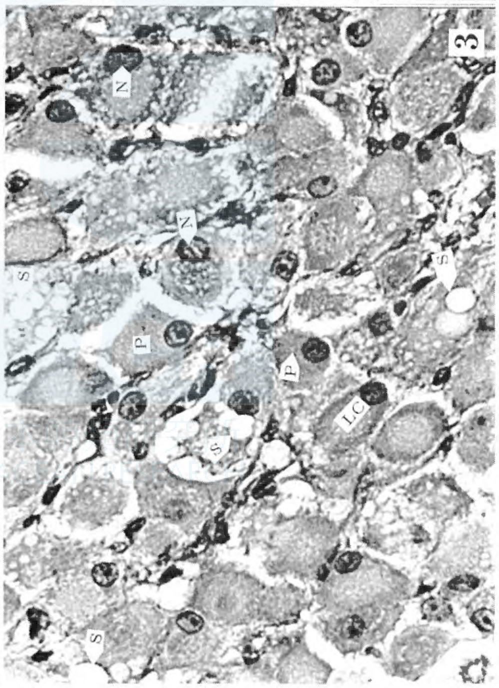

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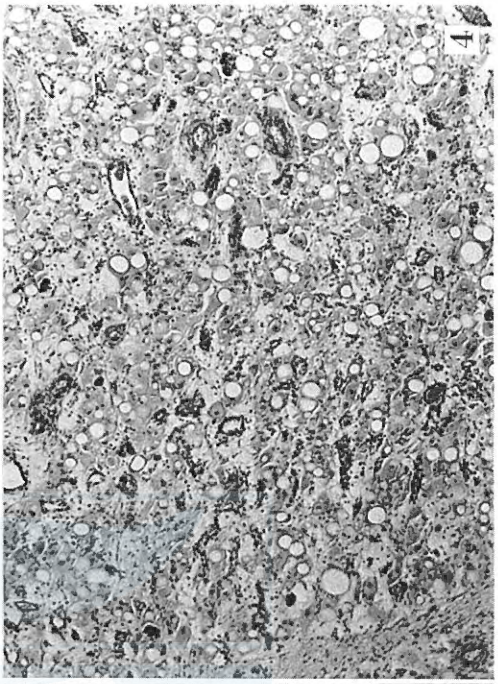


1
CA


2
CA


3
CA


4
CA
CA

A NOTE ON THE AIR-SAC OF RIBBON SEAL

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ABSTRACT

Investigations on the air-sac of seals were carried out by us, using twelve males and three females of the ribbon seal (*Histriophoca fasciata* ZIMMERMANN) and two males of the Okhotsk harvor seal (*Phoca vitulina* LINNAEUS), which were caught off Rausu of the Shiretoko Peninsula, Hokkaido, Japan, in the middle of March and April, 1966. In the rear part of the trachea of the ribbon seal, the cartilage rings are broken to form a slit, 25–46 mm long, which leads to an air-sac on the outer side. The two ends of the broken rings form long and slender valvular projections. The fore part of the air-sac is developed beneath the sternomastoid muscle, and the rear part is between the pectoralis superfacies and the costae. In adult males, the sac is large, but it is smaller in young individuals. Young females have a pair of valvular projections but no air-sac. Even in adult females, development of the air-sac is very poor or entirely absent. The role played by the air-sac is not known. The cartilage rings of harbor seal are broken at the rear part of the trachea, but the break does not form a slit and hence air-sac is not developed.

INTRODUCTION

Studies on the morphology and ecology of the ribbon seal, *Histriophoca fasciata* ZIMMERMANN, have been relatively few, and even the dental formula of this animal had been little known until recently (SCHEFFER, 1960).

The present writers have observed that the ribbon seal has an air-sac branching out of the trachea. An outline of the observation is reported here.

Valuable specimens of the ribbon seal for this study were offered by Mr. Ichimatsu Nedefuji, Misaki-machi, Rausu-cho, Menashi-gun, Hokkaido, who also took care of the lodging for the writers during the period of investigation. We wish herewith to express their sincere gratitude to Mr. Nedefuji. They are also indebted to many persons for helpful suggestions.

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DISCOVERY OF AIR-SAC

Two of us, Wada and Hasegawa, visited Rausu-cho from March 15 to 17, 1966 for the purpose of investigating seals. On March 15, when a male ribbon seal, captured off Rausu by Mr. Nedefuji, was being dissected, Wada noticed a bladder-like membranous sac in the thorax, and surmised if it might be an air-sac. On the following day, four more males and one female were captured. Hasegawa examined them and noted that the sac seemed to occur only in males, its position being located always on the right side of the body, and that the size of the sac was considerably variable according to individuals. However, he could not get sufficient data on this subject as the time was limited.

Later, from April 12 to 14, Abe visited Rausu and made more precise observation of seven males and two females of *H. fasciata* and two males of *Phoca vitulina* LINNAEUS (Okhotsk harbor seal). He examined in particular the size and position of the air-sac and the difference between male and female, as well as the relationship between the length of the body and the development of the air-sac. Later, he cut off the tracheae attached with the sac, preserved them in alcohol, and brought them back to the laboratory for further observation of details.

POSITION AND STRUCTURE OF AIR-SAC

1) *Male*

In the first half of the trachea, the tracheal cartilage forms complete rings without any break, whereas in the latter half, the cartilage rings are broken on the dorsal side of the trachea as illustrated in Fig. 2, III-IX. On the outer side of the both ends of the broken rings, there is a more or less membranous wall, which is developed particularly on the right side, so as to form an air-sac (Fig. 1, I-V; Fig. 2, V-VIII). Accordingly, the break in the rings serves as a passage to the air-sac. This slitlike passage starts at about 50–60 mm from the diverging point of the bronchi and extends forward (toward the neck) (see Pls. 1 and 2). In general, the slit becomes longer as the animal grows up (Table 1).

The sac occurs as a bulge of the relatively thick muscular membrane on the right outer side of the slit in the early stages of the development (Fig. 1, I). The sac grows larger, decreasing the thickness of membrane, and extends forward until it reaches the neck of the animal; it also stretches rearward (toward the hind legs) and, when fully developed, it becomes to cover the whole right ribs (Pl. 1, II; Fig. 1, V). As the sac grows larger, the membrane becomes thinner and translucent. Also, the larger the sac, the better is its rearward development. For example, in Specimen No. 6 the length between the foremost end of the sac and the starting point of the slit is 120 mm, and from there to the rear end of the sac it is 70 mm long. In Specimen No. 7 the measurement by the same method reveals that the sac is 150 mm long in its fore part and 230 mm long in the rear part.

The fore part extends forward, passing through the underside of the sternomastoid muscle. If the sac is small it is concealed by the muscle, but when it

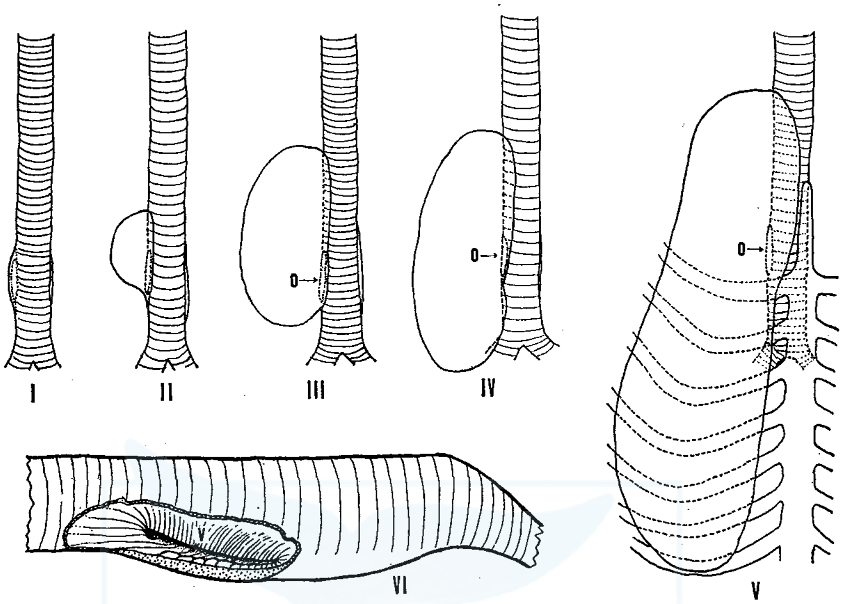

Fig. 1. Developmental precesses of male air-sac and its opening part on the trachea of the ribbon seal. I : No. 1 specimen in Table 1, II : No. 3, III : No. 5, IV : No. 6, V : No. 7, " 0 " in III to V indicates the opening of the sac. VI : rear half of trachea on the right side (No. 5 specimen), showing the opening and the valve (V) of the air sac which in this figure the membraneous sac has been removed. Lower side in the figure VI is the dorsal side, the right tapering part is the bronchus.

grows larger its fore end appears ahead of the muscle. The rear part of the sac is found between the pectoralis superfacies and the costae. Therefore, the existence of the sac would be hardly noticed when the seal is only skinned.

On the right and left sides of the slit, part of the trachea forms a long and narrow valve, with its rear end starting from the diverging point of the bronchi. The valve has a slender crescent shape, being widest at the middle. The right valve is larger than the left in both length and width. The distance between the two valves is largest at the slit (Table 1; Fig. 2 IX). The left valve does not seem to be functional at all, but the right valve, which is widest at the slit, is considered to conduct the important role for taking the air in and out of the sac (Pl, 1, II and III). To clarify the function of these valves, further study is required from the standpoint of histology and ecology.

2) *Female*

The fundamental features of the sac are identical with those of male. A valvular projection is observed at the dorsal inner side of the rear part of the trachea. However, development of a sac is poor in female, and even in a fully grown stage of the animal the sac is of nearly the same size as that of a small male (Pl, 2, IV;

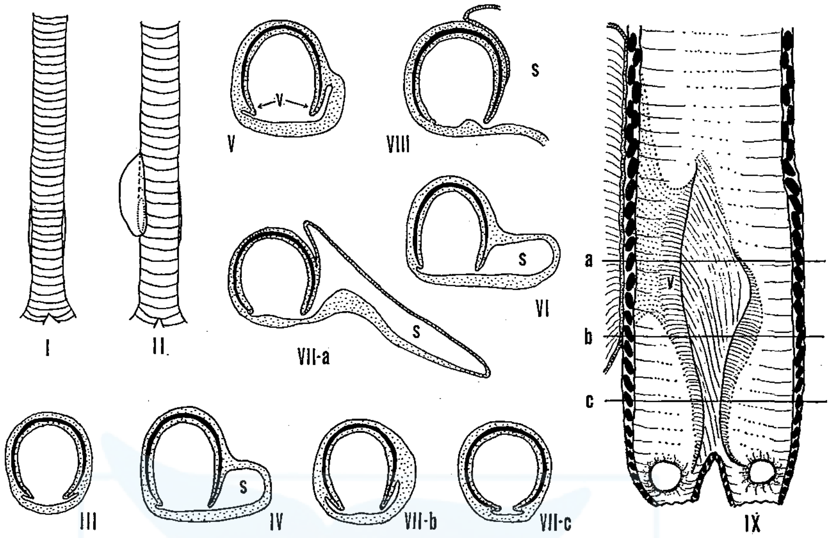

Fig. 2. Developmental processes of air sac of ribbon seals, and cross and longitudinal sections of the sac and trachia. I : No. 10 specimen ; II : No. 11 ; III : cross section at the central part of the valve in No 10 female ; IV, V, VI, VII-a and VIII indicate the cross sections at the central part (" a " line on IX) of valve in specimens 11, 1, 3, 5, 7, respectively ; VII-b and VII-c : cross sections at " b " and " c " lines in IX. Lower side in the figures is the dorsal side of trachea ; V and S : valve and air sac ; IX : longitudinal section showing the dorsal inner side of the opening part of trachea.

TABLE 1. TOTAL LENGTH OF BODY, CONDYLOBASAL LENGTH OF SKULL AND DIMENSION OF AIR-SAC (in mm)

species name				air-sac			right valve		left valve	
specimen's number	sex	total length of body	condylobasal length of skull	length	width	slit length	length	max.-width at non-slitted area	length	max.-width
Histriophoca fasciata Z.										
1	M	1260	—	—	5	—	86	14	82	5
2	M	1230	—	40	15	27	82	9	73	5
3	M	1300	—	55	37	25	92	9	71	4
4	M	1130	177.7	70	35	35	—	11	—	4
5	M	1370	180.7	130	70	40	80	11	68	5
6	M	1360	178.8	190	75	42	—	11	—	4
7	M	1500	201.9	380	110	46	102	13	82	7
8	M	—	—	105	55	—	—	—	—	—
9	M	—	—	430	120	—	—	—	—	—
10	F	1310	178.4	—	—	—	80	8	70	7
11	F	1560	204.6	70	20	40	84	14	80	6
Phoca vitulina L.										
12	M	1450	203.5	—	—	—	24	3	—	—
13	M	1600	222.8	—	—	—	—	—	60	7

— broken and unmeasured.

Fig. 2, I-IV). Hasegawa examined a pregnant individual but could not confirm the existence of the sac. In females, the sac, if any, may not be functional.

COMPARISON WITH OKHOTSK HARBOR SEAL

We dissected two males of Okhotsk harbor seal, which were captured together with the above-mentioned ribbon seals, and examined their trachea for comparison with that of ribbon seals. In that species, too, the cartilage rings are broken in the rear part of the trachea, that is, immediately before the bronchil they diverge. However, the valvular projection is entirely different from that of ribbon seal, as it occurs only on one side. One of the examined specimens had it on the right side (Fig. 3), but the other had it on the left side. Specimen No. 11 is supposedly a relatively large individual, but it had no air-sac nor its trace.

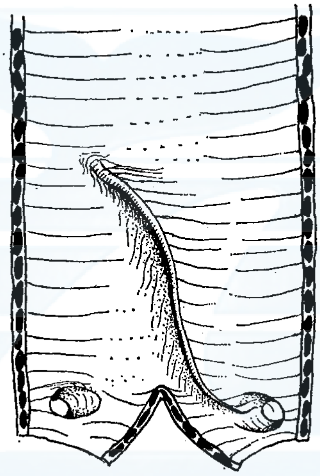

Fig. 3. The longitudinal section of the rear part of trachea of *Phoca vitulina* (adult male).

CONSIDERATION

As to the role played by the sac, we can say nothing more than a conjecture. It is evident, however, that the sac is connected with the trachea through a simple functional valve, and there remains little doubt that the sac serves as an air-sac. The size of the sac differs markedly between male and female, and also varies with the age of individual. These facts may indicate some differences in habit and behavior of individual seals. According to certain hunters, ribbon seals, when chased, would stay under the water for a long time; another hunter, however, says he has experienced no such occasion. Thus, the hunters' comments cannot be relied upon. In fact, the riddle of the sac would remain unsolved until scientific investigations are made on the ecology of ribbon seals.

It is of a special interest that the sac is located on the right side of the body, stretching beneath the sternomastoid muscle or between the pectoralis superfacies and the costae, and that the sac grows larger along with the animal's growth. To give reasonable explanation for these features, anatomical and ecological studies of not only the ribbon seal but also other kinds of seals must be carried out in the future. This is why the present writers refrain possible explanations of the role of the sac.

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* We have found recently that SLEPTSOV'S paper (*Zool. Zhurn.* 19(3): 379-385, 1940) had described the outline of the air-sac of this seal.

EXPLANATION OF PLATES

PLATE I

I: Sac of young male (8 in Table 1). IIa and IIb: Sac of adult male (9 in Table 1). Notice the valve closed (a) and opened (b).

PLATE II

Development of male sac (I-III) and primitive small sac of an adult female (IV). I-IV show those of specimens 3, 5, 7, respectively. Sacs of II to IV have been dissected to show the inside and the opening.

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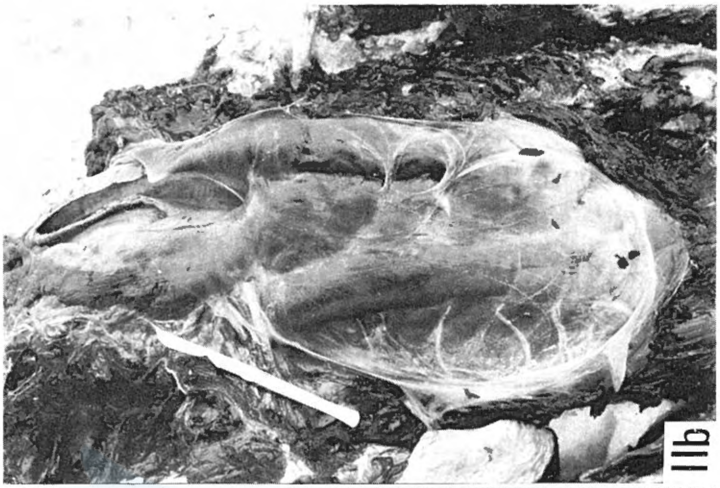
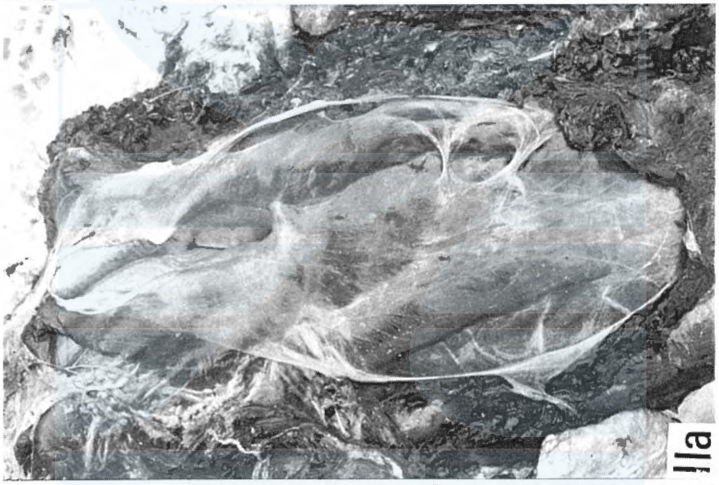


IIb



IIa

I


I


II


III


IV

ON THE NORTHERN EXTREME OF THE PACK-ICE EDGE OBSERVED BY WHALING VESSELS IN THE SUMMER OF THE ANTARCTIC SEASONS 1957/58–1962/63

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During the cruise of exploratory fishing and scouting for sei whales by the freezer, Eihō Maru of Hōkoku Suisan K.K. in 1971/72 Antarctic season, one of the authors (A.K.) got acquaintance with Teruhiko Furuno, skipper of one of the whale catchers belonging to Nippon Suisan K.K. that has been sending a couple of whaling fleets to the Antarctic for many years since 1946. Furuno, one of present authors is a well experienced captain in the Antarctic whaling operation, and is very skillful as the skipper of scouting boat. While we had been on high seas in the Southern Ocean, Furuno kindly permitted me to see and reproduce his important data on the northern extreme of the drifting pack-ice which have been observed during the whaling seasons in some Antarctic regions where the whaling has been most intensively conducted through the past several seasons. The present material is solely based on the data recorded by Furuno.

Since its re-establishment of the pelagic whaling operation to the Antarctic Ocean in 1946/47 season onward, Japan has successively sent thirty-one times of whaling expeditions to date. Each expedition during the seasons of 1957/58 to 1962/63 was operated by using six to seven mother ships, each of which usually accompanied about nine to ten catcher boats. In the whaling grounds those catcher boats are generally dispersed widely over the region to be harvested in order to locate the best place as the whaling ground. They scout about the region by looking for the school of whales, and they also try to locate the position of the pack-ice edge as much as possible along the steaming course since it is one of the most important sea conditions for the stable whaling operation.

It may be easy to suppose that each whaling company keeps such kind of data under their control, and usually those data are placed beyond the public use by reason of confidential material only be opened within the companies. Under these circumstances the figures shown in this report are considered one of those ‘ exhumed ’ material showing the location of northernmost extreme of retreating pack-ice during the austral summer. The figures are based on day-by-day reports exchanged between whale catchers worked out for the corresponding seasons. Although the behaviour of the pack-ice in the high Antarctic Ocean is observed rather

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Sci. Rep. Whales Res. Inst.,
No. 29, 1977, 137–141.

easily at present by using the artificial satellite systems, the material provided in this report may be of interests for many purposes as the evidence of past years.

Although the material provides only a fraction of knowledge on the movement of pack-ice in time and space, one of distinctions be noted may be found in their simultaneousness in obtaining the positions of the pack-ice at the different localities, *i.e.*, they were located within a relatively short intervals of the days, and this would make ones enable to estimate how fast the pack-ice as indicated by the location of northernmost extreme shifts back and forth. Still more, the material would be helpful for estimating the area of ice coverage as to the environmental conditions for the marine life in the regions such as the figures given by Mackintosh (1970). Apart from these the present data may provide a reference in checking the monthly mean position of the pack-ice edge that was reported previously (e.g. Mackintosh

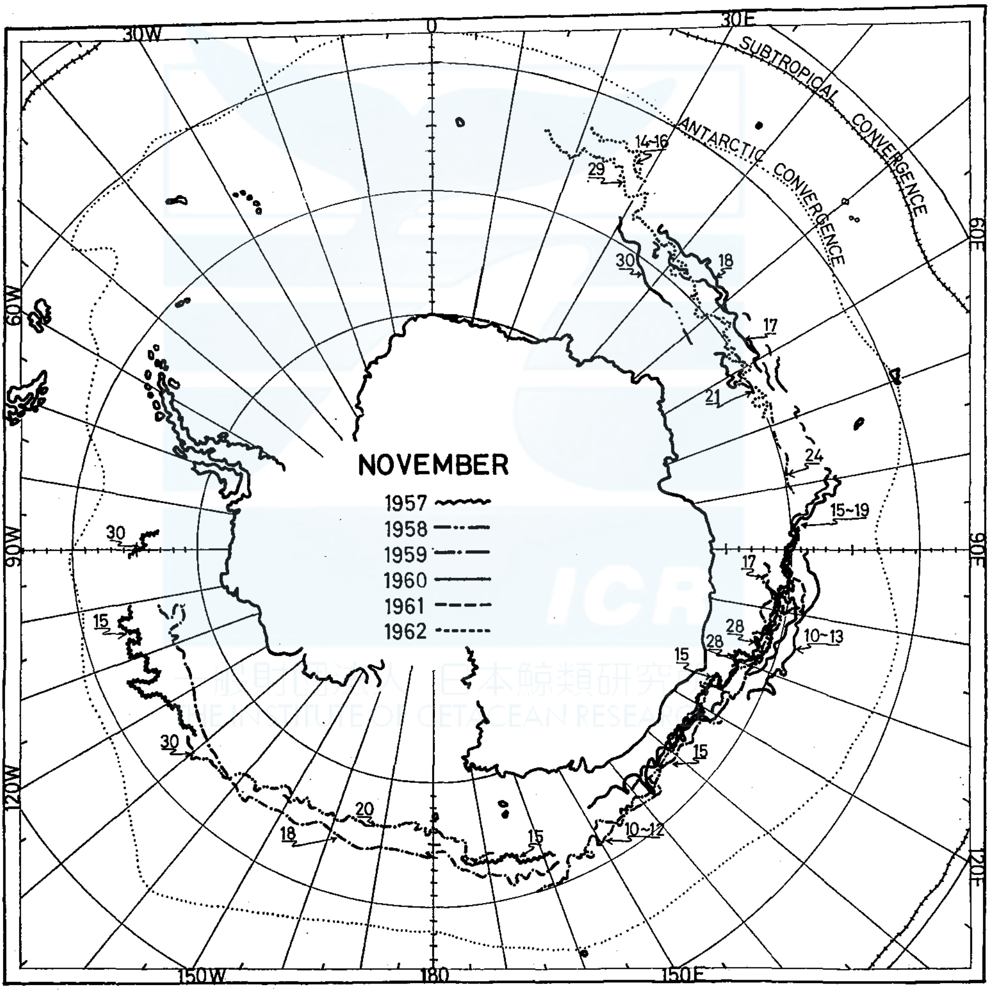

Fig. 1. Northern extreme of the pack-ice edge in November. Numeral in the figure denotes the date of observations.

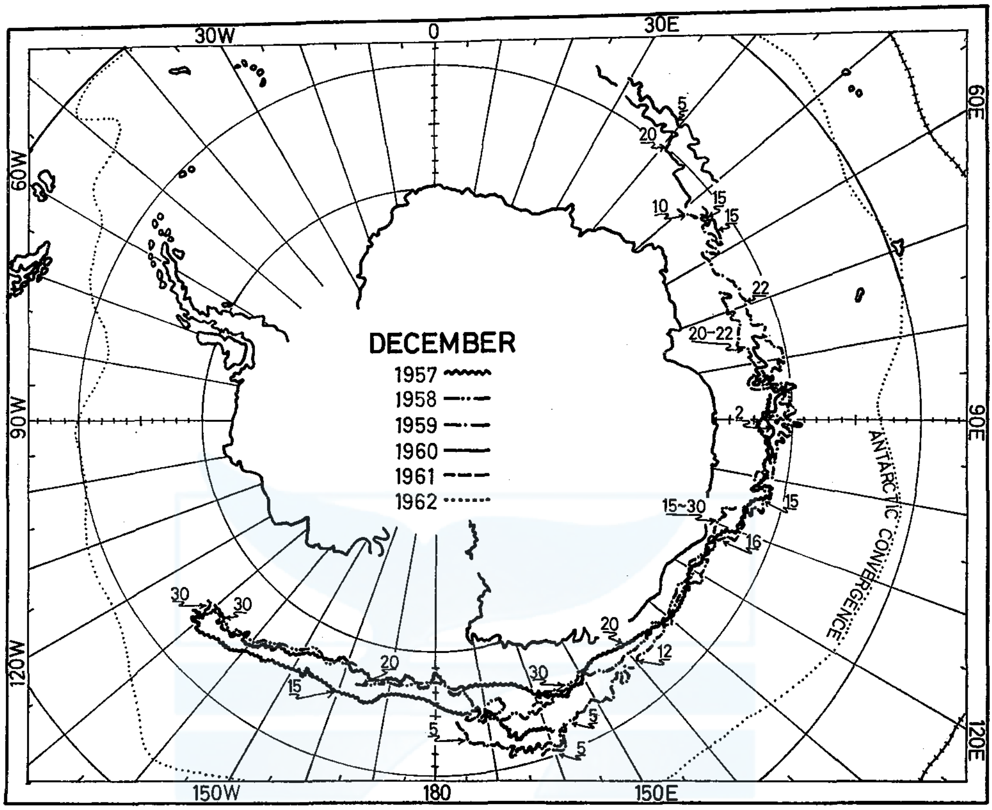

Fig. 2. Northern extreme of the pack-ice edge in December. Numeral in the figure denotes the date of observations.

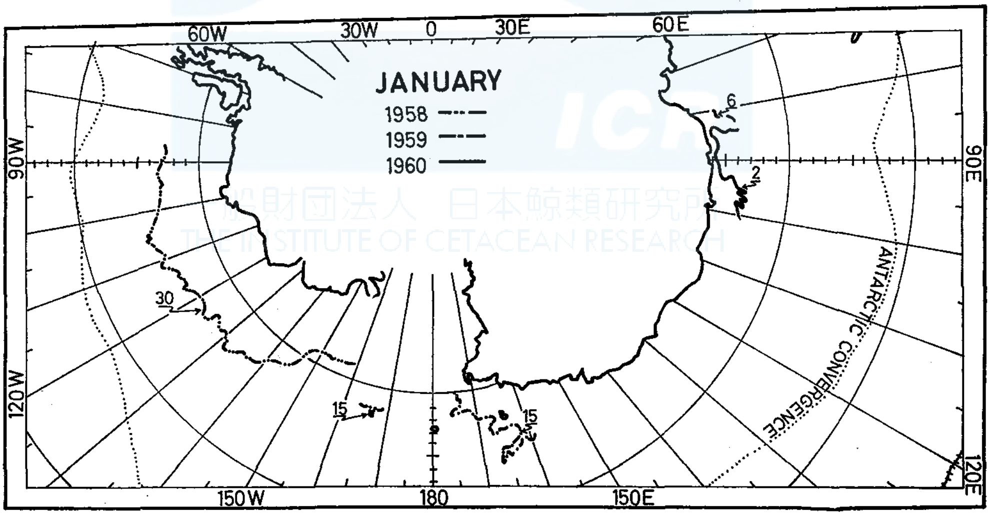

Fig. 3. Northern extreme of the pack-ice edge in January. Numeral in the figure denotes the date of observations.

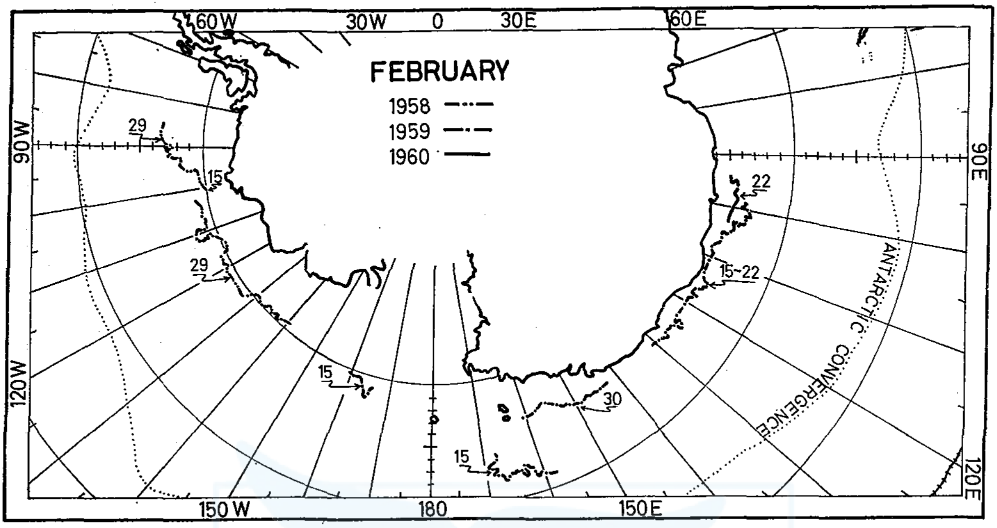

Fig. 4. Northern extreme of the pack-ice edge in February. Numeral in the figure denotes the date of observations.

and Herdman, 1940; Treshnikov, 1967).

Following are the notes based on the communications with Furuno, and these should be took in mind when one consults a matter with the figures demonstrated (Figs. 1–4):

1) The whole data for making those figures were obtained by all whaling boats participated to the Antarctic whaling seasons under the flag of the Nippon Suisan K.K. Two kinds of whaling boats may be distinguished by the purpose of their use; the first one is the whale chaser of actually catching the whales and the second one is the scouting boat which often heads for far distant region in search of possible whaling ground to be harvested in near future. Furuno has been worked out as one of the skippers of those scouting boats throughout the most of his Antarctic life.

2) It was very often or usual that the ship's position was hardly determined for several days or even more than a week due to ill conditioned weather, and therefore there were no other ways but find the ship's position temporarily by the so-called dead reckoning. However, the position was corrected as much as possible whenever the weather permitted to have sun shot.

3) It may be said empirically that the deviation of ship's position due to dead reckoning by rough weather would be usually somewhere around 5 to 6 nautical miles a day from the true position.

4) It was, however, very calm usually in the southern region close to the pack-ice edge, and most of the suggested positions in the figures could be considered correct enough for the purpose of general use.

5) A slight ocean current was noticed in the regions close to the pack-ice, but there was strong current at times when the ship positioned at some distance,

say, 10 to 20 miles off the ice limit though it varied considerably by the place and the seasons.

6) Although there seems to be considerable varieties in the state of pack-ice such as ' open ', ' close ', ' very close ' and so on, there were no specifications in the figures.

7) In the northernmost extreme of tongue-like projection as a shape of pack-ice distribution, the state of pack-ice was usually ' open ' or ' close ' ones. There observed no ' very close ' pack-ice in those above mentioned regions.

8) In the far more southerly region beyond the observed ice limit, it was very often to exist a large ice free waters, especially in the place where the northernmost extreme of the pack-ice greatly expands toward north and forms a tongue-like projection. In these regions there was a good deal of distance between the northernmost ice edge and the second one which lies considerably in the south.

We would like to express our appreciation to Nippon Suisan K.K. and to all personnel who had been participated to the Antarctic whaling operations during the seasons from which our data originated.

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NUMBER 1, JUNE 1948

Akiya, S. and S. Tejima. Studies on digestive enzyme in whale. 3–7

Akiya, S., Y. Ishikawa, S. Tejima, and T. Tanzawa. Studies on tryptase from a whale (*Balaenoptera borealis* L.). 8–10

Akiya, S., S. Tejima, and Y. Ishikawa. Studies on the utilization of whale meat by the use of pancreatic tryptase of whales. 11–14

Akiya, S. and F. Kobo. The test culture of some microorganisms with whale meat peptone. 15–16

Nakai, T. Chemical studies on the freshness of whale meat. I. Evaluation of freshness and changes in quantity of several kinds of nitrogen in whale meat following deterioration of freshness. 17–26

Nakai, T. Chemical studies on the freshness of whale meat. II. On comparison between whale meat and beef on deterioration of freshness and autolysis. 27–30

Tawara, T. On the simultaneous extraction of vitamin A-D and vitamin B_2 complex from the liver of a fin whale (Nagasu-Kujira, *Balaenoptera physalus* L.). 31–37

Tawara, T. Studies on whale blood. I. On the separation of histidine from whale blood. 38–40

Nakai, J. and T. Shida. Sinus-hairs of the sei-whale (*Balaenoptera borealis*). 41–47

NUMBER 2, DECEMBER 1948

Ogawa, T. and S. Arifuku. On the acoustic system in the cetacean brains. 1–20

Yamada, M. Auditory organ of the whalebone whales. (Preliminary report). 21–30

Nakai, T. Chemical studies on the freshness of whale meat. III. Effect of hydrogen-ion concentration on decrease in freshness and titration curve of whale meat with HCl and Na_2CO_2. 31–34

Ishikawa, S., Y. Omote, and Y. Soma. Analytical distillation of vitamin A in the whale liver oil. 35–41

Ishikawa, S., Y. Omote, and H. Kanno. Molecular distillation of sperm whale blubber oil. 42–45

Kaneko, A. Molecular distillation of fin whale liver oil. 46–50

Akiya, S. and K. Takahashi. Determination of tryptophane in whale meat. 51–54

Ishikawa, Y. and S. Tejima. Protein digestive power of sperm whale pancreatic enzyme. 55–60

Tsukamoto, S. Experiment on digestion of whale meat by koji-mould. 61–66

NUMBER 3, FEBRUARY 1950

Ogawa, T. and T. Shida. On the sensory tubercles of lips and of oral cavity in the sei and the fin whale. 1–16

Ohe, T. Distribution of the red marrow in bones of the fin whale. 17–22

Hosokawa, H. On the cetacean larynx, with special remarks on the laryngeal sack of the sei whale and the aryteno-epiglottideal tube of the sperm whale. 23–62

Akiba, T., T. Tsuchiya, M. Umehara, and Y. Natsume. Bacteriological studies on freshness of whale meat. (Report No. 1). 63–70

Ishikawa, Y. Protein digestive power of sperm whale pancreatic enzyme. II. 71–78

Mori, T. and M. Saiki. Properties of fats and oils contained in various parts of a sperm whale body. 79–84

Tawara, T. and R. Fukazawa. Studies on kitol. I. Preparation of kitol from whale liver oil. 85–88

Tawara, T. and R. Fukazawa. Studies on kitol. II. Influence of kitol fraction on the determination of the International Unit of Vitamin A. 89–91

Tawawa, T. and R. Fukazawa. Studies on kitol. III. The effect of sunlight, air and heat on the vitamin A and kitol fractions. 92–95

NUMBER 4, AUGUST 1950

NUMBER 5, JUNE 1951

NUMBER 6, DECEMBER 1951

NUMBER 7, JULY 1952

NUMBER 8, JUNE 1953

NUMBER 9, JUNE 1954

NUMBER 10, JUNE 1955

NUMBER 11, JUNE 1956

NUMBER 12, JUNE 1957

Nishiwaki, M. Very small embryo of cetacea. 191–192

Nishiwaki, M. One-eyed monster of fin whale. 193–195

Ogawa, T. and T. Kamiya. A case of the cachalot with protruded rudimentary hind limbs. 197–208

Uda, M. and A. Dairokuno. Studies of the relation between the whaling grounds and the hydrographic conditions. II. A study of the relation between the whaling grounds off Kinkazan and the boundary of water masses. 209–224

Abe, T. Notes on fishes from the stomachs of whales taken in the Antarctic. I. *Xenocyttus nemotoi*, a new genus and new species of zeomorph fish of the subfamily *Oreosonimae* Goode and Bean, 1895. 225–233

Tsuyuki, H. On the oils contained in various blubbers of northern elephant seal, *Mirounga angustirostris*. 235–240

NUMBER 13, SEPTEMBER 1958

Omura, H. North Pacific right whale. 1–52

Nishiwaki, M. and T. Kamiya. A beaked whale *Mesoplodon* stranded at Ōiso Beach, Japan. 53–83

Nishiwaki, M. and C. Handa. Killer whales caught in the coastal waters off Japan for recent 10 years. 85–96

Ohsumi, S. (Kimura), M. Nishiwaki and T. Hibiya. Growth of fin whale in the northern Pacific. 97–133

Nishiwaki, M., T. Hibiya and S. Ohsumi (Kimura). Age study of sperm whale based on reading of tooth laminations. 135–153

Nishiwaki, M., T. Ichihara and S. Ohsumi (Kimura). Age studies of fin whale based on ear plug. 155–169

Fujino, K. On the serological constitution of fin whale. III. Human B blood group substances in erythrocytes and some notes on anti-fin Ju specific antibodies. 171–184

Nemoto, T. *Cocconeis* diatoms infected on whales in the Antarctic. 185–191

Nemoto, T. and K. Nasu. *Thysanoessa macrura* as a food of baleen whales in the Antarctic. 193–199

Ichihara, T. Gray whale observed in the Bering Sea. 201–205

Ohsumi, S. (Kimura). A descendant of Moby Dick or a white sperm whale. 207–209

Nasu, K. Deformed lower jaw of sperm whale. 211–212

Omura, H. Note on embryo of Baird's beaked whale. 213–214

Uda, M. and N. Suzuki. Studies of the relation between the whaling grounds and the hydrographic conditions. III. The averaged conditions of the whaling grounds and their trends of variation during 1946–55. 215–229

Seki, Y. Observations on the spinal cord of the right whale. 231–251

Kamiya, T. How to count the renculi of the cetacean kidneys, with special regard to the kidney of the right whale. 253–267

Hosokawa, H. and T. Sekino. Comparison of the size of cells and some histological formations between whales and man. 269–301

Ogawa, T., T. Tsunoda and M. Osawa. Amino acid composition of whale meat. 303–307

Ishikawa, Y. A characteristic property of whale oils concerning the absorption of gases. II. On the absorption of nitrogen by whale oils. 309–321

Tsuyuki, H. Component fatty acids of northern elephant seal oil. 323–332

NUMBER 14, SEPTEMBER 1959

Omura, H. Bryde's whale from the coast of Japan. 1–33

Nishiwaki, M. and T. Kamiya. *Mesoplodon stejenegeri* from the coast of Japan. 35–48

Nishiwaki, M. Humpback whales in Ryukyuan waters. 49–87

Cushing, John E., K. Fujino and K. Takahashi. Glycerol-freezing technique as an aid in blood typing of whales. 89–100

NUMBER 15, NOVEMBER 1960

NUMBER 16, MARCH 1962

NUMBER 17, FEBRUARY 1963

NUMBER 18, MARCH 1964

NUMBER 19, APRIL 1965

NUMBER 20, SEPTEMBER 1966

NUMBER 21, JUNE 1969

NUMBER 22, JUNE 1970

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