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THE LIFE HISTORY OF DALL'S PORPOISE WITH SPECIAL REFERENCE TO THE STOCK OFF THE PACIFIC COAST OF JAPAN

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ABSTRACT

The geographical variation of the colour types of the species indicates three local stocks in the northwestern North Pacific and western Bering Sea (WNP/BS), off the Pacific coast of Japan (PJ), and in the Sea of Japan and Okhotsk Sea (SJ/OS).

The catches by the salmon gillnet fishery in WNP/BS and the present and past harpoon fishing in PJ and in SJ/OS, and the age structure based on the cemental growth layers give the following estimation of the life history parameters. The calves are born in August to September at the length of 100 cm after the gestation of 11.4 months, and nursed for about 2 years. Sexual maturity is attained in males at the age of 7.9 years and the length of 195.7 cm, and in females at 6.8 years and 186.5 cm. The mean calving interval is about 3 years, and the annual natural mortality rate of the adult female will be below 0.1. Data are insufficient to indicate the degree of between stocks difference of the parameters.

The weaned immature individuals are distributed in the south in the winter (PJ, WNP/BS, and SJ/OS) and possibly in the summer too (WNP/BS). The segregation of pregnant females by the size of the fetus is expected (WNP/BS). The harpoon fishing mainly exploits the weaned immature and newly matured individuals (PJ and SJ/OS), however the salmon gillnet fishery kills the calves of suckling age and newly matured individuals (WNP/BS). The lactating females are underrepresented in the both fisheries.

INTRODUCTION

The Dall's porpoise, *Phocoenoides dalli* (True 1885), is widely distributed in the northern part of the North Pacific. It ranges from the Sea of Japan and Okhotsk Sea to the west coast of North America as far south as 33°N (Norris and Prescott 1961, Nishiwaki 1967a), and the northern limit will be in the Chukchi Sea (Sleptsov 1961). On the other hand the True's porpoise, *P. truei* Andrews 1911, has a limited distribution off the Pacific coast of northern Japan and of the Kuril Islands. Its southern limit is at about 35°N in the winter season. In the summer it seems to be distributed from 42°N to 54°N, and from the east coast of the Kuril Islands to 168°E (Sleptsov 1961, Ohsumi 1975, Kasuya 1976b).

On the systematic relationship of the two kinds of porpoises, Kuroda (1954) considered, based on the probable incomplete genetic isolation suspected from

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the observation of the school structure and the pigmentation of the fetus, that the True's porpoise is a geographical race and a subspecies of *P. dalli*. Houck (1976), however, through the study of the osteology and external morphology of the porpoises found that only the colour variation attained the plausible level of differentiation in the genus. Finally, considering the fact of coexistence of the two types in the western North Pacific, he concluded that *Phocoenoides dalli* seems to be polymorphic in colour pattern with two major colourmorphs *i.e.* the *dalli*-type and *truei*-type. In the same year Kasuya (1976b) analysed the geographical variation of the ratio of the two types in the northwestern North Pacific, and found that the ratio of *truei*-type in the total *Phocoenoides* caught in the winter season off the Pacific coast of northern Japan (southern part of Sanriku region which covers the coastal part from 38°N to 41°30′N) is about 96% and its ratio in the sightings and in the incidental catch by Japanese salmon gillnet fishery decreases in the offshore waters. This led him to conclude that there can be one coastal population of *Phocoenoides* off the Pacific coast of northern Japan and off the east coast of Kuril Islands, which is entirely or mostly composed of the *truei*-type and intermingles at its northeastern boundary with another offshore population composed of only *dalli*-type. From the fact that the Kuril Islands seems to block the migration of *truei*-type into the Okhotsk Sea, he considered that the *dalli*-type found in the Okhotsk Sea will not pass the Kuril Islands and there will be a third population of *Phocoenoides* in the Okhotsk Sea and the Sea of Japan. However, in the study, he retained the conclusion if the *dalli*-type in the catch off Sanriku region is original in the coastal population or the migrant from other population.

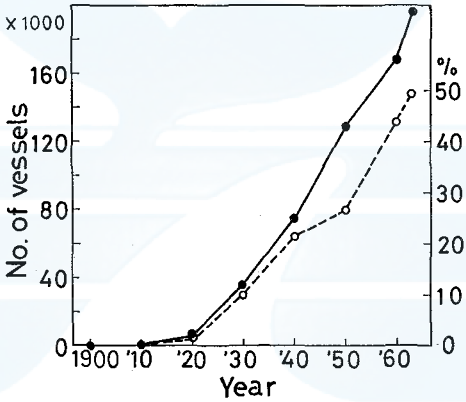

Fig. 1. Number of the Japanese fishing vessels equipped with engine (closed circle and solid line), and its ratio in the total number of fishing vessels (open circle and dotted line), statistics cited from Takagi (1965).

A brief history of the recent exploitation of *Phocoenoides* in the Japanese coastal waters was described by Kasuya (1976b) based on Japanese published records. Some statistics not cited in Kasuya (1976b) and the harpoon fishing gears are reported in Wilke *et al.* (1953). The exploitation of *Phocoenoides*, as well as that of other delphinids, seems to have had a peak in late 1930's to 1940's affected by the social factors during and after the war, and was operated at various part of Japan using the method or fleets introduced from Sanriku coast (Yoshida 1939, Matsui and Uchihashi 1943, Hirashima and Ono 1944, Wilke *et al.* 1953). However, in the recent years, the fishing at most of the places ceased the operation except for the Sanriku coast. The most uncertain is the history of the exploitation in earlier period. It is known that there was operated in the past a driving fishery of dolphins at Oura of Yamada Town on the Sanriku Coast. The operation was made only when the dolphins came close to the entrance of the bay. The species of a catch of 2,385 porpoises made in February 1882 was identified on a photograph as *Lagenorhynchus obliquidens*. However, since the school of *Phocoenoides* is small and usually stays far from the coast, the driving fishery will not have exploited the species. The alternative method taking the species seems to be harpooning the individuals come to the bow wave of the boat. The fishing is most efficient with a vessel with engine. Since the number of the Japanese fishing vessels equipped with engine was negligible before 1920 (Fig. 1), the exploitation of *Phocoenoides* at significant level would have started after late 1920's. This date is almost same with the introduction of motor vessels into the driving fishery of *Stenella coeruleoalba* off Izu coast (Kasuya and Miyazaki 1976a).

The season for the recent porpoise hunting off Sanriku coast is from the last decade of January to the beginning of April when no other fishing is profitable and the market price of the porpoise is high (Kasuya 1976b), and it is operated with hand harpoon and small fishing vessels of about 20 to 30 gross tons. The fishing area ranges approximately between 38°N and 40°N, and between about 10 nautical miles (18 km) and 40 to 50 miles (80 km) off the coast. Accordingly this fishing is mainly harvesting the Japanese east coast population of Kasuya (1976b). The annual catch is about 6,000 individuals. Almost nothing is known about the life history of the individuals of this population.

The offshore population, inhabiting the northwestern North Pacific and western Bering Sea, has been captured incidentally by the Japanese salmon gillnet fishery, which has continued since 1930 with an interruption from 1946 to 1951. The statistics of the incidental catch is not available. Mizue *et al.* (1966) estimated it as about 20,000 individuals in 1964 season (data based on person. comm. of K. Mizue). Though the analysis of the species caught by the salmon gillnet fishery was made by Mizue and Yoshida (1965) and Mizue *et al.* (1966), the absence of the adequate way of age determination limited the accuracy of the studies.

The present study intends to analyse the life history of the porpoise caught by the harpoon fishing off Sanriku coast, together with the supplemental considerations of that of the two other populations distributed in the offshore north-western North Pacific and western Bering Sea and in the Okhotsk Sea and the Sea of Japan.

MATERIALS AND METHOD

The analyses of the school structure are based on the same data used in Kasuya

(1976b). However, few records where the estimation of the school size is less reliable are excluded, and a school observed by Dr Kajihara at the east side of the Soya Straight was added.

TABLE 1. MATERIALS USED IN THIS STUDY

Month*	Jan.	Feb.					Mar.		Apr.	Total
	B	A	A	B	B	B	A	B	B	
Year	'74	'72	'74	'74	'75	'76	'74	'72	'74	
No. examined, males	147	68	52	53	28	127	66	58	9	608
females	75	14	47	50	19	111	69	88	0	473
sex unknown	0	14	0	0	0	4	0	1	0	19
Body length, males	96	53	52	38	28	94	62	53	9	485
females	56	12	47	33	19	93	63	76	0	399
No. aged, males	68	33	4	32	17	87	20	25	8	294
females	42	9	4	26	16	87	35	29	0	248
Testis, histology	55	0	4	27	14	85	14	0	9	208
weight only	0	29	0	0	0	0	0	31	0	60
Females, maturity determined	45	4	17	30	18	78	57	54	0	303

* A: From the 1st to 15th, B: From 16th to the end of month.

The biological information and samples were collected in the years from 1972 to 1976 covering the season from January to April, at the seven landing ports listed below.

Miyako:	39°39′N, 141°57′E
Yamada:	39°28′N, 141°57′E
Funakoshi:	39°27′N, 141°58′E
Otsuchi:	39°19′N, 141°55′E
Kamaishi:	39°14′N, 141°53′E
Ofunato:	39°04′N, 141°43′E
Hosoura:	39°00′N, 141°44′E

Though total of 1,100 individuals were examined, the available informations were variable between the individuals because the internal organs were usually removed before landing.

The body length was measured at nearest 1 cm interval with steel tape on a straight line connecting the tip of snout and bottom of the tail notch. In analysing the body length data, they are usually grouped into 4 cm intervals expressed by $4N \leqq X \leqq 4N+3$, where N indicates a positive integer and X the body length.

The pigmentation was, in the field, classified into the three major categories of *dalli*-type, *truei*-type, and black-type. The pigmentation of randomly selected 537 individuals was recorded on black and white photographs for the further analyses of the individual variation.

The reproductive stage of the female was determined through the observation of mammary gland, ovaries, and the reproductive tract, and recorded as " Immature ", " Pregnant ", " Lactating ", and " Resting ". Since the ovaries and uterus of the immature females are always left on the carcass, the identification of the immature stage is easiest. However, as the ovaries and large portion of uterus of the adult females are often removed by the fishermen, the distinction of the pregnant and resting females is often impossible. In such a case only the maturity was confirmed from the fragments of reproductive tract left in the body cavity.

The ovaries were fixed in 10% formalin solution. The weight and the mean diameter of the corpora and mean diameter of the largest follicle were measured in the laboratory. The mean diameter was calculated as the cube root of the multiple of the three diameters.

One testis and the epididymis were collected from each male and fixed with the same way as ovaries. In the laboratory the smear was taken from the testis tissue at its midlength and from the epididymis at the corresponding position, and the presence and the relative density of spermatozoa were observed after staining with toluidine blue. The histological examination was made on the epididymis, and on the peripheral and central testicular tissues taken from the midlength of the testis. The preparation was made after ordinary way.

The age was determined based on the growth layers in the cementum of the tooth. Several teeth taken from the upper or lower jaw were fixed in 10% formalin. In the laboratory, the tooth was separated from the jaw bone and soft tissue was removed with fingers. Then they were dried and embeded in poliester resin for the convenience of handling. The embeded tooth was ground with whet stones until the center of the pulp cavity was exposed, then it was glued on a clear plastic plate with synthetic resin and the other side was ground to get a thin longitudinal ground section of 10 to 15 μm thickness. The ground section was decalcified in 5% formic acid for several hours, stained with Mayer's haematoxylin for 30 minites, and finally mounted with Canada balsam. The growth layers were counted with a microscope (×150 to ×300).

As mentioned in the next section, at least some of the *dalli*-type individuals caught off the Sanriku region are considered to belong to the offshore population in the northwestern North Pacific and western Bering Sea. However, since there is no way of distinguishing these individuals and the ratio of the total *dalli*-type is so low as 4%, the samples of the two types collected off Sanriku coast were dealt together in the analyses of the growth and reproduction.

Some ancillary materials collected by myself in the southern Okhotsk Sea or by S. Nagahora of the Iwate Prefectural Fisheries Research Laboratory in the northwestern North Pacific are used in this study.

After the analyses of the biological data were nearly completed, Dr A. Takemura of the Nagasaki University provided for me the tooth samples and the biological data of the 107 Dall's porpoises taken by the North Pacific salmon gillnet fishery. Since these materials represent the offshore population in the northwestern North Pacific and western Bering Sea and the age structure of the catch has not been published, they are briefly analysed in the Addendum.

DISTRIBUTION AND SCHOOL STRUCTURE

Distribution of the populations

There is no new information to add the range of the distribution of the three populations of *Phocoenoides* distinguished by Kasuya (1976b). Though Sleptsov (1961) mentions that the *truei*-type is found even in the southern part of the Okhotsk Sea and in the Sea of Japan, it is not supported by other data available to me (Kuzin and Perlov 1975, Kasuya 1976b). However, as it is not impossible to expect few *truei*-types to migrate into the Okhotsk Sea or into the Sea of Japan through the Kuril Islands or the Tsugaru Strait, further study will be needed before arriving at the definite conclusion.

TABLE 2. ANALYSIS OF SCHOOL OF *PHOCOENOIDES DALLI* OFF SANRIKU COAST

School size	Observed no. and %						Probability in %			
	T		TD		D		T	TD[1]	TD[2]	D
1	2	100	0	0	0	0	90.8	—	—	9.2
2	8	61.5	0	0	5	38.5	82.4	8.4	8.4	0.8
3	5	100	0	0	0	0	74.9	22.7	2.3	0.1
4	4	100	0	0	0	0	68.0	29.6	2.4	0.0
5	3	100	0	0	0	0	61.7	37.6	0.7	0.0
6	3	75.0	1[3]	25.0	0	0	56.0	43.3	0.7	0.0
7	3	100	0	0	0	0	50.9	48.9	0.2	0.0
Total	28	82.4	1	2.9	5	14.7	72.4	22.7	4.0	0.9

1): Mixed school *truei*-type exceeding *dalli*-type, 2): Mixed school *dalli*-type exceeding *truei*-type, 3): Five *truei*-types and one *dalli*-type, T: School of *truei*-type, TD: Mixed school, D: School of *dalli*-type.

Wilke *et al.* (1953) stated that the school of *Phocoenoides* containing both *dalli*-type and *truei*-type is not frequent off the southern coast of Hokkaido. Table 2 shows a detailed analysis of the frequency of the two colour types in the schools observed in January, February, May, and June. The location covers the area surrounded by 37°30′N, 41°N, 143°E, and the coast of Japan, which is nearly same with the harpoon fishing ground of the species in the winter season. Only the schools not exceeding 7 individuals are used in the analysis, because the correct estimation of the school size and the identification of the colour types of all the individuals are difficult on the larger schools. Of 34 schools dealt here 5 schools contained only *dalli*-type, 1 school was composed of 5 *truei*-types and 1 *dalli*-type. Other 28 schools classified into the school of *truei*-type includes the two cases, the first is that all the individuals in a school were confirmed as *truei*-type, and the second is the case of 4 schools where only the part of the individuals were confirmed as *truei*-type but the presence of *dalli*-type was not confirmed. The ratio of the *truei*-type in the 34 schools is estimated as 90.8% and that of *dalli*-type 9.2%. The probability of the ratio of the two types in a school was calculated based on the above ratio and on the assumption that the combination of the two types is random. As shown in Table 2, the actual frequency of the mixed schools is much lower than the probability calculated on the assumption of random combination. Especially the discrepancy found for the schools of 3 or less individuals must be significant, because the identification of the individuals is most reliable. If the above calcultion is based on the ratio of *dalli*-type 3.6% observed in the catch off the Sanriku coast, the disagreement with the actual sightings is more exaggerated. This indicates that the school formation of *Phocoenoides* off Sanriku coast is, at least in some degree, dependent on the colour pattern.

Though it is not used in the present analysis, a school of about 20 *dalli*-types sighted in September at 38°30'N, 142°30'E (Nishiwaki 1967b) must be considered by the same way. Mr Y. Jinno, the captain of the research vessel *Tansei-maru*, sighted and tagged in November and December 1972 three schools of the species approximately at 42°05'N, 141°05'E. These schools were composed of 5, 7, and 20 to 25 individuals of the *dalli*-type. The correctness of the record of the pigmentation was confirmed on the photographs. And in May 1974 another school of 3 *dalli*-types was sighted by him at the same position mentioned above

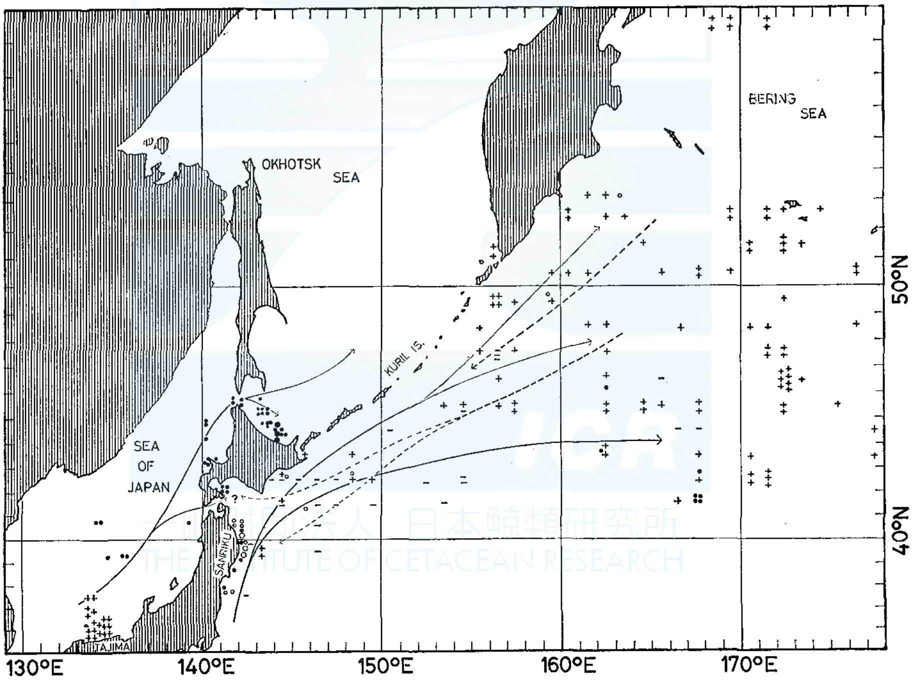

Fig. 2. Position of sighting or of sporadic catch of *Phocoenoides*. Open circle or bar: *truei*-type, closed circle or cross: *dalli*-type, half closed circle: school with two types. Circle indicates the school used for the analyses of the school size, larger circle 10 schools, the smaller one, solid lines the spring-summer migration of the stock off the Pacific coast of Japan or that of the stock in the Sea of Japan and Okhotsk Sea, and dotted line the autumn-winter migration of the stock in the northwestern North Pacific and western Bering Sea.

(Fig. 2). As already indicated by Kasuya (1976b), it is difficult to explain these schools as caused by the random assemblage of the less frequent *dalli*-type.

It will be reasonable to conclude from the above discussions that all the *dalli*-type individuals found off the Pacific coast of Japan are not the members of the Japanese east coast population, but at least some of them, especially those in the schools not containing the *truei*-type, are migrant from the offshore population in the northwestern North Pacific and western Bering Sea or from the Sea of Japan-Okhotsk Sea population. This is consistent with the informations on the ratio of the three colour types analysed in page 10. The interbreeding between the populations will be more scarce than expected from the apparent coexistence of the two types.

Kuroda (1954) stated that a fetus of *truei*-type pigmentation was obtained from a female of *dalli*-type, and suspected the presence of the interbreeding between the two types. His data is based on one of the two fetuses reported by Wilke *et al.* (1953), where more precise description of the fetuses is available. Wilke

TABLE 3. SCHOOL SIZE OF *PHOCOENOIDES DALLI* IN THE WESTERN NORTH PACIFIC AND ADJACENT SEAS

Area & month	School size														Total schools	Mean size
	1	2	3	4	5	6	7	8	10	13	15	20	22	35		
Coastal Pacific (39°–54°N), *truei*-type																
Jan.						2									2	6.0
Feb.		2	1	1			2		2	1					9	6.4
May			1		1		1		1		1	1			6	10.0
Jun.	2	6	3	3	2	2[1]			2						20	3.9
Jul.			1		2				2						5	6.6
Aug.				1											1	4.0
Total	2	8	6	5	5	4	3	0	7	1	1	1	0	0	43	5.7
Coastal Pacific, *dalli*-type																
Feb.		1													1	2.0
May		2	1												3	2.5
Jun.		2													2	2.0
Nov.					1		1								2	6.0
Dec.													1		1	22.0
Total	0	5	1	0	1	0	1	0	0	0	0	0	1	0	9	5.2
Offshore Pacific (42°–44°N, 162°–168°E), *dalli*-type																
May	0	1	3	0	1	0	0	1	0	0	0	0	0	1	7	8.4
Sea of Japan[2], *dalli*-type																
May	2	5	1	0	0	0	0	0	0	0	0	0	0	0	8	1.9
Okhotsk Sea[3], *dalli*-type																
May		1		1											2	3.0
Jun.		2	1												3	2.3
Jul.		6	5	1	1	1	1					1			16	4.3
Sep.		7	4	8	3		3								25	3.8
Total	0	16	10	10	4	1	4	0	0	0	0	1	0	0	46	3.4

1) One mixed school of 5 *truei*-types and 1 *dalli*-type included, 2) Type unidentified 4 schools (10 individuals) included. 3) Type unidentified 2 schools (6 individuals) included.

et al. (1953) state that a [near term] fetus of 89.5 cm obtained from *dalli*-type female on 16 May was " marked, although in indistinct gray tones, like *truei* " but " the pattern of 10 pound fetus [77.8 cm in body length] taken 24 May [from a *truei*-type female] was indistinct ". The feature of the former fetus seems to be continuous to the pigmentation of the newborn calf of the *dalli*-type, where the anterior lateral region is pigmented in dark gray and changes later into black (Kasuya 1976b). Kasuya (1976b) states on the young *truei*-type that the corresponding part is pigmented in light gray tone but its posterior border is indistinct. Accordingly, the example of the two fetuses described by Wilke *et al.* (1953), can not be a proof of the presence of the interbreeding, but can be a suggestion that the two types are distinguishable at the stage of about 80 to 90 cm in body length.

Table 3 shows the school size frequencies of *Phocoenoides* observed mostly by myself and few by other trained observers. The positions of these sightings are indicated by circles in Fig. 2. Other sporadic records of the catch or of sightings indicated by cross or bar are cited from Kasuya (1976b) and Ohsumi (1975), but are not included in Table 3. Part of the latter data could be overlapping since some of their data sources are same. The schools of *Phocoenoides* are usually composed of less than 7 individuals (87.6% of total number of schools). Since the mode exist at 2 individuals, it is suspected that the basic unit of the school of this species would probably be 2 or 3 individuals and that the schools with 4 to 7 individuals will be formed by the aggregation of the basic units. It is also suspected that the uncommon large schools exceeding 10 individuals is formed by the repeated aggregation of the schools. In the present scanty materials, the seasonal variation of the school size is not indicated.

Between the colour types there is observed a slight difference of the school size. If the 32 schools of the *truei*-type sighted from May to September is compared with 54 schools of *dalli*-type sighted in the same season in the Sea of Japan and Okhotsk Sea, the former gives the mean school size of 5.4 individuals and the latter 3.5. The ratio of the schools composed of 4 or more individuals is 59.4% in the former, and 37.0% in the latter. This is an indication of the presence of the difference of the schooling behavior between the two populations. It is not clear, at present, if this difference is caused by the geographical difference of food availability and of the density of porpoise population, or by the difference of the hereditarily decided schooling behavior. However, the fact that the school size of the *dalli*-type in the area where the *truei*-type is dominantly distributed is also sligtly small may suggest the latter possibility.

VARIATION OF PIGMENTATION

Ratio of the three colour types

Table 4 shows the ratio of the three colour types in the catch off Sanriku coast. If all the available data are combined, the ratio of *truei*-, *dalli*-, and black-types in the catch is given as 96.3%, 3.4%, and 0.3% respectively. The ratio of *truei*-type fluctuates between 90.9% and 98.6% in half month groups. And there

TABLE 4. SEASONAL FLUCTUATION OF THE RATIO OF THREE COLOUR TYPES OF *PHOCOENOIDES* IN THE CATCH OFF SANRIKU COAST, IN NUMBER AND PERCENT

Colour types	Jan.		Feb.				Mar.				Apr.		Total	
	B		A		B		A		B		B			
Males														
truei-type	145	98.6	113	94.4	203	97.6	60	90.9	54	93.1	9	100.0	584	96.1
dalli-type	2	1.4	6	4.8	5	2.4	6	9.1	3	5.2	0	0.0	22	3.6
black-type	0	0.0	1	0.8	0	0.0	0	0.0	1	1.7	0	0.0	2	0.3
total	147	100	120	100	208	100	66	100	58	100	9	100	608	100
Females														
truei-type	72	96.0	59	96.7	174	96.7	66	95.7	86	97.7	0		457	96.6
dalli-type	2	2.7	2	3.3	6	3.3	3	4.3	2	2.3	0		15	3.2
black-type	1	1.3	0	0.0	0	0.0	0	0	0	0	0		1	0.2
total	75	100	61	100	180	100	69	100	88	100	0		473	100

A: 1st to 15th, B: 16th to the end of month.

TABLE 5. RATIO OF THREE COLOUR TYPES OF *PHOCOENOIDES* IN THE CATCH OFF SANRIKU COAST, IN NUMBER AND PERCENT

Body length (cm)	156–175		176–195 (♂) 176–187 (♀)		196–217 (♂) 188–195 (♀)	
Males						
truei-type	104	96.3	164	97.6	118	96.7
dalli-type	4	3.7	4	2.4	4	3.3
black-type	0	0.0	0	0.0	0	0.0
total	108	100	168	100	122	100
Females						
truei-type	81	93.1	310	96.9	80	96.4
dalli-type	6	6.9	9	2.8	2	2.4
black-type	0	0.0	1	0.3	1	1.2
total	87	100	320	100	83	100

is detected a slight increase of the *dalli*-type from 1.8% in January to 3.3% in February, and to 5.0% in March.

The ratios of the three colour types in the growth stages are shown in Table 5, where the body length are grouped from the smallest to 175 cm or the mean length at 2 years of age, from 176 cm to the approximate lengths at sexual maturity, and above them. The ratio of the *dalli*-type is highest in the smallest group. However the seasonal change of the ratio is too large to be explained by the higher ratio of *dalli*-type in the juveniles and the seasonal increase of the ratio of the juveniles (Table 14). It is more reasonable, as already suggested by the analysis of the school structure, to consider that there are *dalli*-type porpoises of other population(s) migrating to the Sanriku coast and intermingling with the stock off the Pacific coast of Japan.

Individual variation of the pigmentation

The detailed analysis of the individual variation of the pigmentation is made based on the black and white photographs of 537 individuals caught by the harpoon fishing off Sanriku coast. The pigmentation of the lateral region is classified into the following 14 minor groups.

1. *Truei*-type, spots in the lateral region absent or scarce (Pl. I, Figs 1–2).
2. *Truei*-type, spots abundant in the anterior lateral region (Pl. I, Figs 3–4).
3. *Truei*-type, spots distributed in the entire white area (Pl. I, Figs 5–6).
4. *Truei*-type, spots restricted to the posterior lateral region, in some individuals a vertical belt of spots may exist at mid-lateral (Pl. I, Figs 7–8).
5. *Truei*-type, a vertical belt of spots at anterior lateral region (Pl. I, Fig. 9).
6. *Truei*-type, two vertical belts of spots at anterior lateral region (Pl. I, Fig. 10).
7. *Truei*-type, three vertical belts of spots at anterior lateral region (Pl. II, Fig. 1).
8. *Truei*-type, four or more vertical belts of spots, or belts unseparable (Pl. II, Fig. 2).
9. *Truei*-type, same as type-8 except for the dark background and fused mottling (Pl. II, Fig. 3).
10. *Truei*-type, same as type-8 except for a belt of spots at center of lateral region (Pl. II, Fig. 4).
11. *Truei*-type, all the lateral area grayish (Pl. II, Fig. 5).
12. Black-type, entire body pigmented almost same darkness (Pl. II, Figs 6, 8).
13. *Dalli*-type, without spot (Pl. II, Fig. 7).
14. *Dalli*-type, spots in the posterior lateral region (Pl. II, Fig. 9).

The above classification is somewhat arbitrary. The distinction of type-1 and type-2 depends on the density of the spots in the anterior lateral region and the variation of the two types is continuous. However, they are clearly distinguished from type-4 with spots in the posterior region or from type-3 with spots in the entire lateral region. All the 6 types, from type-5 through type-10, are characterized by the presence of the dense spots forming one or more vertical belts, and the presence of some common factors is suspected. The type-11 and type-12 (black-type) are separated only by the darkness of the lateral region. Since the density of pigmentation of lateral region, especially that of inguinal region, is variable between the individuals classified into black-type, I suspect that the two types could be found as continuous when more data are accumulated. The presence of the vertical belt of spots at mid-lateral region, type-10 and some of type-4, will perhaps be a variety of the spotting in the anterior or posterior lateral region.

As mentioned in the former section, the young *truei*-type porpoise has pale grayish pigmentation at the chest region. This character is not analysed in the present study because such feature is not correctly recorded on the photograph. There is, except for *dalli*-type, expected no significant difference of the mean body lengths between the various types, and it is considered that the pigmentation patterns dealt here are not the growth characteristics. This is same with the case of

TABLE 6. FREQUENCY OF MINOR PIGMENTATION TYPES OF *PHOCOENOIDES* OFF SANRIKU COAST

Types	Males					Females					Unknown		Total	
	No.	%	Body length (cm)			No.	%	Body length (cm)			No.	%	No.	%
			range	mean	SE			range	mean	SE				
1. *truei*-type	157	53.2	149–214	186.1	1.13	102	47.7	160–204	182.1	1.12	17	60.7	276	51.4
2. ,,	78	26.4	164–217	185.4	1.42	60	28.0	163–205	181.5	1.55	9	32.1	147	27.4
3. ,,	18	6.1	168–201	188.6	3.47	19	8.9	171–194	181.8	2.20	0	0	37	6.9
4. ,,	2	0.7	168	168.0	—	2	0.9	159–185	172.0	13.0	0	0	4	0.7
5. ,,	9	3.1	180–198	191.1	2.58	2	0.9	171–178	174.5	3.50	0	0	11	2.0
6. ,,	1	0.3	182	182.0	—	2	0.9	180–186	183.0	3.00	0	0	3	0.6
7. ,,	2	0.7	177	177.0	—	0	0				0	0	2	0.4
8. ,,	2	0.7	168–192	180.0	12.0	4	1.9	166–193	179.0	7.81	0	0	6	1.1
9. ,,	4	1.4	178–190	183.0	3.00	9	4.2	176–194	183.6	3.04	0	0	13	2.4
10. ,,	3	1.0	199–204	201.5	2.50	1	0.5	190	190.0	—	0	0	4	0.7
11. ,,	5	1.7	176–202	186.0	8.08	4	1.9	175–185	180.0	2.89	2	7.1	11	2.0
12. black-type	2	0.7	179–207	200.0	14.0	0	0				0	0	2	0.4
13. *dalli*-type	12	4.1	163–196	175.4	4.12	7	3.3	168–190	175.8	4.10	0	0	19	3.5
14. ,,	0	0				2	0.9	175	175.0	—	0	0	2	0.4
Total	295	100	149-217	—	—	214	100	159-205	—	—	28	100	537	100

1) For the number and the percentage the length unknown individuals included.

the three major colour types.

Though it is left for the future study, several factors will have to be assumed for the explanation of the presence of the various minor colour types. One of the possible example is shown below, where each factor is represented by a group of gene or genes.

Factor A: promotes the melanization of the anterior lateral region
Factor B: promotes the melanization of the posterior lateral region
Factor C: inhibits the melanization of the anterior lateral region
Factor D: inhibits the melanization of the posterior lateral region

The coexistence of a promoter and inhibitor will result in the various density of spotting in the controlled region. When the capitals indicate the presence of the variable number of genes grouped into one of the 4 factors, and the small letter the absence of the genes, most of the pigmentation types could be explained by the following combination.

Truei-type (no spot, or spots in the anterior region, type-1, 2, and 5 through 10, 86.0%): abcd, abcD, abCd, abCD, AbCd, AbCD
Truei-type (spots in the posterior region, type-4, 0.7%): aBcD, aBCD
Truei-type (spots in the entire lateral region, type-3, 6.9%): ABCD
Black-type and type-11 of *truei*-type (2.4%): ABcd
Dalli-type (without spot, 3.5%): Abcd, AbcD
Dalli-type (with spots, 0.4%): ABcD

However the absence of the individuals expressed by ABCd, aBCd, or aBcd, which are expected to have the black posterior area and white or, spotted anterior flank, will need further investigation.

PRENATAL GROWTH

Neonatal length

Because of the restricted fishing season, no full term fetus nor newborn calf was obtained from the catch off Sanriku coast. Mizue *et al.* (1966) analysed the 24 full term fetuses and 19 newborn calves caught incidentally by the salmon gillnet fishery in the northwestern North Pacific and western Bering Sea. The body lengths of the smallest postnatal individual and of the largest fetus were 92 cm and 109 cm respectively, and they concluded that the mean neonatal length of the species will be about 100 cm. Table 7 shows the length frequencies of fetuses and newborn calves in Mizue *et al.* (1966), in Koga (1969), and few data obtained by the research vessel of the salmon fishery and provided by Mr. S. Nagahora. The least squares regression is shown by

TABLE 7. RATIO OF FETUS AND NEWBORN CALF OF *PHOCOENOIDES* IN THE NORTHWESTERN NORTH PACIFIC AND WESTERN BERING SEA

Body Length (cm)	Published records[1]		Present data		Total in %	
	fetus	postnatal	fetus	postnatal	fetus	postnatal
85	4	0	0	0	100.0	0
90	5	1	1	0	85.7	14.3
95	3	2	0	0	60.0	40.0
100	5	7	0	1	38.5	61.5
105	1	2	0	0	33.3	66.7
110	1	2	0	1	25.0	75.0
115	0	4	0	0	0.0	100.0
Total	19	18	1	2	50.0	50.0

1) Cited from Mizue *et al.* (1966) and Koga (1969).

$$y = 3.201x - 269.0$$

where x indicates the body length in cm, and y the ratio of postnatal individuals in %. The body length where the ratio reaches 50% is 99.7 cm, which is rounded and the mean body length at birth 100 cm is obtained for the population of *Phocoenoides* in the northwestern North Pacific and western Bering Sea.

Fetal growth and length of gestation

The fetal growth was estimated from the seasonal change of the fetal length off Sanriku coast. The body lengths of 39 fetuses plotted against the date of catch show a linear increase (Fig. 3). The straight line calculated by the least squares is shown by the following equation,

$$y = 0.3333x + 19.4$$

where x indicates the days from the first of January, and y the fetal length in cm. The fetal growth rate of the Japanese east coast population is about 3.3 mm/day. On 28 August, the extended straight line reaches 100 cm or the mean neonatal length of the population in the northwestern North Pacific and western Bering Sea. This is an approximate estimation of the mean date of birth of *Phocoenoides* off the Pacific coast of Japan. Some inaccuracy must exist in this estimation, because the neonatal length of the offshore population is tentatively used for the Japanese east coast population.

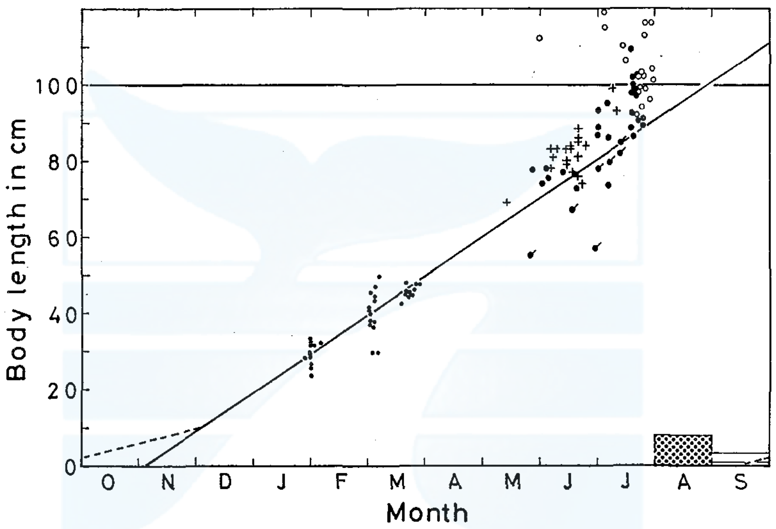

Fig. 3. Seasonal change of the body lengths of fetuses and infants of *Phocoenoides*. Small closed circle and solid line: fetus off Sanriku coast, large closed circle: fetus in the northwestern North Pacific and western Bering Sea (Mizue *et al.* 1966), large closed circle with bar: that in Koga (1969), cross mark: that provided by A. Takemura, open circle: infant in the same area in Mizue *et al.* (1966). Open square indicate the range of two fetuses in the southern Okhotsk Sea (present materials), and dotted square the range of 7 fetuses in the same area in Okada and Hayashi (1951).

It is known that the growth of mammalian fetus is expressed by the earlier slow growth stage and later linear growth stage (Huggett and Widdas 1951, Laws 1959). The backward extraporation of the above fetal growth line crosses with the axis of time on 3 November of the preceeding year. The length of time from this date to the mean date of birth is 300.1 days. If the value of 0.135 estimated by Perrin *et al.* (1976) for the fetal growth of *Stenella attenuata*, which has the gestation slightly shorter than 1 year, is used, the equation of Laws (1959) is shown as follows.

$$t_g - t_o = 300.1$$
$$t_o = 0.135 t_g$$

Where t_0 indicates the length of time from the start of conception to the date when the extended straight line of the growth cuts the axis of time, and t_g the total gestation length. These equations give the total gestation of 346.9 days or 11.4 months (using months of 30.4 days). The mean date of conception is, in the Japanese east coast population, approximately on 17 September.

AGE DETERMINATION

Tooth structure and growth layers

Following observations were made on the thin tooth sections decalcified and stained with haematoxylin. The tooth of the species is constituted of enamel, dentin, and cementum. The enamel does not dissolve in the formic acid, which is different from other delphinids. The decalcified enamel is stained blue with haematoxylin. This is an indication of high content of organic matrix. There are observed many fine growth layers in the decalcified and stained section of enamel.

The neonatal line in dentine is clear as a thin unstainable layer. There are nearly 10 faint minute layers in the prenatal dentine. The growth layers are irregular and unclear in the postnatal dentine laid down after the first layer. Though the pulp cavity is wide on newborn individuals, it is soon filled with postnatal dentine leaving a narrow canal, and the base of the root is finally covered with thick cemental layers. This narrow pulp cavity is connected with the surface of the tooth through canals penetrating the cementum.

The cemental growth layers are, on the longitudinal section, most clearly observed between the level of the proximal end of the fetal dentine and that of the proximal end of the first postnatal dentinal layer. Though the cementum of older individuals is thick at the proximal end of the tooth, the growth layers are not well detected in it.

The individual variation of cementum thickness is large. And there are often observed accessory layers in the thick cementum, which makes the age determination difficult. The accessory layers are usually distinguished through the careful observation of the entire cemental layers of the tooth. The accuracy of age determination of the species by the cemental growth layer is so bat that two independent counts made carefully on a tooth section often give the discrepancy of 20%.

Accumulation rate of the layers

The comparison of the independent counts of the dentinal and cemental layers is shown in Fig. 4, where only the individuals with readable dentinal layers are selected. The number of growth layers in the two tissues is same on the individuals younger than 4 cemental layers. At the older age, however, the accumulation of the dentinal layer seems to cease as in the case of the striped and spotted dolphins suspected by Kasuya (1976a) or the layer becomes indistinguishable.

Mizue *et al.* (1966) estimated the postnatal growth of theo ffshore population in the northwestern North Pacific and western Bering Sea, based on the analysis of the body length and the body weight, that the body length of one year old individual is from 145 to 169 cm and that of the 2 years old is from 170 to 187 cm. Since the breeding season of the species is unimodal and restricted to the summer season, the reliable separation of some young age groups can be done based on the length frequency. An estimation of the accumulation rate of the growth layers is made in comparison with their study. As shown in Table 8, no trace of cemental layer is observed on the teeth of two newborn individuals, 100.5 cm female and 110.0 cm female, caught by the salmon gillnet fishery. The postnatal dentine is not formed in the former individual, but there is observed a very thin postnatal dentine (5 μm in thickness) on the tooth of the latter individual (Pl. III, Figs 1 and 2). On the other hand, the teeth of slightly older individuals, 132 to 159 cm, caught in winter off Sanriku coast have one stainable layer in cementum and the same number of layers in dentine. Most of the 45 aged individuals of the length

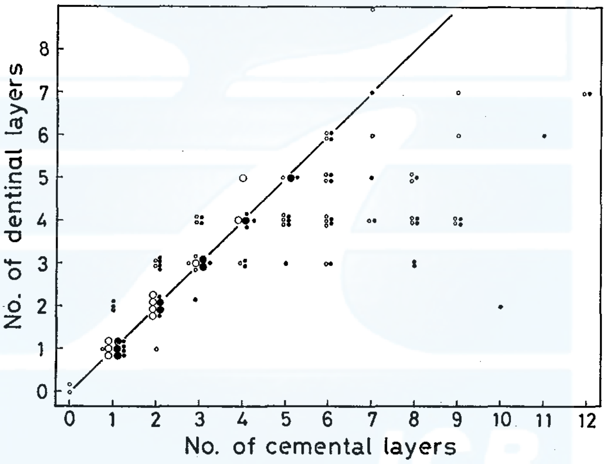

Fig. 4. Scatter diagram of the relationship between the number of dentinal layers and that of cemental layers. Large circle indicates 5 individuals, the small one, open circle female, and closed male. All the available data included.

TABLE 8. COMPARISON OF DENTINAL AND CEMENTAL GROWTH LAYERS OF NEWBORN AND JUVENILE *PHOCOENOIDES*

Body length (cm)	Sex	No. cemental layers	No. dentinal layers	Date of catch	Remarks
100.5	♀	0	0	21, VII, '73	*dalli*-type, N. Pacific
110.0	♀	0	0	26, VII, '72	,, ,,
132.0	♂	1	1	30, I, '74	*truei*-type, Sanriku
149.0	♂	1	1	3, III, '74	,, ,,
156.0	♀	1	1	27, II, '74	,, ,,
159.0	♀	1	—	19, II, '76	black-type, ,,

from 141 cm to 168 cm caught in late May to early July and dealt in the Addendum of this study are considered, though there might be the inclusion of few older individuals, to have been born in the preceeding summer. Among these 45 juveniles, 38 individuals or 84.4% of the total have only one stainable cemental layer in the tooth, and only 7 or 15.6% have two cemental layers. These informations indicate that the cementum is absent on the tooth of newborn individual but the first stainable cemental layer is completed or being deposited in the first winter, and that the deposition of the next layer is not started in the season from late May to early July. This is a strong suggestion that the stainable cemental layer is deposited in autumn and winter season as in the cases of the striped and spotted dolphins (Kasuya 1976a) or of the Baird's beaked whale (Kasuya 1977). Accordingly, the age of the individual with N cemental layers and caught off Sanriku coast can be approximately N−0.5 years, because the birth in the species occurs in summer and the fishing season is from late January to early April.

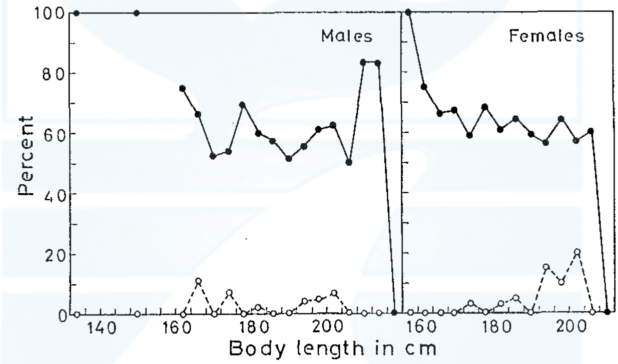

Fig. 5. *Phocoenoides* off Sanriku coast, ratio of the individuals aged (closed circle and solid line), and the ratio of the age indeterminable individuals in the tooth sampled individuals (open circle and dotted line).

The ratio of the individuals aged by the above method is 60.0% of the length known males and 62.4% of the females. As shown in Fig. 5, the ratio is slightly low in the larger individuals, and especially in females. This seems to have been caused by the failure of the preparation, higher frequency of the falling off of the tooth in older individuals, or by the unreadability of tooth layers. However, the bias will not be so large to have significant effect on the analyses in the later sections of this study.

POSTNATAL GROWTH IN THE MALE

Length frequency

The body lengths of 485 males taken off the Pacific coast of Japan ranged from 132 cm to 219 cm, with the mean length of 185.2 cm. Single mode was present at the length group of 180 to 183 cm. As shown in Fig. 6, the ratio of the larger individuals and the mean body length decrease, in both sexes, with the progress of the fishing season. Though the decrease in the half month interval is not significantly large, the change is considered to be significant because the trend continues from late January to late March.

Another important feature of the length frequency is, in both sexes, the scarcity of the individuals below 170 cm and above 200 cm. This will be related, as mentioned in the later sections, with the segregation and the bias caused by the fishing method.

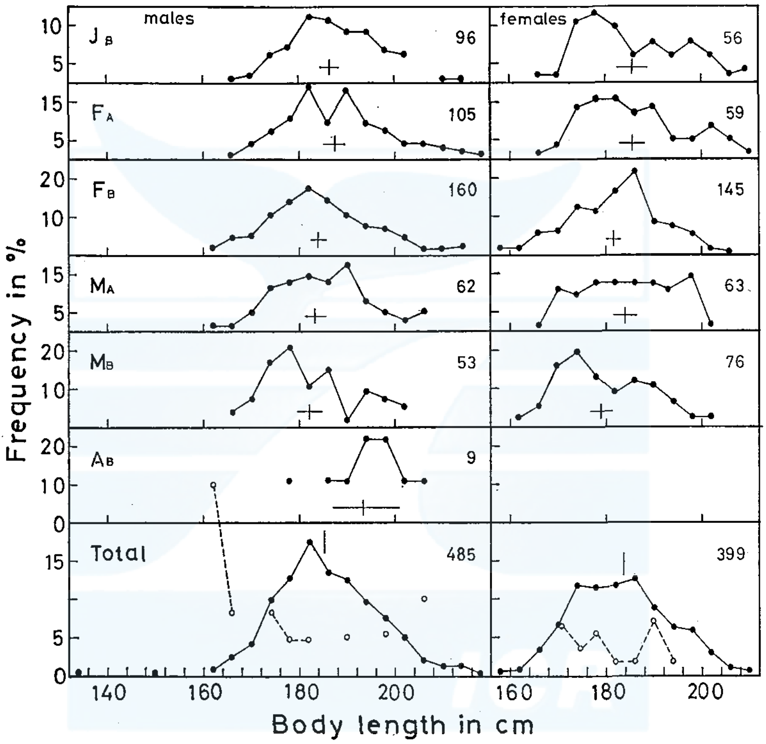

Fig. 6. Body length frequencies of *Phocoenoides* caught by the harpoon fishing off Sanriku coast. Mean (vertical line) and range of two standard errors (horizontal line) are indicated. Suffix A attached to month indicates from the 1st to 15th of the month, B from 16th to the end, and open circle and dotted line the ratio of *dalli-* and black-type in the total *Phocoenoides.*

Growth curve

The relationship between the body length and the age is shown in Fig. 7. It is known in some delphinids that the mean growth curve of the male at the age between 3 and 10 years is expressed approximately by a straight line (Kasuya *et al.* 1974, Kasuya 1976a). In the present species, the mean body lengths at the age from 1.5 to 6.5 years seems to come on a straight line. The least squares regression of these points gives the following equation,

$$y = 3.30x + 169.58, \quad 1.5 \leqq x \leqq 6.5$$

where x indicates the age in years, and y the mean body length in cm. The gradient 3.30 indicates the mean annual growth rate. The corresponding figures of *Stenella coeruleoalba* and *S. attenuata* are 4.40 cm/year and 4.20 cm/year respectively (Kasuya *et al.* 1974). Accordingly it is suggested that in spite of the similarity of the neonatal length and length at 1 year of age, the growth of the later part of the life is much slower in *Phocoenoides* than *S. coeruleoalba*, and that the asymptotic

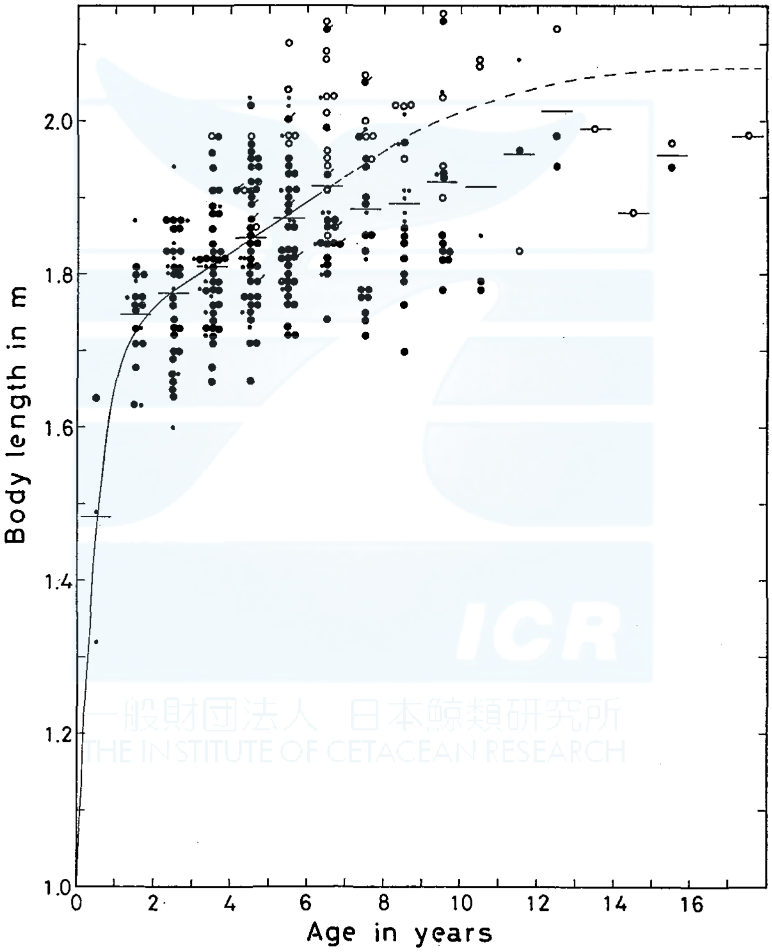

Fig. 7. Male *Phocoenoides* off Sanriku coast, scatter plot of body length on age (N=294). Large closed circle indicates the immature, closed with bar the maturing, open circle the mature, and small closed circle the unidentified individual. Horizontal bar indicates the mean body length.

length of the former species could be much smaller than that of the latter species. Because of the scarcity of the adult individuals, the asymptotic length can not be estimated in the present study. In Fig. 7, it was tentatively assumed to be between 200 and 210 cm and to be attained at or after the age of 15 years as in the case of the female.

Male growth stages

The materials are collected from the catch of harpoon fishing. As the season is limited to January through April, or 5 to 8 months prior to the peak of the mating season estimated in this study, the activity of the male organ will be at the lowest.

For the preliminary examination, the maturity of the male was examined by the following four methods.

1. Epididymal smear: classified into the three stages, " spermatozoon absent ", " scanty ", " copious ".
2. Testicular smear: classified as above
3. Epididymal tissue: classified into the following three stages.
   " Immature ", ductus epididymidis is simple and narrow, and the epithelial cell is low.
   " Maturing ", folds of the ductus epididymidis are developed, but the low epithelial cells are still present at some part.
   " Mature ", folds of the ductus epididymidis are extremely developed, and all the epithelial cells are tall.
4. Testicular tissue: classified into the following three stages by the examination of the peripheral and central testicular tissue.
   " Immature ", both spermatid and spermatocyte absent in the sections examined.
   " Maturing ", central tissue is mature and peripheral tissue immature.
   " Mature ", both central and peripheral tissues are mature [=spermatid or spermatocyte present]

In the above criteria of the maturity of epididymal or testicular tissue, the presence or absence of the spermatozoon is not taken into cosideration, because even in some undoubtedly mature testis the spermatozoon is absent or scanty in the season. The spermatozoon in the testis tissue was, if present, always found with spermatid

TABLE 9. COMPARISON OF THE MATURITY INDICES OF MALE *PHOCOENOIDES* OFF SANRIKU COAST

Testis (histology)	Epididymal smear			Testicular smear			Ductus epididymidis		
	—	+	++	—	+	++	Im.	M'ing	Mat.
Immature	157	0	0	152	5	0	71	11	0
Maturing	10	1	0	13	1	0	0	3	5
Mature	23	7	3	18	14	1	0	1	6
Total, no.	190	8	3	183	20	1	71	15	11
%	94.5	4.0	1.5	89.7	9.8	0.5	73.2	15.5	11.3

—: no spermatozoon, +: scanty spermatozoa, ++: spermatozoa copious.

or spermatocyte, but the latter two not always with spermatozoon.

Among the 208 individuals examined of the testis tissue, there was no individuals where the peripheral testis is mature in spite of the immaturity of the central testicular tissue. Few individuals had no trace of spermatid nor spermatocyte but showed the presence of scanty spermatozoa in the testicular smear. Though these individuals could have been producing the spermatozoa at some restricted part of the testis, they will safely be considered as not acting as an adult male because the ductus epididymidis is not fully developed and no spermatozoon was found in the epididymal smear (Table 9).

On the other hand the individuals with the " mature " testis can be considered as really attained the sexual maturity, because about one third of the individuals of this category showed the presence of spermatozoa in the epididymal smear, and because the spermatocytes or spermatids in the winter season will grow to the spermatozoa by the next mating season.

The most uncertain is the individuals with " maturing " testis. At least some of the males of this category are suspected to act as adult male, because there is a case of the " maturing " male where the spermatozoa are present in the epididymal smear and more than half of the individuals of this category had the " mature " epididymis. However, it is impossible to consider that all of the males of this category are sexually mature, since many individuals of this category still have the " maturing " epididymis. Accordingly the males with the testis of this category are dealt as the maturing, and the males with the testis of two other categories as the immature and mature.

Attainment of sexual maturity in males

Table 10 shows the relationship between the age and the development of the epididymis. The ductus epididymidis start to develop at various age between 1.5 and 9.5 years. The fully completed stage appears at about 4.5 years. Since as mentioned in the later section, there is an underrepresentation of the mature individuals, Table 10 can not be used for the estimation of the mean age at the

TABLE 10. AGE AND DEVELOPMENT OF DUCTUS EPIDIDYMIDIS OF *PHOCOENOIDES* OFF SANRIKU COAST

Age(yrs)	Immature	Maturing	Mature
0.5	0	0	0
1.5	7	1	0
2.5	10	2	0
3.5	13	3	0
4.5	12	2	2
5.5	9	2	1
6.5	4	0	5
7.5	5	2	1
8.5	5	1	0
9.5	2	0	1
10.5	0	1	0

completion of the development of the epididymis.

If the weight of testis and mean diameter of the seminiferous tubules are plotted on the logarithmic scale, there is observed a linear relationship (Fig. 8). The least squares regression of 201 individuals is shown by

$$y = 33.79x^{0.2284}$$

where y indicates the mean diameter of the tubules in μm at the center of testis, and x the weight of testis in grams. Both the immature and mature individuals are expressed by the single equation. This feature is different from that observed on *S. attenuata* (Kasuya *et al.* 1974), which is possibly related with the length of time from the mating season. The absence of the observable seasonal change in the diameter of tubules will also have direct relationship with the restricted season of the samples. In Fig. 8, the points are clearly separated into two groups at the tubule diameter of about 70 μm, or at the testis weight of 25 g. The group with developed testis is mainly composed of the mature individuals, and the opposite the immature. The individuals with the maturing testis, which is smaller in number, situate at the intermediate position. This feature is shown graphically in Figs 9 and 10. The ratio of sexually immature individuals is 50% at the tubule diameter of about 70 μm, and that of sexually mature male at about 80 μm. As the maturing stage must be passed by all the males before attaining the sexual maturity, the former figure corresponds to the mean tubule diameter at the attainment of the maturing stage, and the latter to that at the attainment of sexual maturity.

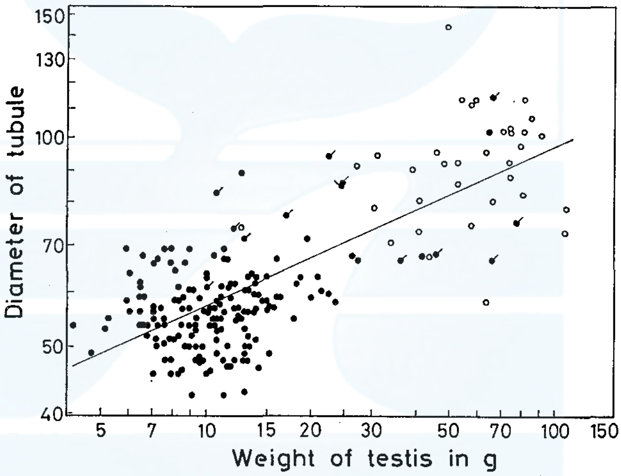

Fig. 8. *Phocoenoides* off Sanriku coast, scatter plot of the mean diameter of seminiferous tubules (μm) on weight of testis (N=201). Closed circle indicates the immature, closed circle with bar the maturing, and open circle the mature.

For the identification of the maturity of the male, the weight of testis is more

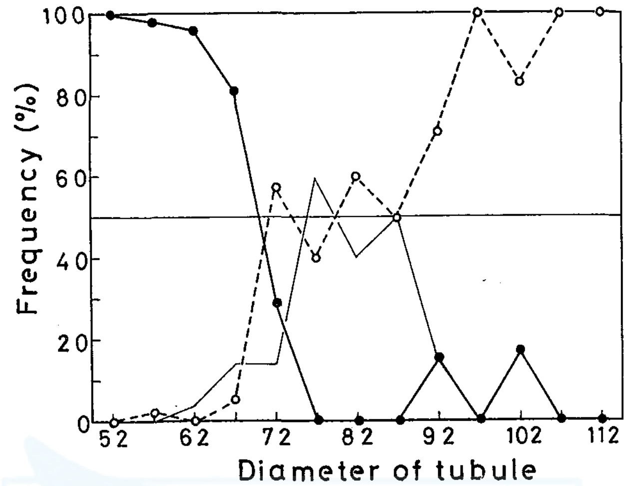

Fig. 9. *Phocoenoides* off Sanriku coast, relationship between the sexual maturity and mean diameter of seminiferous tubules in μm. Closed circle and thick solid line indicate the immature, open circle and dotted line the mature, and thin solid line the maturing.

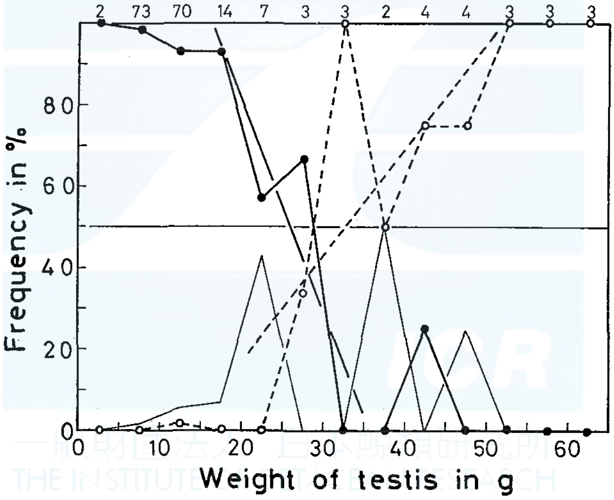

Fig. 10. *Phocoenoides* off Sanriku coast, relationship between sexual maturity and the weight of testis. The numerals at the top indicate the sample size. For symbols see Fig. 9.

practical than the histological examination. The relationship between the maturity and weight of testis is shown in Fig. 10. The ratio of immature individuals decreases in accordance with the increase of the testis weight from 10 g to 45 g. The least squares regression is given by the equation,

$$y = -5.382x + 188.73, \quad 10.0 \leq x \leq 34.9$$

where x indicates the weight of one testis, and y the ratio of immature individuals. The value of y becomes 50% at the testis weight of 25.77 g, which is the mean weight of testis at the attainment of the maturing stage. The relationship between the ratio of mature individuals (y in %) and the weight of testis (x in g) is shown by the following equation.

$$y = 2.560x - 34.10, \quad 20.0 \leqq x \leqq 54.9$$

The mean weight of one testis at the attainment of sexual maturity is obtained from this equation as 32.85 g. This estimation is based on the assumption that there is neither segregation nor difference of the catchability between the individuals of the same testis weight and belonging to the different growth stages. Though this question is not solved in this study, if it exists, the above estimation does not indicate the true figure of the population, but only can be applied in estimating the maturity of the harpoon fishing catch.

Mizue *et al.* (1966) examined the testis of 41 Dall's porpoises caught in the offshore waters of the northwestern North Pacific and western Bering Sea in the season from May to July. Though they did not give the weight of testis at the onset of sexual maturity, it is suspected from the relationship between body length and weight of testes (Fig. 3, Mizue *et al.* 1966, and Fig. 27 of this study) that the sexual maturity will be attained between 100 and 200 g in the weight of combined testes. The maximum weight of the combined testes in the summer catch is about 700 g. These values are more than twice larger than those observed in the winter catch off Sanriku coast. This difference is too large to be attributed to the difference of the population, but more reasonably be considered in connection with the annual reproductive cycle of the male. Mizue *et al.* (1966) state based on the histological examination of the testes that there was found no " fully mature " individuals in the season, and considered that the weight of testes will increase in the coming mating season. Though they did not give the definition of the criterion nor explain if the " fully mature " stage indicates one of the growth stages or one of the stages of the annual reproductive cycle of the adult male, I suspect that they indicated the latter. Then more increase of the testis weight is expected in the mating season in August and September.

Age at the attainment of sexual maturity

In calculating the age at the attainment of sexual maturity, the sexual maturity of some individuals was decided by the weight of testis. Namely the testis weighing 25.7 g or less was classified into the immature, that 32.9 g or more the mature, and the intermediate into the maturing.

As shown in Fig. 11, the age of the youngest sexually mature individual is 3.5 years and that of the oldest immature 15.5 years. The maturing individuals are found in the age of 4.5 to 7.5 years. These figures suggest that the mean age of the male at the attainment of sexual maturity is approximately at 5 to 10 years. The facts that the ratio of the mature males exceeds 50% at the age above 13 years and the number of individuals older than this age is extremely scarce, suggest

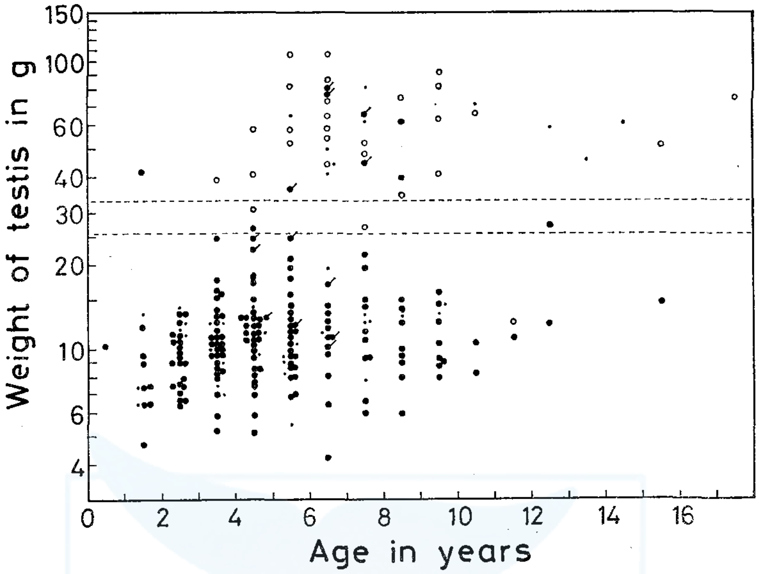

Fig. 11. *Phocoenoides* off Sanriku coast, scatter plot of the weight of testis (logarithmic scale) on age. Dotted lines indicate the mean weights at the attainment of maturing stage and of sexual maturity. For other symbols see Fig. 7.

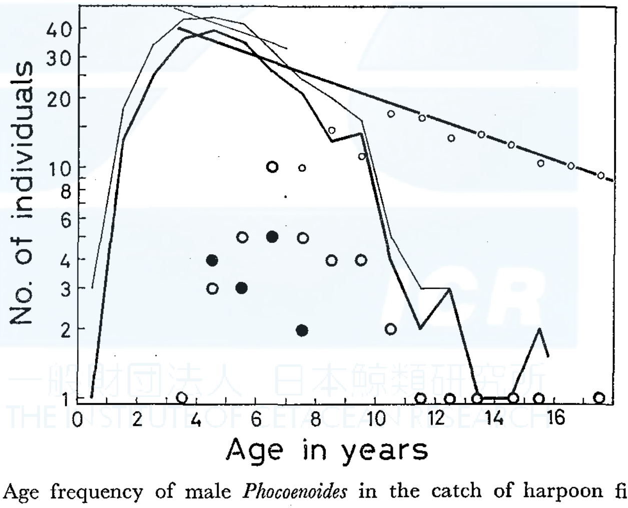

Fig. 12. Age frequency of male *Phocoenoides* in the catch of harpoon fishing off Sanriku coast. Thin solid line indicates all the aged males, thick solid line the maturity known individuals, large open circle the actual number of adult individuals, closed circle that of the maturing, and small open circle number of the adult males corrected for the fishing bias. For further explanations see text.

that the present sample underrepresents the older individuals. Possibly the older males, and especially the adults, will be less attracted by the bow wave of the ship and captured less intensely as in the case of the adult females and suckling calves

TABLE 11. *PHOCOENOIDES* OFF SANRIKU COAST CLASSIFIED BY AGE AND MATURITY, MALES

Age (yrs)	Actual no.			Calculated no. & %					
	Im.	M'ing	Mat.	Im.		M'ing		Mat.	
2.5	25	0	0	25	100.0	0	0	0	0
3.5	35	0	1	35	97.2	0	0	1	2.8
4.5	32	4	3	32	82.0	4	10.3	3	7.7
5.5	27	3	5	27	77.1	3	8.6	5	14.3
6.5	11	5	10	11	42.3	5	19.2	10	38.5
7.5	14	2	5	14	53.8	2	7.7	10.0	38.5
8.5	9	0	4	9	38.3	0	0	14.5	61.7
9.5	10	0	4	10	47.2	0	0	11.2	52.8
10.5	2	0	2	2	10.5	0	0	17.1	89.5
11.5	1	0	1	1	5.8	0	0	16.3	94.2
12.5	2	0	1	2	12.8	0	0	13.4	85.9
13.5	0	0	1	0	0	0	0	14.1	100
14.5	0	0	1	0	0	0	0	12.7	100
15.5	1	0	1	1	8.7	0	0	10.5	91.3
16.5	0	0	0	0	0	0	0	10.4	100

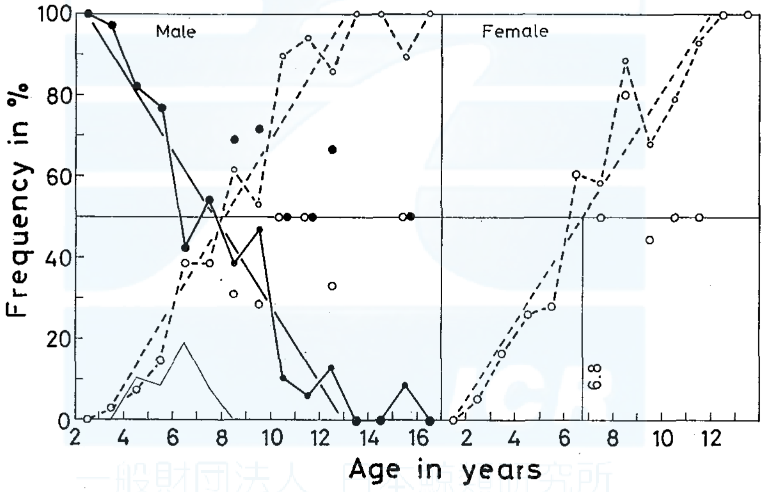

Fig. 13. *Phocoenoides* off Sanriku coast, the relationship between the sexual maturity and age. Closed circle and thick solid line indicate the frequency of immature individuals, open circle and dotted line that of the adults, and thin solid line that of the maturing invididuals. The larger circle indicates the actual frequency and the smaller the frequency corrected for the fishing bias.

mentioned later.

As the increase of the number of the mature males is almost linear at the ages from 3.5 to 6.5 years, the fishing selection by the maturity seems to be less intense at these ages (Fig. 12). Furthermore, as mentioned in the other section, most of the calves seem to be weaned before 3.5 years and the fishing bias related with the nursing can be negligible in the above range. Then the age frequency of the male in these age classes will indicate the approximate survival rate. The least squares regression for the age range gives the total annual mortality rate of 9.7% or 0.102 in the instantaneous rate. The true ratio of the mature individuals in the age classes above 6.5 years is calculated based on the assumption that the mortality rate is same in the older individuals and the shortage of the frequency above the age is caused by the underrepresentation of the adults (Table 11 and Fig. 12).

The corrected ratio of the mature individuals (y in %) is shown by the following least squares equation, when x indicates the age in years (Fig. 13).

$$y = 10.124x - 32.17, \quad 3.5 \leqq x \leqq 13.5$$

The half of the males are sexually mature at the age of 8.1 years, which is an estimation of the mean age at the onset of sexual maturity of the males. The similar regression calculated for the ratio of immature individuals is shown by the following equation.

$$y = -9.534x + 123.52, \quad 2.5 \leqq x \leqq 13.5$$

The ratio of immature males reaches 50% at the age of 7.7 years. This is the mean age when the male attains the maturing stage. The fact that the difference between the two ages is only 0.4 year suggests that the maturing stage is passed within short period.

Another estimation of the age at the attainment of sexual maturity is obtained as the mean of the age of the youngest mature individual and that of the oldest immature. Though this methods gives a more direct estimation than the former, the accuracy is lower because it is based on the small number of samples at the extremities of the ordinary distribution and because the estimation of the age of individuals is less reliable. This method, excluding the two textreme cases, gives (4.5+12.5)/2=8.5 (years), which is sufficiently close to the estimation obtained by the first method.

Body length at the attainment of sexual maturity

The unbiased estimate of the mean body length at the onset of maturing stage and that at the onset of sexual maturity are obtained from the mean growth curve and the corresponding ages estimated above. They are 195.0 cm and 196.3 cm respectively.

As shown in Fig. 14, the rapid increase of the testis weight starts at the body length of 184 cm. This feature is almost identical with the species in the offshore waters of the northwestern North Pacific and western Bering Sea studied by Mizue *et al.* (1966), or dealt in the Addendum of this study. The relationship between the body length and the ratio of sexually mature individuals is shown in Fig. 15. The largest immature male is found in the length group of 212 cm to 215 cm, and the smallest mature male in that of 180 cm to 183 cm. The males in the maturing stage are found at the body length between 176 cm and 215 cm.

The least squares regression between the body length (x in cm) and the ratio

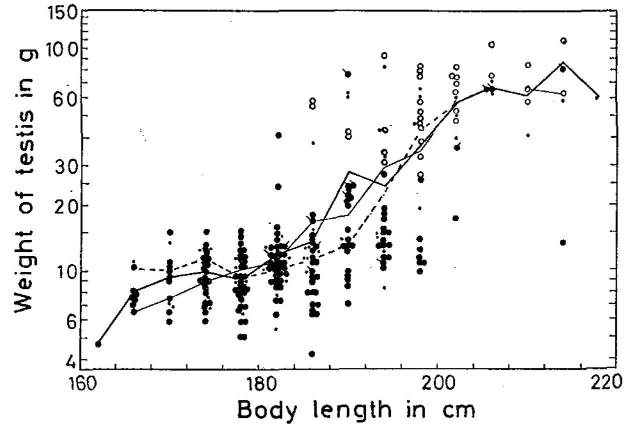

Fig. 14. *Phocoenoides* off Sanriku coast, relationship between weight of testis (logarithmic scale) and body length. Thin solid line indicates the mean in January (n=55), thick solid line that in February (n=157), and dotted line that in March (n=39). For other symbols see Fig. 7. Nine data in April are plotted.

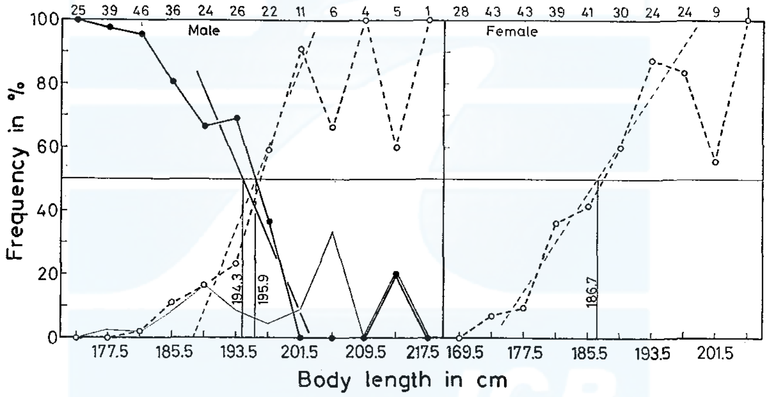

Fig. 15. *Phocoenoides* off Sanriku coast, relationship between sexual maturity and body length. Numerals at the top indicate the sample size. For other symbols see Fig. 13.

of the immature males (y_1 in %) and that between body length and the ratio of mature males (y_2 in %) are as follows.

$$y_1 = -5.8225x+1181.37 \quad 188 \leqq x \leqq 203$$

$$y_2 = 6.4850x-1220.37 \quad 188 \leqq x \leqq 203$$

These equations give 194.3 cm for the body length where half of the individuals are immature, and 195.9 cm for the length where half of the males are mature. The discrepancy between the two lengths is caused by the presence of the males at maturing stage. Since these calculations are not corrected for the fishing bias, the lengths are able to be used only for the purpose to get the unbiased estimate of the maturity of the harpoon fishing catch, but are not applicable to the samples obtained by other method.

Generally speaking, it is not expected even for the Dall's porpoise that the two sets of the body lengths estimated above by the different methods coinside, because the growth of the length seems to be very slow after the attainment of sexual maturity. Similar feature is indicated on *S. coeruleoalba* by Kasuya (1972). The coincidence of the two sets of figures are considered to have been caused by the underrepresentation of older individuals in the present materials.

Conclusion

In the present study the maturity of the male is classified into the three categories of the immature, maturing, and mature. However, this is too complicated for the practical use in the analyses of the life history of the species. For the unbiased classification of the males into two categories of the immature and mature, it will be practical to take the mean of the values at the attainment of the maturing stage and of the mature stage. They are as follows ;

Weight of testis: $(25.77+32.85)/2=29.31$ g
Age : $(7.7+8.1)/2=7.9$ years
Body length : $(195.0+196.3)/2=195.7$ cm

The last figure is practically same with another estimate $(194.3+195.9)/2=195.1$ cm.

POSTNATAL GROWTH IN THE FEMALE

Length frequency

The body lengths of 399 females ranged from 156 cm to 209 cm with the mean length of 183.5 cm (Fig. 6). Single mode will exist at the length group of 184 to 187 cm. The mean length decreases, as in the case of the male, with the progress of the fishing season. The large adult individuals and the juveniles of the suckling age are scarce in the catch.

Growth curve

The relationship between body length and the age in the female is shown in Fig. 16. The mean growth curve seems to be almost identical with that of the male until the age of 3 years, then the growth becomes slower than the male (Fig. 31). Because of the scarcity of the adult females, the growth after the age of 7 years is not directly estimated. Possibly the asymptotic length of between 195 and 205 cm will be attained at about 15 years of age as in the case of *S. coeruleoalba* (Kasuya 1976a). The mean growth curve in Fig. 16 was drawn by eye based on the above assumptions.

Age at the attainment of sexual maturity

As shown in Fig. 17, the combined weight of ovaries is usually smaller than

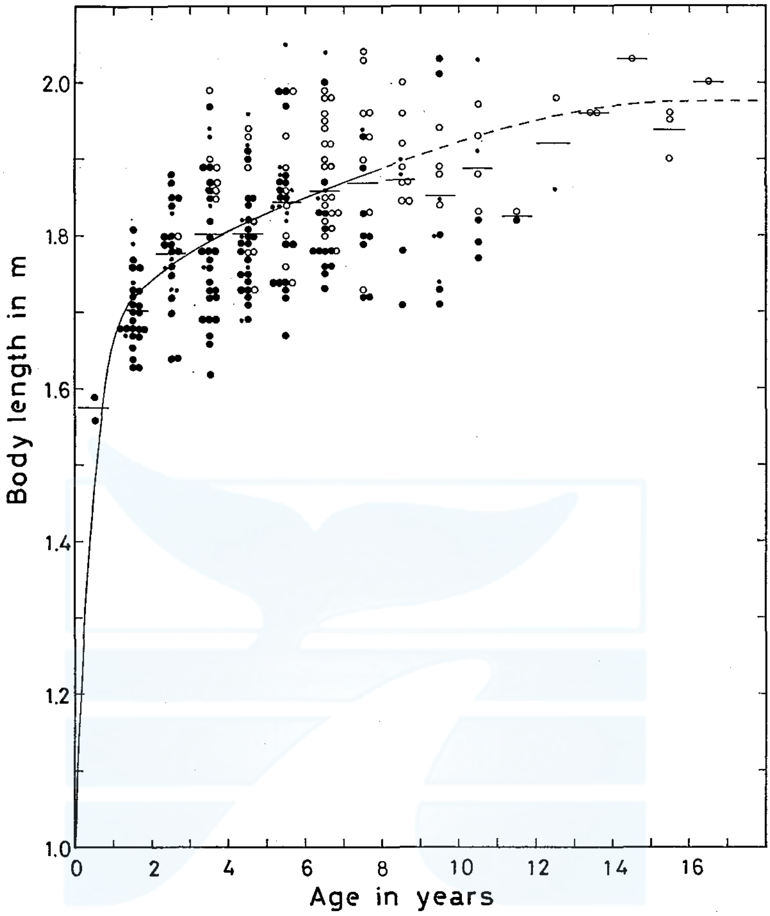

Fig. 16. Female *Phocoenoides* off Sanriku coast, scatter plot of body length on age. Growth curve is drawn by eye. For marks see Fig. 7.

3.5 g in the immature individuals having no follicle measuring 1 mm or more in the mean diameter. However, that of the immature females with the follicle exceeding the size shows heavier weight. The weight of 8 pairs of ovaries with corpus luteum ranged from 6.8 to 14.5 g.

The age of the youngest sexually mature female is 2.5 years, and that of the oldest immature is 11.5 years (Table 12). However, considering the fact that the age determination of this species is less accurate than that of other delphinids and that the ovulation occurs about 0.5 year before or after the fishing season, it will be better to say, excluding the samples at the both limits of the range, that the female attains the sexual maturity at the age between 3 and 11 years. The center of the range situates at 7 years of age, which can be a rough estimate of the mean age of the female at the onset of sexual maturity.

Another estimation of the age at the onset of sexual maturity is calculated

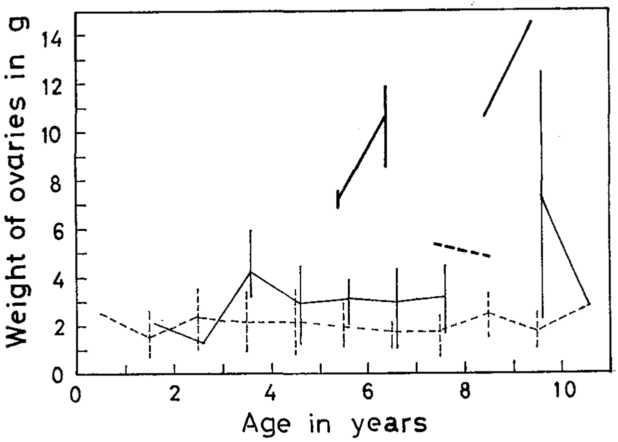

Fig. 17. *Phocoenoides* off Sanriku coast, relationship between combined weight of ovaries and age. Thin dotted line indicates 86 immature females without measurable follicle (≧1 mm), thin solid line 34 immature females with measurable follicle, thick dotted line 2 adult females without corpus luteum, and thick solid line 7 adult females with corpus luteum. Mean and range are indicated.

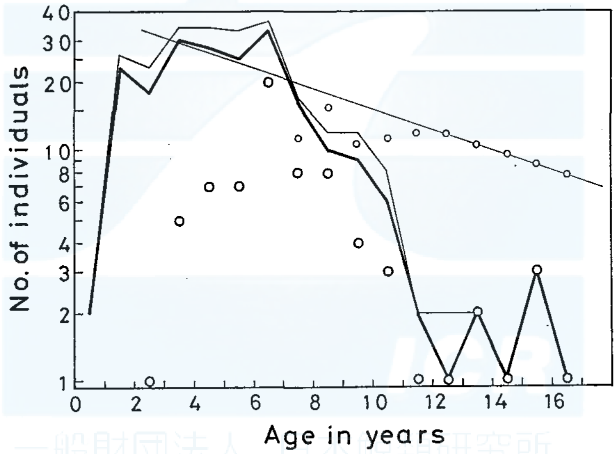

Fig. 18. Age frequency of female *Phocoenoides* in the catch of harpoon fishing off Sanriku coast. For symbols see Fig. 12.

from the ratios of adult females in each age groups. The underrepresentation of the adult females was corrected, using the total annual mortality rate of 9.7%, in the same way as used for the males (Table 12 and Fig. 18). The least squares regression gives the equation

$$y = 9.483x - 14.39, \quad 1.5 \leqq x \leqq 12.5$$

where y indicates the corrected ratio of the adult females in %, and x the age in

TABLE 12. *PHOCOENOIDES* OFF SANRIKU COAST CLASSIFIED BY AGE AND MATURITY, FEMALES

Age (yrs)	Actual no.		Calculated no. & %			
	Im.	Mat.	Im.		Mat.	
1.5	23	0	23	100.0	0	0
2.5	17	1	17	94.4	1	5.6
3.5	25	5	25	83.3	5	16.7
4.5	21	7	21	75.0	7	25.9
5.5	18	7	18	72.0	7	28.0
6.5	13	20	13	39.4	20	60.6
7.5	8	8	8	41.5	11.3	58.5
8.5	2	8	2	11.5	15.4	88.5
9.5	5	4	5	31.8	10.7	68.2
10.5	3	3	3	21.1	11.2	78.9
11.5	1	1	1	7.8	11.8	92.9
12.5	0	1	0	0	11.6	100.0
13.5	0	2	0	0	10.4	100.0

years (Fig. 13). This equation gives 6.8 years for the age when 50% of the females are sexually mature, which is sufficiently close to the figure obtained by the first method.

Body length at the attainment of sexual maturity

The body length at the age of 6.8 years, the mean age at the attainment of sexual maturity, is read on the mean growth curve as about 186.5 cm.

As shown in Fig. 16, the individuals of large body size attain the sexual maturity at an age younger than the smaller. The smallest mature female is found in the length group of 172 to 175 cm, and the largest immature in that of 200 to 203 cm. This range is not significantly different from the values of the stock in the western Bering Sea and northwestern North Pacific (Mizue *et al.* 1966, and Addendum of this study). The least squares regression between the percentage of the adult individuals, y, and the body length, x in cm, is expressed by

$$y = 3.8807x - 674.72, \quad 176 \leq x \leq 199$$

and shown in Fig. 15. This equation gives 186.7 cm for the body length where 50% of the females are sexually mature.

REPRODUCTION

Breeding season

Two different opinions have been published on the gestation length of this species. Okada and Hayashi (1951) considered on the Sea of Japan-Okhotsk Sea stock that mating will take place in about one month from the end of June to the beginning of July. However, in the same paragraph, they tell that the copulation must occur in August. The gestation was considered to last for 7 to 9 months.

One of the reasons for this conclusion is their observation that " Most of the females . . . collected [by them] in August in the Okhotsk Sea were found to be carrying small embryos of about 5.5 mm in length ". Another reason is, though the data source is not clear, that " the adults with embryos of 5 mm in body length were caught commonly in the Okhotsk Sea during the summer from June to August, and the adults caught off Tajima, [southern] Sea of Japan during March and April had either already given birth or had a large fetus of one meter in body length." In their study, no comment was made on the neonatal length.

Mizue *et al.* (1966), on the other hand, estimated the mean neonatal length as about 100 cm from the largest fetus and smallest infant caught by the Japanese salmon gillnet fishery in the western Bering Sea and northwestern North Pacific. They suggested the parturition season in late July to early August, the mating season after the end of salmon fishing season in early August, and consequently the gestation of less than 1 year.

In the present study, the gestation of 11.4 months and the parturition peak in late August were calculated for the population off the Pacific coast of Japan. These conclusions are similar to those estimated by Mizue *et al.* (1966).

The most important difference between the three studies concerns if the peak of parturition of the population in the Okhotsk Sea and Sea of Japan really exists in April as suggested by Okada and Hayashi (1951). If this is correct the length of gestation can be about 7 to 9 months (Okada and Hayashi 1951) and the daily growth rate of the fetus at the linear growth stage can be approximately between $100/30.4(7-7\times0.2)=0.587$ cm/day and $100/30.4(9-9\times0.2)=0.457$ cm/day. On the other hand, Kasuya (1977) showed that there is a linear relationship between the neonatal length of delphinids (x, cm) and the daily fetal growth rate at the linear part of the fetal growth (y, cm/day). The equation was shown as follows.

$$y = 0.001462x+0.1622$$

This equation and the neonatal length of 100 cm give the daily growth rate of *Phocoenoides* as 0.308 cm/day, which is much smaller than the rate calculated above but closer to the value 0.333 cm/day obtained in the former section. This suggests that the parturition season and the gestation length estimated by Okada and Hayashi (1951) is wrong.

The extended line of the fetal growth off the Sanriku coast shows good coincidence with the fetal lengths in May and early June in the western Bering Sea and northwestern North Pacific. However, most of the points in late June and July come above this line. There could be two interpretations for it. One is to consider that the growth of the near term fetus is faster than the previous stage. Another possibility is to expect the segregation of pregnant females in relation to the size of the fetus. Though the precise locations of the samples are not known, the presence of segregation is suggested by the fact that the fetuses in 1968 season (Koga 1969) come below the growth curve and those caught in 1964 and 1965 (Mizue *et al.* 1966) and in 1967 (provided by Dr A. Takemura) come above the line. Possibly the pregnant females of the stock with nearterm fetus will stay, in late June and July, in the waters from the western Aleutian Islands to the east coast of the Kamchatka Peninsula, and the cows with smaller fetus will migrate to further north.

Figure 19 shows the frequency distribution of the estimated date of parturition in the two stocks of the species. The dates were calculated, using the fetal growth curve of the Japanese Pacific coast stock, as the date when calves smaller than 110 cm in body length and all the fetuses might have attained the mean neonatal length of 100 cm. Since the dates and the lengths of fetuses in Mizue *et al.* (1966) were read on their Fig. 2, the accuracy might be worse. An apparent parturition peak exists in late July to early August, or slightly before that of the Japanese Pacific coast population. However, as the larger fetuses are overrepresented in the sample, the real parturition peak will be in late August to early September as in the case of the population off the Pacific coast of Japan.

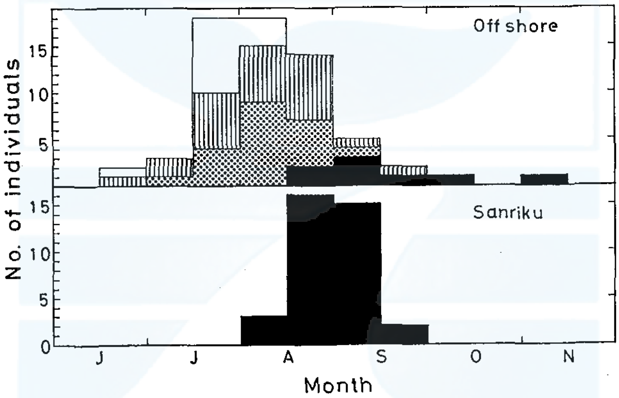

Fig. 19. Frequency of the date of birth calculated from the mean fetal growth curve and fetal length in the catch by salmon gillnet fishery in the western Bering Sea and northwestern North Pacific (Top), and that in the catch of harpoon fishing off Sanriku coast (bottom, based on fetuses). For the offshore stock, white square indicate 12 infants in Mizue *et al.* (1966), square with lines 24 fetuses in the same study, dotted square 20 fetuses provided by A. Takemura, and black square 8 fetuses in Koga (1969).

The mating season is not precisely known for the stock off the Pacific coast of Japan, because of the restricted fishing season and of the inaccuracy of the estimation of the fetal growth in the early pregnancy. However, rough estimation of the range of the season is made by moving the fetal growth curve back and forth. Then, the mating season from middle August to late October with a peak in September is estimated. Possibly this is consistent with the fact that the development of the follicles in the ovary of immature female starts in March (Fig. 20). On the Sea of Japan-Okhotsk Sea population, the occurrence of small embryos in August was confirmed by Okada and Hayashi (1951) and that in September by myself. Accordingly it is reasonable to expect that the mating season and probably the parturition season of the population is not different from those of the stock off the Pacific coast of Japan. At present there is no data to consider that the mating season of the stock in the western Bering Sea and northwestern North Pacific is different from that of two other populations dealt in this study. The concentrated unimodal breeding season of the species is different from the pattern found in the tropical or subtropical species, but seems to be common in all the boreal delphinids (Kasuya 1972).

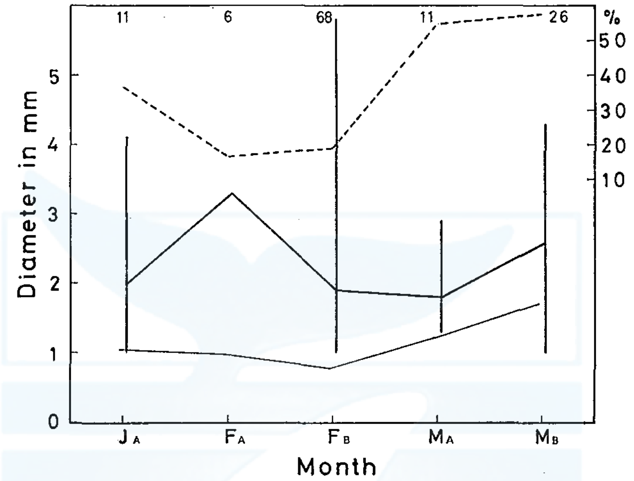

Fig. 20. Seasonal change of the diameters of the largest follicle in the ovaries of immature females off Sanriku coast. Dotted line and right scale indicate the ratio of the females with measurable follicle (≧1 mm), thick solid line the mean diameter and the range of the largest follicles in those individuals, and thin solid line the mean of all the immature females calculated assuming 0.5 mm for the unmeasurable follicles. The suffix A attached to the month indicates from the 1st to 15th of the month, B from 16th to the end, and numerals the sample size.

Sex ratio

Of the 39 fetuses from the Sanriku coast, 21 fetuses or 53.8% of the total were represented by the female. The records of 51 fetuses of the stock in the western Bering Sea and northwestern North Pacific were compiled from 24 fetuses in Mizue *et al.* (1966), 8 fetuses in Koga (1969), and 19 fetuses provided by A. Takemura. They contained 33 females or 64.7% of the total. Though these data suggest the slight excess of the female fetus in the two populations of the Dall's porpoise, further study is needed for the conclusion.

The overall sex ratio of the postnatal individuals seems to be even in the 290 samples captured by the salmon gillnet fishery in the western Bering Sea and northwestern North Pacific (Table 13). However, as shown in Table 14, the feature is slightly complicated in the catch by harpoon fishing off Sanriku coast, if analysed by the season and maturity. The maturity of most of the males was

TABLE 13. SEX RATIO AND MATURITY RATE OF *PHOCOENOIDES* CAUGHT BY SALMON GILLNET IN THE N.W.N. PACIFIC AND W. BERING SEA

Author		1	2	3	Total
Sex ratio[4]					
Adult	N	34	—	—	34
	%	58.8	—	—	58.8
Immature	N	73	—	—	73
	%	42.9	—	—	42.9
Total	N	107	148	35	290
	%	49.5	54.1	40.0	50.7
Maturity[5]					
Male	N	54	—	—	54
	%	25.9	—	—	16.7
Female	N	53	60	14	127
	%	37.7	43.3	57.1	42.5

1) Provided by Takemura, 2) Mizue *et al.* 1966, 3) Koga 1969, 4) Ratio of females, 5) Testes exceeding 150 g in combined weight are dealt as mature.

TABLE 14. SEX RATIO AND MATURITY RATE OF *PHOCOENOIDES* CAUGHT BY THE HARPOON FISHING OFF SANRIKU COAST[1]

Month		Jan.	Feb.		Mar.		Apr.	Total
		B	A	B	A	B	B	
Sex ratio[2]								
Adult	N	44	53	69	35	24	4	229
	%	63.6	49.1	62.3	74.3	66.7	0.0	60.7
Immature	N	108	111	237	90	105	5	656
	%	25.9	29.7	43.0	41.1	57.1	0.0	39.6
Total	N	222	186	488	135	145	9	1,081
	%	33.8	32.8	46.5	51.1	60.7	0.0	43.8
Maturity								
Male	N	96	105	161	62	53	9	486
	%	16.7	25.7	16.1	14.5	15.1	44.4	18.5
Female	N	56	59	145	63	76	0	399
	%	50.0	44.1	29.7	41.3	21.1	—	34.8

A, 1st to 15th. B, 16th to the end of month. 1) Based on body length when genital organ is not studied. 2) Ratio of females.

identified by the histological examination of the testis, however the males with a testis weighing 29.4 g or more were considered as sexually mature when the testis was " maturing " or testis was not examined histologically. The maturity of some other males was classified by the body length (196 cm or more into the mature). The females measuring 187 cm or more were considered as sexually mature, when the reproductive tract was not examined.

The ratio of females in the immature individuals shows an increase from 26% in late January to 57% in late March. The age classes producing such a seasonal fluctuation is from 4.5 to 7.5 years of age, namely the individuals after the com-

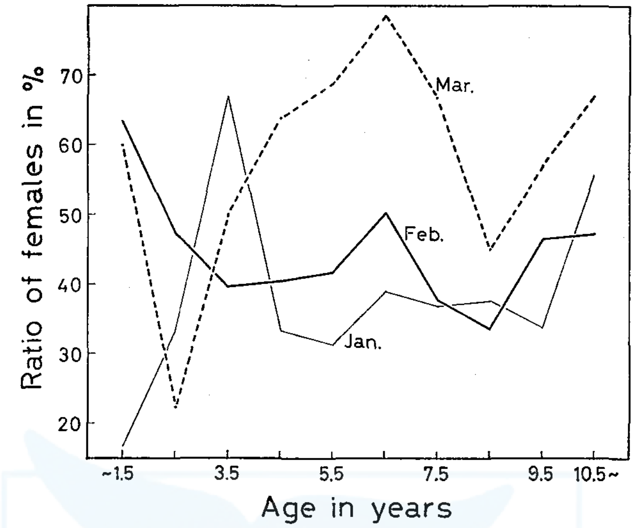

Fig. 21. *Phocoenoides* off Sanriku coast, seasonal change of the sex ratio.

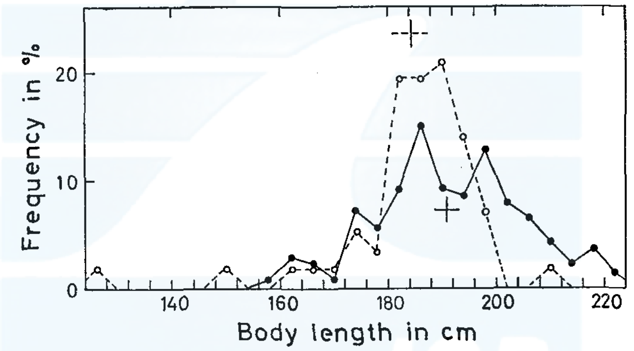

Fig. 22. Body length frequency of *Phocoenoides* caught by the harpoon fishery off Tajima coast compiled from Noguchi (1946). Closed circle and solid line indicate male (n = 140), and open circle and dotted line female (n = 57). Mean body length and the range of two standard errors are indicated.

pletion of weaning and before the attainment of sexual maturity (Fig. 21). The decline of the female ratio at the ages of 7.5 and 8.5 years will have a relationship with the fact that the females attain the sexual maturity about one year earlier than the male and the sexually mature individuals are underrepresented in the catch of harpoon fishing. In the adult individuals the number of the females exceeds that of the males in all the months studied. Though the trend of seasonal change of the sex ratio is same with the immature individuals, the seasonal difference is much smaller.

Noguchi (1946) provided the body length measurements of 197 Dall's porpoises caught by the harpoon fishing off Tajima coast (southern Sea of Japan). There is some question if the length was measured by the same way used in this study because both the modal and mean lengths are about 5 cm larger than the present materials collected off the Pacific coast of Japan (Fig. 22). The date of the catch is somewhere between the middle of March and middle of May. The overall sex ratio is so low as 28.9%, and if the maturity is estimated based on the body length criteria obtained in this study, the ratio of the females in the immature individuals is 26.5% (n=117) and that in the mature 32.5% (n=80).

Maturity rate

The ratio of sexually mature individuals in the catch off Sanriku coast is shown in Table 14. The maturity of some individuals is identified by the body length. The ratio shows, in both sexes, a gradual decrease from late January to late March. The change is more conspicuous in the female, and the maturity rate of the sex in late March is about a half of that in late January.

This result, together with the seasonal change of the sex ratio discussed above, indicates the presence of the segregation by the sex and maturity. The immature individuals seem to have tendency to arrive fishing ground off Sanriku coast after the adult individuals. This tendency is much clear in females than in males.

Reproductive cycle

Since the length of gestation is estimated in the former section as 11.4 months, the lengths of lactation and resting period are estimated in this section. The number of females at each reproductive stage in the catch off Sanriku coast is shown in Table 15. Though the stages were decided through the observation of the reproductive tracts, there are many adult females which reproductive stages were not decided obstacled by the removal of the internal organs. Since they, 34 individuals, were not lactating, they should have been classified into pregnant or resting females. Then the more correct estimates of the pregnant and resting females can be from 58 to 92 and 2 to 36 individuals respectively. If the sample correctly represents the ratio in the population and the length of gestation is 11.4

TABLE 15. RERPODUCTIVE STAGES OF ADULT FEMALES OF *PHOCOENOIDES*1)

Locality	Season		Preg.	P. & L.	Lact.	Rest.	Unknown
Sanriku	Jan.	B	22	1	0	0	2
	Feb.	A	3	0	0	0	6
	Feb.	B	9	0	3	2	22
	Mar.	A	15	4	3	0	3
	Mar.	B	9	0	0	0	1
	Total		58	5	6	2	34
N.W.N. Pacific &	1		20	0	0	0	0
W. Bering Sea	2		24	0	1	1	0
	3		8	0	0	0	0
	Total		52	0	1	1	0

1) For abbreviations see Tables 13 and 14.

months, the mean length of a reproductive stage in months is given by

$$X \cdot 11.4/P$$

where P indicates the number of pregnant females, and X the number of females at one of the reproductive stages.

Above calculation gives the following estimation for the stock off the Pacific coast of Japan.

Simple pregnancy	10.50—10.81 months
Overlapping of pregnancy and lactation	0.90— 0.59 months
Simple lactation	1.09— 0.71 months
Resting	6.51— 0.24 months
Total	19.00—12.35 months

The mean length of calving interval is from 1.0 year to 1.6 years. Though this is extremely short, the cycle is not impossible, if most of the females are conceived in the summer of the parturition. However, the most improbable is the shortness of the lactating period. The overall period of lactation obtained above is only from 1.3 months to 2.0 months. Generally speaking the lactation of the odontoceti last at least for about one year (Brodie 1969, Kasuya 1976a, Perrin *et al.* 1976). It is reasonable to consider, apart from the underrepresentation of the adult individuals, that the lactating females are underrepresented in comparison with the pregnant and resting females.

This is indirectly indicated by the body length frequencies (Fig. 6), where the individuals smaller than 172 cm is scarce and those smaller than 156 cm is almost entirely lacking. The former length corresponds to the age of about 1.5 years on the mean growth curve, and the latter to that of about 0.5 year. Similar

TABLE 16. ESTIMATION OF NURSING PERIOD OF *PHOCOENOIDES* OFF SANRIKU COAST

Age (yrs)	Annual mortality rate			0	0.1	0.15
	No. weaned individuals			Weaning /year	Weaning /year	Weaning /year
	♂	♀	Total			
0.	0	0	0			
0.25				5	5	5
0.5	3	2	5			
1.0				39	39.50	39.75
1.5	18	26	44			
2.0				13	17.40	19.60
2.5	34	23	57			
3.0				21	26.70	29.55
3.5	44	34	78			
4.0				1	8.80	12.70
4.5	45	34	79			
Mean weaning age	—	—	—	1.69	1.96	2.06
Standard error	—	—	—	0.11	0.11	0.11

feature is seen in the catch by harpoon fishing in the southern Sea of Japan studied by Noguchi (1946). In his data the number of individuals under 172 cm is only 14 or 7.1% of the total. The absence of the juveniles does not seem, as mentioned in the latter section, to be a result of the size selection of harpoon fishermen. It is most reasonable to consider that suckling calf and nursing cow are not effectively captured by the harpoon fishing. In the other words, the gradual increase of the catch of calves at the age from 0.5 to 4.5 years will be related with the completion of weaning. As shown in Table 16, such probably weaned individuals start to appear before the age of 0.5 years and cease at 4.0 years of age, and when the sexes are combined the number is hightest between the ages of 0.5 and 1.5 years. Though another interpretation is discussed at the end of this section, this is an estimation of the range of the weaning age. For the correct estimation of the mean age at weaning, the mortality of weaned calves needs to be considered. When n_x indicates the apparent number of calves weaned at the age x, N_x the number of calves weaned at the age x and corrected for the mortality, and M the annual total mortality rate of the weaned calves, there can be the following approximation.

$$N_x = n_{x+0.5} - (1-M) \cdot n_{x-0.5}$$

Defining the age x as the mean age of the calves which have weaned between x −0.5 and x +0.5 years of age, and assuming the total mortality rate of 0, 0.1, and 0.15. The estimates of the mean age at weaning 1.69, 1.96, and 2.06 are obtained. Though the estimation of the mortality rate at these age classes is difficult, the first assumption is without doubt an underestimate and the last possibly an overestimate.

The above calculation is affected by two kinds of biases. The first is the possible inclusion of some sucklings as indicated by the presence in the catch, of 11 females lactating or lactating and simultaneously pregnant. Possibly at least some of the five individuals dealt, in the above calculation, as weaned by the age of 0.5 year could still being nursed. This bias causes the underestimation of the weaning age. If the youngest 11 calves, the number of lactating females, are excluded, the above calculation gives the mean age of 2.07 years (M=0.10). The other bias is caused by the time lag between the end of lactation and the start of the independent life of the calf. As reasonably expected, if the weaned calves stay by the mother for a considerable length of time and protected from the fishery, the above estimation can be higher than the true weaning age. In case of *Stenella coeruleoalba* off the Pacific coast of Japan, the weaned calves are considered to stay in the nursing school for about 1.5 years in the average (Miyazaki 1977b). However, this will not necessarily mean that the weaned calves of *S. coeruleoalba* accompany the mothers. Since the school size of *Phocoenoides* is usually so small as 2 or 3 individuals, there is not expected such a developed social behavior as observed in *S. coeruleoalba*, and the seasonally restricted breeding season of the present species will help the rapid recombination of the school member. Therefore the time lag in the present species will not be so large as in *S. coeruleoalba*. As the conclusion, because the two kinds of biases must exist at the unknown degrees, it will be safe to say that the length of lactation of *Phocoenoides* off the Pacific coast of Japan have the variation from 0.5 year to 3.5 years with the possible average of about 2 years. Further study is needed for the better estimation.

Though the mean length of the resting period, 0.24 to 6.51 months estimated from the ratio of the number of resting females to that of pregnant females, is within the reasonable range, the accuracy is insufficient. The fact that the lactating females and females pregnant and simultaneously lactating are caught in the later part of the fishing season suggests that these females would have been near the end of lactation and weaning peak will exist in between February and the peak of the next mating season in September (Table 15).

The mean calving interval of the species off the Pacific coast of Japan is not precisely estimated. If the above estimation of the lengths of lactation and of resting period is correct, the mean calving interval will be between $(11.4+24+0.24)/12=3.0$ years and $(11.4+24+6.51)/12=3.5$ years. Another estimation is made by assuming that the calves are usually separated from the mother when the mother starts the next gestation. This means, in other words, that the length of lactation estimated above is the sum of the lactating and resting periods. Then the claving interval can be $(11.4+24)/12=3.0$ years. However, since such a detailed discussions are impractical at present, it will be possible only to say that the mean calving interval is approximately about 3 years.

The frequency of reproductive stages of the females caught by the salmon gillnet fishery in the western Bering Sea and northwestern North Pacific was calculated from the published and unpublished data (Table 15). The scarcity of lactating or resting females is similar to the catch by harpoon fishing off Sanriku coast. However, the capture of many calves smaller than 130 cm presumably born within 1 year (one in Takemura's sample and 19 in Mizue *et al.* 1966) indicates the presence of many lactating females in the population. Possibly the lactating females are underrepresented in the catch compared with the catch of the pregnant females. At present there is no exact way of estimating the reproductive cycle of the females in the stock, however an attempt is made in Addendum.

Accumulation rate of corpora in the ovaries

Table 17 shows the relationship between the age and the reproductive stages of the females off Sanriku coast. The age compositions of the lactating and resting females, which are few in number, are same with that of pregnant individuals. The frequency of the corpora number shown in Table 18 indicates, together with Table 17, that most of the adult females caught by the fishery are very young with only 1 or 2 ovulations. Possibly, most of the catch of the adult individuals are before the first conception, in their first gestation, or in the lactation followed by the first parturition. If all the 19 pregnant females which have 1 to 3 corpora are considered as being in their first gestation, the mean number of ovulations experienced before the first conception is 1.3. This is close to the figure 1.67 estimated by the same method for an exploited population of *Globicephala melaena* (Sergeant

TABLE 17. RELATIONSHIP BETWEEN AGE AND REPRODUCTIVE STAGES OF FEMALE *PHOCOENOIDES* OFF SANRIKU COAST

Age (yrs)	Immat.	Mature				
		Preg.	P. & L.	Lact.	Rest.	Total[1]
2.5	17	0	0	0	0	1
3.5	25	1	0	0	0	5
4.5	21	2	0	1	0	7
5.5	18	4	0	0	0	7
6.5	11	16	0	0	0	20
7.5	8	1	2	1	1	8
8.5	2	5	0	2	0	8
9.5	5	4	0	0	0	6
10.5	3	1	0	0	0	1
11.5	2	1	0	0	0	1
12.5	0	1	0	0	0	1
13.5	0	0	1	0	0	2
14.5	0	0	1	0	0	1
15.5	0	0	0	0	0	3
16.5	0	1	0	0	0	1

1) Adults of unknown reproductive stage included.

TABLE 18. RELATIONSHIP BETWEEN NO. OF OVULATIONS AND REPRODUCTIVE STAGES IN ADULT *PHOCOENOIDES* OFF SANRIKU COAST

No. corpora	Preg.	P. & L.	Lact.	Rest.
1	14	0	0	1
2	4	0	1	0
3	1	0	0	0
9	1	0	0	0
Total[1]	58	5	6	2

1) Individuals of unknown corpora number included.

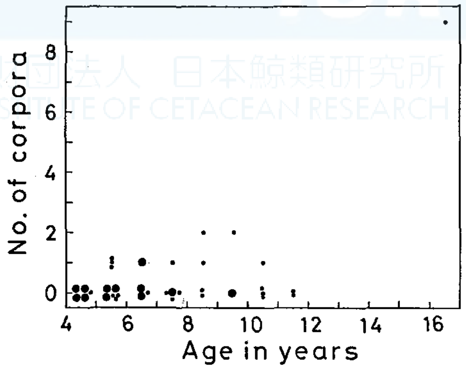

Fig. 23. Scatter plot of the number of copora in the ovaries on age, *Phocoenoides* off Sanriku coast. Large circle indicates 5 individuals, and the small one.

1962), but significantly smaller than the figure 2.08 of an almost unexploited population of *Stenella attenuata* (Kasuya *et al.* 1974).

The scatter plot of the ovulation number on age is shown in Fig. 23. The data is insufficient to estimate the mean annual ovulation rate. The rough estimate of the range is given as from (9−1)/(16.5−5.5)=0.73 to (9−1)/(16.5−11.5)=1.6 per year.

Regression of corpora diameter

The diameters of 20 corpora lutea of pregnancy ranged from 17.2 mm to 24.6 mm, and the mean was 21.7 mm. No accessory corpus luteum was observed. The size distribution of the corpora albicantia of 10 adult females is shown in Fig. 24. There is a group in the size of corpus at the diameter of 6 mm to 8 mm. It is represented by the female nos. 3, 4, 5, 6, 8, caught in the winter season off the Pacific coast of Japan. Since the pregnant individuals are considered to be in their first gestation, these corpora are thought as the corpora of the ovulations in the last summer, namely about 0.5 year after the ovulation or the parturition (no. 3). The larger corpora albicantia of the no. 2 resting female caught in July in the southern Okhotsk Sea are suspected as those of the ovulation in the summer of the capture. The corpus albicans of the no. 1 resting female is considered as derived from the ovulation occurred after the last mating season. Other corpora ablicantia possibly regressed for 1 or more years.

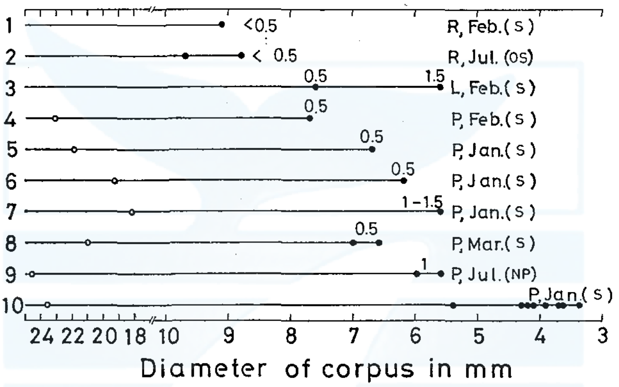

Fig. 24. Distribution of the diameter of corpus luteum (open circle) and of corpus albicans (closed circle). Reproductive stages (R: resting, L: lactating, P: pregnant), Date of catch and location (OS: southern Okhotsk Sea, NP: northwestern North Pacific, S: off Sanriku coast) are indicated. The numerals by the circle indicate the approximate time after the start of regression.

DISCUSSION

The assuption of the nonrandom catch is an important factor in the present study of the life history parameters of the Dall's porpoise. The discussion is made at first step on this problem, then on the segregation of the species and the rates of mortality and recruitment.

The underrepresentation of suckling calves

The scarcity of the juvenile calves at the suckling age is a peculiar feature of the catch by the harpoon fishing off Sanriku coast and in the southern Sea of Japan studied by Noguchi (1946). This is not observed in the incidental catch by the salmon gillnet fishery in the western Bering Sea and northwestern North Pacific. As the cause of this age structure, there can be the following three possibilities.

1. The selection by the fishermen, who generally hopes to get larger individuals.
2. The recent decrease of the recruitment.
3. The scarcity of the cows and suckling calves in the fishing ground, which is caused by the segregation of those individuals.
4. The technical inability of taking the suckling calves.

The first may exist in some degree, because the catch is sold by the weight of the carcass weighed after removing the viscera. However, the effect seems to be almost negligible when the condition of the fishery is considered. Usually the fishing vessels on Sanriku coast arrive at 7 to 8 o'clock at the fishing ground, 10 to 40 or 50 nautical miles (18 to 80 km) off the coast, and search and harpoon the porpoises until 14 to 15 o'clock to return to the port by the evening. Two or less number of porpoises are usually caught from one school. The mean daily catch is only 4 to 6 individuals per ship even when the boats which come back without catch are excluded (Kasuya 1976b). Furthermore, since the porpoises quickly swim around the bow of the boat, there is little chance for 1 to 3 harpooners on the bow to select large individual. If the first hypothesis is correct and the other 3 hypotheses are wrong, there must be more catch of lactating females, because the mean lengths of lactation in odontoceti are at least about 1 year (page 39) and the number of lactating females in a population is expected to be nearly equal to or more than that of pregnant females.

The 2nd hypothesis will be safely denied. Since the exploitation of the Japanese east coast population has continued for more than 30 years and there is detected no indication of the rapid decrease of the population density (Kasuya 1976b), it is difficult to expect a rapid decrease of the recruitment in recent few years.

The 3rd hypothesis will not be denied at present, when it is considered that there is expected a segregation of pregnant females with near term fetus in the summering ground of the offshore stock in the western Bering Sea and northwestern North Pacific, and that the individuals of the Japanese east coast population shows a segregation by the maturity and sex. Further study is needed for the confirmation of segregation of lactating females.

The 4th hypothesis implies that the suckling calves accompanying the mothers migrate to the fishing ground, but are not captured by some ecological or technical reasons. Because the fishermen harpoon only the porpoises riding the bow wave, the above age composition will occur if the mother and calf are less attracted by the boat compared to the weaned juveniles. Actually it is well known that there exist many schools which do not approach the bow of the boat even when fisherwen try to let them do so. According to the personal communication of Mr K. Sasaki, a porpoise hunter, and to my own observations on board of the porpoise hunting boat and on the research vessels, the number of such schools is slightly more than half of the total number of *Phocoenoides* schools sighted. Mr Sasaki tells that even when a school comes to the bow of the ship the presumable mother accompanied by a calf and the very large individuals stay only for a short length of time or stay far from the ship, however, the individuals of the medium size play on the bow wave longer and are the easiest to catch. This is the reason why I consider the 4th hypothesis most probable as the explanation of the scarcity of calves at the suckling age. Therefore the underrepresentation of the calves at the suckling age will be fundamentally ascribed to the behavior of the lactating females discussed in the next section.

The underrepresentation of adult individuals

In the former section, it is shown that the number of adult individuals is scarce, in both sexes, in the catch by harpoon fishing. The analyses of age and of the corpora number in the ovaries of the catch off Sanriku coast suggest that only 6 females have presumably experienced the 2nd gestation and 42 adult females are probably before the 2nd gestation. This could be explained by one of the following two hypotheses.

5. The mortality is high in the population.
6. The older individuals are not captured by the harpoon fishing.

The instantaneous annual total mortality rates of the Dall's porpoise off Sanriku coast tentatively calculated from the right side slope in the age frequencies are as follows.

Male : 0.2185, between 4.5 and 9.5 years of age.
Female : 0.3356, between 6.5 and 10.5 years of age.

As the lactating females are underrepresented in comparison with the pregnant females (page 39), the apparent mortality rate of the females can be expressed slightly higher. If the total mortality rate of the female, M, is same for all the age classes, there can be the following equations, where S_1

$$S_1 = l_0 \int_0^7 e^{-Mx} dx$$

$$S_2 = l_0 \int_7^\infty e^{-Mx} dx$$

$$A = \frac{S_2}{S_1 + S_2}$$

indicates the number of immature females, S_2 that of adult females, l_0 number of females at the age 0, and A the ratio of adult females in the total female population. When 0.2185 the lower figure is taken for M, A is 21.7%. Assuming the sex ratio at birth as 1 : 1, and the length of mean calving interval as 2 years the possible shortest, or 3 years the more reasonable estimate obtained in this study, the gross annual recruitment rate of 5.43% or 3.62% is obtained. Whereas the total annual mortality rate is $(1-e^{-0.2185})\cdot 100=19.6\%$. Accordingly, if there is no bias in the catch, the population must decrease at the rate of about 15% per year. However, the exploitation of the population have continued at least for 13 years at the level of about 6,000 individuals per year (Addendum Table of Kasuya 1976b), and there is detected no indication of rapid decrease of the stock. If the population really decreased at the rate of 15% per year, the stock should have decreased in the 13 years to 12% of the level in 1963. Such a large decrease must have resulted in the decrease of the annual catch and that of the mean daily catch per boat. This is the reason why I consider the 5th hypothesis incorrect.

The indication suggesting the correctness of the 6th hypothesis is obtained by the comparison of the age compositions of *Stenella coeruleoalba* caught by the driving method and by harpoon fishing. The ages were determined based on the dentinal growth layers in case of the individuals younger than 10 to 15 layers, but based on the cemental layers in older individuals (Kasuya 1976a). The age frequencies of 29 males and 35 females in the catch by harpoon fishing were obtained off Taiji (33°35′N, 135°57′E) in the winter of 1971, where the harpoon fishing was operated only for two or three years until the driving fishery of the species started. All the 1388 (564 females and 824 males) samples by driving fishery were obtained off the east coast of Izu Peninsula (34°56′N, 139°09′E) and randomly collected by myself or by Kasuya and N. Miyazaki. They are the catch of following 7 drivings, where only the numbers of the aged individuals are listed. The maturity of the female was decided by the presence of corpus in the ovary and that of the male by the weight of testis (smaller than 15 g immature).

Driving 22: 14, Dec., 1971. Immature school. 62 females (2 to 8 layers, adult absent) and 218 males (2 to 12 layers, adults 2.8%).

Driving 38: 17, Nov., 1972. Nursing school. 101 females (1 to 49 layers, adults 77.0%) and 52 males (1 to 20 layers, adults 53.8%).

Driving 43: 15, Nov., 1973. Nursing school. 89 females (1 to 40 layers, adults 58.1%) and 135 males (1 to 31 layers, adults 62.4%).

Driving 44: 20, Nov., 1973. Nursing school. 111 females (0 to 43 layers, adults 66.7%) and 111 males (1 to 58 layers, adults 68.5%).

Driving 45 and 46: 23 and 24, Nov., 1975. Probably nursing schools, mixed in the harbor. 170 females (0 to 58 layers, adults 59.9%) and 192 males (0 to 58 layers, adults 60.4%).

Driving 47: 3, Nov., 1976. Males dominant. 31 females (2 to 26 layers, adults 29.0%) and 116 males (3 to 46 layers, adults 69.8%).

The fishing grounds of the two fisheries are separated only about 330 km, and considered as being migrated by a single population (Miyazaki *et al.* 1974, Kasuya 1976c). Though the between schools differences of the age composition and of the sex ratio are not small, the population structure will be roughly estimated by combining the 7 schools. The ratio of sexually mature individudals is 55.7%

of the 553 maturity and age known females caught by the driving, and 47.4% of the 816 males. On the other hand, when all the maturity known individuals are included (40 females and 42 males), the corresponding figures of the harpoon fishing are so low as 17.5% and 9.5% respectively, These figures are similar to those of *Phocoenoides* caught by the harpoon fishing both in the amplitude and in the between sexes difference. The bias of the fishing methods is demonstrated more tipically in the age frequencies of Fig. 25. If the instantaneous total mortality rate is calculated from right side slope of the age frequencies of the catch by the driving fishery, the following figures are obtained.

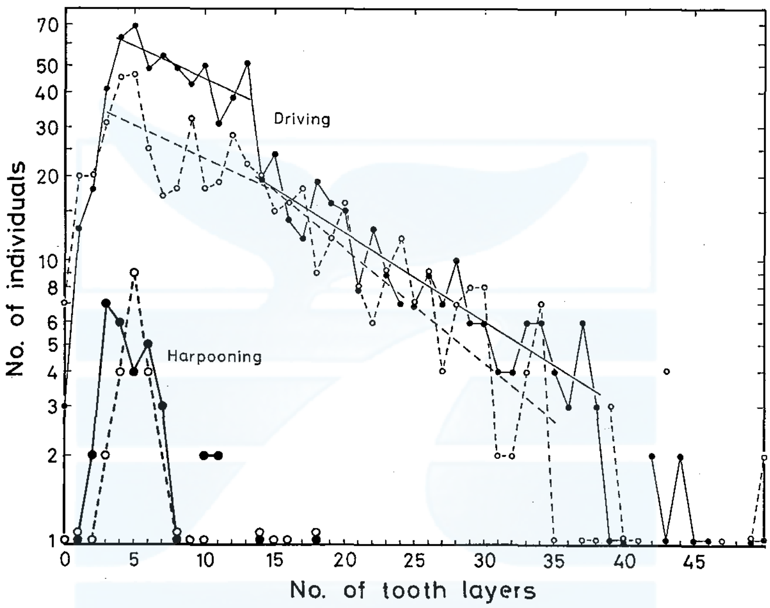

Fig. 25. *Stenella coeruleoalba* off the Pacific coast of Japan, age frequencies of the catch by driving fishery (small circles and thin lines) and that by harpoon fishery (large circles and thick lines). Closed circle and solid line indicate male, and open circle and dotted line female.

Female : 0.0537, 3 to 14 layers
0.0944, 15 to 35 layers
Male : 0.0529, 4 to 13 layers
0.0726, 14 to 38 layers

When the instantaneous natural mortality rate of the adult female is assumed as 0.06 or 0.07 (Kasuya and Miyazaki 1976), the fishing mortality rate of from 0.0244 to 0.0344 is estimated, and then the natural mortality rate of the females before the maturation 0.0193 to 0.0293. The left side slope of the age frequency of the catch by driving fishery seems to be caused by the loss of juvenile calves (Kasuya 1972) and by the segregation of the immature individuals. Especially the inclusion of the data of the immature school, driving no. 22, causes the high frequency of the juvenile females of the ages between 3 and 6 layers and males between 3 and 10 layers.

Though the above age frequency of the catch by the driving are extremely different from the age structure of *Phocoenoides* off Sanriku coast, that of the *Stenella coeruleoalba* caught by the harpoon fishing is similar to the latter in the predominance of the individuals below 9 years of age, the mean age at the attainment of sexual maturity (Kasuya 1972, Miyazaki 1977a).

From these reasons I consider that the 6th hypothesis will be close to the truth. Though the possibility of the segregation is not perfectly denied, it seems to be more reasonable to consider that the Dall's porpoise, as well as the striped dolphin, becomes less attracted by the bow wave of the ship or becomes more cautious of danger soon after the onset of sexual maturity. This change of the behavior has a effect to lower the fishing mortality rates of the adults and suckling calves accompanying the mother. The underrepresentation of the lactating females (page 39) will be explained by the enhancement of the behavior during the lactation in relation to the limited swimming ability of infant, or by a simple fact that lactating females are generally older than the pregnant. The possibility of the segregation of the lactating females is still left to be studied.

The discussions on the age structure of the Dall's porpoise incidentally captured by the salmon gillnet fishery is made in Addendum.

Segregation by age and maturity

In the former sections, the following phenomena are indicated through the analyses of the catch by harpoon fishing off Sanriku coast.

1. In the adult, the female ratio is high and stable throughout the season.
2. In the immature, the ratio of females is low, but increases from late January to late March.
3. In the male, the ratio of the adult is low, and changes little.
4. In the female, the ratio of the adult is high, but decreases from late January to late March.

The different analysis of the same material is shown in Table 19, where the seasonal increase of the ratio of the immature females is clearly demonstrated. These seasonal fluctuations of the composition are difficult to be explained by the catch bias of the fishing, but is reasonable to be considered that the migration of the immature individuals, especially of the female, increases from January to March.

Kasuya (1976b) showed on the catch of the species off Sanriku coast that the catch per day's work of the harpoon fishing boat has a peak in April when the value is about twice of that in January, and concluded that the fishing season closes in April, by the decrease of the demand of the porpoise meat and the migration of other profitable fishing objects, before the peak of the north bound migration of the species. The seasonal change of the catch per fishing boat described by Kasuya (1976b) will indicate, in a strict sence, that of the abundance of the young exploitable age classes, and coincides well with the above feature of the seasonal

TABLE 19. COMPOSITION OF *PHOCOENOIDES* CATCH OFF SANRIKU COAST, SHOWN BY SEX AND SEASON

Sex and Maturity[1]		Jan.	Feb.		Mar.		Apr.	Total
		B	A	B	A	B	B	
Males								
Adult	no.	16	27	26	9	8	4	90
	%	10.5	16.5	8.5	7.2	6.2	44.4	10.2
Immature	no.	80	78	135	53	45	5	396
	%	52.7	47.5	44.1	42.4	39.4	55.6	44.8
Total	no.	96	105	161[2]	62	53	9	486
	%	63.2	64.0	52.6	49.6	45.6	100	55.0
Females								
Adult	no.	28	26	43	26	16	0	139
	%	18.4	15.9	14.1	20.8	12.4	0	15.7
Immature	no.	28	33	102	37	60	0	260
	%	18.4	20.1	33.1	29.6	46.5	0	29.4
Total	no.	56	59	145	63	76	0	399
	%	36.8	36.0	47.4	50.4	58.9	0	45.1
Grand total	no.	152	164	306	125	129	9	885
	%	100	100	100	100	100	100	100

1) Based on body length when genital organ is not studied.

2) One length unknown individual included. For abbreviations see Table 1.

change of the catch composition.

In the Japanese coastal waters the Dall's porpoise is distributed mainly in the waters north of the 17°C isothermal line, and in the waters above this surface water temperature the temperate and subtropical dolphins are dominant (Kasuya 1976b). The 17°C isothermal line moves seasonally from southernmost point at 35°N in February to the northernmost point of 42°N in August along the Pacific coast of Japan (Fig. 26). The surface water temperature at the fishing ground is lowest in February, and it becomes gradually higher in March and April. They will offer a suggestion on the seasonal change of the distribution of the species off the Pacific coast of Japan.

Other indication of the seasonal migration of the population is found in the sighting records of dolphins (Kasuya and Miyazaki 1976b, Kasuya unpub.). The Dall's porpoise arrives off Sanriku coast (38°N to 41°N) in September, but it does not arrive south of 37°N in November. The observation outside of the fishing ground in winter is lacking. In May there migrate many *Lagenorhynchus obliquidens* and few *Grampus griseus* and *Orcinus orca* off Sanriku coast, but there are still found many *Phocoenoides*. The southern limit of *Phocoenoides* in this month is approximately at 37°N on the Pacific coast of Japan, and *Lagenorhynchus* is recorded between 36°N and 42°N. In June *Phocoenoides* retreat to 38°30′ and *Orcinus, Grampus,* and *Globicephala* are recorded south of 39°30′N. However, no Dall's porpoise is recorded south of 42°N in July in spite of the presence of *Lagenorhynchus*, *Orcinus*, *Grampus*, *Delphinus*, and *Tursiops* in the area. The facts that the southernmost sightings of *Phocoenoides* were made in May at about 37°N and that the catch of the species could not be comfirmed at Choshi fish market situating at 35°45′N (Kasuya 1976b) suggest that the southern limit of the ordinary distribution of the species in winter season will be about 36°N in the Pacific coast of Japan.

Possibly the species will arrive at the southernmost range in early February, and be followed by the retreat to the north in February through August. Accordingly the start of the fishing season in the last decade of January coincides nearly with the end of the southbound migration and the begining of northbound migration. The seasonal change of the ratio of the immature females suggests that these individuals migrate to the Pacific coast of Japan earlier than the adults and possibly spend the winter in the southern waters. The adult females, on the other hand, will arrive later and stay in the northern region. The males, possibly the adult too, seems to winter in the further south near the southern limit of the distribution. This is suggested from the catch off Sanriku coast in April (Table 14) and from the catch off Tajima coast studied by Noguchi (1946). The porpoise hunting off Tajima coast (southern Sea of Japan) was operated from late March to early June, and the catch of *Phocoenoides* was replaced in late April by *Lagenorhynchus* the temperate species. Namely the hunting was operated near the southern limit of the dis-

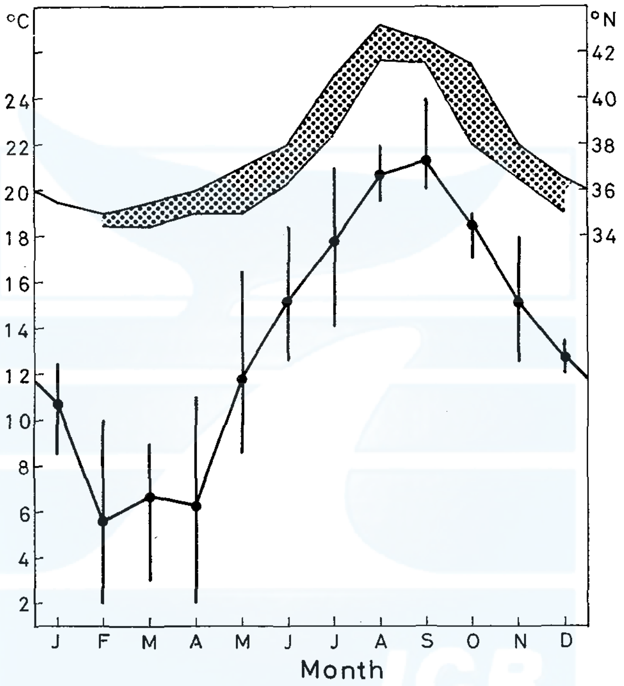

Fig. 26. Surface water temperature off the Pacific coast of Japan. Closed circle and solid line the range and mean at 39°30′N, 142°30′E off Sanriku coast in the five years from 1972 to 1976, and the dotted area the range of the latitude of the 17°C isothermal line at 20 to 30 nautical miles off the coast in the same period (data based on Anon. 1972–1976).

tribution of the stock in the season. If the maturity is determined by the body length there are 140 males of 54 adults and 86 immatures, and 57 females of 26 adults and 31 immatures. The ratio of the males is 71.1% and the maturity rate is 38.6%, and both of these figures are higher than those off Sanriku coast. The maturity rate of the female is similar to the catch off Sanriku coast.

The tendency of the immature individuals being distributed near the southern periphery of the wintering ground seems to exist even in the stock in the northwestern North Pacific and western Bering Sea. This is suspected from the fact that the ratio of *dalli*-type is higher in the juveniles in the catch off Sanriku coast (page 10).

Rates of mortality and reproduction

The total mortality rate of the male at the pubertal ages was estimated as 0.102 in instantaneous rate or 9.7% per year (page 27). However the accuracy of the estimation is doubtful, because it is based on the age frequency of the restricted age classes and limited number of samples. The annual changes of the population structure and of the timing of migration and sampling will cause the bias of unknown degree. The following mathematical approach is made in order to have a suggestion on the possible range of these parameters.

When the abbreviations are defined as follows,

M_1, M_2, M_3: Instantaneous natural mortality rate at the ages between 0 and 2 years, 2 and 7 years, and above 7 years respectively.

F_1, F_2, F_3: Instantaneous fishing mortality rates of the above age groups.

S_1, S_2, S_3: Number of females of the above three age groups.

R: Ratio of females at birth, assumed as 0.5.

C: Calving interval, assumed as 2 or 3 years.

the number of females at each age groups in a stational population is shown by the following approximations.

$$S_1 = l_0\int_0^2 e^{-(M_1+F_1)x}dx$$

$$S_2 = l_0\cdot e^{-2(M_1+F_1)}\int_0^5 e^{-M_2+F_2)x}dx$$

$$S_3 = l_0\cdot e^{-2(M_1+F_1)}\cdot e^{-5(M_2+F_2)}\int_0^\infty e^{-(M_3+F_3)x}dx$$

$$l_0 = S_3\cdot R/C$$

Then the ratio of the adults in the population is calculated by $S_3/(S_1+S_2+S_3)$, and the net production rate by $S(1-e^{-F})/(S_1+S_2+S_3)$, where S indicates the stock size of the exploited age classes and F the sustainable fishing mortality rate of the same age classes. F is calculated from the 3rd and 4th equations by assuming the natural mortality rate. The calculation was made based on the following three hypotheses.

Hypothesis 1: $M_1=M_2=M_3>0$, $F_1=F_2=F_3>0$, nonselective catch and constant mortality rate.

Hypothesis 2: $M_1=M_2=M_3$, $F_1=F_3=0$, $F_2>0$, selective catch and constant natural mortality.

Hypothesis 3: $M_1=2\cdot M_3$ up to 1 year, then $0.25\cdot M_3$, $M_2=0.25\cdot M_3$, $M_3>0$, $F_1=F_3=0$, $F_2>0$, selective catch, natural mortality rate variable.

The first hypothesis is not supported by the results of the present study. The 3rd hypothesis, the most optimistic, is based on the result of the present study indicating the selective exploitation of the juveniles between the weaning and sexual maturity, and on the natural mortality rate of *Stenella attenuata* analysed by Kasuya (1976a). Kasuya (1976a) showed that the mean natural mortality rate of female *S. attenuata* in the entire immature period could be less than a half of that of the adult female, but he suggested that the mortality of the newborn claves could be higher. The low mortality rate before the attainment of sexual maturity is also suggested in the age frequency of *S. coeruleoalba* shown in Fig. 25. This is in the good resemblance with the mortality of the human race, where the mortality rates of the women at the ages between 4 years and 19 years is shown to be at the minimum in the life (Anon. 1976). Possibly this feature will be common in some of the high trophic k-selective mammal species, and is expected for the Dall's porpoise. Accordingly, the natural mortality rates in the 3rd hypothesis are so assumed that the mean annual natural mortality rate in the entire immature stage is a half of that of the adult period and the rate is highest in the early suckling age of 0 to 1 year. The 2nd hypothesis is the intermediate of the first and the 3rd. The natural mortality rate of the adult female, M_3, is assumed as 0.05, 0.075, and 0.10, and the calving interval as 2 years and 3 years. The former cycle is attained when the gestation occures, in most of the adult females, with the interval of one year, and seems to be shorter than the cycle of the Dall's porpoise off the Pacific coast of Japan. The latter cycle, 3 years, is estimated in the present study and seems to be more reasonable.

The results of the calculations are shown in Table 20. It indicates that the

TABLE 20. POPULATION PARAMETERS IN HYPOTHETICAL STATIONAL POPULATION OF *PHOCOENOIDES*

M_3, assumed	0.050		0.075		0.100	
C, calving interval	3 years	2 years	3 years	2 years	3 years	2 years
Nonselective catch, hypothesis-1						
$F_1=F_2=F_3$	0.039	0.063	0.014	0.038	<0	0.013
Net production	3.8%	6.1%	1.4%	3.7%	<0	1.3%
Ratio of adult	53.6%	45.3%	53.6%	45.3%	—	45.3%
Selective catch, hypothesis-2						
F_2	0.171	0.252	0.055	0.136	<0	0.043
Net production	4.0%	6.3%	1.5%	4.0%	<0	1.4%
Ratio of adult	56.4%	48.5%	54.4%	46.9%	—	45.8%
Slective catch, hypothesis-3						
F_2	0.206	0.287	0.107	0.188	0.032	0.113
Net production	4.8%	7.1%	2.9%	5.4%	1.0%	3.6%
Ratio of adult	56.7%	49.0%	55.0%	47.6%	53.6%	46.5%

selective catch of the immature individuals gives slightly higher net production. The fact that the net production is negligible under the assumption of $M_3=0.10$ and $C=3$, suggests that the actual natural mortality rate of the adult female will be below 0.10. If the population off the Pacific coast of Japan is stational with the annual catch of 6,000 individuals, the population need to be between 6,000/0.048= 125 thousands and 6,000/0.015=400 thousands (2nd and 3rd hypotheses with $M=$ 0.05 or 0.075, and $C=3$).

ADDENDUM

Dr A. Takemura of the Faculty of Fisheries, Nagasaki University provided for the present study the biological data and tooth samples of *Phocoenoides* of *dalli*-type caught incidentally by the mother ship salmon gillnet fishery in the western Bering Sea and northwestern North Pacific. Since these samples belong to a stock different from Japanese Pacific coast population, and its biological informations are still very limited, some brief analyses are made in comparison with the results obtained on the latter population.

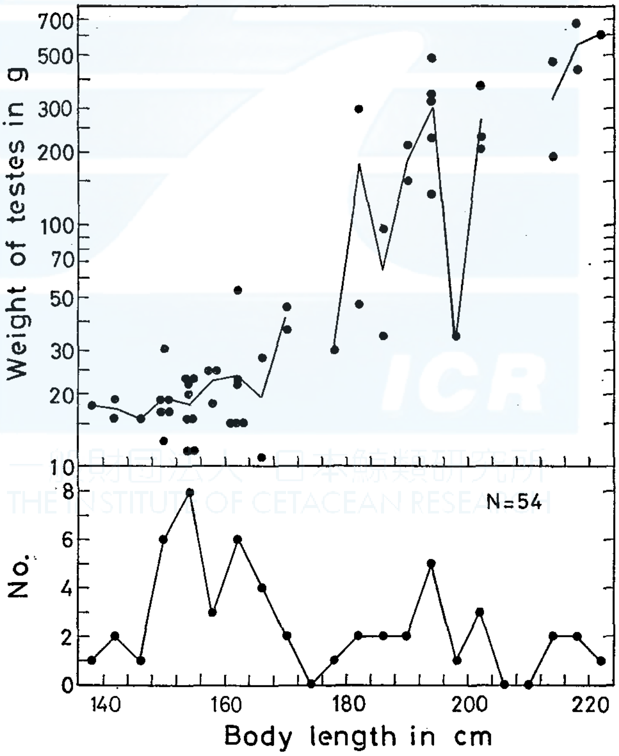

Fig. 27. Male *Phocoenoides* in the western Bering Sea and northwestern North Pacific. Body length frequency (bottom) and scatter plot of the weight of combined testes (logarithmic scale) on body length (top).

The samples were collected in the period from May 23, 1967 to July 9, 1967 on board of a mother ship. The ordinary biological observations were made and recorded by A. Takemura.

Age determination

The age was determined by myself with the same method as used in the former sections. Since the accumulation of the cemental layers is considered as annual and the parturition peak as from late August to early September, the number of stainable cemental layers will approximately coincide with the age of the porpoise in years. However, the length of time from the mean date of catch of the aged individuals, 15th of June, and the expected peak of the parturition in early September will cause some signigicant bias in the estimation of the growth of juveniles. This is the reason why the body length of the porpoise with N stainable layers is plotted in Fig. 27 at the age of (N−1/4) years.

Length and age frequencies

The body lengths ranged from 139 cm to 220 cm in males, and from 144 cm to 212 cm in females. The calf smaller than 130 cm, which is considered as born in the year (Mizue *et al.* 1966), is only one individual in spite of the same sampling

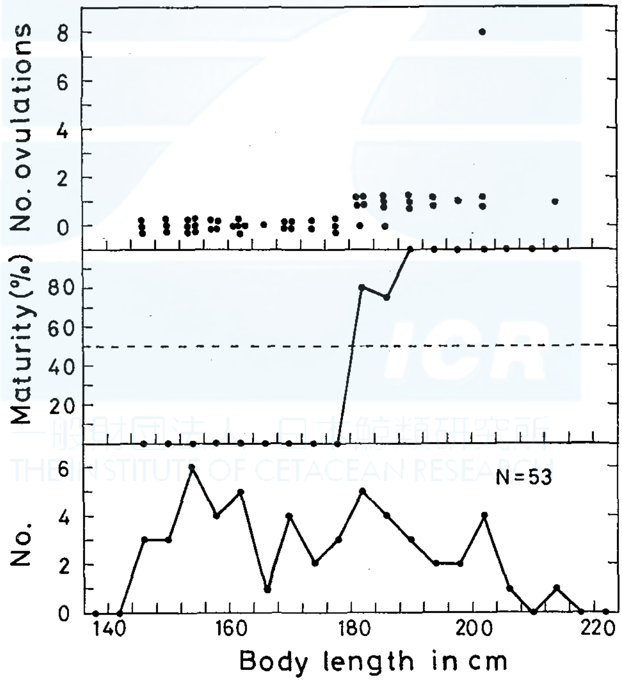

Fig. 28. Female *Phocoenoides* in the western Bering Sea and northwestern North Pacific. Body length frequency (bottom), relationship between body length and the ratio of the sexually mature individuals (middle), and the scatter plot of the number of corpora in the ovaries on body length (top).

TABLE 21. LIFE HISTORY PARAMETERS OF *PHOCOENOIDES* ESTIMATED IN THE PRESENT STUDY

	Parameters		Japanese Pac. Coast	N. W. N. Pac. / B. S.
1.	Length at birth (cm)		—	99.7
2.	Length at 1 year (cm)		165	165
3.	Length at sexual matirity (cm)	♂	195.7	189.1*
		♀	186.5	177.9*
4.	Testis weight at maturity (g)		29.31	50–100
5.	Age at sexaul maturity (years)	♂	7.9	4–5*
		♀	6.8	4–5*
6.	Parturition season		Aug.-Sept.	Aug.-Sept.
7.	Length of gestation (months)		11.4	—
8.	Length of lactation (years)		2	1–2
9.	Calving interval (years)		3	2–3
10.	Prenatal sex ratio (female %)		53.8 (n=39)	64.7 (n=51)

*: Considered as an underestimation of unknown degree caused by the sample bias.

season with Mizue *et al.* (1966), where total of 19 juveniles of the size are recorded. It also need to be noted that the frequency is low, in both sexes, at the lengths about 170 cm to 180 cm. This corresponds with the low frequency at the age of 3 years. The larger individuals are more abundant in the present sample than that from the harpoon fishing.

The presence of a dominant mode at one and two years of age is a feature different from that of the catch by harpoon fishing, where the calves of suckling ages are extremely scarce. The other mode at the older age is nearly same with that of the catch by harpoon fishing.

Sexual maturity

On the males caught by the salmon gillnet fishery, the mean weight of the testis at the attainment of sexual maturity is not estimated. However, the scatter plots of the weight of testes against the body length suggest that the weight would be from 100 to 200 g in the combined weight. Then the sexual maturity seems to be attained at the length from 180 to 200 cm (Fig. 27). This feature is almost same with the data in Mizue *et al.* (1966) and Koga (1969). When the weight of 150 g is tentatively used as the mean weight of testes at sexual maturity, the least squares regression between the ratio of sexually mature individuals and the body length gives 189.1 cm as the length where half of the males are mature (the present data, and those in Mizue *et al.* 1966 and in Koga 1969 included). The half of the males in the present materials are sexually mature at 4 to 5 years of age (Fig. 29).

The present scanty materials suggests that the sexual maturity of the females is attained at a length between 180 and 187 cm (Fig. 27). The corresponding figure read on Fig. 5 of Mizue *et al.* (1966) is from 170 to 190 cm. The least squares regression calculated for the present data and those in Mizue *et al.* (1966) gives 177.9 cm as the length where half of the females are sexually mature. The mean

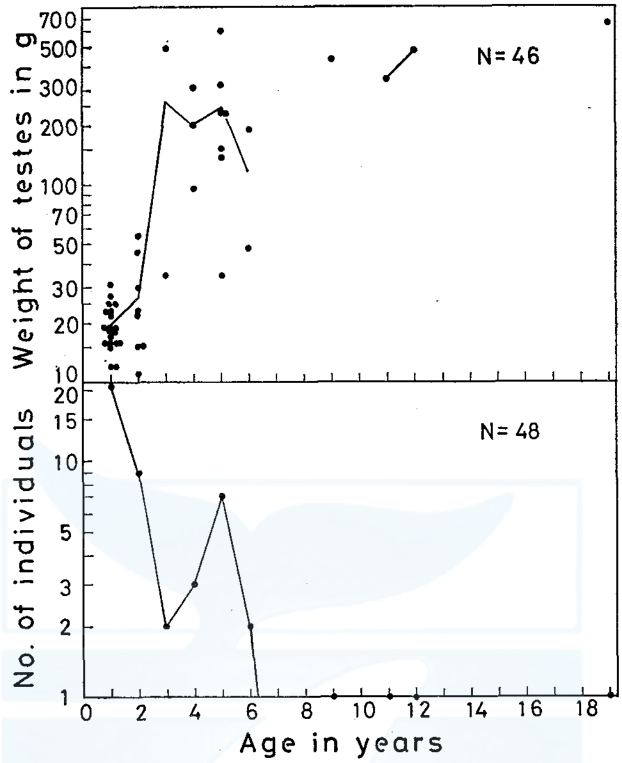

Fig. 29. Male *Phocoenoides* in the western Bering Sea and northwestern North Pacific. Age frequency (bottom) and the scatter plot of the weight of combined testes on age (top). Both are plotted on semi-logarithmic scale.

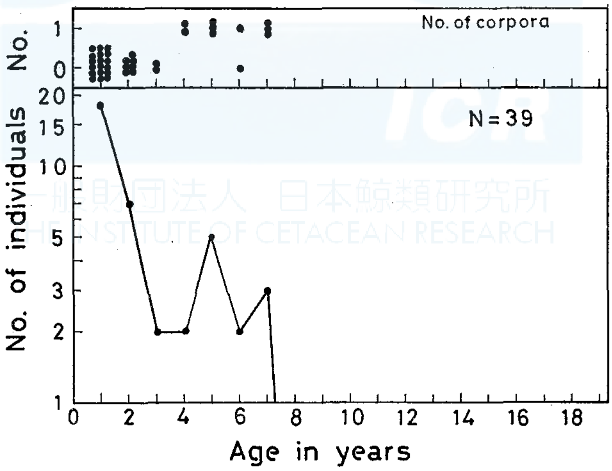

Fig. 30. Female *Phocoenoides* in the western Bering Sea and northwestern North Pacific. Age frequency (bottom) and the scatter plot of the number of corpora in the ovaries on age (top).

age at the attainment of sexual maturity is between 4 and 5 years in the present materials (Fig. 30).

As mentioned later, the mean ages and lengths at sexual maturity estimated above will in some degree be affected by the bias of the sample.

Reproductive stages

The sex ratio and ratio of the adults in the catch by the salmon gillnet fishery are within the ranges of the corresponding figures of the catch by harpoon fishing off Sanriku coast (Tables 13 and 14).

The adult females are almost exclusively composed of the pregnant females (Table 15). The number of corpora in the ovaries is only one in most of the adult females in the present materials (Fig. 27). However, this feature is different from the catch studied by Mizue *et al.* (1966) in 1964 and 1965.

Growth curve

The age-length relationship of the present materials at the ages below 2 years does not seem to be significantly different from the growth curve fitted for the population off the Pacific coast of Japan. However, the body lengths of the individuals from 3 to 7 years of age situates above it (Fig. 31). Although this will indicate the faster growth in the northwestern North Pacific and western Bering Sea population, the following factor can not be neglected. Some premature individuals attain the sexual maturity, in the two stocks, at the age of 3 or 4 years, and these individuals are usually larger than the immature individuals of the same age (Figs 7, 16, and 31). Since the underrepresentation of the weaned juveniles is indicated in the age frequency, it is reasonably expected that at the age of 3 to 7 years the sexually immature individuals, which are smaller in body length, are underrepresented than the adults of the same age. This bias causes the mean growth curve to be higher than truth.

Discussion and conclusion

The Dall's porpoise caught incidentally by the salmon gillnet fishery are constituted mainly of the possible suckling calves and the young adults of both sexes. The incidental death of many calves and few lactating females are of contrast. Mr S. Nagahora of the Iwate Prefectural Fisheries Research Laboratory informed me several observations where mother stays by a dead or alive calf entangled in the gillnet. The calf is less experienced and will easily be entangled in the gillnet, and perhaps the accident of the calf will indicate for the mother the presence of the gillnet. This can be an explanation of the low mortality of the lactating females. The decrease of the catch of the calves from 1 year through 3 years will be a reflection of the completion of weaning. Some juveniles will already be weaned by the age of 1 year and will be underrepresented in the present material. This age structure suggests the mean nursing period of from 1 year to 2 years, and consequently the mean calving interval of 2 to 3 years.

The reason of the low mortality of the weaned immature individuals is not

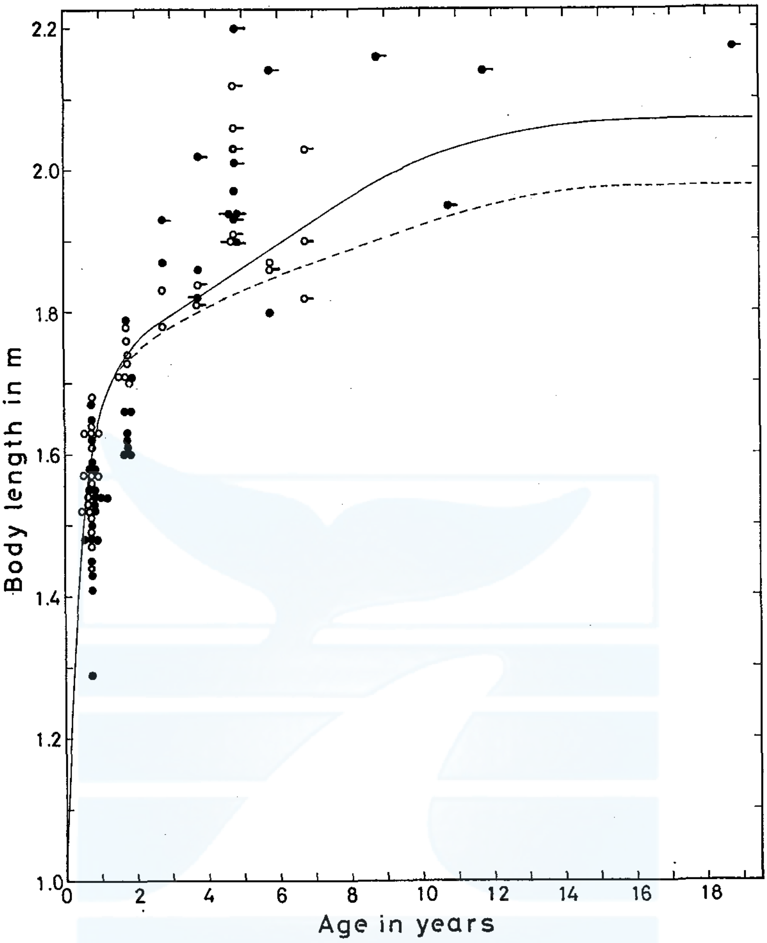

Fig. 31. *Phocoenoides* in the western Bering Sea and northwestern North Pacific. Scatter plot of the body length on age. Closed circle indicates male, and open circle female, and the circle with bar the adult. The solid line (male) and dotted line (female) are growth curves fitted for the species off Sanriku coast.

clear. Possibly one of the following two reasons is working for it.

1. Presence of segregation, the weaned immature individuals are distributed outside of the sampling area in the season.
2. Change of the behavior at the weaning and at the attainment of sexual maturity.

The difference of the food preference between the growth or reproductive stages is reported by Mizue *et al.* (1966). The nonpregnant females were feeding almost exclusively on squid, but the pregnant females on more variety of food organisms including fish and shrimp. It is not clear in their study if the difference of food items is related to the difference of the location or to that of the real preference.

However, since the segregation by maturity and sex is suggested in the wintering ground off the Japanese coast (pages 10 and 50), it will be more reasonable to support the first hypothesis.

The scarcity of the individuals over 7 years of age will indicate the underrepresentation of the older individuals. Possibly the older and more experienced individuals are not usually entangled in the gillnet.

Since the immature, and probably smaller, individuals at the ages above 4 years are underrepresented compared with the adult larger individuals of the same ages, the mean body lengths and mean ages at the attainment of sexual maturity obtained in the present study can be the underestimations. Therefore it is unreasonable, at present, to conclude that the difference of the growth between the stock off the Pacific coast of Japan and that in the northwestern North Pacific and western Bering Sea is so large as observed in the present materials.

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Dr A. Takemura of the Faculty of Fisheries, Nagasaki University, kindly provided the tooth specimens and the biological data of the porpoise caught incidentally by the salmon gillnet fishery. Mr S. Nagahora and Mr J. Iwagiri of the Iwate Prefectural Fisheries Research Laboratory, Mr T. Okazaki of the Far Seas Fisheries Research Laboratory kindly recorded the colour types of the porpoise caught incidentally by the research vessels of the salmon gillnet fishery. Dr Y. Naito of the National Institute of Polar Research, Dr N. Miyazaki of the National Science Museum, and Dr T. Kajihara and Dr M. Iwata of the Ocean Research Institute provided the sporadic records of the porpoise in the Japanese coastal waters. This study is indebted also to the crews of the research vessels *Hayachinemaru*, *Enoshimamaru*, *Hakuhomaru* and *Tanseimaru*, Mr S. Miyoshi the owner and crews of the whaling boat *Ginseimaru* no. 2, and to the staffs of various fish markets in the Sanriku region for their cooperation. This study was technically assisted by Misses Y. Oka, M. Oya and S. Wada. I would like to convey my deep appreciation to all who assisted and cooperated in this study.

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EXPLANATION OF PLATES

PLATE I

The individual variation of the pigmentation pattern of *Phocoenoides dalli* caught by the harpoon fishing off Sanriku coast.

Fig. 1. Type-1, male.
Fig. 2. Type-1, male.
Fig. 3. Type-2, 195 cm, male.
Fig. 4. Type-2, 177 cm, male.
Fig. 5. Type-3, female.
Fig. 6. Type-3, male.
Fig. 7. Type-4, 168 cm, male.
Fig. 8. Type-4, male.
Fig. 9. Type-5, 178 cm, female.
Fig. 10. Type-6, 182 cm, male.

PLATE II

The individual variation of the pigmentation pattern of *Phocoenoides dalli* caught by the harpoon fishing off Sanriku coast.

Fig. 1. Type-7, male.
Fig. 2. Type-8, 193 cm, female.
Fig. 3. Type-9, 181 cm, female.
Fig. 4. Type-10, 204 cm, male.
Fig. 5. Type-11, female.
Fig. 6. Type-12, 207 cm, male. White patches on dorsal fin and chest region are artifact of the reflection of light.
Fig. 7. Type-13, 168 cm, female.
Fig. 8. Type-12, ventral view of the individual shown in Fig. 6.
Fig. 9. Type-14, 175 cm, female.
Fig. 10. Type-3, male. An individual different from that in Fig. 6, Plate I.

PLATE III

Tooth sections of *Phocoenoides dalli*, decalcified and stained with haematoxmylin. Abbreviations are as follows.

C: Cementum, D: Dentine, E: Enamel, M: Periodontal membrane, N: Neonatal line in dentine, Open circle: Dentino-cemental boundary, Closed circle: Cemental growth layer.

Figs 1 and 2. 110 cm, female, *dalli*-type, 26, July, 1972, 46°43′N, 162°24′E. Born in the year of catch, no cemental layer is deposited.

Figs 3 and 4. 149 cm, male *truei*-type, 3, March 1974, off Sanriku coast. Presumably born in the preceding summer. One unstainable and a stainable cemental layers are deposited. Cementum of this individual is extraordinary thick, and an accessory layer is present.

Figs 5 and 6. 182 cm, male, *truei*-type, 21, Feb., 1976, off Sanriku coast. Sexually immature. 9 stainable layers in cementum.

PLATE IV

Figs 1 and 2. 196 cm, male, *truei*-type, 27, Feb., 1974, off Sanriku coast. 12 stainable layers in cementum. For abbreviations see Plate III.

Fig. 3. Immature testis tissue. 185 cm, *truei*-type, 20, Feb., 1976, off Sanriku coast. Weight of testis 10.8 g.

Fig. 4. Immature testis tissue. 174 cm, *truei*-type, 20, Feb., 1976, off Sanriku coast. Weight of testis 7.2 g.

Fig. 5. Mature testis tissue. 194 cm, *truei*-type, 19, Feb., 1976, off Sanriku coast. Weight of testis 43.9 g.

Fig. 6. Mature testis tissue. 190 cm, *truei*-type, 20, Feb., 1976, off Sanriku coast. Weight of testis 41.4 g.

Tissues in Figs 3 to 6 are taken from the center of the testis.

PLATE V

The growth stages of the epididymal tissue of *Phocoenoides dalli* caught off Sanriku coast. Scale indicates 0.1 mm.

Fig. 1. Immature epididymis. 184 cm, *truei*-type, 18, Feb., 1976. Weight of testis 6.4 g.

Fig. 2. Immature epididymis. 166 cm, *truei*-type, 20, Feb., 1976. Weight of testis 7.3 g.

Fig. 3. Maturing epididymis. 191 cm, *truei*-type, 18, Feb., 1976. Weight of testis 24.7 g.

Fig. 4. Maturing epididymis. 206 cm, *truei*-type, 17, Feb., 1976. Weight of testis 66.2 g.

Fig. 5. Mature epididymis. 194 cm, *truei*-type, 19, Feb., 1976. Weight of testis 43.9 g.

Fig. 6. Mature epididymis. 212 cm, *truei*-type, 19, Feb., 1976. Weight of testis 81. 7 g.

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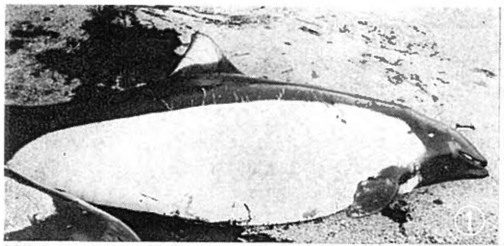
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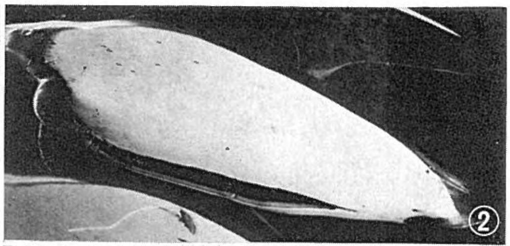
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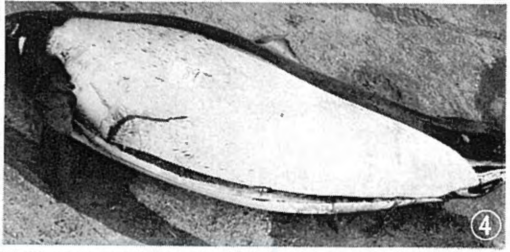
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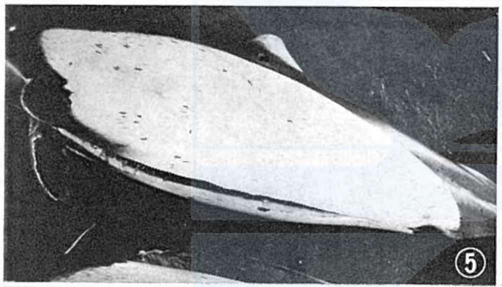
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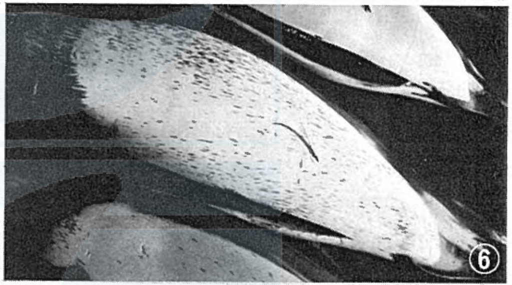
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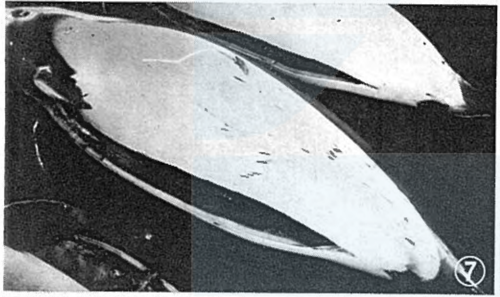
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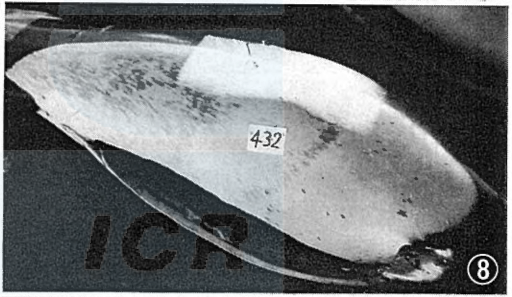
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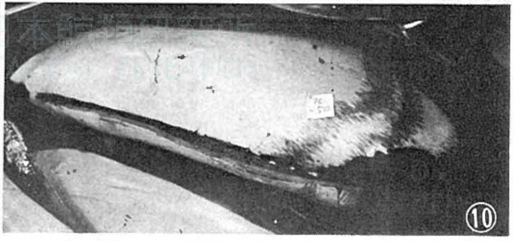
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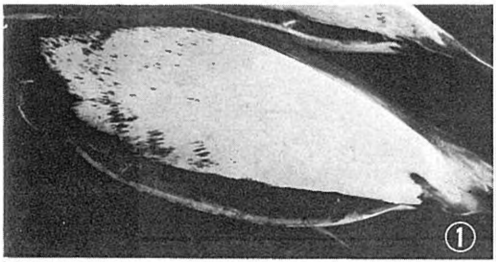
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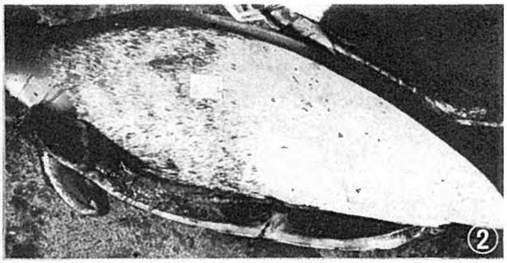
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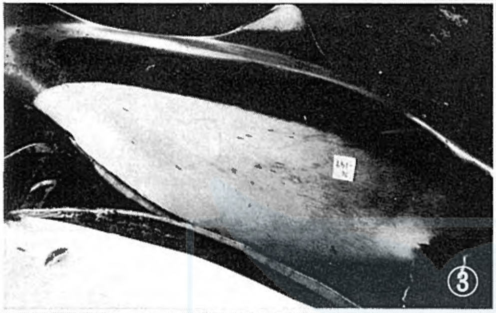
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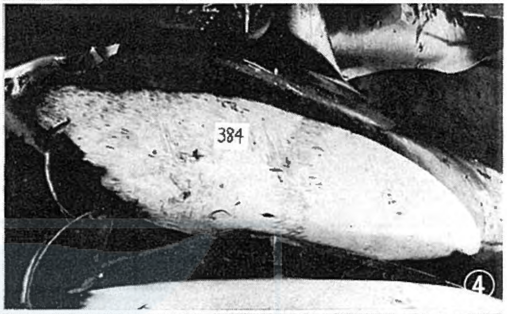

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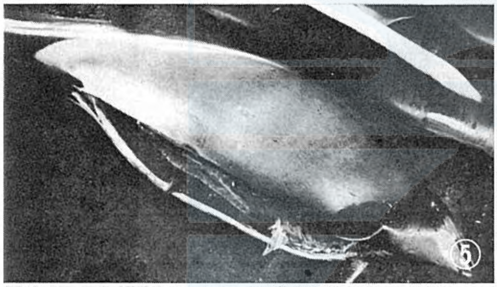
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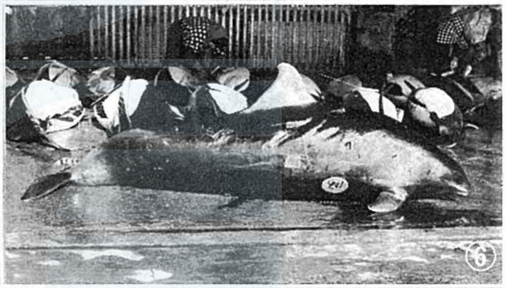
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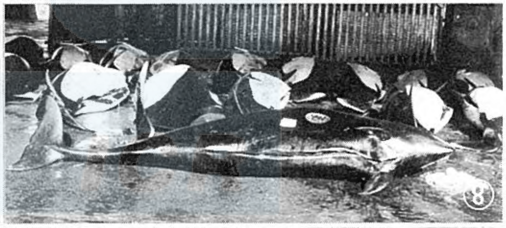
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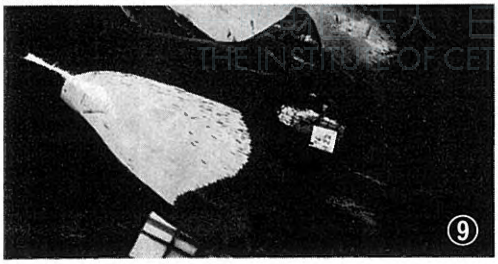
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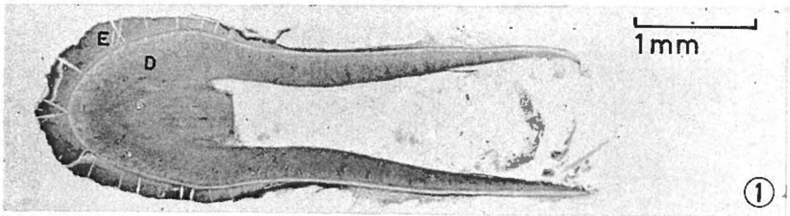

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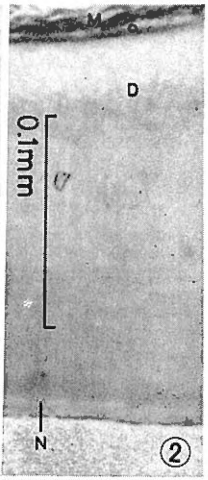

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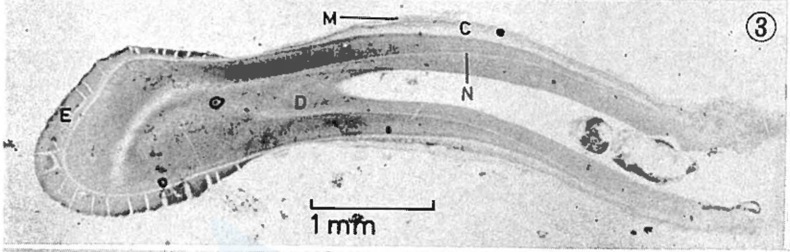

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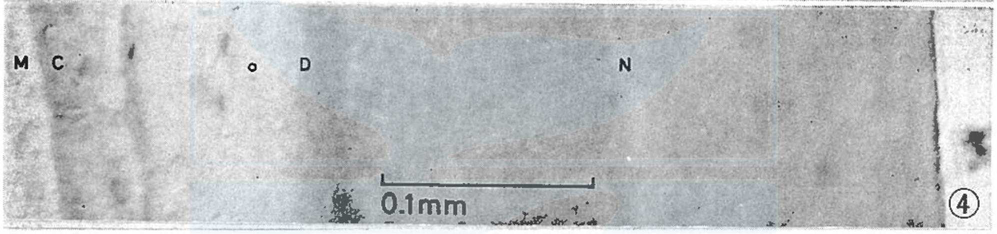

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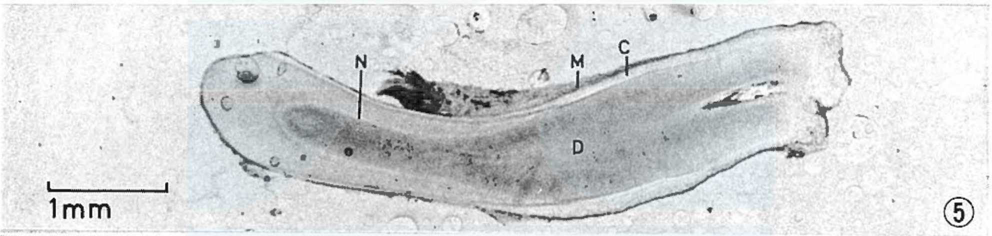

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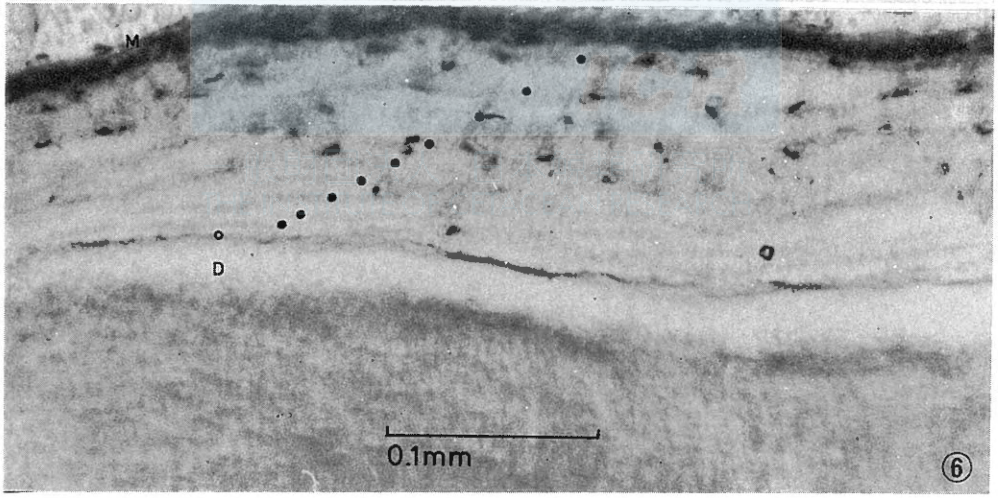

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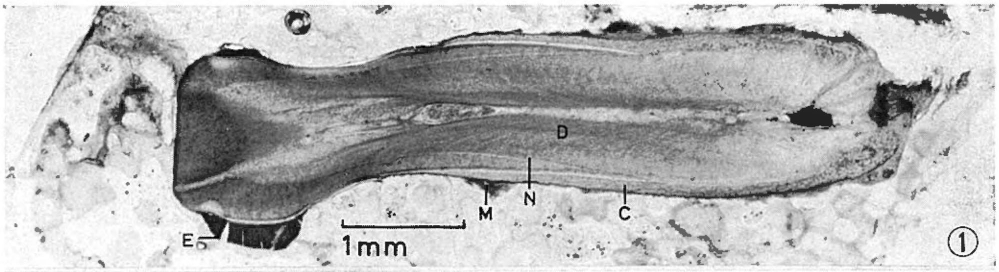
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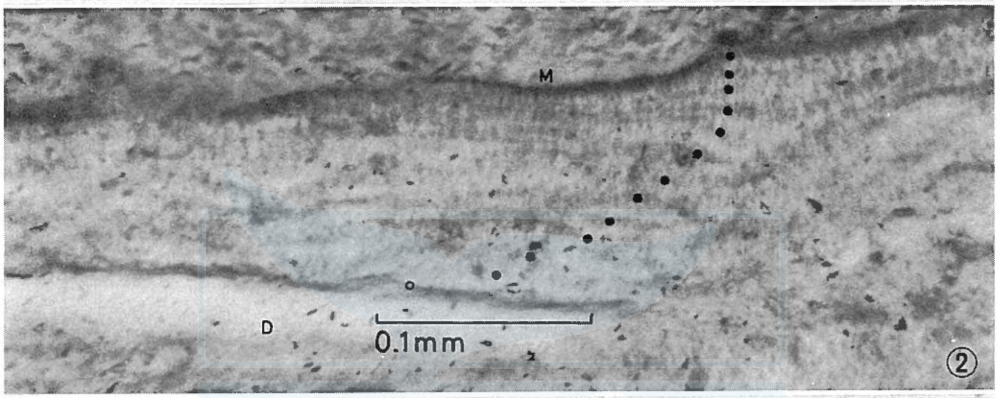
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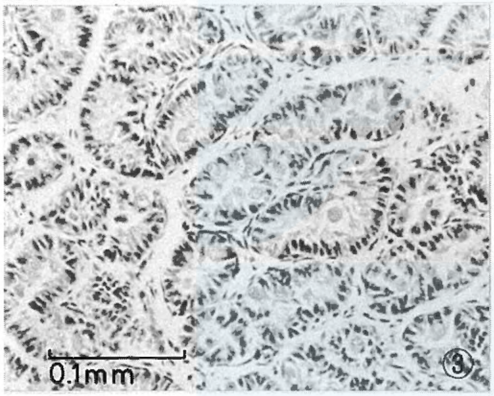
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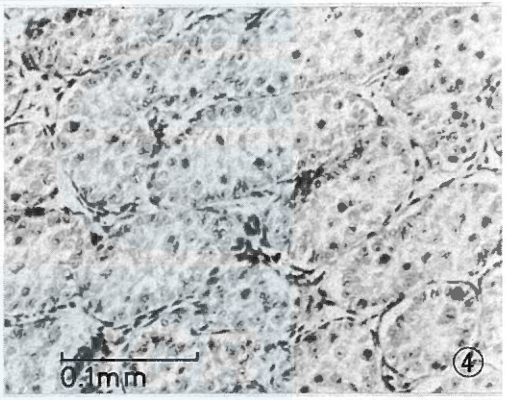
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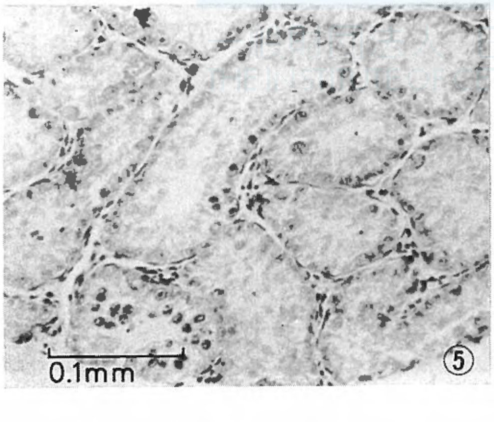
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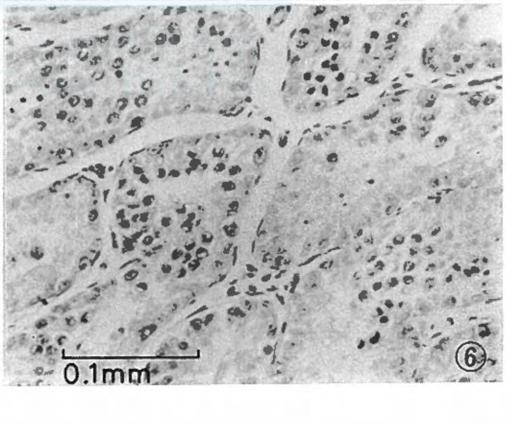
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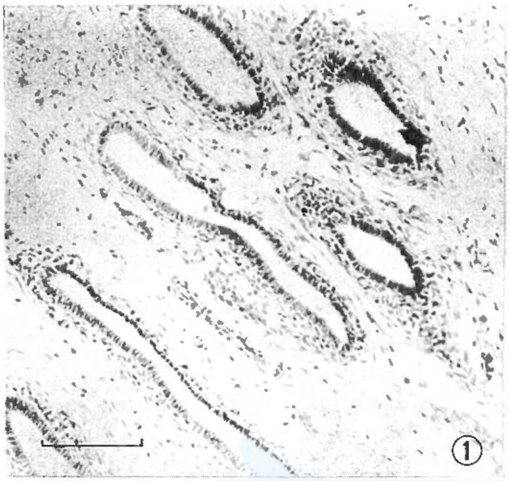
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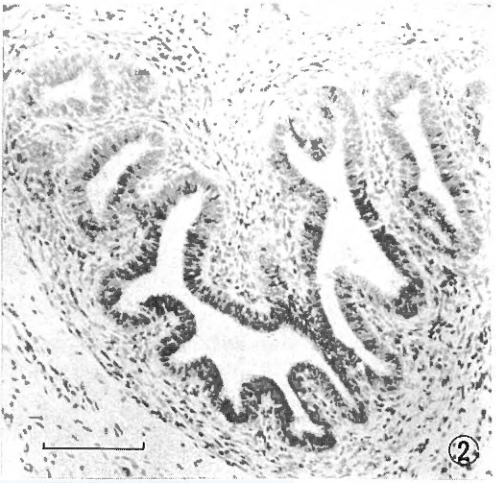
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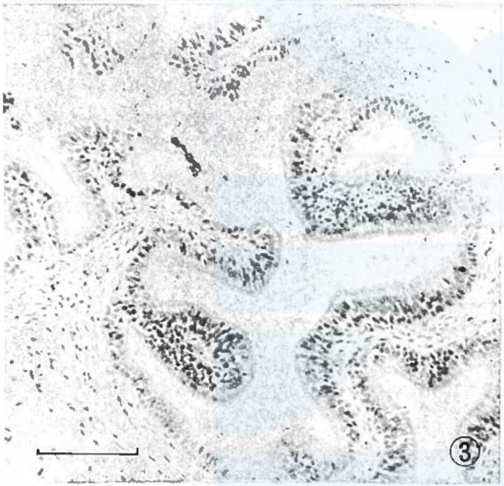
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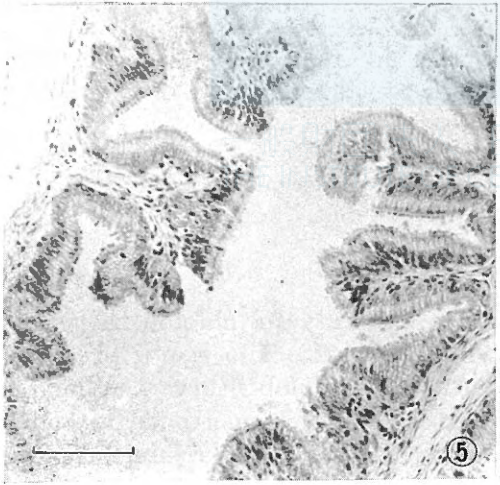
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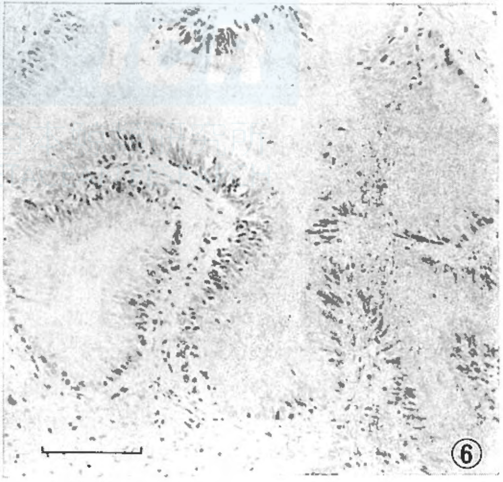
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SCHOOL STRUCTURE OF THE STRIPED DOLPHIN OFF THE PACIFIC COAST OF JAPAN

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AND

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ABSTRACT

School structure of the striped dolphin, *Stenella coeruleoalba* (Mayen, 1833) was studied on 5,958 dolphins from 45 schools caught on the coast of Izu Peninsula from 1963 to 1973. The animals of the species may not be mixed with those of any other species. Most of the schools examined were formed with less than 500 individuals (85.8%). The southbound schools are larger than the northbound ones. The schools can be classified into three types, the juvenile, the adult, and the mixed schools. Each adult and mixed school can again be divided into two categories, mating and non-mating. In the years when the Kuroshio currents came closely to the fishing area in the coast of Izu, number of adult schools is superior, but in other year, number of juvenile schools is dominant. Calves remain in the adult schools for about one to two years after weaning and then move into the juvenile school. Young females which once left the adult school and got into the juvenile school, rejoin into the adult school. Major number of those females choose the non-mating school to go in ,and only remainders join into the mating school, while nearly equal number of males seems to go into the mating and non-mating schools after they reached sexual maturity. The males which chose the non-mating school change to the mating school when they attain social maturity. In the adult school, fully matured females seems to gather together and are joined by socially mature males, then they form a unit of mating school. One mating school holds one to several such units. After most of females fertilized, socially mature males seem to leave the mating school. The mating school naturally turned out to the non-mating school.

INTRODUCTION

The striped dolphin, *Stenella coeruleoalba* is widely distributed in the tropical and subtropical waters of the Pacific and Atlantic Oceans (Nishiwaki 1972). About ten thousand striped dolphins are caught annually by driving fishery or by the method of hand harpoon on the coast of Japan (Ohsumi 1972, Miyazaki *et al.* 1974). Considerable studies have been done till now by many scientists on age determination, growth, reproduction, food, distribution, migration, and stock etc.

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of the species ; (Nishiwaki and Yagi 1952, Hirose *et al.* 1970, Hirose and Nishiwaki 1971, Kasuya 1972, Ohsumi 1972, Miyazaki *et al.* 1973 and 1974, Nishiwaki 1975, Kasuya and Miyazaki 1976, Kasuya 1976 and Miyazaki 1977). To study school structure of *S. coeruleoalba* is to recognize the mechanism within the school of the animals and instinctive behavior for maintenance and evolution of the species.

There have been limited number of reports on the school structure of smaller cetaceans until recently. Kleinenberg *et al.* (1964) studied on the herd structure of the beluga, *Delphinapterus leucas* caught in the tangle net in reproductive season. From the analysis of herd composition they reported that there are family groups in a school, which consist of adult females with calves of variety of ages, they also reported that males form independent groups but immature animals never form groups separately, and more distinct separation by sex and age appears within the herd at the end of the main breeding season. Sergeant (1962) described that there are two kinds of the unit of herd organization on *Globicephala melaena*, that is, a small breeding herd with excess of mature females over mature males and with a group of females in much the same stage of reproduction, and a probable non-breeding herd with larger number of adult males and fewer juvenile females. Kasuya *et al.* (1974) suggested a hypothetical school formation and its breakup by reproductive activities in the Japanese population of the spotted dolphin, *Stenella attenuata*, and they mentioned that juveniles of the population leave breeding schools and form a school separately and sometime rejoin in a breeding school at puberty. Perrin *et al.* (1976) reported, however, that juveniles probably do not form a school separately in the population of the spotted dolphin in the eastern Pacific. Study on the school structure of the striped dolphin has done little except by Kasuya (1972). He reported on the changing of school structure by condition and activities of breeding. However, he analized the composition of relatively fewer number of schools and did not examine in detail of the sexual condition of all the individuals of the nine schools.

This study was done in order to know the school structure of *S. coeruleoalba* more clearly and more in detail.

MATERIALS AND METHODS

Biological data were obtained from 5,958 striped dolphins of 45 schools caught during seven years from 1963 to 1973 (Table 1) by the driving fisheries at Kawana and Futo, located on the east coast of the Izu Peninsula (Fig. 1). The data of the five schools, Nos 1, 2, 3, 4 and 7 were taken by Dr Tabayama and those of other two schools, Nos 5 and 6, were by Dr Kasuya and those of one more school (No. 13) were examined by Dr Hirose. The compositions of the four schools, Nos 8, 22, 44 and 45, were examined by the help of Dr Kasuya. Fishing records and catch statistics on the east coast, and only catch statistics on the west coast of Izu Peninsula were investigated and used in this study.

Body length was measured in centimeter, straightly from the tip of snout to the notch of tail flukes.

Mammary glands were observed on the spot and individuals were classified

TABLE 1. LIST OF MATERIALS USED IN THIS STUDY. J) JUVENILE SCHOOL, A) ADULT SCHOOL, MI) MIXED SCHOOL, A—M) MATING ADULT SCHOOL, A—N) NON-MATING ADULT SCHOOL, MI—M) MATING MIXED SCHOOL, AND MI—N) NON-MATING MIXED SCHOOL

School No.	School type	Date killed	Time found	Number of dolphins		Percentage of examination	Researcher
				caught	examined		
1	—	22 Oct. '63	—	453	30	6.6	Tobayama
2	Mi	5 Nov. '63	—	242	54	22.3	Tobayama
3	A	9 Nov. '63	—	34	31	91.2	Tobayama
4	J	14 Nov. '64	—	36	36	100	Tobayama
5	A —N	16, 18, 22 Nov. '68	—	1,700	413	24.3	Kasuya
6	Mi—N	17 Nov. '68	—	344	322	93.6	Kasuya
7	A	18 Nov. '68	—	423	168	39.7	Tobayama
8	A	12 Oct. '70	—	265	89	33.6	Miyazaki and Kasuya
9	J	13 Oct. '70	—	293	64	21.8	Miyazaki
10	A	21 Oct. '70	08:00	324	68	21.0	Miyazaki
11	A	24 Oct. '70	08:15	49	44	89.8	Miyazaki
12	Mi	29 Oct. '70	08:20	48	34	70.8	Miyazaki
13	A —N	22 Nov. '70	08:00	1,832	125	6.8	Hirose
14	—	25 Nov. '70	05:00	365	16	4.4	Miyazaki
15	Mi	2 Dec. '70	09:00	260	260	100	Miyazaki
16		10 Dec. '70	06:30	84	84	100	Miyazaki
17	J	2 Oct. '71	07:25	393	176	44.8	Miyazaki
18	A —N	4 Oct. '71	06:10	101	58	57.4	Miyazaki
19	Mi	5 Nov. '71	06:44	25	25	100	Miyazaki
20	J	17, 18 Nov. '71	07:37	636	362	56.9	Miyazaki
21	A —M	20 Nov. '71	07:15	140	100	71.4	Miyazaki
22	J	15 Dec. '71	08:30	903	306	33.9	Miyazaki and Kasuya
23	A —M	3 Oct. '72	07:23	31	30	96.8	Miyazaki
24	Mi—M	4 Oct. '72	07:25	225	96	42.7	Miyazaki
25	A —M	7 Oct. '72	10:25	120	32	26.7	Miyazaki
26	A —M	8 Oct. '72	08:45	94	41	43.6	Miyazaki
27	A —M	13, 15, 16 Oct. '72	05:51	574	217	37.8	Miyazaki
28	Mi—M	14, 18, 19 Oct. '72	06:20	305	124	40.7	Miyazaki
29	A —N	17, 19, 20 Oct. '72	05:45	238	124	52.1	Miyazaki
30	J	23 Oct. '72	10:00	48	48	100	Miyazaki
31	J	26 Oct. '72	10:05	54	40	74.1	Miyazaki
32	A —M	1 Nov. '72	07:15	63	63	100	Miyazaki
33	Mi—N	5 Nov. '72	07:30	284	122	43.0	Miyazaki
34	A —M	9 Nov. '72	08:05	239	127	53.1	Miyazaki
35	J	10 Nov. '72	09:00	45	27	60.0	Miyazaki
36	A —N	15 Nov. '72	06:18	243	126	51.9	Miyazaki
37	A —N	16 Nov. '72	07:35	200	76	38.0	Miyazaki
38	A —N	17, 20 Nov. '72	07:30	372	212	57.0	Miyazaki
39	Mi—N	21 Nov. '72	05:35	293	132	45.1	Miyazaki
40	A —M	23, 26 Nov. '72	06:40	535	140	26.2	Miyazaki
41	—	26 Nov. '72	—	2,327	415	17.8	Miyazaki
42	—	26 Nov. '72	—				Miyazaki
43	Mi—N	7, 9 Dec. '72	05:50	912	180	19.7	Miyazaki
44	A —N	19 Nov. '73	—	414	251	60.6	Miyazaki and Kasuya
45	A —M	20, 22 Nov. '73	—	1,724	470	27.3	Miyazaki and Kasuya
Total				18,240	5,958	32.6	

into the lactating and the nonlactating stages.

Ovaries were collected from majority of the female specimens and fixed in 10% formalin solution, and later, each ovary was weighed and number of corpora lutea and albicantia were counted in the laboratory.

Sexual condition of the female specimens were determined by presence or absence of corpora lutea or albicantia, weight of left ovary, and observation on mammary glands. The females which had ovaries with corpus luteum or albicans, were calssified as the mature, those which had ovaries with corpus luteum, were classified as the pregnant, those which had lactating mammary glands were classified as the lactating, and among the mature females, those which were neither pregnant nor lactating, were classified as the resting. Among the immature females, the animals in which left ovary had weighed more than 2.0 g, were calssified to be the puberty.

Testes were collected from majority of the male specimens, and their weight was measured. Sexual condition of males was determined by usual histological examination (Miyazaki 1977). The males which had testis containing exclusively spermatogonia, were classified as immature, the ones which had spertmatogonia and spermatocytes, were classified as puberal, and those which had spermatozoa were classified as mature; To make the matter clearer, 20 tubules in one slide section of each testis were selected at random and examined. The animals having the testis containing spermatozoa in only one tubule are classified as Type MI and those in all 20 tubules are Type MIII, and Type MII contains those of between the two types. It is apparent that the more testis weight increase, the more development of testis progress. There was no distinct differences between the weight of left and right testes in the examination. In the case that histological examination was not able, sexual condition of males was determined only by the weight of left testis. The males with left testis weight less than 6.8 g were classified into the immature, those between 6.8 g and 15.4 g were in the puberal, and those more than 15.5 g were in the mature, respectively. The mature males of the left testis weight 15.5 to 39.2 g are Type MI, those from 39.3 to 68.8 g are MII and those

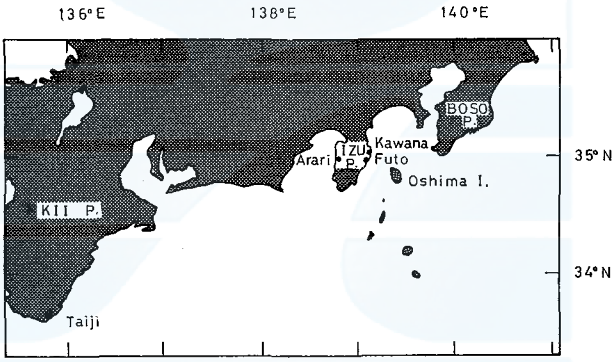

Fig. 1. Map showing the positions of collection.

more than 68.9 g are MIII, respectively.

From each dolphin, several teeth were collected from middle of the tooth row. After usual preparation, opaque layers of dentine in the longitudinal thin section of the teeth were counted under binocular microscope ($\times 20-\times 50$) by transmitted light.

Age determination of 930 dolphins from six schools, Nos 5, 6, 22, 28, 44, 45 were done by Dr Kasuya. Until 13 layers lamination reading is not varied much by readers, but usually it is difficult after 14 layers.

Recognition of the school at field

Kawana and Futo Fishermen's Unions on the east coast of the Izu Peninsula operate dolphin-fishing in cooperation, harvest of which is mostly *S. coeruleoalba* migrating into Sagami Bay and nearby waters in autumn and winter. The main fishing season is from October to January. On fine days, four driving boats, each three or more fishermen on board, (size of boat: 6–8 m in length, capacity 8–10 tons, maximum speed: 20 knot) start from Kawana and Futo fishing ports at about five o'clock in the morning. They reach the main fishing ground at about seven. The four boats disperse each other, three to six miles apart, to search dolphin schools. When one of the boats discovers a school of dolphins it calls other three through wireless and then they circle the school together, drive the dolphins to the direction of port by making underwater sound of high frequency (50 or more kHz). Ten to twenty small boats (5 to 6 tons) are waiting at the mouth of port and they help the former four boats to drive dolphins into the port and then block them at the mouth of the port with fishing nets (Fig. 2). Then the fishermen haule dolphins out of water. When two schools were sighted at the same time, it is said that they skillfully maneuver the two schools into one and drive them to the port. We observed however, that those two schools seemed not to be mixed completely and they were driven to the port swimming separately. But as

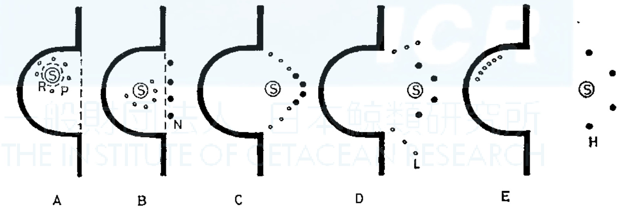

Fig. 2. Schematic figures of the catching process of striped dolphins in driving fishery (cited from Ohsumi (1972) with slight modification). A: Picking up the dolphins on board after squeezing them with net, B: Closing of the mouth of the bay after the driving of the school into the bay, C: Driving of the school into the bay with help of slower driving boats, D: Driving of the school into a bay by high-speed scouting boats, E: Finding of a school of dolphins by four high-speed scouting boats, S: School of dolphins, H: High-speed scouting boat, L: Slower driving boat, N: Set net, P: Picking up boat and R: Surrounding net. The driving fishery is oparated in the order from E to A.

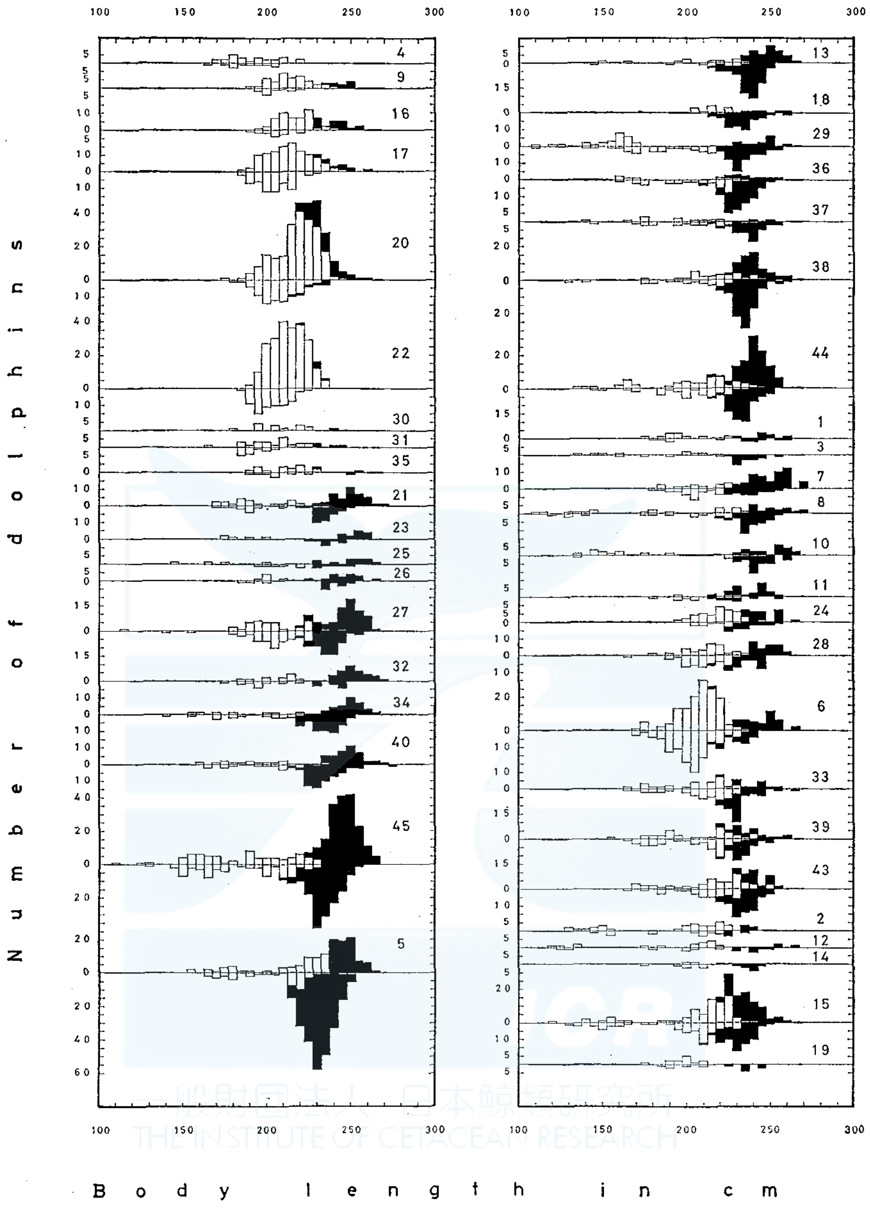

Fig. 3. Body length frequencies of 43 schools of striped dolphins. White areas indicate the immature or puberal dolphins, and black the mature. Areas above the horizontal line indicate males and those below females in each school. Numbers at the right indicate the school no.

a matter of fact it was difficult to separate individuals in the two schools when examining the school composition, because dolphins belonged to both schools were coming in rush and hauled in a short period of time. Therefore, in such

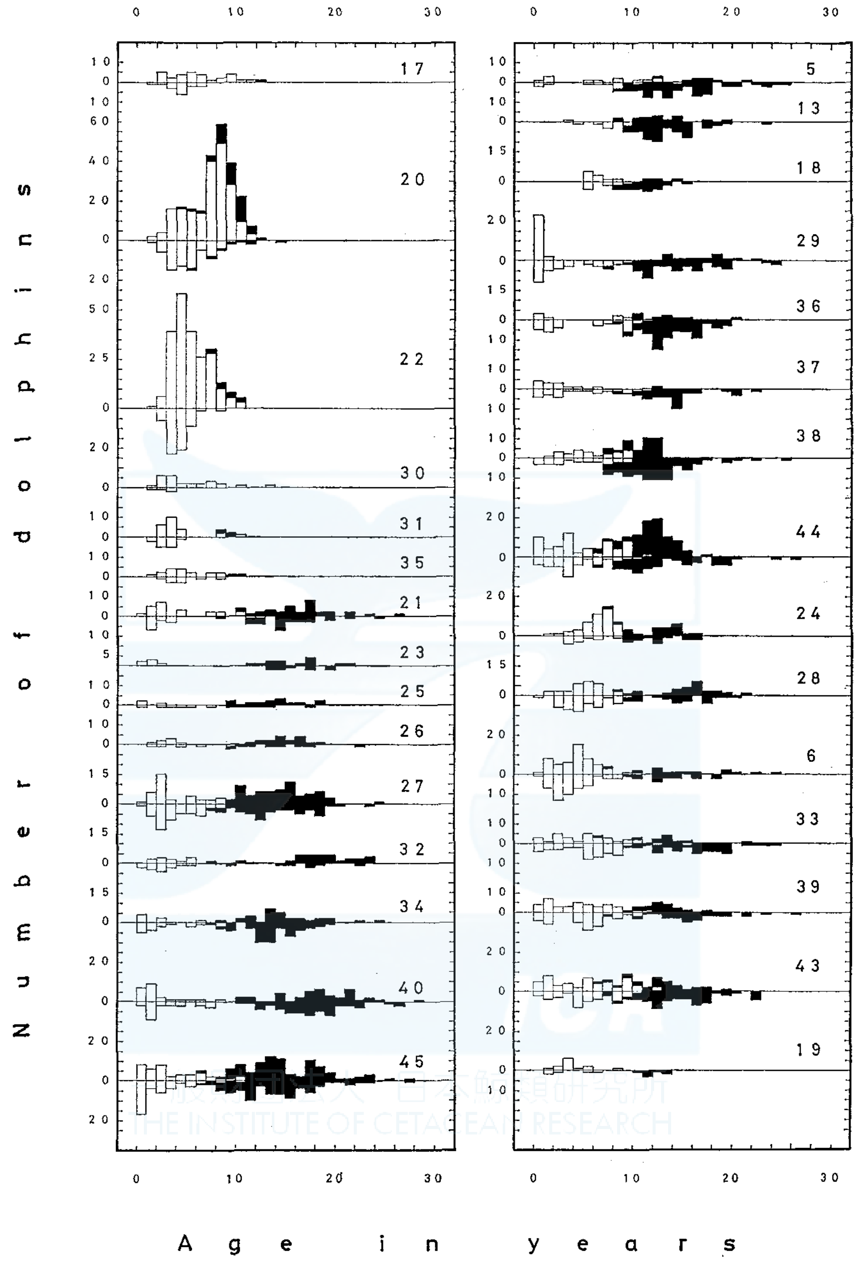

Fig. 4. Age frequencies of 30 schools of striped dolphins. White areas indicate the immature or puberal dolphins, and black the mature. Areas above the horizontal line indicate males and those below females in each school. Numbers at the right indicate the school no.

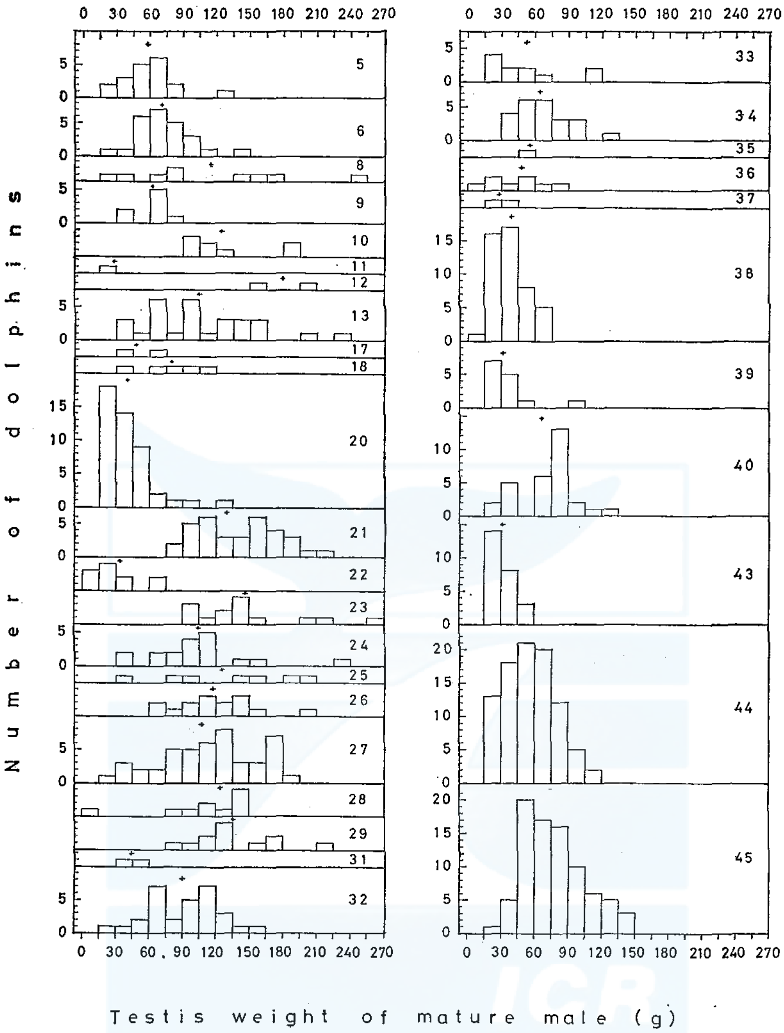

Fig. 5. Frequencies of the left testis weight of mature males of 33 schools of striped dolphins. Crosses indicate average. Numbers at right indicate the school no.

cases, the two schools is studied collectively.

The frequency of body length of the 43 schools is shown in Fig. 3, the age frequency of 30 schools is shown in Fig. 4, and the frequency of the weight of left testis of mature males in the 33 schools is in Fig. 5. And Table 2 shows the life history parameters which are thought to be necessary for analysis of the school composition and discussion on the school structure on *S. coeruleoalba*.

TABLE 2. OUTLINE OF LIFE HISTORY OF STRIPED DOLPHINS CITED FROM MIYAZAKI (1977)

Gestation (months)	12
Mean length at birth (cm)	100
Length at 50% weaning (cm)	174
Length at 50% puberty (cm)	
male	210
female	209
Length at 50% sexual maturity (cm)	
male	219
female	216
Length at physical maturity (cm)	
male	238
female	225
Age at 50% weaning (years)	1.5
Age at 50% puberty (years)	
male	6.7
female	7.1
Age at 50% sexual maturity (years)	
male	8.7
female	8.8

SCHOOL SIZE

In this chapter, the school size of *S. coeruleoalba* is studied, i.e. its seasonal change, diurnal fluctuation, geographical variety, and relation between size and composition are examined based on the catch statistics, fishing records and biological investigations.

School size

Analysis of the school size of *S. coeruleoalba* (Tables 3 and 4) was made based on the catch statistics of 307 schools caught on the east coast of the Izu Peninsula from 1949 to 1974 and of 214 schools caught on the west coast of the peninsula from 1949 to 1970. Among those schools the smallest was formed by 8 individuals and the largest was as many as 2,136 animals. Most schools (85.8% of all) held less than 500 animals and only a few schools had more than 1,000 animals. During the observation from a driving boat or from land, there were three schools which held small units inside, (School Nos 27, 33 and 34). School No. 27 held three small units of approximately 50, 200 and 300 individuals, respectively. School No. 33 also held three small units of about 30, 50 and 200. And school No. 34 held two small units of each about 100. Each small unit of animals swam separately from others. On the other hand, at least 8 schools (School Nos 11, 12, 19, 23, 30, 31, 32, 35) are considered to be such a small unit, because their 50 or so individuals were not apparently swimming separately when they were seen. These sorts of school behavior of striped dolphins were also seen at open sea. From above, it can be said that the size of the small unit may be 30 to 300 individuals. A large

TABLE 3. SCHOOL SIZE OF STRIPED DOLPHINS CAUGHT ON THE EAST COAST OF IZU PENINSULA FROM 1949 TO 1974

Season		School size			
		Range	Total	No. of schools	Average
Sep.	E	—	—	—	—
	M	408	408	1	408
	L	132	132	1	132
Oct.	E	29– 507	3,946	17	232
	M	19– 574	3,756	16	235
	L	19– 604	5,479	23	238
Nov.	E	11– 459	4,747	26	189
	M	17–1,840	12,043	35	344
	L	9–2,136	19,300	46	419
Dec.	E	11–1,976	11,281	35	322
	M	16–2,133	13,049	37	353
	L	23–1,053	8,999	31	290
Jan.	E	33–1,659	7,165	18	398
	M	8– 420	1,526	10	153
	L	30– 553	986	9	110
Feb.	E	24– 109	161	3	54
	M	—	—	—	—
	L	—	—	—	—
Total		8–2,136	92,978	308	302

E: Early; M: Middle; L: Late

school of more than 1,000 individuals has often had several small units similar to those.

Seasonal change

Figure 6 shows the seasonal change of school size based on the catch statistics on the east coast of the Izu Peninsula, where dolphin fishing is operated in autumn and winter. But on the west coast, there has been harvested throughout the year whenever dolphins were avairable. On the west coast, small schools of less than 300 animals have been caught in any season, but large schools of more than 1,000 animals have been caught in the seasons from April to May and again December through January. While on the east coast, larger schools are caught only in the main fishing season from November to January.

Figure 7 shows the size frequency of the schools caught on the both sides of the Izu Peninsula. The figure indicates that there is no significant difference in school size between the two localities in autumn-winter season, but apparent size difference can be seen in the schools caught on the west coast in spring-summer season. Some scientists consider that the schools caught in autumn-winter must be southbound and those in spring-summer must be northbound. The figure is one of the proofs of this consideration.

Table 5 shows size of southbound and northbound schools. The southbound schools are generally larger (average 306) than northbound ones (average 156).

TABLE 4. SCHOOL SIZE OF STRIPED DOLPHINS CAUGHT ON THE WEST COAST OF IZU PENINSULA FROM 1949 TO 1970

Season		School size			
		Range	Total	No. of schools	Average
Jan.	E	53–1,321	4,622	15	308
	M	24– 615	2,083	12	174
	L	31– 486	3,040	14	217
Feb.	E	21– 846	1,255	7	179
	M	—	—	—	—
	L	50– 260	310	2	155
Mar.	E	93	93	1	93
	M	—	—	—	—
	L	10— 88	98	2	49
Apr.	E	16– 254	516	6	86
	M	24– 800	2,365	12	197
	L	45–1,114	3,503	12	292
May	E	44– 358	933	5	187
	M	49– 358	1,797	10	180
	L	11–1,026	3,277	19	172
June	E	16– 386	1,237	13	95
	M	24– 459	2,230	14	159
	L	19– 253	1,038	9	115
July	E	47– 326	640	5	128
	M	20– 48	148	4	37
	L	10– 320	392	4	98
Aug.	E	67	67	1	67
	M	—	—	—	—
	L	—	—	—	—
Sep.	E	63	63	1	63
	M	—	—	—	—
	L	—	—	—	—
Oct.	E	—	—	—	—
	M	—	—	—	—
	L	613	613	1	613
Nov.	E	11	11	1	11
	M	—	—	—	—
	L	—	—	—	—
Dec.	E	41– 80	121	2	61
	M	46–1,289	8,371	19	441
	L	26–2,005	10,151	23	441
Total		10–2,005	48,974	214	229

E. Early, M: Middle, L: Late

From this phenomenon it may be that schools of *S. coeruleoalba* are going up north in smaller school and coming down south in larger school. This change may come from their school structure which reformed in the north.

Diurnal and geographical variation of school size

Among the data of 307 schools caught on the east coast of the Izu Peninsula

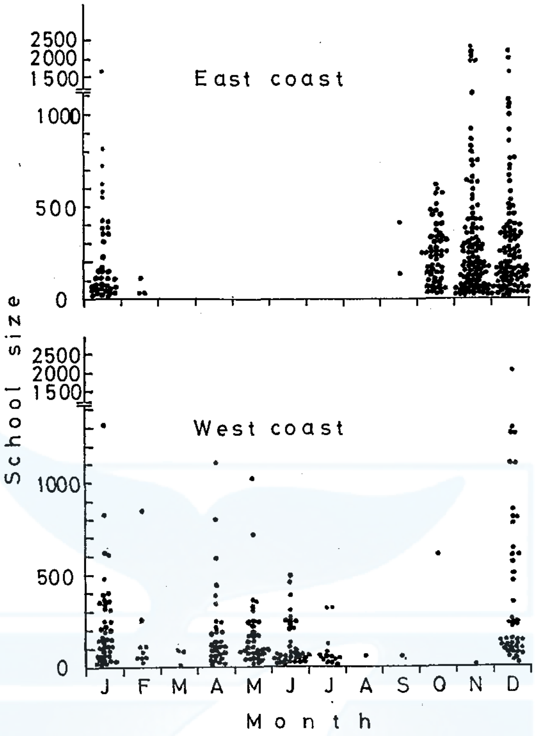

Fig. 6. Scatterplot of school size of striped dolphins caught on the east and west coats of the Izu Peninsula.

from 1949 to 1974, those of 112 schools were useful to be analyzed in diurnal and geographical variation of school size, because they are recorded on a fishermen's log book in detail. All the 112 schools were sighted in the period between 05 : 00 and 15 : 00, especially concentrated (75% of all) between 05 : 00 and 09 : 00 and biggest number of schools were sighted between 07 : 00 and 08 : 00 (Fig. 8).

Figure 9 is the sighted positions of the schools in early morning (05 : 00–09 : 00) and in daytime (09 : 00–15 : 00) are compared by school size group. The smaller schools of less than 1,000 animals were sighted around Ohshima Island and at the mouth or inside the Sagami Bay in early morning and daytime but the larger schools of more than 1,000 animals were sighted around Oshima Island only in early morning. Table 6 shows the ratio of schools sighted in daytime against those in all through the sighting hours by school size group. The ratio suggests that larger schools come more frequently in early morning than in daytime. From this data, it can be said that larger schools of *S. coeruleoalba* may come close to or be formed at Ohshima Island in early morning.

Relation between school size and school composition

The schools of *S. coeruleoalba* can be divided into three types by school com-

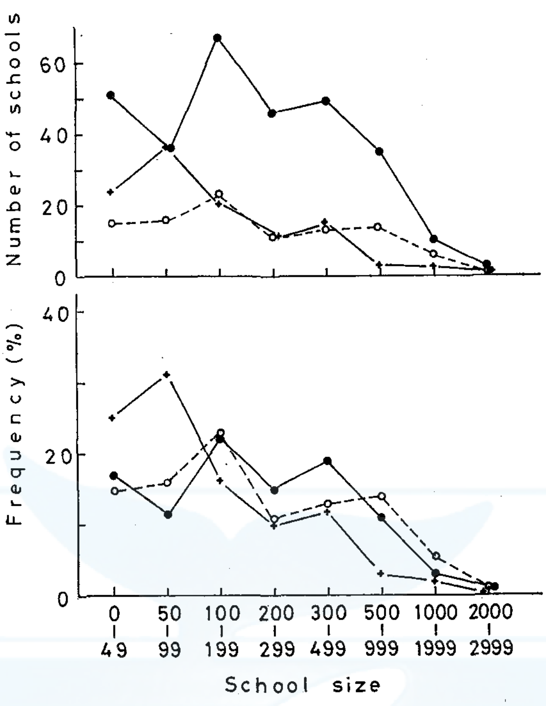

Fig. 7. Number of schools of striped dolphins and its frequency in each school size group. Closed circle and solid line: east coast, autumn-winter catch. Open circle and dotted line: west coast, autumn-winter catch. Ccross and solid line: west coast, spring-summer catch.

TABLE 5. SIZE DISTRIBUTION OF SCHOOL OF STRIPED DOLPHINS CAUGHT ON THE EAST AND WEST COASTS OF IZU PENINSULA FROM 1949 TO 1974

Locality (season)	School size									
	0–49	50–99	100–199	200–299	300–499	500–999	1000–1999	2000–2999	Total	Ave.
East coast	51	36	67	46	59	35	10	3	307	303
(autumn-winter)	(16.6)	(11.7)	(21.8)	(15.0)	(19.2)	(11.4)	(3.3)	(1.0)		
West coast	15	16	23	11	13	14	6	1	99	316
(autumn-winter)	(15.2)	(16.2)	(23.2)	(11.1)	(13.1)	(14.1)	(6.1)	(1.0)		
West coast	29	36	20	11	14	3	2	0	115	156
(spring-summer)	(25.2)	(31.3)	(17.4)	(9.6)	(12.2)	(2.6)	(1.7)	(0)		
Total	95	88	110	68	86	52	18	4	521	273
	(18.2)	(16.9)	(21.1)	(13.1)	(16.5)	(10.0)	(3.5)	(0.8)		

Figures in parentheses indicate percentage.

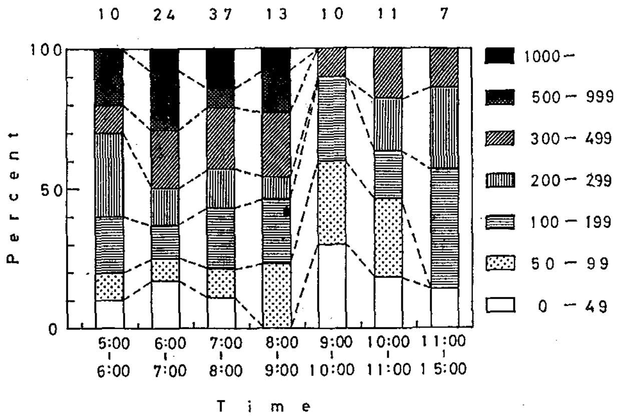

Fig. 8. Diurnal change of frequency of school size of striped dolphins. Numbers at the top indicate sample size.

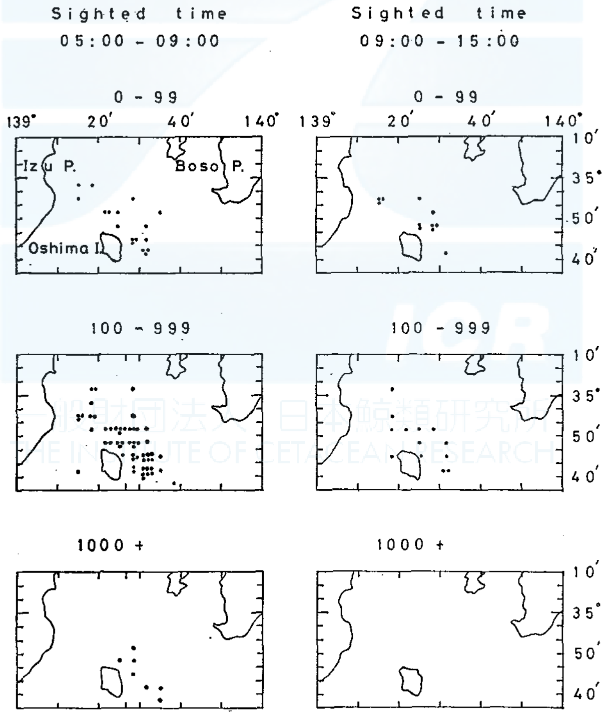

Fig. 9. Sighting positions of schools of striped dolphins by each school size group in the early morning (05: 00–09: 00) and in the daytime (09: 00–15: 00).

TABLE 6. RELATION BETWEEN SIZE AND SIGHTED TIME OF SCHOOLS OF STRIPED DOLPHINS

School size	Sighted time		Total	Ratio (Daytime/Total)
	Early morning (05:00–09:00)	Daytime (09:00–15:00)		
0– 99	17	11	28	0.39
100–999	54	13	67	0.20
1,000–	7	0	7	0

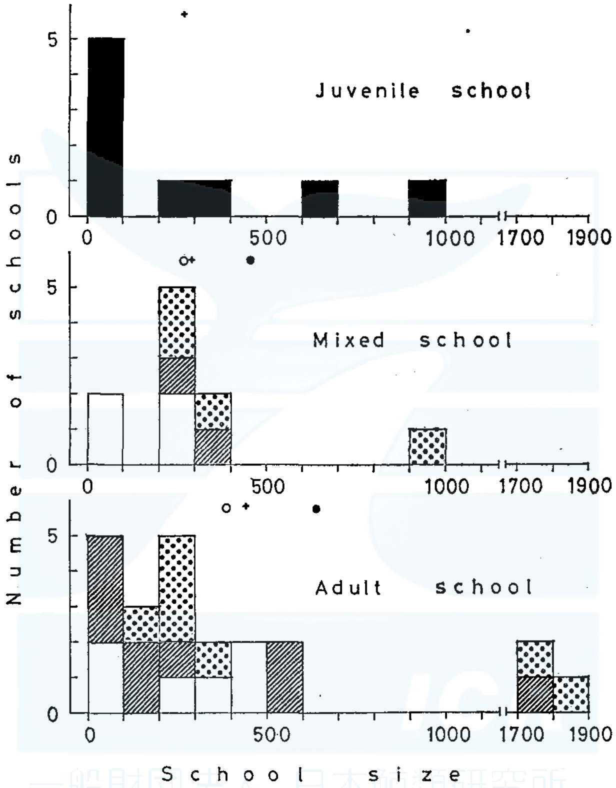

Fig. 10. Frequencies of the school size of striped dolphins in the juvenile, mixed and adult schools. Hatched areas indicate the mating school, dotted the non-mating, white the unidentified, and black the juvenile. Open circle indicates the average school size of the mating schools, closed circle that of the non-mating, and cross the total.

position, such as juvenile, adult and mixed schools (see page 81). More in detail, both adult and mixed schools are to be distinguished one from the other by categories as mating and non-mating schools. Figure 10 shows the size frequency of 9 juvenile, 22 adult and 10 mixed schools. Size of the juvenile schools is of 36–903 animals, (average 277, standard deviation: 295), that of the adult is 31–1,832, (average 442, s.d.: 543) and that of the mixed is 25–912 (average 294, s.d.: 299), respectively. There seems to be no significant meaning in the differences among the three types of school in average size. Analyzed from school composition, all of the very large schools of more than 1,000 animals are the adult type (Fig. 10). If these very large schools are excluded, average size of adult school is 235 animals. The number is similar to those of the juvenile and the mixed schools. School size frequency of each type has a peak at 300 animals or less. From these informations it can be said that the unit of school of *S. coeruleoalba* seems to be 300 animals or less. Size of 9 mating and 8 non-mating schools belong to the adult type, ranges from 31 to 1,724 (average 391, s.d.: 507) and 101 to 1,831 (average 638, s.d.: 659), respectively. On the other hand, 2 mating and 4 non-mating schools of the mixed types ranges from 225 to 305 (average 265, s.d.: 40) and 284 to 912 (average 458, s.d.: 263), respectively. Compared the adult and mixed schools, there seems no apparent differences in average size between the mating and non-mating schools.

CLASSIFICATION AND CHARACTERISTICS OF THE SCHOOLS

Classification

As a criterion, the schools, of which more than 20% of all animals or more than 100 animals of a school had been examined, were applied for analysis. So two schools Nos 1 and 14 were excluded. The schools, Nos 41 and 42 were also excluded because the animals of the two schools mixed themselves before they were hauled. Then 41 out of 45 schools were used for analyzing the school composition or discussion on the school structure.

The animals younger than 1.5 years or smaller than 174 cm in body length are considered as sucking calves and they are accompanied by mother. Then these sucking calves were excluded in calculation of the immaturity rate of the school. Ratio of immature and puberal animals excluding sucklings, against the total number of animals in a school is a useful indicater in knowing character of school composition. The immaturity rate of the school was also calculated as above. In cases that histological examination of the testes or detailed examination of ovaries were not able, testis weight, age, and body length of male and age and body length of females were taken to substitute them in order to know whether the animals have attained sexual maturity.

Figure 11 is the frequency ~~of~~ immaturity rate of the 41 schools, in which three modes are appeared. The first peak is seen between 20% and 40%, schools in this peak can be classified as adult schools because they hold mature animals mostly. The third peak is appeared between 90% to 100%, those in this peak are juvenile schools which hold immature animals as a majority, and the second peak is between 50% and 60% and the schools of this peak are mixed schools. These mixed schools are mixture of immature and mature animals, and they have the school composition between former two school types. The immaturity rates of school No. 2 and No. 6 are 77.5% and 80.3%, respectively. Although both immaturity rates are closer to the rate of the juvenile school than that of the mixed school, those two schools are put into the mixed school group because two schools, No. 2 and No. 6 hold many sucklings (No. 2 had 14 individuals: 25.9% of all in the school) (No. 6 had 18 individuals: 5.6% of all) and school No. 6 also hold many older males of more than 13.5 years (17 individuals: 11.8% of animals whose age were able to be identified).

As a result of above classification, 9 juvenile, 22 adult and 10 mixed schools are counted. Immaturity rates of juvenile schools range from 77.4% to 100%, that of adult schools are from 7.4% to 35.9%, and that of mixed schools are from 44.6% to 80.3%, respectively.

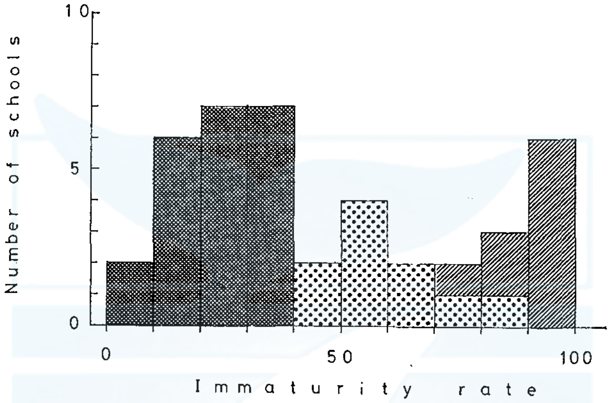

Fig. 11. Frequency of the immaturity rate of schools of striped dolphins. Double hatched areas indicate the adult school, dotted the mixed, and hatched the juvenile.

The juvenile school

Sex ratio indicates number of males by every one female. Sex ratio of the juvenile schools ranges from 1.93 to 6.25, and the ratio of all the juvenile schools in total is 3.07 (Table 7). The juvenile schools are in any case formed by both males and females, and number of males always exceeds.

The maturity rate compares the number of sexually matured individuals against the total number of animals in each school, excluding sucklings. Out of 9 juvenile schools, 8 schools (School Nos 9, 16, 17, 20, 22, 30, 31, 35) had small number of mature males (maturity rate: 8.0% to 27.9%) and only one school, No. 20 had a few mature females (maturity rate: 9.5%) (Tables 7 and 8). The maturity rate of females in all the juvenile schools (2.9%) is lower than that of the males (9.5%).

Figure 12 shows the total age composition of the 6 juvenile schools. In the figure, age of males ranges from 1.5 to 13.5 years and that of females are from 1.5 to 14.5 years. There are two modes seen at the age of 4.5 and 8.5 among males, and one mode appears at the age of 3.5 among females. The age composition

TABLE 7. RATIO OF REPRODUCTIVE CONDITION OF FEMALE AND SEX RATIO IN JUVENILE SCHOOL

School no.	Suckling	Immature**	Mature						Total	Sex ratio***
			unknown	pregnant	p. & l.	lactating	resting	total*		
4	0	11	0	0	0	0	0	0	11	2.27
		100%		0	0	0	0	0		(—)
9	0	10	0	0	0	0	0	0	10	5.40
		100%		0	0	0	0	0		(—)
16	0	16	0	0	0	0	0	0	16	4.25
		100%		0	0	0	0	0		(—)
17	0	60	0	0	0	0	0	0	60	1.93
		100%		0	0	0	0	0		(—)
20	0	76	3	0	0	2	3	5	84	3.31
		90.5%		0	0	40.0	60.0	100		(8.00)
22	0	69	0	0	0	0	0	0	69	3.43
		100%		0	0	0	0	0		(—)
30	0	4	0	0	0	0	0	0	4	6.25
		100%		0	0	0	0	0		(—)
31	0	13	0	0	0	0	0	0	13	2.08
		100%		0	0	0	0	0		(—)
35	0	9	0	0	0	0	0	0	9	2.00
		100%		0	0	0	0	0		(—)
Total	0	268	3	0	0	2	3	5	276	3.07
		97.1%				40.0	60.0	100		(15.4)

*: Excluding the unkown mature female. **: Percentage of the total excluding the suckling
***: Sex ratio of the total excluding the suckling and sex ratio of the mature animals (in parentheses).

(Fig. 4) shows that most animals in the juvenile schools are immature but a few animals are in the puberal or mature stage. The figure also shows the number of individual of both sexes increasing after weaning at the age of 1.5, and number of females begin to decrease at the age of 4.5 years or about 3 years before the attainment of puberal stage. At the age of 8.5, that of males is decreasing just after attaining sexual maturity at the age of 8.7. Although sex ratio of the animals younger than 8 years is 2.0, that of older than that age is 12.0. This means the difference between sexes in the time of leaving and joining the schools.

The average testis weight of 75 mature males obtained from 7 juvenile schools is 42.9 g (Table 8), and eleven individuals (14.7%) had testes heavier than 68.9 g, which may be a proof of highly activated spermatogenesis. The weight of testes shows that the sexual conditions of mature males in the juvenile school is naturally less developed than those in the adult schools (see page 84).

Considering from detailed examination on the ovaries obtained from the juvenile school No. 20, five mature females are all in the resting stage. Number of corpora albicantia of each individual ranges from one to three. The age of the five females is from 8 to 12 years suggesting that the females have just attained sexual maturity.

TABLE 8. MATURITY FREQUENCIES OF MALE OF JUVENILE SCHOOL

School no.	Suckling	Immature*	Mature*	Testis weight in g.					Total**
				6.7	6.8–15.4	15.5–39.2	39.3–68.8	68.9	
4	0	25	0	0	0	0	0	0	25
		100%	0	0	0	0	0	0	
9	0	23	3	16	4	1	2	5	54
		42.6%	5.6	29.6	7.4	1.9	3.7	9.3	
16	0	49	19	0	0	0	0	0	68
		72.1%	27.9	0	0	0	0	0	
17	0	103	8	1	2	1	0	1	116
		88.8%	6.9	0.9	1.7	0.9	0	0.9	
20	0	209	15	1	4	32	13	4	278
		75.2%	5.4	0.4	1.4	11.5	4.7	1.4	
22	0	78	1	132	16	7	2	1	237
		32.9%	0.4	55.7	6.8	3.0	0.8	0.4	
30	0	23	1	0	0	1	0	0	25
		92.0%	4.0	0	0	4.0	0	0	
31	0	22	0	0	1	0	4	0	27
		81.5%	0	0	3.7	0	14.8	0	
35	0	16	1	0	0	0	1	0	18
Total	0	548	48	150	27	42	22	11	848
		64.6%	5.7	17.7	3.2	5.0	2.6	1.3	

*: Maturity of testis was identified by eye in the field

**: Excluding the suckling

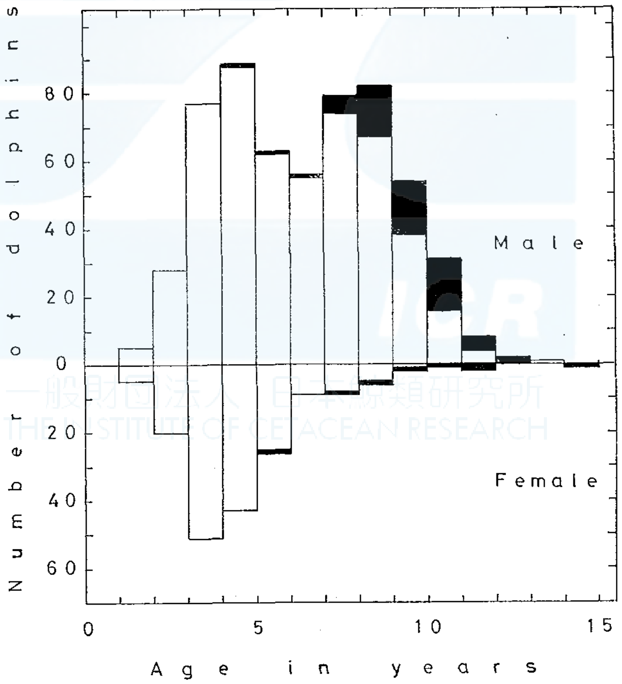

Fig. 12. Age composition of the total juvenile schools of striped dolphins. White areas indicate the immature or puberal dolphins, and black the mature.

The adult school

The adult school may in any case holds both sexes of animals. Sex ratio of the adult schools of this study is varied (from 0.12 to 2.32) (Table 9). Summing up the whole animals in the 22 adult schools, the sex ratio of males against females is 0.78 (Table 9), and then number of females is larger than that of males. School composition of adult schools is somewhat different from that of juvenile schools. The ratio of the number of socially mature males, which are considered to take part in reproduction (see page 99), against the total number of lactating and resting females, which are considered as waiting fertilization is 1.43. The ratio shows a female might mate with more than single socially mature male at the time of reproduction.

The maturity rate of every school shows big varieties in both sexes (male; from 0 to 93%, female; from 42.9% to 100%). In all adult schools in total, maturity rate of males is 77.8%, very close to the rate of females (78.4%) (Tables 9 and 10). The result is a big difference from the sex maturity ratio of the juvenile schools.

Figure 13 shows the clearly recorded age composition of 17 adult school in total. According to the figure, the adult schools are formed with males of 0 to 26.5 years old and females of 0 to 29.5 years old. There are two modes seen at the age of 0 to 1 year and 12 to 13 years of both sexes. The number of animals of both sexes begin to decrease at 1.5 years. The age composition indicates that the animals of both sexes leave the adult school after weaning. Although the number of animals younger than 1.5 years are almost same between sexes (sex ratio: 1.16), the age from 1.5 to 7 years, females than males may remain in the adult school after the weaning stage. Once decreased number of animals of both sexes is increasing from the age of 7 years and goes up till 12–13 years. The sex ratio from 7 to 9 years is 0.71 and after 9 years is 0.76. From this data it is considered that young animals from outside may rejoin the adult school when they become puberal stage. After newcomers joined the schools, sex ratio is almost unchanged through puberal and mature stages.

Average testis weight of the 579 mature males obtained from 22 adult schools is 82.9 g, and 346 individuals (59.8%) had testes heavier than 68.9 g suggesting that they had highly activated spermatogenesis, that is, roughly 60% of mature males of the adult schools are in the highly developed reproductive conditions.

Compared the average testis weight of mature males of 22 schools, there is a big variety, from 29.1 to 147.2 g (Table 13). Checking the average testis weight of the adult schools from the viewpoint of monthly catch, that of individuals caught in October is 113.6 g; there is one mode seen at 110–140 g, and that in November is 70.2 g; one mode is noticeable at 40–80 g (Fig. 14). Apparently testes weight are heavier in October catch than in November catch. On the other hand, age compositions of adult school caught in October and November are almost similar each other. According to Miyazaki (1977) testis weight of males of more than 9 years old is lighter in November and heavier in October. These informations suggest that the difference in testis weight between two months is naturally not by

TABLE 9. RATIO OF REPRODUCTIVE CONDITION OF FEMALE AND SEX RATIO IN ADULT SCHOOL

School no.	Suckling	Immature**	Mature						Total	Sex ratio***
			unknown	pregnant	p. & l.	lactating	resting	total*		
3	1	3	16	0	0	0	0	0	20	0.21
		15.8%		0	0	0	0	0		(0)
5	12	40	30	84	4	87	22	197	279	0.46
		15.0%		42.6	2.0	44.2	11.2	100		(0.44)
7	0	24	20	0	0	0	0	0	44	2.82
		54.5%		0	0	0	0	0		(5.60)
8	8	10	4	7	0	19	4	30	52	0.59
		22.7%		23.3	0	63.3	13.3	100		(0.47)
10	1	2	5	6	0	10	10	26	34	0.64
		6.1%		23.1	0	38.5	38.5	100		(0.55)
11	1	8	2	0	0	0	4	4	15	2.07
		57.1%		0	0	0	100	100		(4.00)
13	0	10	4	29	6	22	4	61	75	0.63
		13.3%		47.5	9.8	36.1	6.6	100		(0.60)
18	0	8	16	17	0	1	0	18	42	0.38
		19.0%		94.4	0	5.6	0	100		(0.15)
21	7	7	1	5	0	18	4	27	42	1.49
		20.0%		18.5	0	66.7	14.8	100		(1.36)
23	0	0	1	7	0	3	0	10	11	1.45
		0%		70.0	0	30.0	0	100		(1.27)
25	1	5	1	5	0	2	0	7	14	1.23
		38.5%		71.4	0	28.6	0	100		(1.88)
26	0	5	0	10	0	2	0	12	17	1.41
		29.4%		83.3	0	16.7	0	100		(1.50)
27	7	42	18	29	0	9	4	42	109	1.02
		41.2%		69.0	0	21.4	9.5	100		(1.25)
29	16	16	3	21	0	29	0	50	85	0.19
		23.2%		42.0	0	58.0	0	100		(0.25)
32	4	8	2	3	0	2	1	6	20	2.63
		50.0%		50.0	0	33.3	16.7	100		(4.00)
34	8	8	15	45	1	10	1	57	88	0.44
		10.0%		78.9	1.8	17.5	1.8	100		(0.44)
36	9	19	34	24	1	20	3	48	110	0.12
		18.8%		50.0	2.0	41.7	6.3	100		(0.10)
37	6	17	11	15	0	11	2	28	62	0.14
		30.4%		53.6	0	39.3	7.1	100		(0.05)
38	6	17	1	99	0	7	2	108	132	0.62
		13.5%		91.7	0	6.5	1.9	100		(0.45)
40	10	11	3	27	3	17	6	53	77	0.72
		16.4%		50.9	5.7	32.1	11.3	100		(0.71)
43	5	32	21	19	0	21	5	45	103	1.38
		32.7%		42.2	0	46.7	11.1	100		(1.44)
44	29	33	14	62	20	45	4	131	207	1.24
		18.5%		47.3	15.3	34.4	3.1	100		(1.26)
Total	131	325	222	514	35	335	76	960	1,638	0.79
		21.6%		53.5	3.6	34.9	7.9	100		(0.78)

*: Excluding the unknown mature female. **: Percentage of the total excluding the suckling.
***: Sex ratio of the total excluding the suckling and sex ratio of the mature animals (in parentheses).

TABLE 10. MATURITY FREQUENCIES OF MALE IN ADULT SCHOOL

School no.	Suckling	Immature*	Mature*	Testis weight in g.					Total**
				6.7	6.8–15.4	15.5–39.2	39.3–68.8	68.9	
3	4	4	0	0	0	0	0	0	4
		100%	0	0	0	0	0	0	
5	12	18	81	2	2	4	10	5	122
		14.8%	66.4	1.6	1.6	3.3	8.2	4.1	
7	0	12	50	0	0	0	0	62	124
		9.7%	40.3	0	0	0	0	50.0	
8	9	6	7	3	1	1	2	6	26
		23.1%	26.9	11.5	3.8	3.8	7.7	23.1	
10	11	2	9	2	0	0	0	8	21
		9.5%	42.9	9.5	0	0	0	38.1	
11	0	5	22	0	0	2	0	0	29
		17.2%	75.9	0	0	6.9	0	0	
13	3	5	10	2	1	3	4	22	47
		10.6%	21.3	4.3	2.1	6.4	8.5	46.8	
18	0	11	0	0	0	1	0	4	16
		68.8%	0	0	0	6.3	0	25.0	
21	6	14	4	0	0	0	0	34	52
		26.9%	7.7	0	0	0	0	65.4	
23	3	2	0	0	0	0	0	14	16
		12.5%	0	0	0	0	0	87.5	
25	2	1	8	0	0	1	0	6	16
		6.3%	50.0	0	0	6.3	0	37.5	
26	0	4	3	2	0	0	2	13	24
		16.7%	12.5	8.3	0	0	8.3	54.2	
27	4	22	29	4	3	4	5	37	104
		21.2%	27.9	3.8	2.9	3.8	4.8	35.6	
29	26	0	1	0	0	0	0	12	13
		0	7.7	0	0	0	0	92.3	
32	1	10	2	0	0	1	8	21	42
		23.8%	4.8	0	0	2.4	19.0	50.0	
34	4	2	9	1	0	3	12	8	35
		5.7%	25.7	2.9	0	8.6	34.3	22.9	
36	4	0	1	2	2	3	2	2	12
		0%	8.3	16.7	16.7	25.0	16.7	16.7	
37	6	6	0	0	0	2	0	0	8
		75.0%	0	0	0	25.0	0	0	
38	1	18	3	1	10	28	16	2	78
		23.1%	3.8	1.3	12.8	35.9	20.5	2.6	
40	15	7	2	1	0	4	14	20	48
		14.6%	4.2	2.1	0	8.3	29.2	41.7	
43	12	2	3	24	14	23	41	28	135
		1.5%	2.2	17.8	10.4	17.0	30.4	20.7	
44	36	11	99	24	2	7	31	46	220
		5.0%	45.0	10.9	0.9	3.2	14.1	20.9	
Total	159	162	343	68	35	87	147	350	1,192
		13.6%	28.8	5.7	2.9	7.3	12.3	29.4	

*: Maturity of testis was identified by eye in the field.
**: Excluding the suckling.

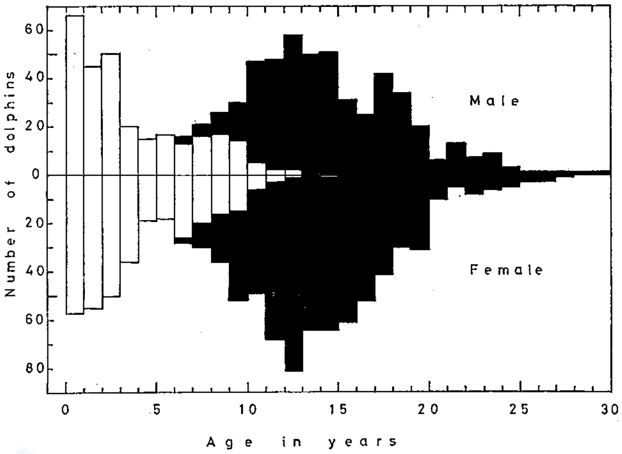

Fig. 13. Age composition of the total adult schools of striped dolphins. White areas indicate the immature or puberal dolphins, and black the mature.

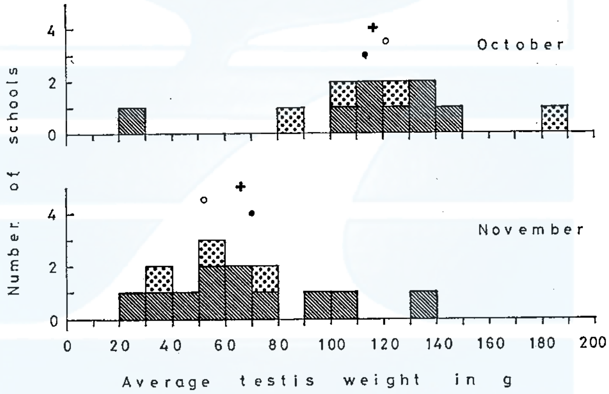

Fig. 14. Frequencies of the average testis weight of the mature males in each school of striped dolphins. Hatched areas indicate the adult schools, and dotted the mixed. Closed circle indicates the average of adult schools, open circle that of the mixed, and cross the total.

age composition but by some reproductive condition of animals.

Among 20 adult schools, 14 schools (70.0%) hold females of all pregnant, lactating, and resting stages, 5 schools hold those of pregnant and lactating but not resting, and only one school (5%) had neither pregnant nor lactating females (Fig. 15). There is, however, no school holds females exclusively in pregnant stage nor those in lactating (Table 9). These facts may suggest that the adult school structure is commonly holding all pregnant, lactating, and resting females. There seems to be small number of schools which lack resting females, or pregnant but school structure otherwise may be rare. There are six schools which had females

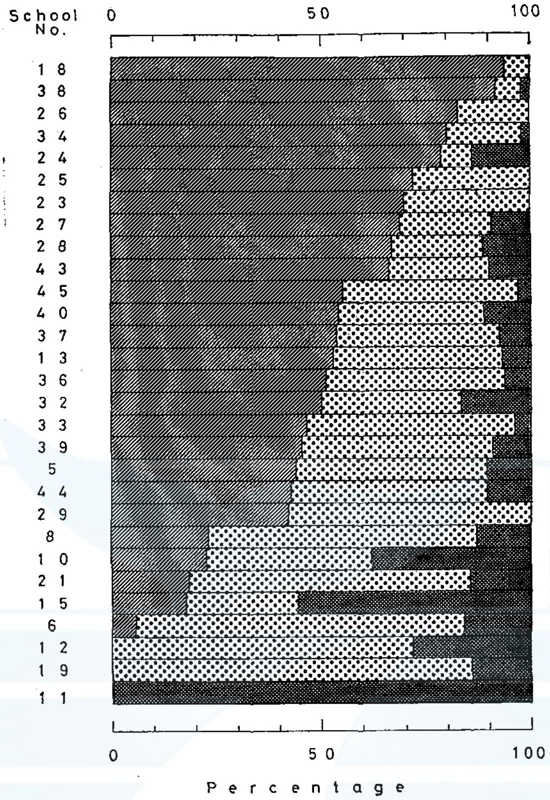

Fig. 15. Percentage of the pregnant, the lactating, and the resting females to the total mature females in each school of striped dolphins. Hatched areas indicate the pregnant females, dotted the lactating, and double hatched spots the resting.

who showed simultaneously pregnant and lactating stages, the number of those females is only 35 all through the adult schools and the ratio of them against the number of all mature females is very small (3.6%). Figure 15 shows frequency of the pregnant, lactating and resting females against all mature females, excluding unknown individuals, in ratio by each school. The ratio of the pregnant females varies, from 0 to 94.4% (average: 53.5%); one mode is seen at 40–60%, that of lactating ones ranges from 0 to 66.7% (average 34.9%); one mode is appear at 30–50%, that of resting ones shows widest variety, from 0 to 100% (average: 7%), there is one mode at 0–10%. Above data suggests that the average structure of the adult school includes 40–60% of pregnant, 30–50% of lactating and less than 20% of resting females.

The mixed school

As well as the adult school, the mixed school holds, in any case, both sexes of animals and sex ratio varies (from 0.47 to 2.32). Summing up the number of animals in whole ten schools, number of males is slightly larger than that of females; sex ratio is 1.06 (Table 11). This ratio is situated at the middle between those of juvenile and adult schools. Maturity rate of males of the whole mixed schools is 35.4%, the rate is just middle of those of juvenile and adult schools (Table 12). While maturity rate of females in each school is from 15.3 to 70.0% (Table 11), and that of the whole mixed school is 46.3%, the rate is a little higher than that of male.

Figure 16 shows total age composition of 7 mixed schools. According to the figure, age of males ranges from 0 to 24.5 years and of females from 0 to 26.5 years; peaks are seen at 5–6 years, and 12–13 years of both sexes, the former 5–6 years is similar to the age composition of the juvenile schools and the latter 12–13 years is so to that of the adult schools.

In the age composition (Fig. 4), it is understood that fundamentally the mixed school has two types of composition, one holds both sexes of immature and puberal animals as majority and the other holds those of mature animals as majority. However, there are a few mixed schools with other type of composition. School

TABLE 11. RATIO OF REPRODUCTIVE CONDITION OF FEMALE AND SEX RATIO IN MIXED SCHOOL

School no.	Suckling	Immature**	Mature						Total	Sex ratio***
			un known	pregnant	p. & l.	lactating	resting	total*		
2	4	9	4	0	0	0	0	0	17	2.08
		69.2%		0	0	0	0	0		(1.25)
6	9	111	1	1	0	15	3	19	140	1.33
		84.7%		5.3	0	78.9	15.8	100		(2.00)
12	3	4	0	0	0	5	2	7	14	1.27
		36.4%		0	0	71.4	28.6	100		(0.43)
15	17	45	4	9	0	14	29	52	118	1.32
		44.6%		17.3	0	26.9	55.8	100		(1.20)
19	2	3	0	0	0	6	1	7	12	1.20
		30.0%		0	0	85.7	14.3	100		(0)
24	0	11	3	11	0	1	2	14	28	2.32
		39.3%		78.6	0	7.1	14.3	100		(1.35)
28	1	36	7	12	0	4	2	18	62	0.92
		59.0%		66.7	0	22.2	11.1	100		(1.08)
33	6	36	13	13	0	14	1	28	83	0.47
		46.8%		46.4	0	50.0	3.6	100		(0.27)
39	13	32	2	14	0	14	3	31	78	0.68
		49.2%		45.2	0	45.2	9.7	100		(0.61)
43	4	32	15	33	0	12	5	50	101	0.75
		33.0%		66.0	0	24.0	10.0	100		(0.43)
Total	59	319	49	93	0	85	48	226	653	1.06
		53.7%		41.2	0	37.6	21.2	100		(0.81)

*: Excluding the unknown mature female. **: Percentage of the total excluding the suckling.
***: Sex ratio of the total excluding the suckling and sex ratio of the mature animals (in parentheses).

TABLE 12. MATURITY FREQUENCIES OF MALE IN MIXED SCHOOL

School no.	Suckling	Immature*	Mature*	Testis weight in g. 6.7	6.8–15.4	15.5–39.2	39.3–68.8	68.9	Total**
2	10	22	5	0	0	0	0	0	27
		81.5%	18.5	0	0	0	0	0	
6	8	87	15	40	7	2	11	12	174
		50.0%	8.6	23.0	4.0	1.1	6.3	6.9	
12	5	11	1	0	0	0	0	2	14
		78.6%	7.1	0	0	0	0	14.3	
15	9	66	67	0	0	0	0	0	133
		49.6%	50.4	0	0	0	0	0	
19	1	12	0	0	0	0	0	0	12
		100%	0	0	0	0	0	0	
24	1	23	6	10	9	2	0	15	65
		35.4%	9.2	15.4	13.8	3.1	0	23.1	
28	2	26	18	2	1	0	0	9	56
		46.4%	32.1	3.6	1.8	0	0	16.1	
33	3	20	0	2	3	5	4	2	36
		55.6%	0	5.6	8.3	13.9	11.1	5.6	
39	10	19	1	1	4	15	3	1	44
		43.2%	2.3	2.3	9.1	34.1	6.8	2.3	
43	8	33	2	1	9	20	6	0	71
		46.5%	2.8	1.4	12.7	28.2	8.5	0	
Total	57	319	115	56	33	44	24	41	632
		50.5%	18.2	8.9	5.2	7.0	3.8	6.5	

*: Maturity of testis was identified by eye in the field.
**: Excluding the suckling.

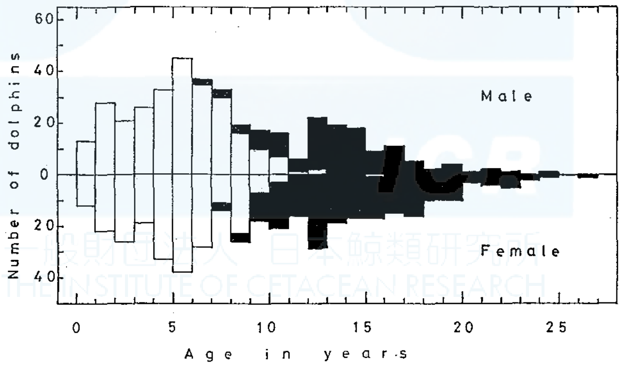

Fig. 16. Age composition of the total mixed schools of striped dolphins. White areas indicate the immature or puberal dolphins, and black the mature.

No. 19, for example holds mature individual of exclusively females and immature ones of both sexes, and school No. 24 for another example, holds mature animals of both sexes and individual in puberal stage of exclusively males.

Average testis weight of mature males in all the mixed schools is 65.3 g, among those animals, 37.6% (namely 41 mature males) had testes heavier than 68.9 g suggesting that they had possibly active spermatogeneses. The rate 37.6% is a little lower than that of the adult schools. Average testis weight of every mixed school also ranges widely from 31.2 to 180.4 g (Table 13). Apparent testis weight variety can be seen between the animals caught in October and in November (Fig. 14). Weight of testes from the schools caught in October ranges from 104.4 to 180.4 g (average 136.5 g) and those from November caught are from 32.4 to 70.2 g (average 51.8 g) (Fig. 14). Namely, weight of testes are heavier in October and become lighter in November. This phenomenon is common in the adult schools.

Out of ten mixed schools, nine were examined of sexual condition of females. Most of the school held (77.8%) females of all pregnant, lactating and resting stages, but a few schools lacked pregnant females (Fig. 15). There was no female who showed simultaneously pregnant and lactating stages, in any school.

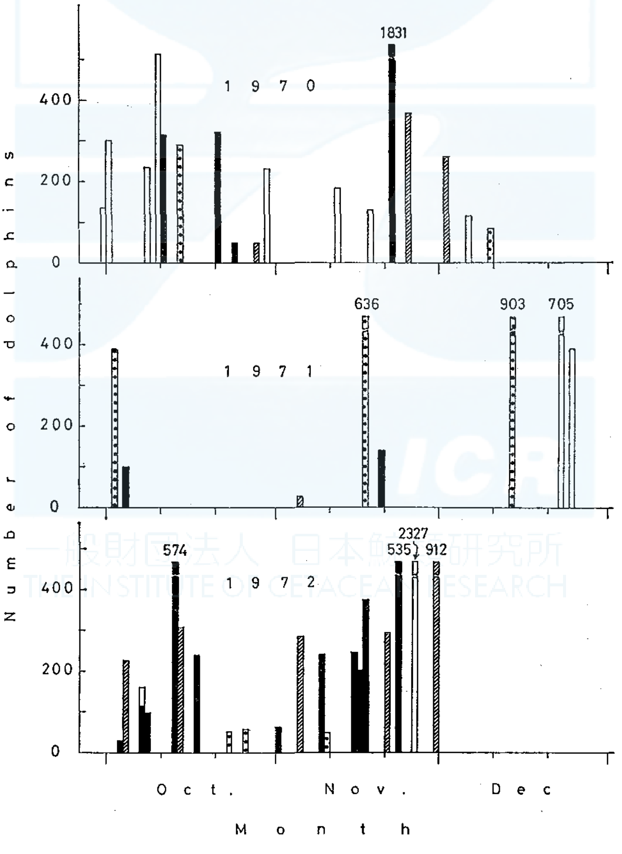

Fig. 17. School size, date of catch, and school composition of striped dolphins are shown in each year during 1970 through 1972. Black areas indicate the adult school, dotted the juvenile, hatched the mixed, and white the unidentified.

DISTRIBUTION OF THE SCHOOLS

Distribution of the schools was presumed from the compositions of 33 schools investigated over the three fishing seasons in the period from 1970 to 1972, from the catch record of Kawana and Futo Fishermen's Union over the five fishing seasons in the period from 1970 to 1974, and from the location of the Kuroshio Current was taken up as a big factor to influence distribution of this species.

Generally, the isothermal layer of 15°C at about 200 m depth was an indicator to tell the location of the Kuroshio. According to the data on the Kuroshio by the Maritime Safety Agency, distance between the main fishing area of this species and the Kuroshio in the season from October to December was 7.0 nautical miles in 1970, 52.5 n.m. in 1971 and 9.4 n.m. in 1972. That is, the Kuroshio was closer to the area in 1970 and 1972 than in 1971. In 1970 and 1972, 5 juvenile, (18.5%), 15 adult (55.6%) and 7 mixed (25.9%) schools were caught. While in 1971, 3 juvenile (50.0%), 2 adult (30.0%) and 1 mixed (20.0%) schools were

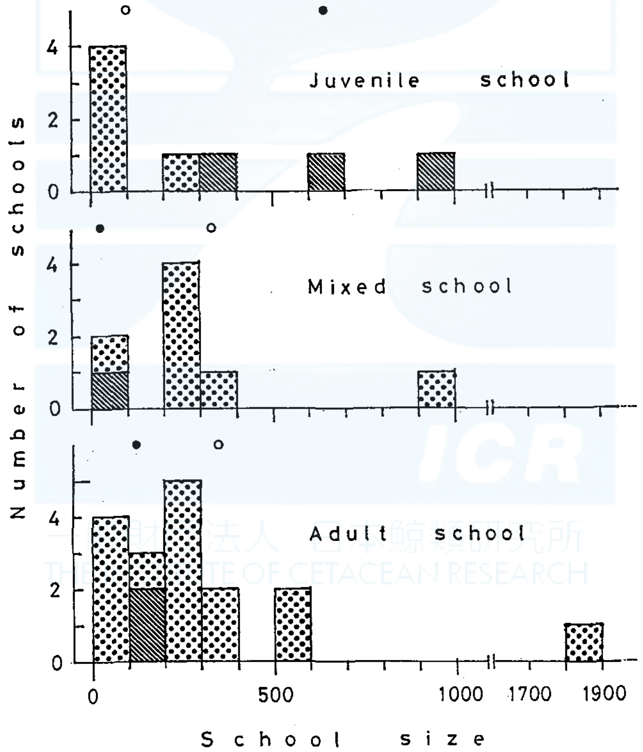

Fig. 18. Frequencies of school size of striped dolphins in the juvenile, mixed, and adult schools. Dotted areas indicate the catch in the year when the Kuroshio currents close to the coast, and hatched the catch in the year when the Kuroshio distant from the coast. Open circle indicates average size of the schools caught in the former year, and closed circle that in the latter year.

harvested (Fig. 17). Namely, in the year when the Kuroshio was closer, comparatively larger number of adult schools but lesser number of juvenile schools came into the area. Figure 18 is the school size frequency by school type. The figure shows that in the year when Kuroshio was closer, size of adult schools varies widely as

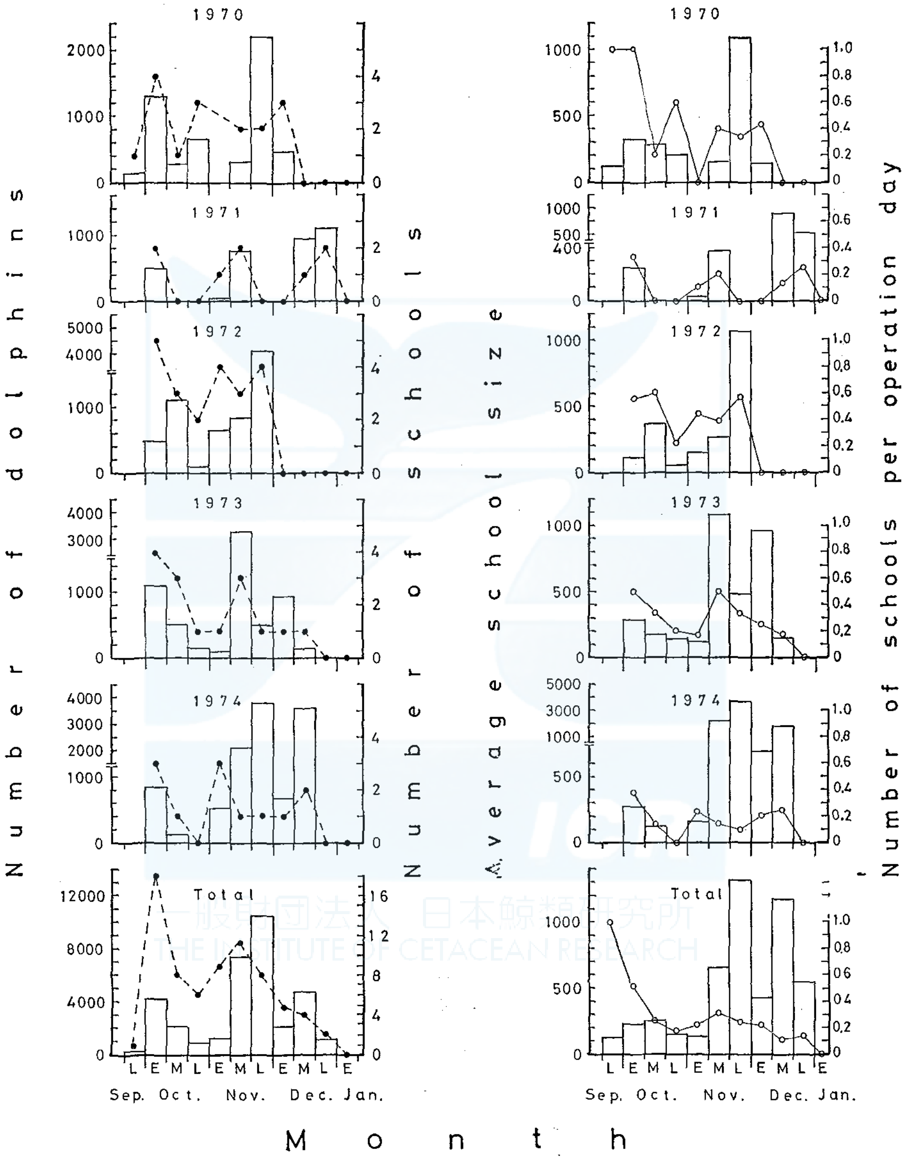

Fig. 19. Frequencies of number of striped dolphins, number of schools, average school size, and number of school per operation day are shown in five fishing seasons during 1970 through 1974. Closed circle and dotted line indicate number of schools, open circle and solid line number of schools per operation day.

from 31 to 1,832 individuals (average: 345), while in the year of distant Kuroshio, range of adult school size is narrow as 101 to 140 animals (average: 120). On the other hand size of the juvenile schools were relatively smaller in the years when the Kuroshio is closer as from 45 to 293 animals (average 105), while the Kuroshio was distant, size of those ranged from 393 to 903 animals (average 664). The average size in the latter year is almost six times as large as that of the former. Apparently, school size as well as distribution of the schools of this species were influenced by the location of the Kuroshio.

Figure 19 shows number of animals and schools caught, and average school size and number of schools per operation day, by the year. In every graph of the four items, based on the data of five fishing seasons during 1970–1974, two peaks are seen in October and November. Number of animals form higher peaks in November than in October. On the other hand number of schools form higher peaks in October. Accordingly, the peaks of average size are higher in November but those of number of schools per operation day is higher in October. As the fishing ground of *S. coeruleoalba* along the east coast of the Izu Peninsula is a limited area, number of schools per operation day can be an indicator of density of schools coming to the area seasonally.

RELATIONAL COINCIDENCE OF ANIMALS WITHIN THE SCHOOL

Puberal males

In the age composition of males in school Nos 17, 22, 30, 31 and 35, each one mode is recognized at the age of 4.5 years. This mode is formed with immature males. While in the age composition of an unique school, No. 20, there are two modes at 4.5 and 8.5 years, and the latter mode is higher. Presumed from age, animals of the latter mode mostly are puberal males with some mature ones. Presumably, school No. 20 was formed in the case when puberal males coming out of a juvenile school joined by a group of immature males. Based on the age compositions of Nos 24, 28, 33, 39 and 43, puberal male group is perceived (Fig. 4), however, acutally, puberal males seem not to form the school without coincidence of immature or mature individuals.

Immature and mature animals

Examined the frequency of coincidence of immature and mature animals in 22 adult schools in Fig. 20, numbers of immature males and females against mature females show positive co-relation. And numbers of immature males and females against mature males also show positive co-relation. These mean that both sexes of immature animals frequently coincide with mature males and females in adult schools. Considering age composition of striped dolphins after weaning stage, immature females may more often remain in the adult school than immature males.

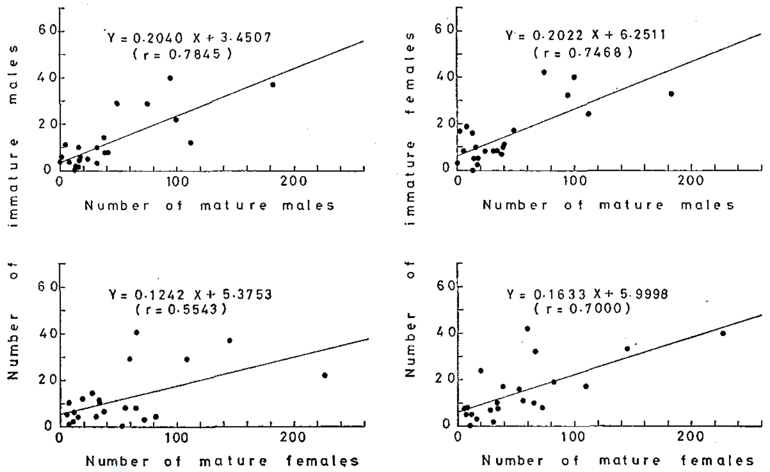

Fig. 20. Relation between the immature and the mature striped dolphins. Immature dolphins in this case mean the puberal or immature dolphins excluding the suckling.

Mature females

In the frequencis of body length of fetuses and newborn calves (less than 182 cm in length) in every 27 schools (Fig. 21), there are two or more peaks in most schools. It is suggested that the mature females who had fetuses in the same size were fertilized in a same mating season as well as the females who accompanied with newborn calves in the same size. It seems likely that females fertilized nearly at same time, do not change their schools spontaneously one by one, but move out and in as a group. Considering that many schools have plural modes in themselves, it can be said that groups of females nearly simultaneously fertilized may gather together to form a bigger group within a school.

In order to analize the relation between mature females in detail, adult females are divided into five stages by corresponding body length of fetuses or newborn calves. First, pregnant females are divided into three stages, early pregnancy (had fetuses of less than 32 cm in length), middle pregnancy (had fetuses of 33–67 cm) and late pregnancy (had fetuses of more than 68 cm), and remainders are divided into lactation (accompanied by calves of less than 174 cm) and post lactation (accompanied by young animals of 174–182 cm). In the present study the actual relation between calves and their mothers can not be obtained. Then, trying to know how frequently coincide each stage of females in the schools, the relation between peaks of body length composition of fetuses and newborn calves was shown in Fig. 22. As in the case of school No. 45, for example, three peaks were seen in the school composition, the relation between the first and second peaks of length composition of fetuses and newborn calves, that between the second and third peaks, and that between the third and first peaks were plotted in Fig. 22. These plots suggest that the band of early pregnant and lactating females, that of

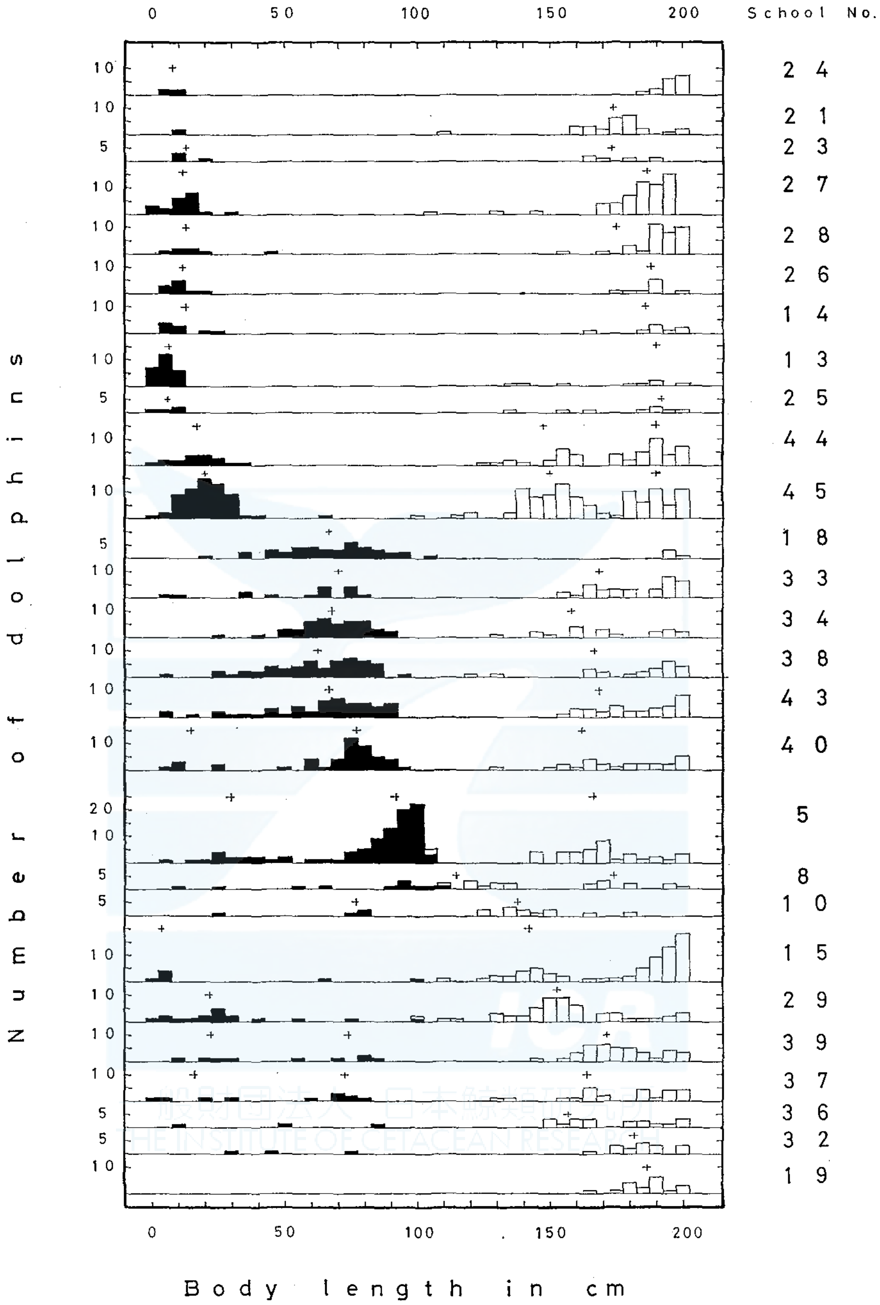

Fig. 21. Body length frequencies of collected fetuses and newborn calves of striped dolphins in each school. Black areas indicate fetuses, white newborn calves and cross the peak.

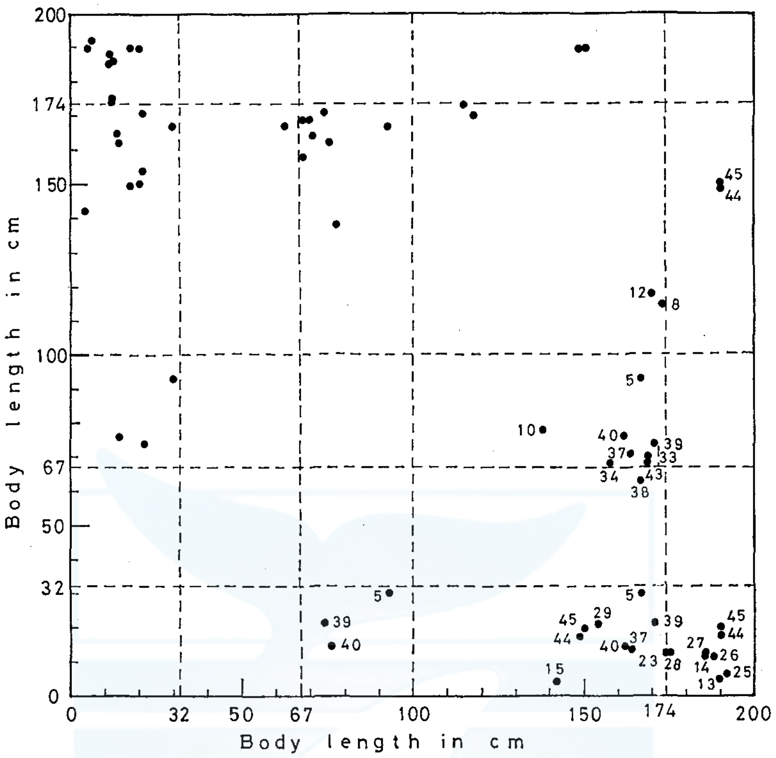

Fig. 22. Relation between peaks in body length frequencies of fetuses or newborn calves of striped dolphins in each school. Numbers indicate the school no.

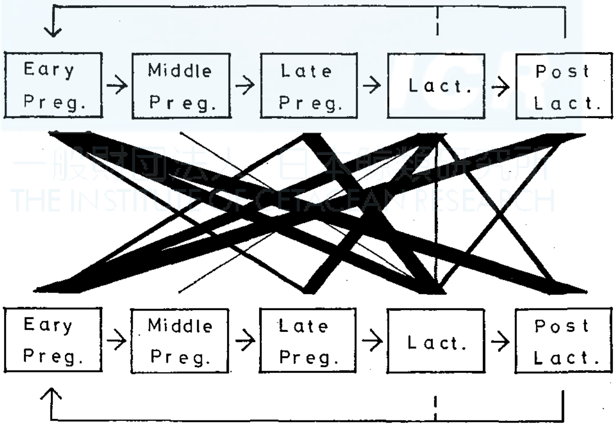

Fig. 23. Relation between the mature females. Thickness of line indicates the degree of relational coincidence of mature females. Arrows mean the direction of the change of sexual conditions.

lactating and post lactating females, and that of post lactating and early pregnant females appear to closely associate each other. Total plots of 22 adult schools are summed up and they are schematically figured in Fig. 23. This suggests that groups of females waiting for or shortly after fertilization, or those of shortly before or after partulition have higher coincidence.

Mature males

As mentioned before, 222 mature males can be divided into three stages as MI, MII and MIII according to the histological examination of testes. Ratio of the males of type MIII against all the mature males at each age is shown in Fig. 24. At 13.5 years, males of MIII reach 50% and naturally, the ratio grow higher with age. As the males of MIII proved in examination their highly activated spermatogenesis, males of older than 13.5 years are in full maturity of reproduction.

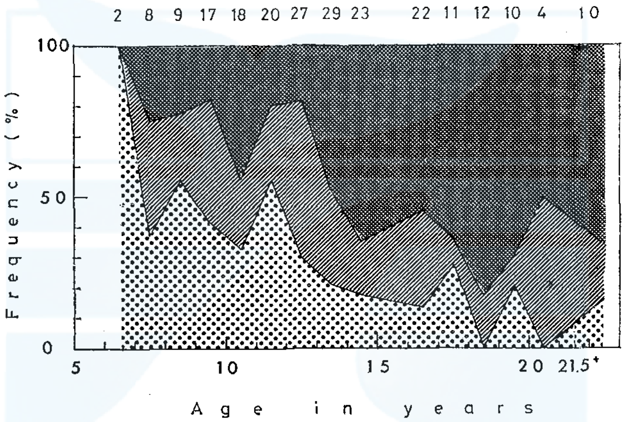

Fig. 24. Relation between age and percentage of mature striped dolphins of MI, MII, and MIII types to the total mature males (from bottom to top). For MI, MII and MIII types see text. Numbers at the top indicate sample size.

In juvenile schools most mature females have just reached maturity but are not yet fertilized, and most mature males have light testes and not yet participate in mating. As the oldest male is 13.5 years, it may be that males of about this age go out of juvenile schools. In the age composition of school Nos 6, 24, 28, 33 and 39, there are two modes of males in each, the first one is understood as indication of immature and puberal males and the second one is that of mature males. Those five schools are considered to be mixed schools, the mature males belonged to the first mode seems to have been originated in a juvenile school, not yet participate in mating, but the mature males belonged to the second mode seems to have originated in an adult school and already have participated in mating. Making these reading of figure as a standard, the youngest males which have participated in mating in each school, were presumed. It was around 13.5 years in age except one younger individual in school No. 39. Considering this age of youngest par-

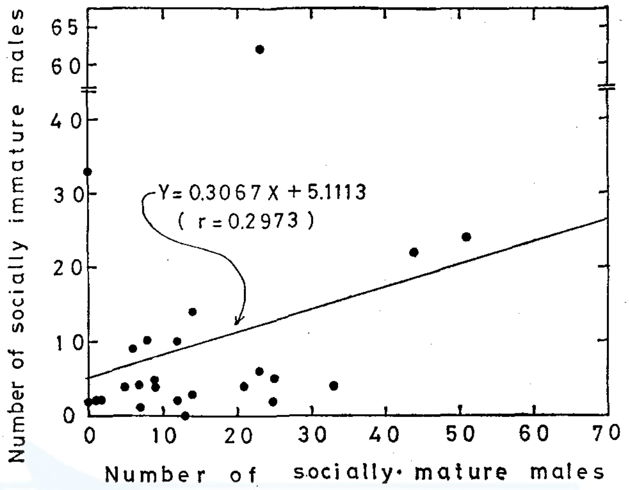

Fig. 25. Relation between socially immature males and socially mature males.

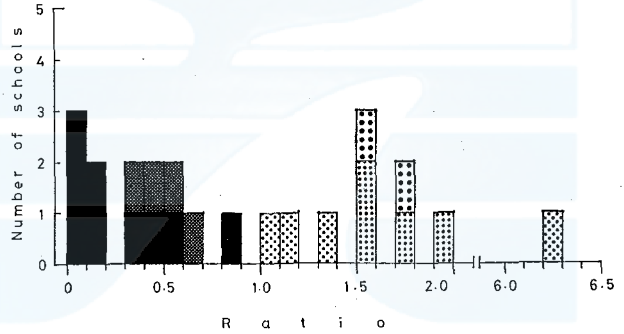

Fig. 26. Frequency of the ratios of the socially mature males to the mating females. Black areas indicate the non-mating adult schools, black with white spot the non-mating mixed, small dotted the mating adult, and large dotted the mating mixed.

ticipant with the results of histological examinations of testes, it may be that, males become socially mature at about 13.5 years old. The mature males younger than this age is defined as socially immature males in this study. In order to know coincidence of socially mature males and socially immature males, both stages of males were plotted in Fig. 25 from 24 schools. It seems that there are no apparent relational coincidences.

Mature females and males

The females in early pregnant, lactating, and resting stages are considered as waiting or shortly after fertilization, and defined as mating females. On the other hand, females of middle and late stages of pregnancy are considered not to participate in mating for a time being and defined as non-mating females. Fre-

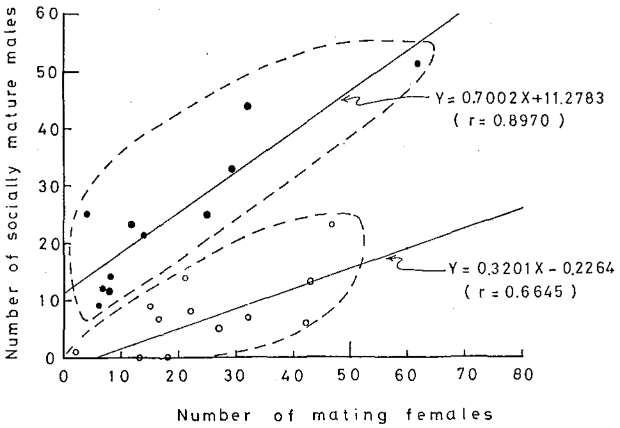

Fig. 27. Relation between the socially mature males and the mating females. Open circles indicate the non-mating schools and closed circles the mating.

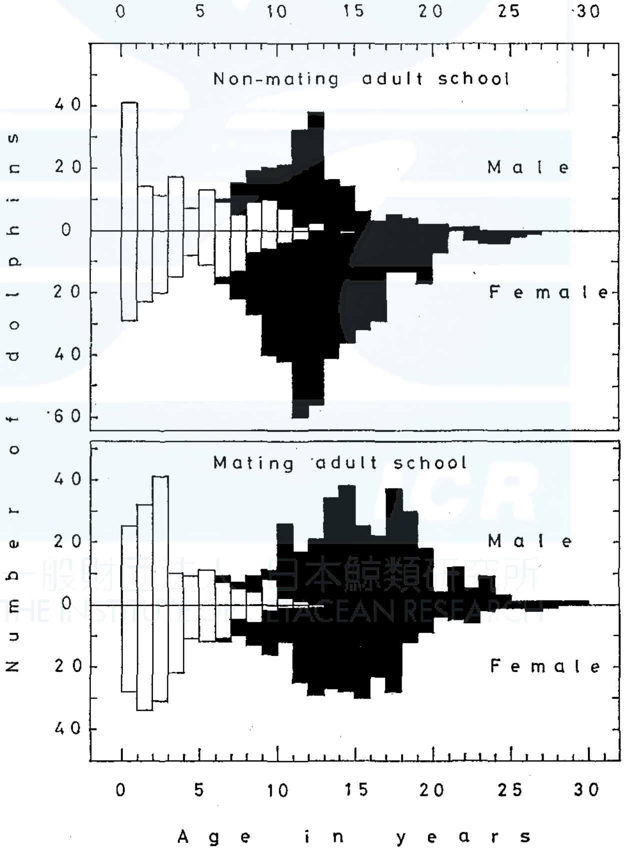

Fig. 28. Age compositions of the mating and non-mating adult schools of striped dolphins. White areas indicate the immature or puberal dolphins and black the mature.

quency in ratio of number of socially mature males against mating females of 17 adult and 6 mixed schools are shown in Fig. 26. In this figure there are two peaks at the ratio 0–0.1 and 1.5–1.6. According to the above definition, the total 23 schools are able to be divided into two categories. Those schools, of which the ratio of socially mature males against mating females is lower than 0.9, are called as non-mating schools and those, of which ratio is higher than 1.0, are called as mating schools. Eight adult schools (Nos 5, 13, 18, 29, 36, 37, 38, and 44) and four mixed schools (Nos 6, 33, 39 and 43) are in the non-mating category, and nine adult schools (Nos 21, 23, 25, 26, 27, 32, 34, 40 and 45) and two mixed schools (Nos 24 and 28) are in the mating category. Number of mating females and socially mature males of every school are plotted in Fig. 27. This figure seems to rationalize the division of mating and non-mating schools, and socially mature males and mating females are frequently coincident in the schools. Collective age composition of both categories of adult school is in Fig. 28 and that of mixed schools is in Fig. 29. Compared the age compositions of those two categories of schools, it is a matter of course that socially mature males are recognized more frequently in mating schools and the males in mating schools have better developed heavier testes than males of non-mating schools (Fig. 30). As majority of females in mating schools are waiting or shortly after fertilization, and majority

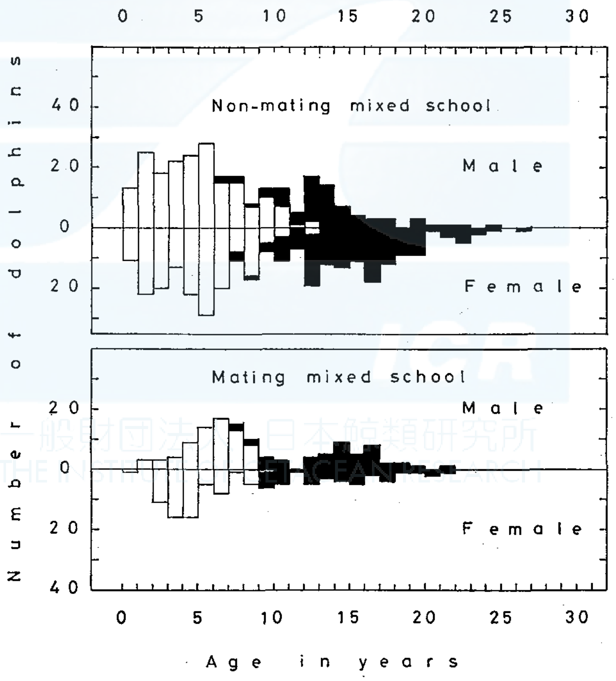

Fig. 29. Age compositions of the mating and non-mating mixed schools of striped dolpins. White areas indicate the immature or puberal dolphins and black the mature.

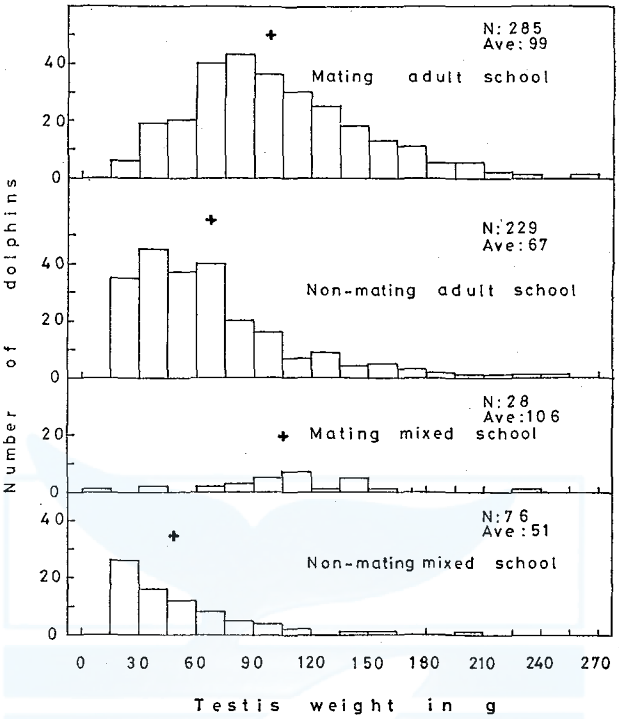

Fig. 30. Frequencies of testis weight of mature males in the mating and non-mating schools. Cross indicate average testis weight.

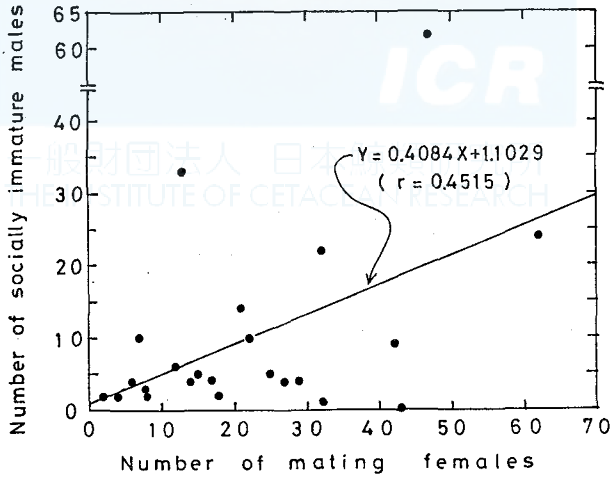

Fig. 31. Relation between the socially immature males and the mating females.

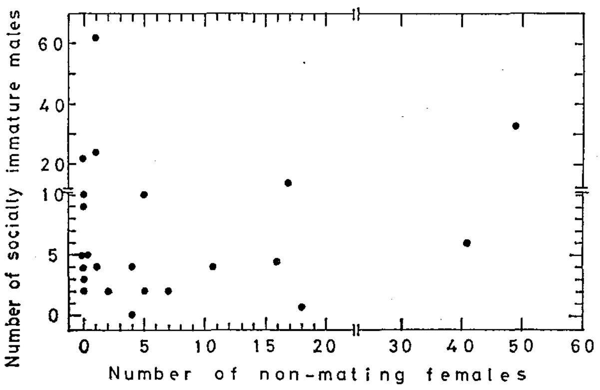

Fig. 32. Relation between the socially immature males and the non-mating females.

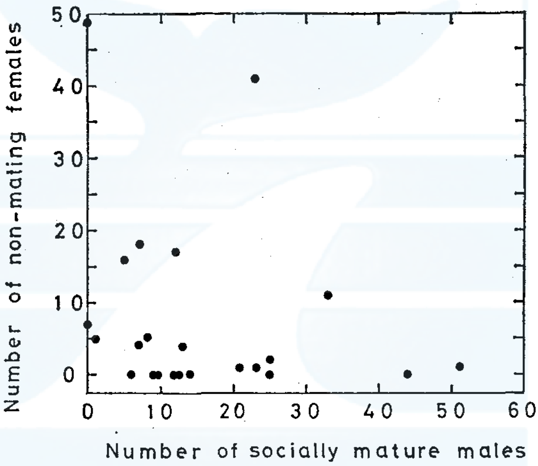

Fig. 33. Relation between the non-mating females and the socially mature males.

of females in non-mating schools are expecting or shortly after parturition, socially mature males are considered to move between mating and non-mating schools according to the reproductive conditions of mature females. Figure 31 shows that mating females have some coincidental relations with socially immature males, but not so high frequency as with socially mature males. In Figs 32 and 33, non-mating females have little or no such relational coincidence with socially mature males nor socially immature males.

BEHAVIOR, IN AND OUT OF THE SCHOOLS

Immature animals from the adult to the juvenile school

Age composition of all the adult schools is in Fig. 12 and that of the juvenile schools is in Fig. 13. In the juvenile schools number of juveniles of both sexes is

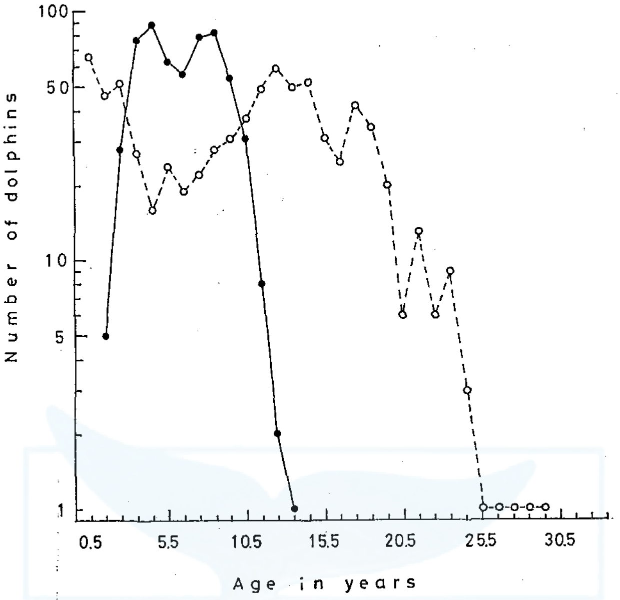

Fig. 34. Comparison of age compositions of males between the juvenile and the adult schools. Open circle and dotted line indicate the males in the total adult schools, and closed circle and solid line the males in the total juvenile.

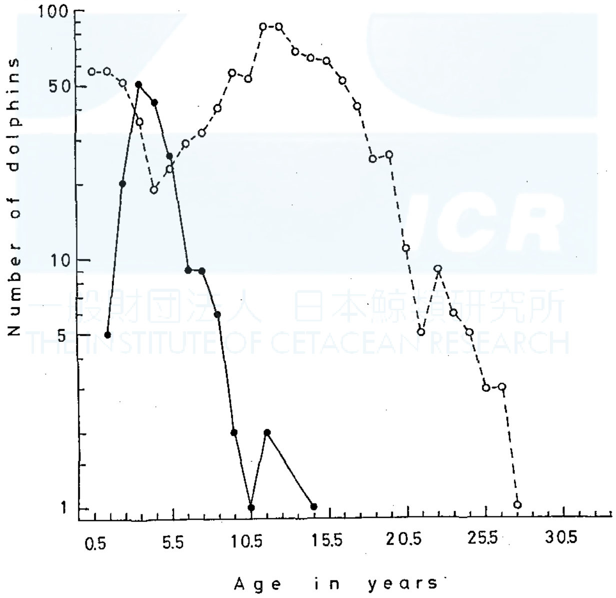

Fig. 35. Comparison of age compositions of females between the juvenile and the adult schools. Open circle and dotted line indicate the females in the total adult schools, and closed circle and solid line the females in the total juvenile.

increasing gradually from the age from 1.5 to 5 years. But in the adult school, reverse tendency is seen. Both tendencies suggest that juveniles get out from the adult school into the juvenile school.

Based on the body length composition of fetuses and newborn calves in the adult schools and age composition of all the juvenile schools, it is understood how long animals stay in the adult school, and when they get out of the adult school. Figure 21 shows that there are groups of newborn calves born in a same season in the adult schools, and if these young animals moved into the juvenile school as a group, the age composition of the juvenile school should have shown big increase at a certain age. But there is a gradual upward curve after 1.5 years. Accordingly, it may be reasonable to consider that juveniles get out of an adult school spontaneously one by one, not as a group.

In average, 2.5 years of males (Fig. 34) and 3.0 years of females (Fig. 35) get out of the adult school and join into the juvenile school. The average age is obtained as the age of coincidence of decrease and increase between both types of the schools. The figure also means that after weaning, males remain in the adult school for about one year and the females for about 1.5 years before they get out one by one.

Females from the juvenile to the adult school

According to the age composition of females in every juvenile schools (Fig. 4), the juvenile schools hold many immature females and a small number of puberal ones. Number of animals is decreasing from the age of 4.5 years and puberal ones appear just at this age. There are few females older than 8.5 years, the time of just reaching puberty. Weight of the left ovaries of 60 females in school No. 22 proves that only one (1.7%) is in the puberal stage ; the individual had left ovary more than 2.0 g. That is, young females leave the juvenile school before the time of reaching puberty.

Compared the age composition of the juvenile and the adult schools, the juvenile schools have a peak at 3.5 years and the number of animals gradually decrease from 4.5 years while in the adult school animals are increasing at the same age. Females leave the juvenile school in age between 4.5 to 9.5 years (Fig. 35). Decrease in number of females of the juvenile schools coincide with increase in that of the adult school at 5.7 years, before the attainment of puberty. There are mature females, though very small in number, also rarely seen in the juvenile schools as in the school No. 20.

From the viewpoint of mating conditions, both adult and mixed schools can be divided into two categories, namely mating and non-mating schools. In the age composition of females, compared the two categories of schools at the age from 1.5 to 6.5 years, numbers of females of the two show almost same values, and again compared at the age older than 12.5, values are almost same again (Fig. 36). But compared the number of females at the age from 7.5 to 12.5 years, the number is large in the non-mating schools while in the mating schools the number is small. Referring to the fact that in the juvenile schools the number at the same age is

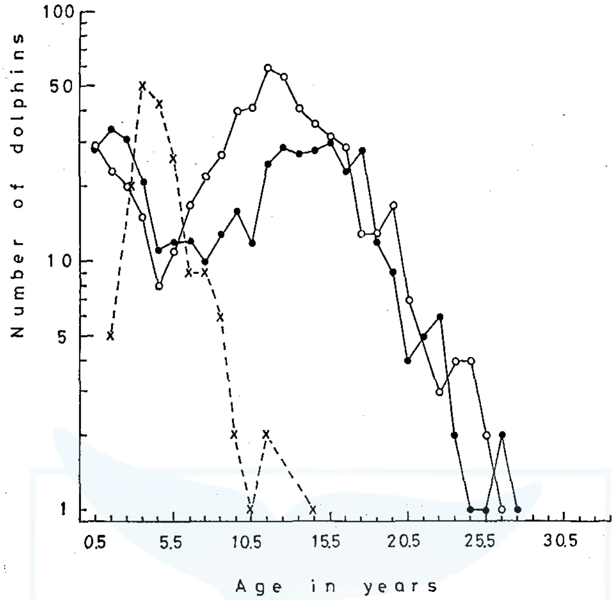

Fig. 36. Comparison of age compositions of females among the juvenile, the mating adult, and the non-mating adult schools. Open circle and solid line indicate the females in the non-mating adult school, closed circle and solid line the females in the mating adult, and cross and dotted line the females in the juvenile.

very small, females leaving from the juvenile schools might move first into a non-mating school and then move again into a mating school when they attain sexual maturity.

Males from the juvenile to the adult school

According to the age composition of the juvenile schools, school Nos 17, 22, 30, 31, 35 (Fig. 4), they hold males among immature animals as majority and small number of puberal ones. Number of males is decreasing from 4.5 years and puberal males appear at the same age. Very few males remain in the school after 8.7 years (50% of males presumed to attain sexual maturity at this age.) Result of histological examination on the testes of the males in school No. 22 tells that puberty rate is maximum 12.5% at 8.5 years (Fig. 37). And after 8.5 years, sexual maturity rate is increasing, but there is no male who had highly developed testis with active spermatogeneses like the males of type MIII. Although histological examination on animals of school Nos 17, 30, 31 and 35 was impossible, males of those schools were likely to have developed similar stage of sexual condition as males in school No. 22 because of almost the same age composition. On the other hand, age composition of school No. 20 shows two modes at 4.5 and 8.5 years. The former peak is composed of a big number of immature males and the latter is of big number of puberal males with small number of mature males. Figure 4

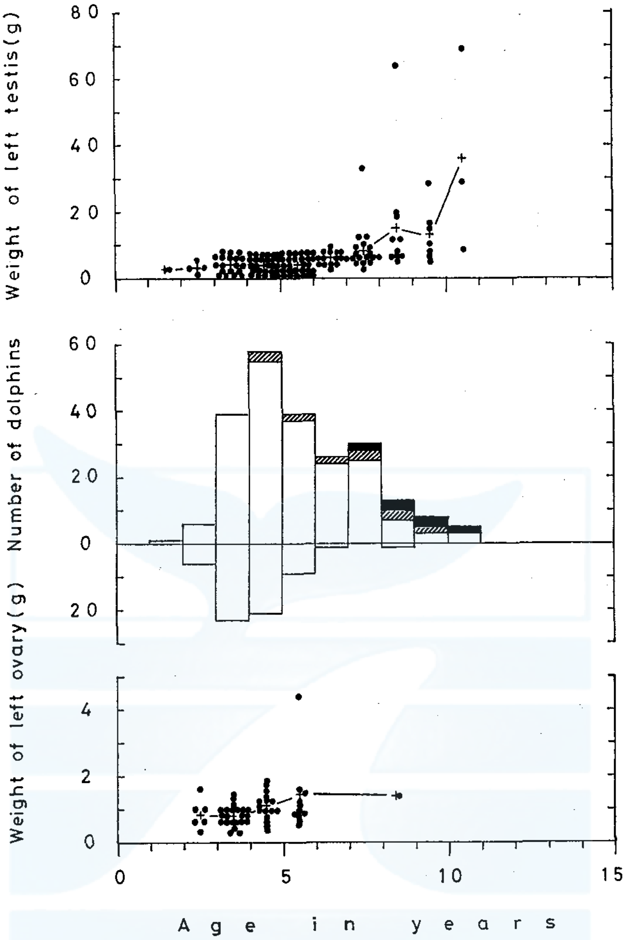

Fig. 37. Age composition, relation between age and the left testis weight, and relation between age and the left ovary weight in school No. 22. Black areas indicate the mature dolphin, hatched the puberal, white the immature and cross average.

suggests the fact that most of the juvenile schools hold major number of immature males and smaller number of puberal ones, and a few of them hold many puberal males with small number of mature ones.

Observing the age composition of males of all the adult and juvenile schools together (Figs 12 and 13), the number of males at the age from 8.5 to 11.5 years is small in juvenile schools but big in adult schools. As the condition of school No. 20 shows, the males seem to leave from the school at the stage of reaching sexual maturity. Regarding the increase and decrease in number of males from 8.5 to 11.5 years, decrease in the juvenile schools coincide with increase in the adult schools at 10.5 years (Fig. 34). The fact may prove that males in the juvenile school rejoin into the adult school just after they attained sexual maturity. However, some males seem to leave the juvenile school a little earlier, within the age of puberal stage.

As mentioned before, the adult schools can be divided into the mating and non-mating schools by reproductive condition. In the age composition, number of animals is decreasing after 12.5 years in the non-mating and after 17.5 years in the mating school (Fig. 28). The decrease of number in the non-mating schools seems to have been caused by some sexual condition, because the males attain social maturity at 13.5 years in average (ready to court females), and the decrease begin at this age. In younger years, from 1.5 to 12.5 years, fluctuation of number is similar in the both categories of schools (Fig. 38). Taking all the above tendencies into consideration, it can be said that males from juvenile schools move into both mating and non-mating schools, and stay there till they attain social maturity. Among those males, individuals who joined non-mating school seems to move again into the mating school after socially matured.

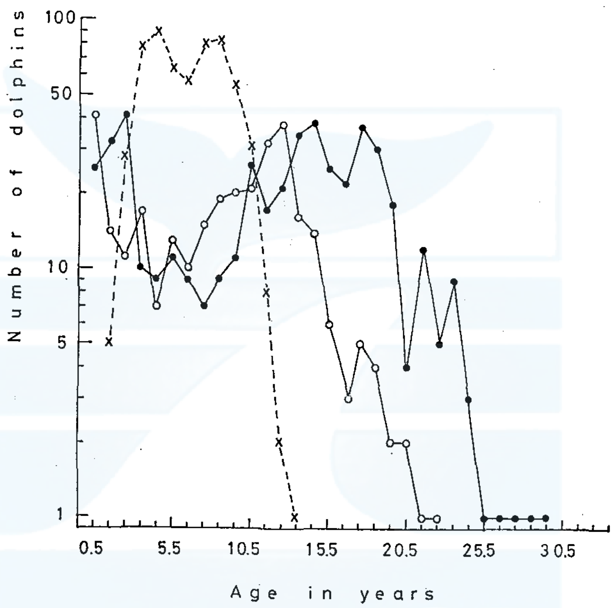

Fig. 38. Comparison of age compositions of the males among the juvenile, the mating adult, and the non-mating adult schools. Open circle and solid line indicate the males in the non-mating adult school, closed circle and solid line the males in the mating adult, and cross and dotted line the males in the juvenile.

Mature animals' behavior in the both categories of adult schools

Table 13 shows (1) ratio of number of socially mature males against mating females, (2) average body length of fetuses, (3) average age of sucklings and (4) average testis weight of mature males. From those data, something can be considered related to the animals in and out of the schools.

TABLE 13. SCHOOL COMPOSITION OF STRIPED DOLPHINS CAUGHT ON THE COAST OF IZU PENINSULA. A) IMMATURE RATE, B) AVERAGE BODY LENGTH OF FETUSES IN CM, C) AVERAGE AGE OF SUCKLING, D) AVERAGE LEFT TESTIS WEIGHT OF MATURE MALES IN G, E) NUMBER OF SOCIALLY MATURE MALES, F) NUMBER OF SOCIALLY IMMATURE MALES, G) NUMBER OF MATING FEMALES, H) NUMBER OF NON-MATING FEMALES, AND I) RATIO OF SOCIALLY MATURE MALES TO MATING FEMALES

School no.	A	B	C	D	E	F	G	H	I
1	53.3	—	—	—	—	—	—	—	—
2	77.5	—	—	—	—	—	—	—	—
3	30.4	—	—	—	—	—	—	—	—
4	100	—	—	—	—	—	—	—	—
5	15.9	79.0	—	57.8	7	1	32	18	0.21
6	80.3	—	—	70.2	9	5	15	0	0.60
7	21.4	—	—	—	—	—	—	—	—
8	28.6	76.8	—	114.4	—	—	—	—	—
9	82.5	—	—	63.9	—	—	—	—	—
10	11.1	65.0	—	126.1	—	—	—	—	—
11	30.2	—	—	29.1	—	—	—	—	—
12	60.0	—	—	180.4	—	—	—	—	—
13	14.8	4.5	—	104.9	6	9	42	0	0.14
14	46.7	12.5	—	—	—	—	—	—	—
15	47.4	19.2	—	—	—	—	—	—	—
16	77.4	—	—	—	—	—	—	—	—
17	94.3	—	—	48.5	0	1	—	—	—
18	32.8	56.1	—	80.2	1	2	2	5	0.50
19	68.2	—	—	—	1	2	—	—	—
20	80.1	—	—	40.3	0	44	—	—	—
21	24.1	11.1	1.64	139.9	25	5	25	0	1.00
22	96.4	—	—	35.4	0	10	—	—	—
23	7.4	12.6	1.19	147.2	12	2	8	0	1.50
24	57.0	7.0	1.25	104.4	12	10	7	0	1.71
25	20.7	6.8	0.38	127.9	9	4	6	0	1.50
26	26.8	9.1	1.88	118.8	14	3	8	0	1.75
27	34.5	11.1	1.14	108.8	44	22	32	0	1.38
28	55.6	15.9	1.44	124.7	21	4	14	1	1.50
29	19.5	29.5	0.41	136.8	13	0	43	4	0.30
30	93.1	—	—	—	—	—	—	—	—
31	90.0	—	—	44.3	0	4	—	—	—
32	31.0	50.3	0.63	90.8	25	2	4	2	6.25
33	54.0	51.8	1.36	52.9	7	4	17	4	0.41
34	9.6	68.3	0.68	65.0	23	6	12	41	1.92
35	92.6	—	—	55.0	0	2	—	—	—
36	20.4	62.2	0.99	47.9	5	4	27	16	0.19
37	35.9	48.0	0.68	28.5	0	2	18	7	0
38	22.5	62.1	0.89	38.2	0	33	13	49	0
39	51.4	45.9	0.88	32.4	8	10	22	5	0.36
40	16.5	62.1	0.99	66.7	33	4	29	11	1.14
41	—	—	—	—	—	—	—	—	—
42	—	—	—	—	—	—	—	—	—
43	44.6	55.2	0.89	31.2	14	14	21	17	0.67
44	30.9	17.3	1.09	56.8	23	62	47	1	0.49
45	17.9	20.0	—	75.7	51	24	62	1	0.82

Comparing the reproductive level of mature males and females, relation between average body length of fetuses and the average testis weight of mature males shows negative correlation (Fig 39). Then it can be said that those adult schools hold big number of females in early gestation and relatively large number of well matured males. Investigating the relation between the age of sucklings and the level of testis development (in weight), average testis weight is getting heavier when sucklings reached 1.5 years, the age is just at the beginning of weaning in average (Fig. 40). Meaning of this relation is that those schools where there are many calves at the end of sucking hold many well matured males. The relation between the average body length of fetuses and the average age of sucklings (Fig. 41) indi-

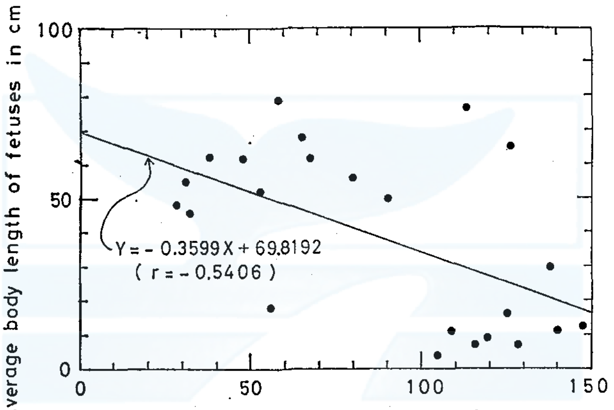

Fig. 39. Relation between the average body length of fetuses of striped dolphins and the average weight of the left testis of mature males in each school.

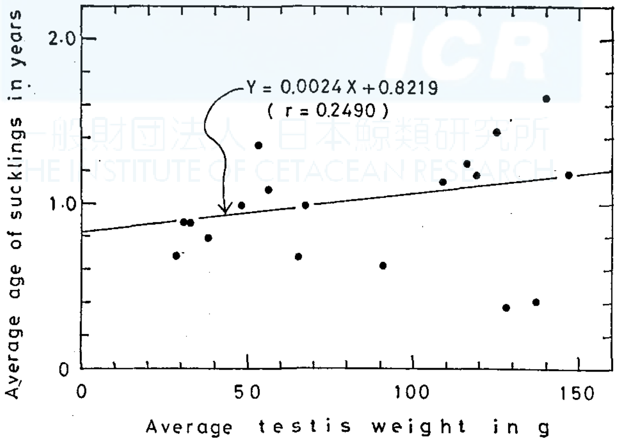

Fig. 40. Relation between the average age of the sucklings of striped dolphins and the average weight of the left testis of mature males in each school.

cate negative correlation. This relation shows that those schools hold many females in early gestation as well as large number of females in later lactation. Comparing the ratio of the number of socially mature male with that of mating females and the average testis weight of mature males (Fig. 42), the result is positive correlation. This means that those schools having lots of mature males with heavier testis have higher rate of socially mature males against mating females. The results might tell that well matured males get out from the school, in which many non-mating females are staying, and are drawn to the school where many mating females are in.

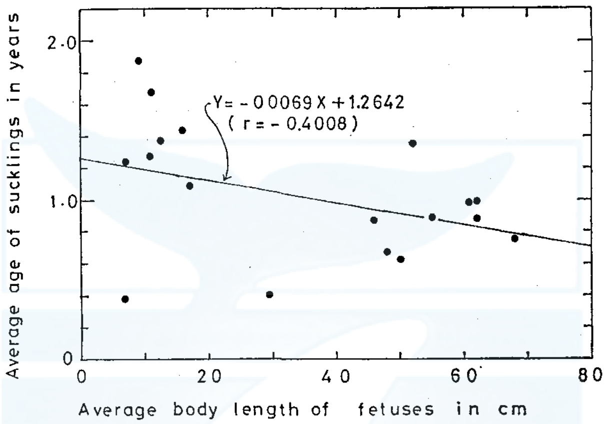

Fig. 41. Relation between the average age of the sucklings of striped dolphins and the average body length of fetuses in each school.

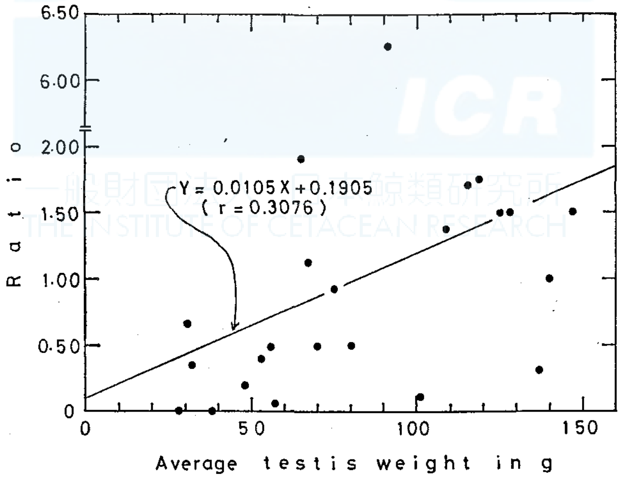

Fig. 42. Relation between the ratio of socially mature males to the mating females and the average testis weight of the lef testis of mature males in each school.

DISCUSSION AND SUMMARY

It is known that the schools or individuals of different species of dolphins sometimes swim together not only in captive but also in wild. However, in cases of *S. coeruleoalba*, it has never been observed in wild that animals of the species swam in any connection with those of other species. In the case that schools of *S. coeruleoalba* and *S. attenuata* were chased together into Futo harbor and kept in captive for three days from November 16 to 18, 1973, individuals of each species swam separately without mixing each other. This reveals that animals of *S. coeruleoalba* may not mix with those of other species as their characteristic behavior.

From observation on board and the analysis of school size, it is known that a large school of *S. coeruleoalba* holds several small schools of about 30 to 300 individuals in it. Such small schools hold the basic units of a mature female with a calf, of the mature male and female, and of young animals. Those observation prove a characteristic behavior of the striped dolphin in making schools.

Kasuya *et al.* (1974) studied on the schools of *S. attenuata* caught on the coast of Izu Peninsula and reported size frequency of the schools, in which 85% of the total catch of animals are from the smaller schools of less than 500 individuals and 4.5% were from bigger schools of more than 1,000 individuals. This school size frequency fits well to that of *S. coeruleoalba* of the present study. Comparing the size frequencies of the southbound and the northbound schools, it can be said that the species of animals are going up north in smaller schools and then coming down south in larger schools. But in the main fishing season of the coast, in southbound schools from November to January and northbound schools from April to May, large schools of more than 1,000 animals are seen in south or north bound schools. In the year when the Kuroshio is closely located to the fishing area, number of adult schools is larger, and in the other year when the Kuroshio is distant, that of juvenile schools is larger and school size in the latter year is remarkably large. But the adult school size is similar in both years. Accordingly the school size change of *S. coeruleoalba* may have been caused by the changes of school structure, of migration route, and of oceanographic condition. According to Saayman and Tayler (1973), the schools of *Tursiops aduncus* expands and shrinks during a day. As the result of this study, larger schools more than 1,000 animals may come close to or be formed at Oshima Island in early morning. It can be said that school size of striped dolphins may change largely by gathering and dispersing movement during a day, but further study is needed to explain this size change more exactly.

By the frequency of maturity rate of both sexes, the schools can be classified into three types, (1) the juvenile school which mainly composed of immature animals of after weaning and puberal ones, (2) the adult school which is of mature animals and sucklings, and (3) the mixed school of immature, puberal and mature animals together. As mentioned before, the mixed schools' composition is just middle of the juvenile and adult schools, and mostly caught in the year when the Kuroshio is closer. That is, abundant schools come to the area and tend to mix themselves, the mixed school seems to be formed naturally or during the driving schools are forced to be mixed.

Juvenile schools of *S. coeruleoalba* are often observed as schools of exclusively immature animals, but schools of only puberal animals is not found. Nevertheless, the group of puberal animals seems to exist in a school together with groups of immature or mature animals of the school. The analysis of school composition of *S. attenuata* on the Pacific coast of Japan (Kasuya *et al.* 1974) suggests that the species have the immature school similar to the juvenile school of *S. coeruleoalba.* Perrin *et al.* (1976) described that juveniles probably do not school separately in the eastern Pacific population of *S. attenuata.* This is only a presumption, but difference in school structure between the findings by Perrin and this study on *S. coeruleoalba* might have occurred in a different fishing method or in the divergency of the stages of dolphins examined in the studies.

Both the adult and the mixed schools can be divided into two categories, namely mating and non-mating schools. Mating schools are of animals ready to mate and non-mating schools are of animals not yet ready for mating. And in the adult schools, number of socially matured males (ready to court) seems to move between those mating and non-mating schools. In the mating school of *S. coeruleoalba,* slightly excess number of socially matured males over mating females suggests that this species has efficient mating system. They may have no such intense fighting among males as seen among the bulls of *physeter catodon,* and all socially matured males may take part in the mating.

There are variety of modes of fetuses and newborn calves seen in Fig. 21. It can be presumed from this figure that individuals of this species do not stay in a certain school, they may have mobility, if they were stable, there would be more periodical modes of fetuses and newborn calves.

As a conclusion of this study, dolphin's movements between schools are as follows. Male calves in the adult schools stay for about a year after weaning and then they move into the juvenile school when they grown up to 2.5 years in average. Female calves also stay in the adult school for about a year and a half after weaning and move into the juvenile school at 3.0 years in average. That is, young males leave the adult school a little earlier than young females. Similar behavior is seen in the animals of *S. attenuata* (Kasuya *et al.* 1974). However, some immature individuals remain in the adult school after weaning. Females in the juvenile school rejoin into the adult school about three years before they reach puberty and there they are growing up to mature females, then, most of them move first into the non-mating school but some of them directly into the mating school. And the females in the non-mating attain sexual maturity after three years, then they move again into the mating school. Immature males grow up to mature through puberal stage in the juvenile school. Puberal males in the juvenile school seem to form a group among themselves within the school and will stay for about a year and a half after they attained sexual maturity, then they move into the adult school. When animals of both sexes move into the adult school, they chose mating or non-mating schools by some instinct and will attain social maturity there. The males who attained social maturity in the non-mating school seem to move again into the mating school. When mature females become ready to mate, they leave the non-mating school and form a small mating school with socially matured males. And several such mating school seem to gather together to a large mating school. After most of females in the mating school fertilized, socially mature males and some mature females seem to leave the school. Then the mating school naturally turned out to the non-mating school, in which fertilized females before or after parturition and some socially mature males remain. Those movements of dolphins in and out of schools are shown in Fig. 43. As shown in Fig. 43, all animals of *S. coeruleoalba* do not fix themselves in a certain school, but they move in and out of schools instinctively in accordance with their growth and sexual conditions.

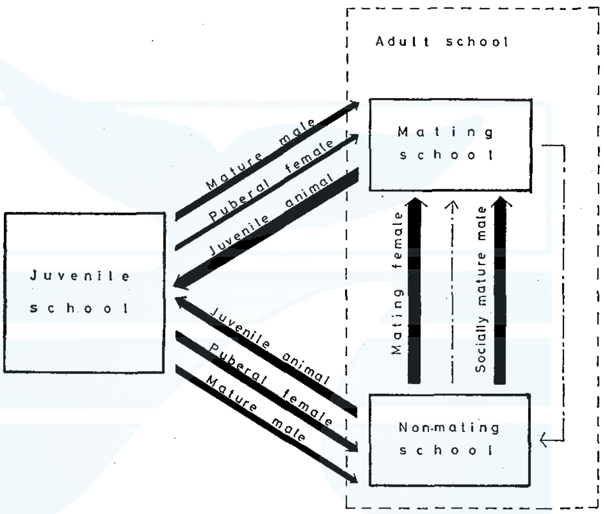

Fig. 43. Schematic figure showing the exchange of dolphins between schools. Thickness of line indicates relative amount of dolphins, arrows direction of movement of the dolphins, and chain line shift of school composition.

ACKNOWLEDGMENTS

This study would not have been possible without the kind help of the fishermen's cooperative unions at Kawana, Futo and Taiji. We are indebted to Dr. T. Tobayama of Kamogawa Sea World and Dr K. Hirose of Tokai Regional Fisheries Research Laboratory for providing the data, and Mr N. Oguro of the Oyster Research Institute for collecting the samples. Our greatest thanks are due to Dr T. Kasuya, who gave us kind help in collecting the samples and useful criticism. We also thank Drs T. Kajihara and K. Numachi of the Ocean Research Institute of Tokyo University for their valuable advices.

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WHALE OBSERVATION AND WHALE MARKING OFF THE COAST OF CHILE IN 1964

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ABSTRACT

The voyage of the whalecatcher *Indus XIV* to observe and mark whales off the coast of Chile between 28° and 37°S in November-December 1964 repeated the track of a similar voyage in October-November 1958, and a major object was to compare the abundance of exploited whale species after six years.

Four blue whales sighted in 1964 prompts a discussion on *Balaenoptera musculus intermedia* and *B. m. brevicauda* off Chile.

The abundance of fin whales had drastically reduced from 5.1 per 100 miles sailed in 1958 to 0.1 in 1964. This is attributed to Antarctic whaling and also, in 1964–66, to intensive fin whaling off Chile, and it is recommended that the Permanent Commission of the South Pacific prohibit the taking of fin whales off Chile and Peru until the stock shall have recovered.

One sei whale was sighted in 1964, and the sei whales and Bryde's whales off Chile are discussed.

In November-December 1964 there were sighted 11.9 sperm whales per 100 miles sailed compared with 1.7 in October-November 1958. This is attributed to a seasonal influx into the area of the breeding stock moving southwards. Thus it is not suggested that the sperm whale stock had increased between 1958 and 1964, but there was no evidence of a decline.

Results on the distribution in 1958 and 1964 of the different classes of sperm whale schools, in relation to surface temperature, do not support the proposal of an orderly segregation across the Humboldt Current from cold to warmer water of solitary males, bachelor schools and female schools. The results lead to a review of sperm whale distribution and surface temperature in other seas, and it is concluded that in the southern hemisphere the temperatures at the subtropical convergence are in general those at the limits of

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female distribution.

The large Humboldt Current squid, *Dosidicus gigas*, is important in the diet of sperm whales of the Southeast Pacific, and an unsuccessful attempt was made to correlate the distribution and abundance of sperm whales with those of *Dosidicus gigas*, as revealed by squid fishing during night stations worked in 1964.

The distribution and abundance of blackfish, tentatively identified as *Globicephala melaena edwardi*, were very similar in 1958 and 1964, the abundance being 11.0 per 100 miles sailed in 1964 and 13.2 in 1958. These results were to be expected from an unexploited species. It is recommended that the blackfish off Chile be exploited by a controlled fishery.

There is a critical review of sightings in Chilean seas of whales recorded as *Hyperoodon planifrons*. An unidentified toothed whale sighted in 1964 is described, and also dolphins, believed to be *Tursiops* sp., and porpoises, *Phocoena* sp., which lead to a review of the species of *Phocoena* and *Cephalorhynchus* described from the Southeast Pacific.

One fin whale and 53 sperm whales were marked in 1964. Two of these sperm whales have since been recovered, one showing a local displacement of the stock, and the other, recovered from Antarctic Area I, giving direct evidence of the migration into the Antarctic of male sperm whales from the breeding stock of low latitudes.

There are discussed two recoveries from other whale marking voyages off Chile since 1958. A recovery of a Soviet mark is evidence that the same fin whales are moving off the coast of Chile from year to year, and a sei whale marked off southern Chile and recovered in Antarctic Area II after 9 years shows that sei whales have a migration route between Chile and the Antarctic similar to the route established for fin whales by whale marking in 1958.

Because of this direct evidence that the same fin whales, sei whales and male sperm whales are being exploited in the Southeast Pacific and in the Antarctic, there is urgent need for close cooperation between the Permanent Commission of the Southeast Pacific and the International Whaling Commission.

There are described the results of fishing for fish and squid during 18 brief oceanographical stations when the ship was stopped at night. The squids were all *Dosidicus gigas* and there are notes on feeding and length at sexual maturity in this species.

INTRODUCTION

Expeditions to observe and mark whales began in South America with voyages off the coast of Chile in 1958 and from the coast of Ecuador towards and beyond the Galápagos Islands in 1959. Observations of whales on these voyages, which were undertaken at the same time of the year (October-November), gave valuable results on the distribution and relative abundance of the various species in the areas surveyed, and off Chile they demonstrated a ground for fin whaling on the oceanic edge of the Humboldt Current which had not previously been exploited: the marking of fin whales off Chile, by subsequent recoveries of marks in Area II of the Antarctic, established that the fin whales hunted from the coast of Chile in spring are a migrant stock also exploited by pelagic whaling in the Antarctic in summer (R. Clarke, 1962; translation in Spanish, 1963). A further expedition was conducted off the coast of Chile in 1964 and is the subject of this report. Since 1964 there have been additional cruises off Chile (Aguayo, 1966; Aguayo and Maturana, 1966, *unpublished reports*), and some whale marking has been conducted in Peruvian seas (Mejia, 1964; Mejia and Poma, 1966).

We here present the results of the expedition off the coast of Chile in 1964. The objects were to resume the marking of whales, and, by repeating the tracks of the voyage of 1958 at the same time of the year, to learn something of the effects of whaling by comparing the quantities of whales sighted and their distribution after a lapse of six years. The voyage in 1958 was conducted in the whalecatcher *Indus X* between 28° and 36°S from 21 October to 6 November (Fig. 2). In the event, the voyage of 1964, conducted in the whalecatcher *Indus XIV*, faithfully repeated the tracks of *Indus X*, with a small extension added to the south (Fig. 1), but took place a month later in the year, from 24 November to 17 December. This was because of delays which could not be avoided. Whales in their seasonal rhythms are moving all the time, more or less, so that this difference of a month had to be taken into account in our comparisons, although it does not invalidate our major conclusion that the sperm whale stock in the area surveyed off Chile in 1964 showed no depletion after six years, whereas the fin whale stock had been heavily depleted.

Although the principal results of the voyage of 1964 were submitted by the first author to the government and the whaling industry of Chile in an interim report dated 5 January 1965, we have only now been able to complete the present report for publication in detail. Besides the main account on whales, we discuss as relevant the fishing for squid which was a part of the brief oceanographical stations worked at night whilst the ship lay drifting. Fifty three sperm whales and one fin whale were marked during this expedition.

THE VOYAGE

The expedition of 1964 was conducted between 24 November and 17 December in the chartered whalecatcher *Indus XIV* (Captain José Porra) as two cruises which repeated the tracks of the expedition of 1958 (Fig. 2), with a small extension to the south made possible by the time at our disposal (Fig. 1). Our track lay in the upwelling region across the breadth of the Humboldt Current; throughout the voyage the water temperature at the surface was taken every two hours, with usually an additional observation of temperature whenever whales were sighted. Once or twice we had good reason to continue sailing after dark, but otherwise it was our practice to stop engines at dusk and lie each night, so as to avoid missing whales in the hours of darkness. Thus, as on the expedition of 1958, we were able each night to make regular observations and collections in the current, including fishing for fish and squid.

On the first cruise we sailed from Valparaíso on 24 November to explore the northern part of the area. In the following days, as we continued in the track of the expedition of 1958, first WSW across the body of the current, then northerly, and then east again to close the coast, there were two sightings of solitary whales (believed by Captain Parra to be bottlenosed whales), plenty of blackfish, and on two occasions schools of a small whale which was of great interest since it could not be identified, and which is discussed at length on p. 150. However, no great whales were seen until the morning of 28 November, when, steaming northwards and parallel to the coast some ten miles distant, we sighted near Punta Lengua de Vaca the only sei whale we were to encounter on this expedition. Later the same day we came upon the first sperm whales; we marked nine out of a group of 16 when 11 miles west of Isla Choros which is one of the chain of islands strung along the coast, between 29°00′S and 29°35′S, northward of Coquimbo. As we steamed north past the islands the following day, 33 sperm whales were seen and three were marked. At 1300 we were at the latitude of Huasco, being the furthest north explored during the expedition of 1958. We decided to search further north during the remainder of this day, but had sighted only two more sperm whales when darkness fell; we turned south again, sailing through the night to pick up next morning, 30 November, the track of 1958 in daylight. Sailing southwards towards Coquimbo we again approached the chain of islands and came upon 30 sperm whales off Isla Chañaral, the most northerly of the chain: fifteen of these whales were marked. That same afternoon, when three miles west of Isla Pájaros, we marked six from a group of schools amounting to 26 sperm whales. We had not long resumed our course when we sighted a magnificent concentration of sperm whales, comprising 90–110 whales within an area five miles long by three miles wide. There were harem schools, nursery schools, and schools which could not be classified, being either mixed schools of immature males and females, or bachelor schools. The various schools split and regrouped a good deal, and at one time nearly all the whales in the area had joined in five schools of 30, 28, 20, 8 and 8 whales. Many of the whales were less than 36 ft (11.0 m) long, which we consider the minimum length at which a whale can be marked with certainty that it will not be harmed by the mark (see p. 155). Nonetheless, we managed to mark 19 of the bigger whales before the light began to fail and we resumed our course for Coquimbo, where we were expected for water and provisions that evening. Next day, sailing from Coquimbo again in the track of the expedition of 1958, we observed several large schools of blackfish, and a few dolphins, but no great whales. On the afternoon of 2 December, reaching our furthest west on this leg during the expedition of 1958, we used the remaining hours of daylight to explore further west as far as 75°W, where we turned back, having seen no cetaceans all day, and steamed ESE through the night to pick up the track of 1958 next day. Again no cetaceans were seen as we sailed diagonally across the current to complete the first cruise in Valparaiso on the afternoon of 4 December. Conditions of wind and sea for sighting whales had been good throughout the cruise.

After bunkering in Valparaíso we sailed towards midday of 7 December on the second cruise which explored the southern part of the area. Following the line of the coast as far as Constitución, according to the trace of 1958, we first went close inshore there to look unsuccessfully for a seal rookery reputed to inhabit Piedra de la Iglesia, and afterwards made our departure from the coast. Sailing westward across the current we sighted and marked a solitary fin whale on 9 December, 97 miles west of Constitución ; this was the only fin whale we saw during the expedition. Later, on 9 December, we encountered two solitary sperm whales, one of which was marked, and a blue whale which was chased unsuccessfully. At 0700 on 10 December, at the position corresponding to Station I_{10} in Fig. 2, we left the track of 1958 to begin the short extension which time allowed us. As we changed course a pair of blue whales were sighted, and afterwards a solitary blue whale, but these whales were chased unsuccessfully. The new course took us WSW as far as 36°S, 76°W, and then ESE across the current to Talcahuano, where we arrived on the afternoon of 11 December, having seen only the blow of a whalebone whale afar, and some porpoises. At Talcahuano we took water and provisions, and sailed on 12 December NW×W towards the position of Station I_{10} (35°20′S, 75°23′W) so as to resume the track of 1958. This position was reached at 0820 on 13 December ; shortly afterwards the weather deteriorated, and the ship was hove-to in heavy seas and a strong wind, until the morning of 14 December when conditions improved and we resumed our course. Again on 15 December conditions for sighting whales were poor, and we hove-to for some hours, not wishing to leave this area, where we might hope to find baleen whales, until conditions had improved. Course was resumed in the afternoon, and so we continued in good weather for the rest of the voyage towards Valparaíso, where we arrived to complete the expedition in the early hours of 17 December, having called at the whaling station of Quintay for a few hours on 16 December. During the four days since leaving Talcahuano we had seen no great whales.

WHALE OBSERVATION

Figure 1 shows the positions and numbers of the kinds of whales sighted in 1964. For comparison, the corresponding chart for the expedition of 1958 is reproduced from R. Clarke (1962, Fig. 2) as Fig. 2. Details of schools (Table 6 in the present paper and Table 3 in R. Clarke (1962)) are not necessarily shown in the charts which give only the aggregate numbers of whales observed around a particular geographical position, called a ' sighting ': this is an encounter with whales which may refer to any number of animals, from one to a large concentration comprising numerous schools and perhaps single whales also. There are indicated on the charts those parts of the track where now and then a vessel sailed for a period in darkness, or where, because of bad visibility or heavy weather, the conditions for sighting whales were poor (see R. Clarke and Ruud, 1954). Table 1 is an annotated record of all whales, dolphins and porpoises observed during the voyage of 1964.

The abundance of the various species of whales are expressed as the numbers of whales sighted per 100 miles of effective distance sailed for whale observation.

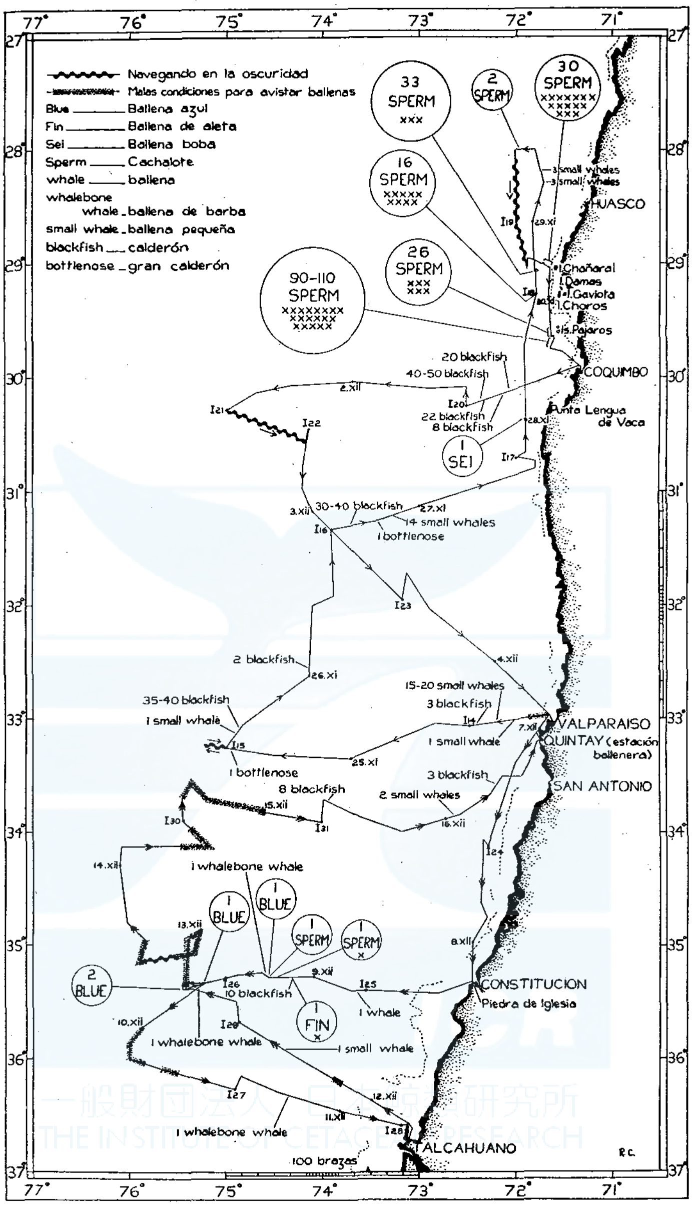

Fig. 1. The voyage of the whalecatcher *Indus XIV* off the coast of Chile between 24 November and 17 December 1964. The species and numbers of whales sighted and the numbers of whales marked are shown; a cross represents each whale marked. The dates are noon positions. Brief oceanographical stations, I_{14} to I_{31}, are also plotted.

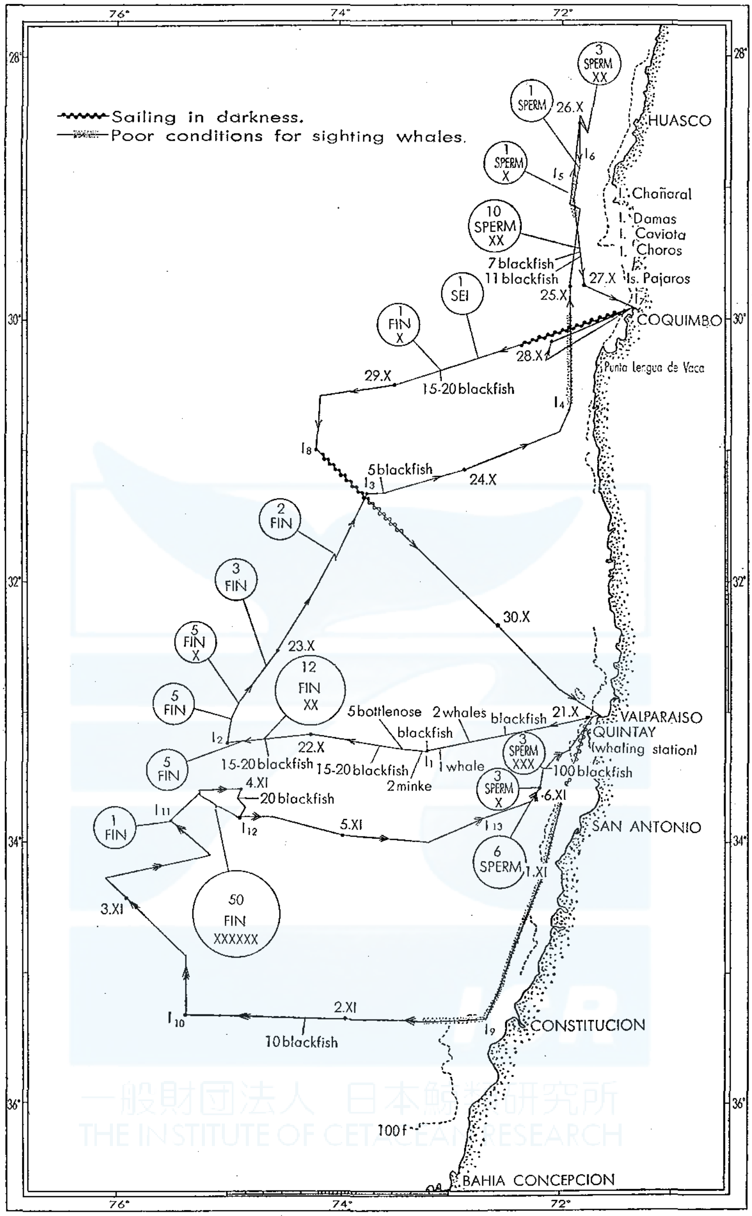

Fig. 2. The voyage of the whalecatcher *Indeus X* off the coast of Chile between 21 October and 6 November 1958. Reproduced with permission from *Norsk Hvalfangst-tidende,* 1962, p. 271.

TABLE 1. WHALES, DOLPHINS AND PORPOISES SIGHTED OFF THE COAST OF CHILE IN 1964

Species	Date and Time	Position	Surface temp. °C	Nos. of whales	Schooling	Direction	Remarks	
Blue whale								
Balaenoptera musculus	9. xii/1555	35°17′S, 74°33′W	17.0°	1	Solitary	SW	Length 21.5–23 m (70–75 ft).	
	10. xii/0705	35°23′S, 75°26′W	17.6°	2	(Separate)	SW	Both about 20 m (65 ft). They were separate at first. One was moving SW and was later joined by the other when chased.	
	— /0750	35°20′S, 75°13′W	17.6°	1	Solitary	S		
Fin whale								
Balaenoptera physalus	9. xii/1305	35°16′S, 74°18′W	17.5°	1	do.	SSW	Length 16.5–18 m (55–60 ft). Accompanied by 10 blackfish and 6–8 dolphins	
Sei whale								
Balaenoptera borealis	28. xi/0745	30°22′S, 71°55′W	14.5°	1	do.	S	Length about 13.5 m (45 ft)	
Unidentified large whalebone whales	9. xii/1610	35°14′S, 74°35′W	17.0°	1	do.		Blowing far off	
	10. xii/0840	35°23′S, 75°17′W	17.6°	1	do.		do.	
	11. xii/0824	36°19′S, 74°21′W	16.2°	1	do.		Blew infrequently far off. Possibly a sei whale	
Sperm whale								
Physeter macrocephalus	28. xi/1830	29°16′S, 71°47′W	15.0°	16	Two of 5	SW	Unclassified schools	Dispersed a mile or so from each other
					3 and 2	S	Batchelor schools	
					1 Solitary	S	Pl. I, Fig. 1.	
(*For further details see Table* 7)	29. xi/0705 /0815	29°03′S, 71°48′W to 29°05′S, 71°48′W	15.5°	33	4 and 6	SW	Harem schools (Pl. I, Fig. 2)	Dispersed over a wide area
					One of 9		Harem school	
					Pair		Batchelor pair	
					2 Solitary	SW	Small males	
					1 Solitary		Small male	
					3 pairs	SW	Unclassified	
					One of three		Unclassified	
	29. xi/1645	28°00′S, 71°58′W	18.2°	2	Pair	E	Unclassified	
	30. xi	29°00′S, 71°43′W to	14.8° to					

	0715–1020	29°02′S, 71°39′W	16.0°	30	11, 8, 3, 8		Unclassified	
	30. xi 1345–1555	29°35′S, 71°38′W to 29°38′S, 71°38′W		26	8, 8 and 5		Nursery schools	Dispersed over a wide area
					2		Cow and calf (Pl. II. Fig. 1)	
					2 solitary		Small males	
					1 solitary		Large bull	
	30. xi 1610–1915	29°40′S, 71°86′W to 29°45′S, 71°39′W	18.1° to 18.7°	90–110	30, 28, 20 8 and 8		This concentration, of which 94 were schooling as shown at a certain moment, included harem schools, nursery schools and unclassified schools dispersed over a wide area. There were also a few young solitary males, although these eventually joined the schools.	
	9. xii/1500	35°17′S, 74°29′W	17.1°	1	Solitary	E	Large bull	
	/1550	35°17′S, 74°33′W	17.0°	1	Solitary		Large bull	
Unidentified large whales	9. xi/0648	35°23′S, 73°38′W	—	1	Solitary		Blowing far off	
Blackfish								
Globicephala melaena edwardi	24. xi/1930	33°03′S, 72°24′W	16.2°	3	Schooling			
	26. xi/0725	33°05′S, 74°52′W	16.6°	35–40	do.	W	Chased for observation (Pl. II. Fig. 2). Colour notes (see text).	
	— /1255	32°32′S, 74°08′W	17.2°	2	do.	E		
	27. xi/0712	31°18′S, 73°41′W	16.5°	30–40	do.		Accompanied by 8 dolphins.	
	1. xii/1725	30°07′S, 72°04′W	16.8°	20	do.	S	Colour notes (see text)	
	— /1750	30°08′S, 72°08′W	16.9°	8	do.			
	— /1855	30°12′S, 72°20′W	17.2°	22	12, 6, 4	S		
	— /1905	30°12′S, 72°22′W	17.2°	40–50	Schooling		School comprised whales of 3.7–4.6 m. (12–15 ft) with calves of about 2 m. (6 ft). Colour notes (see text).	
	9. xii/1305	35°16′S, 74°18′W	17.5°	10	do.	SSW	School comprised whales of 3.7–4.9 m. (12–16 ft), but with one (a male) of about 7.5 m (25 ft). Accompanied by a fin whale and 6–8 dolphins.	
	16. xii/0612	33°44′S, 73°57′W	16.4°	8	do.	S		
	— /1535	33°35′S, 72°11′W	17.2°	3	do.	NE		

Continued . . .

TABLE 1. Continued.

Species	Date and Time	Position	Surface temp. °C	Nos. of whales	Schooling	Direction	Remarks
Bottlenosed whales?	25. xi/1750	33°66′S, 74°57′W	16.3°	1	Solitary		See text.
	27. xi/0808	31°16′S, 73°26′W	16.5°	1	do.		
Unidentified small whales	24. xi/1650	33°00′S, 72°02′W	15.9°	1	Solitary		Only the flukes were seen.
	— /1755	33°02′S, 72°11′W	16.0°	15–20	Schooling	NW	Chased for observation. Length about 6.0 m. (20 ft). Notes on form and colour. See text and Pl. III. Fig. 1.
	26. xi/0705	33°08′S, 74°54′W	16.6°	1	Solitary		
	27. xi/0712	31°13′S, 73°16′W	16.7°	14	Schooling		Chased for observation. Length 4.5–6.0 m. (15–20 f). Notes on form and colour. The same species seen 1755/24. xi. See text.
	29. xi/1402	28°18′S, 71°43′W	18.2°	3	Schooling		Length about 9 m. (30 ft).
	— /1440	28°11′S, 71°41′W	18.4°	3	Schooling		
	12. xii/1738	35°55′S, 74°24′W	16.6°	1	Solitary		
	16. xii/1240	33°51′S, 72°36′W		2	Pair		
Dolphins *Tursiops* sp.	25. xi/1850	34°04′S, 75°04′W	16.2°	8–10	Schooling		Length about 2.4 m. (8 ft). Colour notes. (see text)
	27. xi/0712	31°18′S, 73°41′W	16.5°	8	do.		As those on 25. xi/1850. Notes on form and colour (Pl. III. Fig. 2). Accompanying 30–40 blackfish.
	1. xii/1830	30°11′S, 72°16′W	16.9°	6	do.	SW	Length 1.5–1.8 m. (5–6 ft). As those on 25. xi/1850.
	9. xii/1305	35°16′S, 74°18′W	17.5°	6–8	do.	SSW	Length about 2.4 m (8 ft). As those on 25. xi/1850. Accompanying a fin whale and 10 blackfish.
Porpoises *Phocoena* sp.	8. xii/1940	35°24′S, 73°32′W	17.6°	15–20	do.		Length 0.9–1.5 m. (3–5 ft). Mostly 1.2 m. (4 ft). Notes on form and colour. See text.
	9. xii/0930	35°20′S, 73°47′W	17.2°	50–60	do.	NW	As those on 8. xii/1940.
	11. xii/1005	36°22′S, 74°13′W	16.2°	20	do.	S	As those on 8. xii/1940.
	— /1010	36°22′S, 74°12′W	16.2°	6	do.		As those on 8. xii/1940.
	16. xii/1020	33°59′S, 73°07′W	16.2°	20	do.	NW	As those on 8. xii/1940.

TABLE 2. EFFECTIVE DISTANCES SAILED FOR WHALE OBSERVATION OFF THE COAST OF CHILE IN 1964 AND 1958

Miles	1964 Complete expedition	1964 In the track of 1958	1958 (R. Clarke, 1962, p. 273)
Total distance sailed, *less*	2,516	2,122	1,820
Distance sailed in darkness	162	162	99
Distance sailed in poor conditions for sighting whales	205	164	140
Approaches of ports	56	40	16
Effective distance sailed for whale observation	2,093	1,756	1,565

This 'effective distance' represents the total distance sailed less the distances sailed in darkness, in poor conditions for sighting whales, and in the approaches to ports (Table 2).

Table 3 presents the numbers of whales observed per 100 nautical miles of effective distance sailed in three sets of results: those from the complete expedition of 1964; those from this expedition less the extension to the southward, that is, following only the track of 1958; and those from the expedition of 1958 itself (R. Clarke, 1962, Table 1). In the event the extension to the south produced little of interest, apart from the blue whales seen, and for the purposes of comparing the abundance of whales we are mainly concerned with the second and third sets of results, those from the expeditions of 1964 and 1958 conducted over the same track.

Results from the two voyages may be compared because on each the sighting effort was just about the same. The ships were of similar size (*Indus X*, 292 tons; *Indus XIV*, 315 tons), and the vigilance of observation was similar, for in each ship there were at all times during daylight hours a lookout in the masthead barrel, and a whaling officer (usually the captain) and at least one scientist on the bridge. There is evidence in the results themselves that they do give a fair indication of the relative abundance of the various whale species and that comparison of the results in 1958 and 1964 is significant. Thus, the stock of blackfish off the coast of Chile is not at present exploited and therefore we may expect that in the same area in the same season the population will remain unchanged from year to year. The results show this for the same track sailed in 1958 and 1964, whether the abundance is expressed as numbers observed per 100 nautical miles of effective distance sailed (Table 3), or, since blackfish are gregarious like sperm whales, as sightings per 100 nautical miles sailed, and numbers of whales per sighting (Table 4, from Figs. 1 and 2). This is further discussed on p. 148. It may be objected that, whereas dolphins and porpoises also are not exploited, Table 3 gives quite different results for the numbers of dolphins and porpoises observed per 100 nautical miles sailed in 1958 and 1964; but here it is not expected that the results are a good indication of abundance, because the blows of these small cetaceans cannot be seen at any distance, and recording them seems to be fortuitous to some extent, depending on whether they are breaching at the time, or whether they interest themselves in approaching the vessel, or happen to be directly in its path.

TABLE 3. COMPARISON OF THE ABUNDANCE OF WHALES OBSERVED DURING TWO EXPEDITIONS OFF THE COAST OF CHILE IN 1964 AND 1958

Groups or species of whales		1964 Complete expedition			1964 Following the track of 1958			1958 (Clarke, 1962, Table 1)		
		Nos observed	Average nos.	Nos per 100 miles sailed	Nos observed	Average nos.	Nos per 100 miles sailed	Nos observed	Average nos.	Nos per 100 miles sailed
Larger Whales	All whales:	209–229	219	10.5	204–224	214	12.2	115	115	7.4
	Whalebone whales	9	9	0.4	4	4	0.2	85	85	5.4
	Blue	4	4	0.2	1	1	0.1	—	—	—
	Fin	1	1	>0.1	1	1	0.1	84	84	5.4
	Sei	1	1	>0.1	1	1	0.1	1	1	0.1
	Unidentified	3	3	0.1	1	1	0.1	—	—	—
	Sperm whales	199–219	209	10.0	199–219	209	11.9	27	27	1.7
	Unidentified large whales	1	1	>0.1	1	1	0.1	3	3	0.2
Smaller whales, dolphins and porpoises	Minke whales	—	—	—	—	—	—	2	2	0.1
	Blackfish	181–206	194	9.3	181–206	194	11.0	198–213	206	13.2
	Bottlenosed whales	2*	2*	0.1*	2*	2*	0.1*	5	5	0.3
	Unidentified small whales	40–45	43	2.1	39–44	42	2.4	—	—	—
	Dolphins	28–32	30	1.4	28–32	30	1.7	239–249	244	15.6
	Porpoises	111–126	119	5.7	85–100	93	5.3	—	—	—

* Identification as bottlenosed whales uncertain (see p. 149).

When discussing the results, it is at times helpful to refer to Table 5, showing the catches of whales from the coast of Chile in recent years (1955–1975). The table is used only in a general way, as it would be misleading to extract much from it on the comparative abundance of the different species: the catches are aggregate figures from three whaling stations (at Iquique, Quintay and Talcahuano; see R. Clarke, 1962, Fig. 1) which in different years have pursued varying policies involving varying catching effort in regard to the selective hunting of sperm whales and whalebone whales; for example, between 1964 and 1967 whaling from Quintay was conducted by a Japanese concession which concentrated solely on hunting whalebone whales for meat production, which explains the increase in captures from Chile of blue, fin and sei whales in those years and the reduction in the sperm whale catch (see also Aguayo, 1974).

TABLE 4. SIGHTINGS OF FIN WHALES, SPERM WHALES AND BLACKFISH OFF THE COAST OF CHILE IN 1964 AND 1958

		1964 complete expedition	1964 In the track of 1958	1958 (R. Clarke, 1962, Fig. 2)
Fin whales	Number of sightings	1	1	9
	Sightings per 100 miles sailed	0.05	0.06	0.51
	No. of whales per sighting	1	1	9.3
Sperm whales	Number of sightings	8	8	7
	Sightings per 100 miles sailed	0.38	0.46	0.45
	No. of whales per sighting	26.1	26.1	3.8
Blackfish	Number of sightings	11	11	11
	Sightings per 100 miles sailed	0.53	0.63	0.70
	No. of whales per sighting	17.6	17.6	18.7

General results

During the complete expedition of 1964 there were observed 209–224 great whales, comprising four blue whales, one fin whale, one sei whale, three whalebone whales too far away to be identified, 199–219 sperm whales, and one large whale seen afar which could have been a sperm whale or a whalebone whale. Only three blue whales and two of the unidentified whalebone whales were seen on the southerly extension of the course (Fig. 1), so that, comparing results from the same track in 1958 and 1964, large whales (all species of commercial interest) appeared to be nearly twice as abundant in 1964 (Table 3). This was because of the numbers of sperm whales seen, for a feature of the results is the great reduction in the abundance of fin whales between 1958 and 1964.

Blue whales (Balaenoptera musculus)

It is noteworthy that, whereas no blue whales were sighted in 1958, four of the species were sighted in 1964. They were far from land, towards the oceanic border of the Humboldt Current, one in the most southern part of the track of 1958 and the other three where the extension to the south had just begun (Fig. 1).

Perhaps we were not far enough south at this time of the year for blue whales in 1958, because, since modern whaling began in Chile in 1908, the south of the country, between 37° and 40°S, has been noted for blue whales (Risting, 1922, p. 558 ; Cabrera and Yepes, 1940, p. 313), whilst in recent years Aguayo (1974) has observed some farther south, between 43° and 46°S, in 1966.

The blue whales seen in 1964 were travelling southwest or south (Table 1), and might be thought, at this time of the year, to have been migrants of the main stock of southern blue whales, travelling to their summer feeding grounds in the Antarctic. But this may not be so. Dr. Tadayoshi Ichihara has suggested, from the length composition of the blue whale catch and the shape of the baleen plate, that blue whales from Chile may be pigmy blue whales (Nasu, 1966, p. 159). This sub-species of blue whale, *Balaenoptera musculus brevicauda*, has been identified and described by Ichihara (1961, 1963, 1966) from the South Indian Ocean, where in summer it is distributed between 0° and 80°E, but does not extend into the Antarctic further than 54°S, although in winter it has since been reported by Dr. R. G. Chittleborough from the west coast of Australia (Ichihara, 1966, p. 82) and by Gambell (1964) from the east coast of South Africa. The main stock of southern blue whales, whose migration extends to the ice edge in summer, is now distinguished, according to Rice and Scheffer (1968), as the sub-species *Balaenoptera musculus intermedia*. This ' main ' stock has in fact been so decimated by Antarctic whaling that it was estimated to comprise, in all oceans south of the equator, less

TABLE 5. WHALES CAUGHT FROM THE COAST OF CHILE, 1955–1975. FROM INTERNATIONAL WHALING STATISTICS (1968–1976)

Year	Blue	Fin	Humpback	Sei	Sperm	Right	Total
1955	150	359	5	32	746	6	1,298
1956	209	202	3	48	1,171	—	1,633
1957	100	69	5	39	2,299	—	2,512
1958	166	73	—	16	2,062	—	2,317
1959	80	70	3	17	2,062	1	2,233
1960	131	52	2	13	1,886	—	2,084
1961	142	16	3	13	2,160	—	2,334
1962	11	34	4	9	2,280	—	2,338
1963	31	11	1	6	1,494	—	1,543
1964	112	136	—	47	1,213	—	1,508
1965	371	265	6	439	267	—	1,348
1966	128	84	7	210	669	1	1,099
1967	65	7	—	139	533	—	744
1968	—	25	1	83	319	—	428
1969	—	—	1	31	221	—	253
1970	1	3	—	17	270	—	291
1971	1	3	—	1	246	2*	253
1972	—	—	—	15	337	—	352
1973	—	—	—	14	232	—	246
1974	—	2	—	32	130	—	164
1975	—	—	—	58	48	—	106

* ' Other whales ', not necessarily right whales.

than 1,000* animals, during 1962/63, the last season for exploiting the main stock in the Antarctic before it was completely protected by the International Whaling Commission (*Rep. int. Whal. Commn*, 1967, p. 40). Nonetheless substantial catches making a total of 676 blue whales were caught in Chile during the Japanese concession for whalemeat between 1964 and 1967 (Table 5). In view of the low estimate reported for the whole southern 'main' stock in 1962/63, such catches from just one coastline, the coast of Chile, in the years after 1963 would scarcely be explicable if all these whales were from what was left of the main stock. This evidence alone suggests that there must exist in the Southeast Pacific a subspecies of the blue whale which does not migrate into the Antarctic and is similar to, or identical with, the pigmy blue whale *B. m. brevicauda*. Its presence has now been confirmed by Aguayo (1974) who identified ten specimens as pigmy blue whales among 168 blue whales examined in 1965/66 and 1966/67 at Quintay. It is indeed surprising, from the figures discussed here, that the proportion of pigmy blue whales was not greater in Aguayo's sample. Meanwhile it is now clear that both *B. m. intermedia* and *B. m. brevicauda* occur in the Southeast Pacific, but much needs to be discovered about their respective abundances, ranges and seasonal movements.

Fin whales (Balaenoptera physalus)

In 1964 only one fin whale was observed, on 9 December, some 96 miles due west of Constitución; it was travelling SSW and was presumably migrating towards the Antarctic (Table 1, Fig. 1). This is an abundance of 0.1 whales per 100 nautical miles sailed, whereas on the same track in 1958 there were sighted 84 fin whales or 5.1 per 100 nautical miles sailed (Table 3). If we look at abundance in another way, as the frequency of sighting fin whales, then in 1958 they were sighted on nine occasions, and there were 9.3 whales per sighting (Table 4).

Notwithstanding these results, it is seen in Table 5 that a large catch of fin whales was in fact made from Chile in 1964. The explanation is that most of these whales were taken by the Japanese concession which was whaling from Quintay for whalebone whales for meat production between 1964 and 1967. Thus, during the expedition of 1964 when *Indus XIV* sighted only one fin whale, there were at this time four Japanese whalecatchers sighting and catching fin whales in a part of the area covered by our expedition. But there was no comparison in the sighting effort. We were informed (by Captain Parra†) that on the Japanese catchers (which were fast modern vessels fitted with echo whalefinders) there were at all times at least twelve men looking out for whales, four at the masthead (two in the barrel and one in either rigging), four on the bridge and four on the poop, with a substantial prize awarded to the first man to sight a whale. It follows that every fin whale within the vicinity of such catchers must indeed have been sighted and captured. We therefore do not consider that the catches recorded in Table 5 contradict our results, which point to a very considerable reduction in

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* Gulland (1972), reviewing the earlier analyses, revised this estimate upwards to a catchable stock of about 4,000 in 1963, but his figure still seems sufficiently low to support the argument here following.

† One of us (A.A.L.) subsequently confirmed Captain Parra's information.

the fin whale population off this part of the coast of Chile between 1958 and 1964.

From recoveries in Antarctic Area II of marks fired into fin whales during the expedition of 1958, it has been established that fin whales off the coast of Chile in spring are migrating to summer feeding grounds in the Antarctic (Brown, 1960, 1961a, 1962a, 1962b ; R. Clarke, 1962). It follows that since these whales are a population in movement, and since the expedition of 1964 (24 November to 17 December) was conducted a month later than that of 1958 (21 October to 6 November), there is a little uncertainty about a strict comparison of the results. It might even be argued that in 1964 we were too late to sight more than one straggler from a fin whale population which had already moved southward out of the area ; but this would require an independent check, such as figures on the monthly catch per unit of effort from Quintay in earlier years, and these could show that fin whales in the past have been more abundant in the area later than October-November, rather than at this time, or earlier. It is important to recall that migrating whales move through an area, not as a simple block, but as a procession over a period of time, and, further, that in the Antarctic the fin whale population does not reach its peak until February. This being so, we believe that whatever may have been the effect of a difference of a month in the time of the two surveys, the expedition of 1964 showed such an impoverishment of fin whales as can only in the main be explained by overfishing of fin whales on the pelagic grounds of the Antarctic, which has brought about a severe decline in the southern fin whale population in recent years. The intensive hunting from Quintay by the Japanese concession for whalemeat would also have had its local effect, but this had only begun in 1964 and is not likely to have been more than a contributory factor at that time.

According to the Report to the International Whaling Commission of the Special Meeting on Antarctic Fin Whale Stock Assessment, held at Honolulu in March 1970 (*Rep. int. Whal. Commn*, 1971, p. 38), various estimates of the fin whale population in the southern hemisphere gave an average of about 172,000 in 1958 which had by 1964 declined to about 71,000, little more than a third of its size six years previously. Moreover, the fin whale populations which have been most severely depleted by pelagic whaling on the summer feeding grounds are those which resort to Antarctic Area II, which is the sector south of the Atlantic ; and whale marking has shown that some part, probably the major part, of the fin whales migrating off the coast of Chile do not stay in Area I, the Pacific sector due south of the route, but pass eastward through Drake Strait into Area II, where between 1960 and 1961 all the marks were recovered from four out of eleven fin whales marked off Chile in 1958 (see R. Clarke, 1962, Fig. 1 and p. 280).

Commenting on the results of whale marking, R. Clarke (1962, p. 283) observed ' . . . although the numbers of marked whales involved are too small to be conclusive, it is hard to avoid the impression that, since four whales within three years have been recaptured in the Antarctic from eleven marked off Chile, the exploitation in the Antarctic of fin whales from Chile may well be substantial '. The expedition of 1964 has shown the effect of this exploitation. Maintenance of a fin whaling industry on the coast of Chile depends on effective regulation of pelagic whaling in the Antarctic. In an effort to build up the depleted fin whale stocks, the International Whaling Commission set the Antarctic catch limit after 1967 at a figure rather less than the best estimate for the combined sustainable yield of the southern fin and sei whale stocks (see R. Clarke, 1968), and after 1972 at a figure less than the estimate for maximum sustainable yield of the fin and sei whale stocks separately; after 1974 separate catch quotas were provided for fin whales in the Antarctic Areas I–VI; in the 1975/76 season the prescribed fin whale catch was only allowed in Area I south of Chile, until in 1976 the Commission prohibited the taking of fin whales throughout the southern hemisphere by its member nations (*Int. Commn Whal.*, *Schedules*, 1972–1976). After the substantial catches at the time of the Japanese concession for whalemeat in 1964–1967 from the depleted fin whale stock migrating to the Antarctic off the west coast of South America, the catches in Chile have been few (Table 5) and they have diminished in Peru in recent years (*International Whaling Statistics*, *1976*), which is to be expected from the known condition of the stock. There is now urgent reason for the Permanent Commission of the South Pacific to follow the example of the International Whaling Commission and prohibit the taking of fin whales from Chile and Peru until the stock shall have recovered. As R. Clarke pointed out in 1962, rational exploitation of the stocks of whales in the Southeast Pacific cannot be achieved unless there is close cooperation between the Permanent Commission and the International Whaling Commission (see also p. 159).

Sei whales (Balaenoptera borealis)

One sei whale, moving south, was sighted on the expedition of 1964, off Punta Lengua de Vaca (Table 1, Fig. 1). In 1958 also a single sei whale was sighted, farther west at about the same latitude (Fig. 2). Although little can be said of a single sighting, one would certainly expect the abundance (0.1 per 100 miles sailed) not to have changed between 1958 and 1964, because very few sei whales were captured from Chile until 1965–1967 when substantial catches contributed to the Japanese operation for meat production from whalebone whales at Quintay (Table 5).

Bryde's whale, *Balaenoptera edeni*, has now been recorded from Iquique on the coast of Chile (R. Clarke and Aguayo, 1965), and so it is possible that the sei whales seen on the expedition of 1958 and 1964 may in fact have been Bryde's whales. It is generally accepted that the two species can only be distinguished at sea if it is possible to get a good view of the top of the head which only in Bryde's whale bears a ridge on either side of the median ridge common to the head of both species (Omura, 1962). But a ship has to approach so close for a chance to make out these side-ridges that, in the normal circumstances of a survey for whales, Bryde's whale and the sei whale are not likely to be distinguished by this character. However, the form and size of the spout may also afford a clue. One of us (A. A. L.) was informed by Japanese whaling captains in 1966 that the spout of Bryde's whale is wider and lower than that of the sei whale, and this has since been confirmed to A. A. L. by Dr. Masaharu Nishiwaki. Bryde's whales in the North

Pacific are in general limited to waters of 20°C or warmer (Omura and Nemoto, 1955), or mostly to waters warmer than 18°C with very few whales penetrating to 15°C (Nemoto, 1959, p. 247). Consequently the two whales seen around 30°S in 1958 and 1964 were more likely to have been sei whales, for the surface temperature was 14.5°C at the position of sighting the whale of 1964 (Table 1, Fig. 3).

There is now direct evidence from whale marking that some at least, of the sei whales off Chile migrate like the fin whales to the Antarctic in summer (see p. 159).

Sperm whales (Physeter macrocephalus*)

Abundance. In 1964 there were sighted 199–219 sperm whales or 11.9 per 100 nautical miles sailed, compared with 27 whales, or 1.7 per 100 nautical miles sailed on the same track in 1958 (Table 3). However, since half of the whales seen in 1964 comprised the great concentration of 90–110 whales encountered south of Isla Pájaros on 30 November (Fig. 1), we should also consider the frequency of sighting sperm whales, where results for the two voyages are just about the same, being 0.46 of a sighting per 100 nautical miles sailed in 1964, and 0.45 in 1958, although the numbers of whales per sighting were seven times greater in 1964 than in 1958 (Table 4). Distribution was similar on the two expeditions in that all except two of the sperm whales seen in 1964 were close to the chain of islands stretching from Isla Chañaral southward to Isla Pájaros, where were seen half the sperm whales recorded in 1958, although in 1964 we saw none on the ‘ San Antonio ground ’ which had provided the balance of the sperm whales seen in 1958 (Figs. 1 and 2).

The chances, then, of encountering sperm whales in 1964 and 1958 were just about the same, but in 1964 there were many more whales in the encounters. We believe that this was because, as will be explained when schooling and immigration are discussed, there were in 1964 more whales schooling and the schools were larger, due to a seasonal influx of whales into the area over the interval between October-November, when the expedition of 1958 took place, and November-December, when the survey was repeated in 1964. Thus it is not suggested that the results necessarily indicate an increase of the sperm whale stock in this area between 1958 and 1964, but they certainly do not indicate any decline in the stock during the period.

There was a sharp decline in sperm whale catches from Chile after 1964 (Table 5), but this can be explained, at least in part, by the dedication of one station (Quintay) to hunting whalebone whales for meat production, and to the low price of sperm oil which discouraged much effort in sperm whaling from the other two stations in Chile.

However, Saetersdal, Mejía and Ramírez (1963) have analysed whaling statistics from Peru, and have concluded that by 1961 sperm whales off Peru were probably already being over-exploited. Further, Arriaga (1976) cites reports (which we

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* Husson and Holthius (1974) have argued convincingly that *Physeter macrocephalus*, Linnaeus, 1758 has precedence over *P. catodon*, Linnaeus, 1758 as the valid name for the sperm whale.

have not seen) by Mr. Jorge Mejía in 1964 and 1965 which claimed a progressive reduction after 1961 of the sperm whales off Paita, Peru, as shown by a diminution in the catch per catcher's days work between 1961 and 1965. (In more recent years we believe that catch per unit of effort is less reliable as an index of abundance, because part of the effort in Peru has latterly been directed towards large catches of sei (or Bryde's) whales. Now Saetersdal, Mejía and Ramírez extended their conclusions to the Southeast Pacific as a whole, on the reasonable assumption that the same sperm whale stock is being exploited from Chile and Peru. This matter is being currently investigated, and all the evidence to emerge so far, from external characters and teeth (R. Clarke, Aguayo and Paliza, 1968), from morphometry using the allometry equation (R. Clarke and Paliza, 1972) and from morphometry using canonical analysis (Machin, 1974), indicates that the sperm whales off Chile and Peru do indeed form a single, continuous stock.

Our observations at sea off Chile in 1964 did not therefore show that decline in the sperm whale population since 1958 which the results of Saetersdal, Mejía and Ramírez, and later of Mejía, would have led us to expect. However, whatever may have been the condition of the stock off Chile in 1964, it is now generally agreed that an appraisal of the present condition of the Southeast Pacific sperm whale stock is urgently required (Scientific Consultation on Marine Mammals, Bergen, 1976. Document ACMRR/MM/SC/Rep. 1, Addendum to Appendix).

Schooling. The sperm whale is gregarious and polygamous, and the significance of schooling to the reproduction and population dynamics of the species has been emphasised by R. Clarke (1956, p. 277), Gambell (1967, 1972) and Best (1970b). Detailed information on the structure of schools, that is, the sexing of the component whales, their condition of immaturity and maturity, and stages in the sexual cycle, requires that sighting from ships or aircraft of particular schools be combined (as some investigators, especially Best, have attempted) with subsequent biological examination of carcases after all or some of the individuals comprising these schools have been shot. The major difficulty in attempting to classify sperm whale schools solely by observation at sea is that small males in schools cannot be distinguished from females, unless the latter are accompanied by calves. Nonetheless, the main kinds of schools can be distinguished to a certain extent. This is because we know that, whilst males may be solitary or schooling, females are invariably in schools (R. Clarke, 1956, p. 277), and because females rarely exceed 11.7 m (38 ft) in length, so that whales judged to be longer than 11.7 m are understood to be males. Thus, *solitary* sperm whales of any size are males (Pl. I, Fig. 1). Schools where the whales are all larger than 11.7 m are *bachelor schools*. Then two kinds of schools containing females may be recognised. *Harem schools* are those where one, or sometimes two or three, large whales are together with small whales, at least one of which is known to be a female because accompanied by a calf (Pl. I, Fig. 2). In such a school one of the large whales will be the harem-master. *Nursery schools* are those of small whales (less than 11.7 m), some of which are accompanied by calves (Pl. II, Fig. 1). This is as far as the observer can go at sea, and leaves him with a number of unclassified schools. These would include (if they could be identified) the bachelor schools of males smaller than 11.7 m, the mixed schools of immature males and females which associate ' as boys and girls go to school together ' (see R. Clarke, 1956, p. 279), and also those harem schools which cannot be definitely identified as such, because of the absence of a calf or calves to betray the presence of females among the smaller whales present. It should be added that when harem schools and nursery schools are identified at sea, it is not thereby inferred that all the small whales (less than 11.7 m) present are females, because the examination of catches from such schools has shown that immature and puberal males may also be present (R. Clarke, 1956, p. 279 ; Caldwell, Caldwell and Rice, 1966 ; Best, 1970b).

Sperm whale schools were classified in this way during the surveys off Chile

TABLE 6. FREQUENCIES OF THE SIZES OF SCHOOLS OF WHALES SIGHTED OFF THE COAST OF CHILE IN 1964. IN THIS TABLE SOLITARY WHALES ARE ALSO INCLUDED, AS ' SCHOOLS OF ONE '

Nos of whales in a school	Blue	Fin	Sei	Sperm	Black-fish	Bottle-nose	Uniden-tified small whales	Dol-phins	Por-poises
1	2	1	1	8		2	3		
2	1			7	1		1		
3				3	2		2		
4				1					
5				2					
6				2				1	1
6–8								1	
8				6	2			1	
9				1					
8–10								1	
10					1				
11				1					
12									
14							1		
15–20							1		1
20				1	1				2
22					1				
28				1					
30				1					
30–40					1				
35–40					1				
40–50					1				
50–60									1
Total schools	3	1	1	34	11	2	8	4	5
Total whales	4	1	1	203*	194	2	43	30	119
Av. nos per school	(1.3)	(1)	(1)	6.0	17.6	(1)	5.4	7.5	23.8
Av. nos per school in 1958	—	2.6	—	1.4	22.9	(5)	—	18.8	—

* In the concentration of 90–110 Sperm whales on 30 November, the count from the sizes of schools at a certain moment came to 94, which explains the apparent discrepancy between the total for all sperm whales given here (203) and that in Table 3 (199–219, average 209).

in 1958 (R. Clarke, 1962, Table 2) and in 1964 (Table 7). When numbers of sperm whales are sighted at a particular position they may, depending upon latitude and season, comprise schools of some or all of the observable classes scattered over a wide area ; thus, the great concentration of 90–110 whales sighted on 30 November 1964 comprised solitary whales, bachelor schools, harem schools, nursery schools and unclassified schools dispersed over 15 square miles of sea (Table 1). Such concentrations are not to be confused with the *herds* which are occasionally encountered at sea (Bennett, 1840, vol. II, p. 171 ; R. Clarke, 1956, p. 279) ; the sperm whale herd is formed only when the animals are migrating, and consists of schools which have come together as a tight body of whales, one hundred to several hundred strong, all travelling in the same direction. No herds were seen in 1958 or 1964. Schools of sperm whales may not remain stable when approached for observation and marking. Solitary males, several hundred yards apart when first sighted, may subsequently school together or join existing schools ; nursery schools may also join together and separate again in schools of different size, and so may unclassified schools: but harem schools appear to be more stable, as might be expected from such breeding groups (Table 7).

Immigration. Table 6 shows the frequencies of the sizes of schools, including those of solitary whales as ‘ schools of one ’. Using this classification sperm whale schools off Chile in November-December 1964 were on average more than four times larger (6.0 whales per school) than in October-November 1958 (1.4 whales per school). This is because relatively few solitary males were seen in 1964 (3.9% of all sperm whales observed) compared with those seen in 1958 when they comprised 56% of the total. R. Clarke (1962), noting this result that 56% of sperm whales were solitary off Chile in October-November 1958, whereas only 4% were solitary at the same time of the year in a survey conducted from the coast of Ecuador to the Galápagos Islands in 1959, suggested that with increasing latitude the female stock thins out and the males increasingly adopt the solitary habit ; but the present results indicate that this was too broad a generalisation which did not sufficiently take account of seasonal changes in the spread of schools and in the pattern of schooling.

The sperm whale schools seen in 1964 included numbers of females, females with calves, and young whales of either sex, as shown by the harem schools, nursery schools and unidentified schools recorded in Table 7. In five instances where these schools appeared to be travelling in a definite direction, the movement of four schools was southwest and of one east. Two bachelor schools were also seen travelling south, and in the class of solitary males, one was moving south, another southwest and one east. None of these whales were among those large numbers seen on 30 November 1964 close to the chain of islands north of Coquimbo (Fig. 1, Table 1), for here no steady direction of movement could be discerned for any of them (which included the large concentration of 90–110) and all were confidently believed to be feeding. But it may be said that, where whales were travelling, their movement was predominantly southerly. On the other hand no direction predominated in the sperm whales observed on the same track in October-Novem-

TABLE 7. CLASSIFICATION OF THE SCHOOLS OF SPERM WHALES SIGHTED IN 1964

Classification	Date and Time	Position	Surface Temp. °C	Nos of whales	Schooling	Direction	Remarks
Solitary males:	28. xi/1830	29°16′S, 71°47′W	15.0°	1		S	A solitary from the sighting of 16 sperm whales, Pl. I, Fig. 1.
	29. xi/0705	29°03′S, 71°48′W	15.5°	2	Separate	SW	Small males 9–10.5 m (30–35 ft) From the sighting of 33 sperm whales
	— /0815	29°05′S, 71°48′W	15.5°	1			Small male about 9.8 m (32 ft)
	30. xi/1345	29°35′S, 71°38′W	18.3°	2	Separate		Small males, from the sighting of 26 whales
	— /1510	29°38′S, 71°38′W	18.7°	1			Large bull which sounded for 45 minutes when chased and had not emerged when the chase was abandoned. From the sighting of 26 whales
	9. xii/1500	35°17′S, 74°29′W	17.1°	1		E	Large bull about 17.3 m (57 ft)
	— /1550	35°17′S, 74°33′W	17.0°	1			Large bull
Bachelor schools:	28. xi/1830	29°16′S, 71°47′W	15.0°	5	One of 3	S	From the sighting of 16 sperm whales
					Pair	S	
	29. xi/0815	29°05′S, 71°48′W	15.5°	2	Pair		From the sighting of 33 sperm whales
Harem schools:	29. xi/0705	29°03′S, 71°48′W	15.5°	10	one of 4	SW	School comprised one male (11.6–12.2 m, 38–40 ft), one female (10.7–11.6 m, 35–38 ft) with calf (5.5 m, 18 ft) and another whale presumably female, of 10.7–11.6 m (35–38 ft).
					One of 6	SW	Pl. I, Fig. 2.
	— /0815	29°05′S, 71°48′W	15.5°	9	One of 9		School included two calves, each about 6 m (20 ft). The three harem schools above were from the sighting of 33 sperm whales.
	30. xi 1610–1915	29°40′S, 71°36′W to 29°45′S, 71°39′W	18.1° to 18.7°	—	—		Harem schools were present in the concentration of 90–110 sperm whales.
Nursery schools:	30. xi/1345	29°35′S, 71°38′W	18.3°	16	Two of 8		One school comprised two calves each 5.5–6.1 m (18–20 ft), swimming on either side of a female of 11 m (36 ft), another whale of 11 m, and then four whales of 9 m (30 ft).

	— /1510	29°38′S, 71°38′W	18.7°	5	One of 5		School comprised two females, each 9.8 m (32 ft) with their calves of 5.5 m (18 ft), and with another whale of 9.8 m.
	— /1345	29°35′S, 71°38′W	18.3°	2	One of 2		Mother and calf (Pl. II, Fig. 1) The three nursery schools and the mother and calf above were from the sighting of 26 sperm whales.
	30. xi 1610–1915	29°40′S, 71°36′W to 29°45′S, 71°39′W	18.1° to 18.7°	—	—		Nursery schools were present in the concentration of 90–110 sperm whales
Unclassified schools:	28. xi/1830	29°16′S, 71°47′W	15.0	10	Two of 5	SW	Each school with at least two males, about 13.5 m (45 ft), and the remaining whales of 10.5–12 m (35–40 ft). They could have been bachelor schools or harems. From the sighting of 16 sperm whales.
	29. xi/0705	29°03′S, 71°48′W	15.5°	6	Three pairs	SW	All about 9–10.5 m (30–35 ft). May have been bachelor pairs.
	— /0815	29°05′S, 71°48′W	15.5°	3	One of three		This school and the three pairs above were from the sighting of 33 sperm whales.
	— /1645	28°00′S, 71°58′W	18.2°	2	Pair	E	Probably a bachelor pair, but no sizes were recorded.
	30. xi 0715–1020	29°00′S, 71°43′W to 29°02′S, 71°39′W	14.8° to 16.0°	30	11, 8, 8, 3		In this sighting of 30 whales, all were animals of medium or small size, being not more than 40 feet. At first 6 separate whales (males) were sighted, all within a few hundred yards of each other, apparently scattered for feeding. More whales appeared, and the individuals joined schools which broke and reformed. At one time there were four schools of 11, 8, 8, 3. Possibly all were batchelor schools.
	30. xi 1610–1915	29°40′S, 71°36′W to 29°45′S, 71°39′W	18.1° to 18.7°	—	—		Unclassified schools were present in the concentration of 90–110 sperm whales.

ber 1958, and R. Clarke (1962) concluded that there was nothing to suggest that they were migrating.

Townsend (1935) published world charts showing the positions month by month of captures of sperm whales recorded in the log-books of the sailing whaleships between 1761 and 1920. In equatorial latitudes of the Pacific sperm whales were taken at all times of the year, and, as R. Clarke (1962) has observed, the charts show also an abundance of sperm whales off Peru and Chile, with indications of a spread southward in summer. With the evidence of these charts in mind, the differences observed in this region off Chile in 1964 compared with 1958—larger schools and fewer solitary males, more females and calves and young whales, and a general southerly movement of the whales not actively feeding—all indicate an influx of sperm whales from the north over the period between October-November (of 1958) and November-December (of 1964). This influx would represent a spread southward in early summer of some part of the breeding stock.

Observations of sperm whales off the west coast of South Africa suggests that 'large bulls over 45 ft (13.5 m) in length join the female schools for the main breeding season' (Best, 1969a). In the Southeast Pacific the main pairing season has been estimated to last from June to December with a peak in September (R. Clarke, Aguayo and Paliza, 1964). During the expedition off Chile in 1958, most of the 15 solitary male sperm whales sighted (R. Clarke, 1962, Table 3) were large individuals: Clarke's unpublished records show that, of six solitary males whose lengths were estimated, five were between 48 ft (14.6 m) and 52 ft (15.9 m) long. It is therefore possible that the large solitary males, which formed the majority of the sperm whales sighted in these latitudes off Chile in October-November (of 1958) had by November-December (of 1964) either schooled as harem males with arriving females, or, failing to secure harems, had schooled with other bachelors; or perhaps they had moved further south on the way to spend the summer in the Antarctic. However, since the peak of conceptions is in September, most of the pairing may be considered to have taken place to the north of the area surveyed. On the other hand, parturition in Southeast Pacific sperm whales extends mainly from November to May, with a peak in February (R. Clarke, Aguayo and Paliza, 1964), and we believe that the results from material now being analysed will confirm our impression that this area between 28° and 36°S, especially in its southern part, is a calving ground for the breeding stock which begins to accumulate there, as the observations from 1958 and 1964 now show, during November and December. (There is evidence that elsewhere sperm whale calving grounds are in similar warm temperate latitudes, as the Azores around 38°N (R. Clarke, 1956) and South African seas off Durban in 30°S (Gambell, 1967) and off Saldanha Bay in 33°S (Best, 1969b); whilst Pervushin (1966) and Gambell, Lockyer and Ross (1973) have actually observed sperm whales calving, respectively in March in 37°01′S, 71°44′E and in February in 33°49′S, 28°02′E). Of the calves seen in harems and nursery schools during the expedition of 1964 there were seven whose estimated lengths were recorded (Table 7); they ranged from 5.5 m (18 ft) to 6.1 m (20 ft), so that none were newborn nor young-of-the-year, for the length of the sperm whale

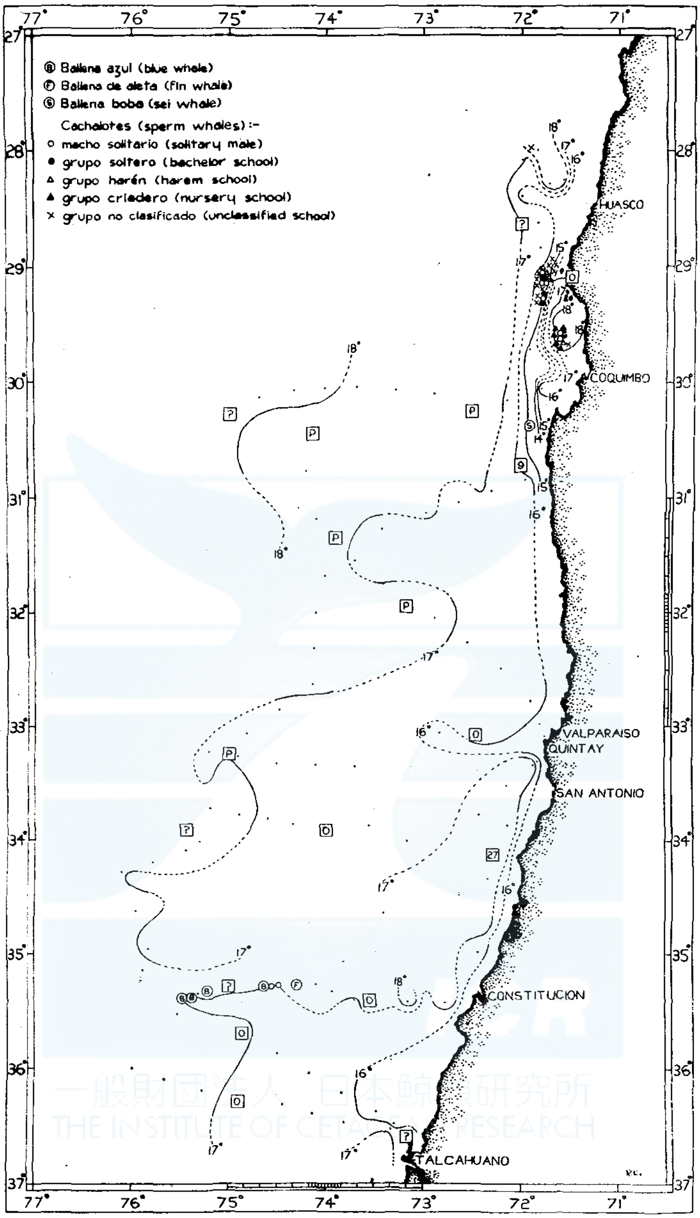

Fig. 3. Surface isotherms during the voyage of *Indus XIV* off the coast of Chile between 24 November and 17 December 1964. There are plotted the sightings of the larger whales; and (in square boxes) the numbers of strikes and/or captures per hour of the Humboldt Current squid *Dosidicus gigas* during the oceanographical stations.

neonate in the Southeast Pacific has been estimated by R. Clarke, Aguayo and Paliza (1964) at 4.02 m (13 ft 2 in): they will have been young of a previous calving season, because lactation is protracted in the sperm whale and the calf is weaned, at least in the North Atlantic, when about 6.7 m (22 ft) in length (R. Clarke, 1956, p. 275). Since the peak of the calving season is in February, it was not to be expected that we should see any number of newborn calves in the voyage of November-December 1964.

We have dealt here with immigration of sperm whales into the area surveyed. On p. 156 we record direct evidence from whale marking of the migration of male sperm whales from this area into the Antarctic.

Distribution and water temperature. In his report on the surveys conducted off Chile in 1958 and from Ecuador towards and beyond the Galápagos Islands in 1959, R. Clarke (1962) wrote:

'Female sperm whales do not range beyond about 40° North and South (Matthews, 1938, p. 160), apparently because they avoid cold water, so it would be expected that a similar exclusion might be traced, meridionally rather than latitudinally, in an upwelling region like the Humboldt Current where typically the water is coldest near to the coast and becomes progressively warmer towards the oceanic boundary. Schubert (1951, 1955), from observations made in pelagic factory ships whaling on the coasts of Peru and Chile in 1938 and 1951 (including the latitudes explored by *Indus X* in 1958) concluded that there was an orderly segregation from the coast westward of solitary males in water of 15°–17°C, bachelor schools in water of 16°–18°C, and female schools in water of 17°C and warmer. Temperature observations on the two expeditions discussed here, so far as they go (Table 2), only partly support Schubert's conclusions.'

Further data on the distribution of sperm whales and water temperature were collected on the expedition off Chile in 1964. Table 7 includes the surface temperatures observed at the positions where the various classes of sperm whales were sighted. In Fig. 3 the whales sighted are plotted according to their classes on a chart of the surface isotherms prepared from the two-hourly temperature observations made throughout the expedition.

The surface isotherms are of interest in themselves as showing two regions of active upwelling in this area of the Humboldt Current during the period of the expedition: thus, the isotherms run close together and parallel to the coast from south of Quintay to Constitución (about 33°20′S to 35°20′S), where in fact no sperm whales were seen during the survey; and from south of Huasco to south of Coquimbo (28°40′S to 30°40′S), where nearly all the sperm whales were seen. In this latter upwelling region the 14°C isotherm runs more or less north and south to westward of the chain of islands between Is. Chañaral and Is. Pájaros, with increasing temperatures to either side, indicating an inshore eddy of comparatively warm water (rising to 19°C) which embraces the islands and extends to the mainland coast. The great concentration of 90–110 sperm whales, first sighted three miles from Is. Pájaros on 30 November, was within this eddy at temperatures of 18.1° to 18.7°C (Table 1). This concentration comprised harem schools, nursery schools and unidentified schools, and also a few solitary young bachelors which eventually schooled.

In Table 8 the records on surface temperatures and the classes of schools from Table 7 are presented with those from the previous expedition off Chile in 1958, and the expedition from the coast of Ecuador to the Galápagos Is. in 1959. Figure 3 and Table 8 do not support Schubert's conclusions which we are therefore unable to accept. Solitary males have been observed in water as warm as 22.6°C, and nor is it credible that this class of sperm whale, which is widespread in all seas from the equator to the polar ice, should confine itself to relatively cold water. Females in harem schools have been observed in water as cold as 14°C. That bachelor schools were observed only in the small range of 15.0–15.5°C we consider an accident due to the paucity of data for this class, for bachelor schools were observed, though not recorded in detail and therefore not included in Table 8, in the great concentration off Is. Pájaros in water of 18.1° to 18.7°C.

TABLE 8. THE CLASSES OF SPERM WHALE SCHOOLS AND SURFACE TEMPERATURE. FROM THREE VOYAGES IN THE SOUTHEAST PACIFIC.

Classification of schools	1964		1958 (Clarke, 1962, Table 2)		Ecuador to Galápagos Is. 1959 (Clarke, 1962, Table 2)		Summary	
	No. of whales	Temp °C	No. of whales	Temp °C	No. of whales	Temp °C	No. of whales	Temp °C
Solitary males	9	15.0-18.7	15	13.6-15.3	5	21.4-22.6	29	13.6-22.6
Bachelor schools	7	15.0-15.5	3	15.3			10	15.0-15.5
Harem schools	19+	15.5-18.7	5	14.0			24+	14.0-18.7
Nursery schools	23+	18.1-18.7			80-100	17.9	103-123+	17.9-18.7
Unclassified schools	51+	14.8-18.7					51+	14.8-18.7

However, Table 8 does suggest that nursery schools are limited to water not colder than 17.9°C, say 18°C. We may reasonably believe that this is because of the thermal requirements of the calves. Even so, the limitation is not a rigorous one, for the nursery schools in the concentration off Is. Pájaros in 1964 will have needed to cross water of 14°C to enter the warm eddy, and indeed, two of the harem schools observed in water of 15.5°C on 29 November included calves (Table 7). But it is noteworthy that both these harem schools were travelling, not lingering nor feeding, and the suggestion is that females with their calves seek out water of 18°C or more, although in the seeking the calves may tolerate colder water. It may be that the nursery school, a grouping of small whales, females and calves, becomes an expedient in upwelling regions to serve the requirements of the mother for food and the calf for warmth: we may imagine that the calves are 'parked' in the nursery schools in warm water, as for instance the eddy off Is. Pájaros, whilst some of the mothers go off to feed in the adjacent upwelling stream, perhaps leaving their calves in the care of 'aunties' such as exist in some other animal communities.

Observations elsewhere have also demonstrated that female sperm whales are tolerant of colder water than has been claimed by Schubert, and later by Gilmore (1959) and Radovich (1961) who gave limits of 20°C and 17°C respectively. Actually the limits of tolerance must not be those of the mother whales and other adult females, but rather those of the accompanying calves and juveniles whose thermal requirements are one of the factors which limit their diving range, because, as Gaskin and Cawthorn (1967) have noted, adult sperm whales of both sexes may be in comparatively warm water at the surface and quickly find themselves in water near freezing when diving for food at depth.

When Pervushin (1966) observed sperm whales calving, the surface temperature was 17.5°C. Females in the North Pacific are occasionally taken as far north as the Aleutian Islands in 52°N when the summer temperature of the sea is above the normal of 13°C (Nishiwaki, 1966a). This agrees with the lowest surface temperature, 14°C, at which (in 1958) harem schools were seen in the Southeast Pacific, although in another paper Nishiwaki (1966b) says that in the North Pacific females may enter seas as cold as 10°C, but not colder. However, he makes no mention in either paper of calves accompanying the females. Earlier, Matsuura (1935) had even recorded harem schools sometimes entering water as cold as 3°–10°C off Japan, again without mention of calves, although Berzin (1971, p. 182) refers to Russian observations of females with calves at temperatures below 3°–10°C in the Sea of Okhotsk and off the Kurile Islands. In the western South Pacific Gaskin (1971) records a harem school (in Cook Strait) in water about 10°–12°C as an abnormal occurrence, and gives records of 14°–16°C as realistic limiting temperatures for nursery schools; regarding latitude, Gaskin (1973) mentions an extreme record of a female taken in 54°55′S, but puts the normal limits at 50°S in the western South Pacific. Thus, although the statement that female sperm whales do not range beyond 40° North and South holds good as a generalisation, the limit in the southern hemisphere has been put more precisely in oceanographical terms by Bannister (1968) and Best (1976) as the subtropical convergence. This lies for the most part around 40°S but in places extends nearly to 50°S, whilst 'the water just north of the convergence has a temperature of at least 11.5°C in winter and 14.5°C in summer' (Deacon, 1937, Fig. 4 and p. 72): these ranges just about encompass the latitudinal and temperature limits for female sperm whales reviewed here, save for those mentioned by Matsuura and Berzin.

Distribution and the squid Dosidicus gigas. Sperm whales of the Southeast Pacific, like those in most other parts of the world, feed mainly upon squid.

R. Clarke (1962), referring to the great numbers of large squid seen at the surface at night during the expeditions off the coast of Chile in 1958 and from Ecuador to the Galápagos Islands in 1959, observed that the specimens collected seemed to be identical with the common Humboldt Current squid *Dosidicus* (*Ommastrephes*) *gigas*. Now in other oceans, ommastrephids with a similar habit, abounding at the surface, are not known to be eaten by the sperm whale, or are rarely eaten. Drawing attention to this interesting circumstance, R. Clarke emphasised nonetheless the possibility that sperm whales of the Southeast Pacific might in the event be found to be feeding on *D. gigas*, when study of the biology and distribution of this squid would become important to the whale investigations.

Recently M. R. Clarke, MacLeod and Paliza (1976) have reported on cephalopod remains from the stomachs of sperm whales examined in Chile and Peru. They have not only established the presence of beaks of *D. gigas* in stomachs from Paita and Pisco in Peru, but have also estimated that, although this large bulky species only constituted 3.6% of the total number of beaks in the samples, it contributed 31.6% of the squid flesh swallowed by the whales. It appears therefore that in the Southeast Pacific *D. gigas* is one of the most important species of squid in the nutrition of sperm whales.

The identification of *D. gigas* beaks in the stomach contents was made by Dr. Malcolm Clarke as early as 1963, when the samples were sent to the National Institute of Oceanography in England (see R. Clarke, Aguayo and Paliza, 1968, Part I.). Consequently, during the expedition off Chile in 1964 we arranged to fish for squids each night when the ship lay drifting, so as to look for any correlation between our sightings of sperm whales and the distribution and abundance of the squids. It is with these results that we are here concerned: an account of the fishing methods and some observations on the squid themselves are included in ' Other work on the voyage ', p. 162.

Fishing was conducted mostly at 25 or 50 m. All the squids we caught were the same species, and the fourteen specimens preserved were later identified as *D. gigas* by Mr. Patricio García-Tello (p. 163). This makes us confident that the large squid we saw around the ship, and the ' strikes ' not captured were all *D. gigas*. In Fig. 3 the numbers in square boxes represent the abundance of the squid as the number of strikes and/or captures per hour's fishing (Table 10) at each of the Stations I_{14} to I_{31} (Fig. 1). The letter ' P ' within a box indicates those stations where no strikes or captures were made during the routine fishing period, but squid were known to be present, either because they were seen at the surface or because they were caught at some time in the night by the watch after the station work had been completed. At five of the stations, for one reason or another (Table 10) no fishing was undertaken, and here a question mark appears in the box.

We had expected a correlation between the presence of numerous sperm whales, an abundance of *D. gigas*, and positions of active upwelling, but the results supported no such correlation. The greatest abundance of squids, yielding 27 squids per hour's fishing, were at station I_{24} in the region of active upwelling south of San Antonio, but no sperm whales were observed there; nor were sperm whales observed at station I_{17} where squids were also abundant (nine per hour's fishing) in the southern part of the active upwelling in the Coquimbo area. On the other hand no squids were caught at station I_{18} in the northern part of this upwelling region, although sperm whales were abundant at and near station I_{18}; actually *D. gigas* is so abundant in this region of the chain of islands north of Coquimbo that the only factory for making squid meal in Chile is working here on the mainland coast (García-Tello, 1965). Figure 3 also shows that squids were present further westward in water of surface temperature between 17° and 18°C where no sperm whales were seen. There are several possible reasons for these unexpected results: the stations were comparatively few; the total fishing time at any station was usually 30 minutes or less, and never more than one hour; and although various baits of fish and meat were used, we might have done better with no bait at all, for the best catch (at Station I_{24}) was taken with an unbaited *tota* (see p. 163): or perhaps there was no correlation possible because the whales were feeding mostly in the day when the *D. gigas* were at a deeper level and displaced horizontally from our stations.

We have thought it worthwhile to report these results because, although routine observations and exploratory fishing for oceanic surface-living squid have been conducted before (Baker, 1960), this is the first time to our knowledge that observations on sperm whales have been combined with exploratory fishing for a squid known to be a constituent of the diet. It is hoped that more work of this kind will be done on future voyages in the Southeast Pacific. The fishing methods need to be improved by experiment, and then standardised and conducted more intensely. Fishing seems at present to be the most reliable way to measure abundance of these squids, because (as Baker (1960) has observed in regard to *Ommastrephes pteropus*) the squids move in and out of the illuminated area around the ship so quickly that they cannot be counted; also the fact that no squid may be seen at the surface is no guarantee that they are not present twenty or so metres down.

It is not surprising that *D. gigas*, because of its size and abundance, should be eaten by sperm whales in the Southeast Pacific: it is surprising that related squids of similar habit in other oceans should be eaten rarely or not at all. Betesheva and Akimushkin (1955) claimed that in the North Pacific *Ommastrephes sloanei pacificus* is only rarely eaten, a statement later modified by Akimushkin who said (1963, p. 196) that it is not eaten. The squid abundant at the surface in the North Atlantic, *Ommastrephes pteropus*, is not known to be eaten by the sperm whale (Baker, 1957; M. R. Clarke, 1962), although M. R. Clarke (1966, p. 105) says that specimens of *Ommastrephes* discussed by Baker (1957, 1960) included not only *O. pteropus* but also *O. caroli* and possibly *O. bartrami* which Kawakami (1976) has now recorded from the stomachs of sperm whales in the Northwest Pacific. Dr. Malcolm Clarke has informed us that the surface living squid of the Indian Ocean, *Symplectoteuthis oualaniensis* has not be recorded from sperm whales in that ocean, although some of the beaks examined from sperm whales at Paita, Peru are believed to belong to this species (M. R. Clarke, MacLeod and Paliza, 1976). It is not clear why sperm whales outside the Southeast Pacific should pay little or no attention to the surface frequenting ommastrephids. Betesheva and Akimushkin (1955) and Berzin (1971, p. 201) believe that *O. sloanei pacificus* is confined to the surface and that sperm whales feed at deeper levels; yet *O. pteropus* has been recorded from the surface to depths as great as 1,000 m (Baker, 1960), and we believe—from the accumulating evidence on the food of sperm whales in various seas—that these whales are feeding at all levels from the surface to substantial depths. Again, *S. oualaniensis* and *D. gigas* have light organs (Roper, 1963; M. R. Clarke, 1965) and *D. gigas* has been observed to emit a brilliant blue light (García-Tello, 1964), so it might be thought that in these squids the light betrays the squid to the sperm whale; but *O. pteropus* is also bioluminescent (Roper, 1963; M. R. Clarke, 1965) and is not known to be eaten.

Blackfish (Globicephala melaena edwardi)

Results on the distribution and abundance of blackfish off Chile need to be prefaced with remarks on the species identification. As R. Clarke (1962) has observed, these blackfish in the parochial sense 'are to be referred to *Globicephala chilensis* which Philippi (1896) described as a new species from two almost complete skeletons cast up on the coast of Chile'. On three occasions some of the blackfish sighted in the expedition of 1964 (Table 1) were approached closely enough to observe the pigmentation. These bore a whitish saddle-shaped area behind the dorsal fin (Pl. II, Fig. 2) and a whitish streak behind the eye. In one large school of 40–50 whales sighted at 1905 on 1 December, one adult of about 4.6 m. (15 ft) was posed upright in the water, apparently watching the vessel, and it was seen to have a white patch on the throat. The saddle-shaped white area behind the dorsal fin and the whitish steak behind the eye are the distinctive external characters which Rayner (1939) used to describe the southern blackfish, *G. leucosagmaphora.* According to F. C. Fraser, in Ellermann, Morrison-Scott and Hayman (1953), *leucosagmaphora* is antedated by *edwardi* A. Smith, 1834. R. Clarke (1962), discussing the blackfish sighted off Chile in 1958, noted that 'Davies (1960) believed that differences between the northern and southern forms did not warrant more than subspecific importance at most, and so he distinguished a northern *G. melaena melaena* from a southern *G. melaena edwardi.* He drew attention to records of southern *Globicephala* which apparently lacked the dorsal white saddle, and to a record of northern *G. melaena* which possessed the saddle, and explained that he and other authors found no differences between the skulls of *Globicephala* from Tasmania, the Falkland Islands, the Cape of Good Hope and Kerguelen'. Davies' proposal has since been accepted by Sergeant (1962a), who has made an intensive study of the North Atlantic blackfish, and by Rice and Scheffer (1968) in their classification of marine mammals: Hershkovitz (1966, p. 96) lumps the southern and northern forms together, saying that distinctions are based on 'individual or pod variables' and are without geographical basis, but this would seem to us to go too far whilst so little anatomical material has been examined from great areas like the Southeast Pacific. R. Clarke was content to leave the blackfish sighted off Chile in 1958 (and also off the coast of Ecuador in 1959) as *Globicephala* sp., because he had been able to observe only the white saddle and not the whitish streak behind the eye described by Rayner, and also because True (1903) considered that Philippi's *G. chilensis* could be distinguished by characters in the skull and backbone from *G. melas* (*melaena*). But now that we have observed the white streak behind the eye, and also the white throat which agrees with Rayner's description of *leucosagmaphora* as being similar in its ventral white pigmentation to *melaena,* it appears reasonable to identify the blackfish of the Southeast Pacific as *G. melaena* *edwardi*. However, the identification is tentative only, for it is based upon the pigmentation of the body which certainly seems to vary a good deal in *Globicephala*. The matter will not be settled until specimens of blackfish from the west coast of South America are examined anatomically and osteologically, when the differences claimed by True can be confirmed or denied. Meanwhile, if records of blackfish in the Southeast Pacific all refer to *G. melaena edwardi*, its range is continuous from the south of Chile (Cabrera and Yepes, 1940, p. 300, Tierra del Fuego ; Norris, cited by Aguayo, 1975, Golfo de Penas ; Philippi, 1893, 1896, Isla Chiloé ; Aguayo, 1975, the region from 49° to 33°S ; Gilmore, 1971, Isla Mocha) through central Chile (Philippi, 1893, 1896, Los Vilos ; Oliver, 1946, Concepción ; R. Clarke, 1962 ; the present paper) and far out at sea near Isla San Ambrosio off northern Chile (Gilmore, 1971) to the length of the coast of Peru (Scammon, 1874, p. 87 ; R. Clarke, 1962 ; Guillen and Flores, 1965 ; Mejia and Poma, 1966 ; Aguayo, 1975) and the coast of Ecuador (Scammon, 1874, p. 87 ; R. Clarke, 1962 ; Leveque, 1963).

During the expedition off Chile in 1964 there were seen 181–206 blackfish, all of them in the track of 1958, for none were sighted on the extension southwards to Talcahuano. They were sighted on eleven occasions (Table 1), and the general distribution of these sightings across the body of the Humboldt Current, from 20 to as much as 160 nautical miles from the coast, was similar to the distribution of 1958 (Figs 1 and 2). In 1964 the abundance of blackfish as numbers per 100 nautical miles sailed (Table 3) was very similar to the abundance in 1958 (respectively 11.0 and 13.2 per 100 nautical miles sailed) ; the abundance measured in this gregarious species as sightings per 100 nautical miles sailed (Table 4) was just about the same in 1964 and 1958 (0.63 and 0.70 per 100 nautical miles sailed), as were the number of whales per sighting (17.6 and 18.7). The stock of blackfish off Chile is not exploited at present, and the numbers are therefore likely to remain steady from year to year, so that these results from two surveys over the same track at very nearly the same time of the year were to be expected ; we have earlier noted (p. 127) that to have obtained these expected results makes us confident that our results for the abundance of other whales may be significantly compared.

In 1964 the direction of movement of the blackfish was noted at seven sightings (Table 1) ; the directions were south or southerly on four occasions, and west, east and northeast on the others, suggesting, as far as they go, that the general trend of movement might be southerly. The sizes of schools are shown in Table 6 : the average numbers per school were 17.6 in 1964 and 22.9 in 1958, when the average was somewhat swelled by one sighting of a school of about 100 whales (R. Clarke, 1962, Table 3) ; these figures agree well with the sizes of schools in the North Atlantic where Sergeant (1962b) says ‘ the pelagic herds comprise on average about 20 individuals and rarely include more than 100, . . . ’. In Table 1 there are some notes on the estimated sizes of the blackfish we encountered ; they include one whale, which from its size must have been a male, estimated at 7.5 m (25 ft). This was probably an over-estimate, for the largest of 1,275 males measured in the North Atlantic was 6.17 m or 20.2 ft (Sergeant, 1962b) ; however, it is possible that blackfish grow bigger in the southern hemisphere for few southern blackfish have been measured, the largest, 5.89 m (19.3 ft), being from a sample of ten males belonging to a school stranded in Tasmania (Scott, 1942).

Blackfish sometimes mingle with other cetaceans. This was observed in two of the eleven encounters with blackfish in 1964; on one occasion a school of 30–40 was accompanied by eight dolphins (see p. 151), and on another a school of ten accompanied 6–8 dolphins and a fin whale (Table 1). In 1958 they were seen to be mingled with other cetaceans on four occasions, respectively with sperm whales, fin whales (twice) and a fin whale with dolphins (R. Clarke, 1962). Gilmore (1971) and Aguayo (1975) have also reported them mingled with bottlenosed dolphins (*Tursiops* sp.) off Isla San Ambrosio in Chilean seas. In other seas their association with sperm whales have been reported by Gaskin and Cawthorn (1967), and with dolphins and porpoises by Sergeant and Fisher (1957), Norris and Prescott (1961), Brown (1961b), Fiscus and Niggol (1965) and Pilleri and Knuckey (1968, 1969). As Gilmore (1971) has noted, the habit of the blackfish of mingling with other cetaceans is widespread and appears to be characteristic of *Globicephala.*

From the results of the expeditions of 1958 and 1964 we recommend that consideration should be given to exploiting the blackfish resource off the coast of Chile (see also Aguayo, 1975). At the present time blackfish are hunted in Norway, the Faeroe Islands, Greenland, Newfoundland, the Lesser Antilles and Japan. The *International Whaling Statistics* (1976, LXXVII, Table Z5) give the catches from these countries (except the Lesser Antilles) between 1964 and 1968. In the Faeroe Islands and Newfoundland the whales are driven ashore (Williamson, 1945; Sergeant, 1962b). At St. Vincent in the Lesser Antilles of the Caribbean, there is a hand harpoon fishery from open boats (Mitchell, 1975, p. 82). In Japan and Norway they contribute with other cetacean species to the 'small whale' catch taken pelagically by small vessels using the harpoon gun, as described by Omura, Maeda and Miyazaki (1953), Jonsgård (1955) and Foote (1975). Similar small whalecatchers would be required in Chile, where the schools of blackfish do not (so far as we are aware) come close enough to the coast to be driven ashore. Blackfish meat is edible: in Japan and the Faeroe Islands it is used for human consumption, and in Norway and Newfoundland it is used for animal food, including food for mink and fox farms. If blackfish whaling is started in Chile, then from the beginning there should be established a research programme to monitor continuously the stock under exploitation.

Bottlenosed whales

There were two occasions on the expedition of 1964 when Captain Parra sighted a solitary whale which he reported as a bottlenosed whale (Table 1, Fig. 1). Little is known of the true southern bottlenosed whale, *Hyperoodon planifrons,* of which there are only twenty records of flesh or bone at the present time (Gianuca and Castello, 1976). A number of sighting records have been published, but nearly all of these are unreliable, because the species can easily be confused at sea with certain other ziphioid whales. Therefore we cannot be sure that the two whales reported by Captain Parra were definitely *H. planifrons*, although they may well have been, since R. Clarke (1962) recorded five *H. planifrons* in 33°15′S, 73°27′W on the expedition of 1958. We accept Robert Clarke's identification because during the Antarctic whaling season of 1947–48 he arranged for a specimen of *H. planifrons* to be shot, and combined a complete examination of the specimen with his photographs and observations of the living whale (see Fraser, 1964); but on the expedition off Chile in 1964 he was not on deck to confirm Captain Parra's sighting.

There are other reports from Chilean seas of whales believed by the observers to be *H. planifrons*. Two were reported in Drake Strait in December 1965 (Aguayo and Torres, 1967), and in 1966 there were reported 14 animals in March-April and six in December, and in 1973 a solitary animal in February (Aguayo, *unpublished*). Duguy (1973) also saw two whales in Drake Strait in December 1972 which he thought were probably *H. planifrons*. There is one report which we do not accept even as a possibility: Gianuca and Castello (1976) said ‘ Morzer Bruyns (1971) saw a pod off Chile estimated to comprise about 40 specimens (May, 1965)’; actually Bruyns (1971, p. 149) saw only records where an unidentified observer had reported 40 pilot whales (blackfish) but which Bruyns, solely from notes on their pigmentation, thought ‘ must have been ’ the southern bottlenosed whale.

Unidentified small whales

There were eight sightings in 1964 of small whales which we could not identify (Table 1). On most occasions they were too far away, and there is nothing more to be said about them, but we are here concerned with two sightings, at 1755 on 24 November and at 0712 on 27 November, of a species of whales which we have never seen before.

On both occasions the schools were chased for observation, the first time for 35 minutes and the second time for nearly three hours, when an unsuccessful attempt was made to harpoon a specimen. Photographs were taken but we could not approach them closely. When chased they soon became scared and ran fast, keeping their distance from the ship steaming at 13 knots. Each time the school stayed together during the chase, and on the first occasion the school was noted as running in single line abreast. The first sighting was a school of 15–20, the whales being about 6.0 m (20 ft) long; the second sighting comprised a school of 14, all about 4.5–6.0 m (15–20 ft) long. Some of the external characters are shown in Pl. III, Fig. 1. The head was somewhat bulged, and we caught a glimpse of the snout of one individual: it was bluntly rounded, without any sign of a beak. The dorsal fin was conspicuously high, rising stoutly from a wide base, with the axis inclined slightly backward; the anterior margin was steep, with scarcely any curve until it swept back to form the blunt tip; the posterior margin was shallowly concave. The whales did not at any time show more of the body surface above the water than the midline of the flanks, so nothing can be said of the ventral colouration. The back posterior to the dorsal fin was dark, almost black. The forepart of the body was greyish-white of a streaky pattern, extending in some individuals from the head to the anterior emargination of the dorsal fin, and in others from the head to the region just behind the dorsal fin which thus appeared to rise up like a dark island in a white surround. The dorsal fin itself was generally dark, although streaks of white invaded the base in varying amounts, and one whale had the length of the anterior margin of the fin white, and the remainder dark.

These whales are certainly odontocetes, if only for the single blowhole (Pl. III, Fig. 1). They have no beak, and so are not ziphiids but delphinids. They are not killer whales *Orcinus orca*, for the dorsal fin, although high, is really not like that of either the male or female killer, and nor do they have the bold piebald pigmentation of the killer. The pigmy killer whale, *Feresa attenuata*, is too small and has a different dorsal fin (Nishiwaki, Kasuya, Kamiya, Tobayama and Nakajima, 1965, Fig. 6). Risso's dolphin, *Grampus griseus*, has a similar pigmentation when observed at sea, and the dorsal fin is similar to, although not so high and rather more falcate than, the fin of our whale (Pilleri and Knuckey, 1968, Pls VIII–XI; Mitchell (edit.), 1975, Fig. 24); but Risso's dolphin does not exceed 4 m (13 ft) in length. As may be seen from Pilleri's photographs of the false killer whale, *Pseudorca crassidens*, at sea (1967, Pls. I–IV), the dorsal fin of the false killer comes closest to that of our whale in shape, although the false killer's fin is not so high; the body size of the false killer is also about the same, and although the colour is said to be black, relieved only by white scar marks, there appear to be small white patches on the back of some individuals in Pilleri's photographs, and white markings on the head and flippers of stranded specimens photographed by J. G. Mead (in Mitchell (ed.), 1975, Fig. 14).

We can only conclude that these whales seen off Chile in 1964 may be a new species, possibly of the genus *Pseudorca* or *Grampus*. It is clearly important to obtain specimens as soon as opportunity affords. The animal agrees well with the 'undescribed whale' reported and figured by Wilson (1905, p. 472; 1907, p. 4 and Whales, Plate I) as 20–30 feet long, black above but with some white about the mouth or chin, and characterised by a high dorsal fin 'erect, pointed and sabre-shaped'; several were seen in the Ross Sea during the British National Antarctic Expedition (1901–1904), but they have never been reported since.

Dolphins (Tursiops sp.)

We have already explained (p. 127) the observed difference in abundance of dolphins sighted off Chile in 1964 (1.7 per 100 nautical miles sailed) compared with their abundance over the same track in 1958 (15.6 per 100 nautical miles sailed).

Dolphins were sighted on four occasions during the expedition of 1964 (Table 1). They were all of the same species which we have not been able to identify with certainty. They were in schools of between six and ten animals. At one sighting the school was accompanied by blackfish, and at another, by blackfish and a fin whale (p. 149). The estimated lengths of the dolphins varied from 1.5 m (5 ft) to 2.4 m (8 ft). Two which played at the bow of the ship could be observed fairly closely, and were photographed when just under water (Pl. III,

Fig. 2). All were slender dolphins, similar in build, dorsal fin and flukes to the common dolphin, *Delphinus delphis*, but with a different colouration. The tailstock was strongly compressed. The beak was fairly short. The anterior border of the flipper was convex: the posterior border was concave from the tip to a point near the insertion; at this point, where the flipper had its greatest breadth, the posterior border became convex, curving inwards to the insertion. The colour was lead-brown above, relieved by some white mottling, especially on the head. In some individuals there were white scratch marks and scars. The lead-brown colour extended to the dorsal fin and the flippers and to the dorsal aspects of the beak and the flukes. The ventral surface was white, including the ventral aspects of the beak and the flukes. The flanks were also white as far as the mid-lateral line of the body.

The compressed tailstock suggests a species of *Lagenorhynchus*. But the form of the flipper is a *Tursiops* characteristic, and there are no features in our notes which exclude *Tursiops*, unless it be that the better known species of *Tursiops* are somewhat more robust than these dolphins. The colour is similar to that of *Tursiops catalania* as described by Fraser (1948). *Tursiops* in the Southeast Pacific is definitely known from two skulls and some notes on body colour from photographs of the individuals which provided them: they are from Talara, Peru and from Isla Santa Cruz, Galápagos Islands, and Hershkovitz (1963) identified them as *T. nesarnack catalania*, which in 1966 he included as a synonym of *T. truncatus aduncus*. Grimwood (1969) has since identified this species as common in Peruvian coastal waters, from Máncora to the Chilean border. We are inclined to think that the dolphins observed in 1964 were a species of *Tursiops*, and Aguayo (1975) was of the same opinion, but we would not commit ourselves until specimens are available for study.

In 1958 also many of the dolphins seen were not identified, although R. Clarke (1962) did report sightings of *Lagenorhynchus cruciger* and the common dolphin *Delphinus delphis*, neither of which were seen in 1964. R. Clarke has discussed previous records of *L. cruciger* from Chile. He saw nothing remarkable about the *D. delphis* he observed (*unpublished notes*), but Banks and Brownell (1969) examined two specimens of the common dolphin from the coast of Peru and concluded that the body proportions fitted those of *D. bairdii* from the Gulf of California, adding ' it appears that there is a *bairdii*-like population of dolphins in the eastern South Pacific Ocean '. But whatever differences may exist between the stocks of common dolphins in different oceans, they can hardly warrant more than the subspecific rank afforded them by Hershkovitz (1966) who gives *D. bairdii* as *D. delphis bairdii*.

Aguayo (1975) has recorded other species of dolphins from Chilean seas.

Porpoises (Phocoena sp.)

Porpoises (*Phocoena* sp.) were sighted on five occasions during the expedition off Chile in 1964 (Table 1). The sightings ranged from 50 to 85 nautical miles from the nearest land, which is unusual for *Phocoena* which is regarded as a coastal form. Their abundance was 5.3 per 100 nautical miles sailed. No porpoises were encountered sailing the same track in 1958 (see p. 127).

All the porpoises were of the same species. The numbers in schools were as few as six to as many as 50–60. One school of 15–20 was feeding on ' sardine ' (*anchoveta ?*) shoals when first sighted ; another school, of 50–60, was accompanied by flocks of petrels. Both these schools were approached for observation. When chased they ran faster than our maximum speed of 13 knots. Whilst running they repeatedly leapt from the water in true porpoise fashion. They were small, stout porpoises, between 0.9 m (3 ft) and 1.5 m (5 ft) long, mostly about 1.2 m (4 ft). The shapes of the head and dorsal fin were typical of the common porpoise, *Phocoena phocoena.* The animals were coloured lead-brown above and white beneath. The white of the ventral surface extended to the flanks where it merged with the dorsal lead-brown in an area of dirty white. The flukes were darkly pigmented.

Norris and McFarland (1958) reviewed the genus *Phocoena* and concluded that there were only four valid species, *spinipinnis*, *sinus*, *phocoena* and *dioptrica.*

Burmeister's porpoise, *Phocoena spinipinnis* and the spectacled porpoise, *Phocoena dioptrica*, are known only from the southern hemisphere. *P. spinipinnis* is common along the coasts of Chile and Peru, and is known from Uruguay and Argentina (Brownell and Praderi, 1976). The ten records of *P. dioptrica* are from Uruguay, Argentina as far as Tierra del Fuego, the Falkland Islands and South Georgia (Brownell, 1975). But Allen (1925) considered that *P. dioptrica* Lahille 1912 was ' with little doubt ' the same as *Phocoena obtusata* described by Philippi (1893) from a single specimen caught in Talcahuano Bay on the coast of Chile. Fraser (1948) thought this only a possibility, and in 1968 argued that Philippi's *obtusata* should not be given priority until further evidence were forthcoming. Praderi (1971) considered *P. obtusata* a doubtful species. When we examined Philippi's text and figure (1893, Plate III, Fig. 1) we were convinced by Allen's argument that the two species are identical, and there appeared to be confirmation from Donoso-Barros (1975) who examined the holotype of *P. obtusata* in the Museo Nacional de Historia Natural, Santiago de Chile and considered it the same as specimens of *P. dioptrica* in the Museo de la Plata, Argentina. However, Brownell (1975) has also examined the holotype of *P. obtusata* and he believes that it is in fact a species of *Cephalorhynchus.* We therefore accept that the identity of *P. obtusata* still remains in doubt. In 1903 True had suggested, from the appearance of Philippi's figure, that *P. obtusata* might be a *Cephalorhynchus.* Hershkovitz (1966) placed *P. obtusata* simultaneously in the synonymy of *Cephalorhynchus eutropia* Gray, 1846 and in the synonymy (but with a question mark) of *P. dioptrica.*

C. eutropia is a rare dolphin of Chilean seas known mostly from skulls and two skeletons. From characters of the skull True (1903) found this to be almost certainly conspecific with *Tursio* (*Phocoena*) *albiventris* Perez, published by Philippi (1896) who had earlier (1893) named this dolphin *Phocoena* (*Hyperoodon ?*) *albiventris* Perez from a description and figure of the external form and colour provided by Dr. Perez Canto. It had been caught near Valparaiso. In 1896 Perez Canto himself published his description as *Phocoena albiventris* Perez Canto. His account of the head, dorsal fin and flipper of *P. albiventris* conform with those of the genus *Cephalorhynchus*. His dolphin was small (1.36 m, 4 ft 6 in), greenish-black above, extending to the flanks, with throat and belly white and a white patch behind the flipper. The flukes were pigmented. There was ' a dark line on the sides which runs from front to behind. (This line is not seen in the figure)'. Fraser (1948) called it the white-bellied dolphin, *Cephalorhynchus albiventris*. The ' handsome black and white beakless porpoises ' seen by Murphy (1925, p. 255) near Huacho, Peru may have been specimens of *Cephalorhynchus eutropia*, although Murphy thought they were probably *C. albifrons*, a species which Hershkovitz (1966) includes in the synonymy of *C. hectori* from New Zealand waters. Recently Aguayo (1975) has recorded that Dr. Kenneth S. Norris, in an unpublished report of 1968, took two specimens of a dolphin or porpoise which he identified as *C. eutropia*, and saw many more of the same species at sea between 37° and 40°S on the coast of Chile.

Now the porpoises we saw on the expedition of 1964 were neither Burmeister's porpoise nor the spectacled porpoise. The first author has become familiar with the appearance of *P. spinipinnis*, first in the fish market at Chimbote (R. Clarke, 1962, p. 279, footnote) and thereafter in the markets at Chimbote, Ancón, Callao, Pucusana, San Andres and Ilo, whilst he was fishing on the coast of Peru during 1971 and 1972. Another of us (A.A.L.) has also observed a school of eight *P. spinipinnis* at the mouth of the Loa River in Chile in 1965 (Aguayo, 1975). *P. dioptrica* should be easily recognised at sea, being very distinctly marked in black and white and showing sexual dimorphism of the dorsal fin (Fraser, 1968; Brownell, 1975). On the other hand our porpoises could have been, with regard to size and colour pattern, the white-bellied dolphin *C. eutropia* as described by Perez Canto; his ' dark line on the sides ' could have been the dirty white area on the flanks of our porpoises where dark and white merged. But again, our field notes say that the head and dorsal fin were typical of *Phocoena*.

We come now to compare the northern species, *Phocoena phocoena* and *P. sinus*, with our porpoise. In the external characters we were able to observe, it only differs from *P. phocoena* in its rather smaller size and the lead-brown colour of the back which is black in *P. phocoena*. The latter is widely distributed in northern seas, but it has not been reported from the southern hemisphere, which is not to say that our porpoise may not be a southern race of the species. On the other hand, Norris and McFarland (1958) described a new porpoise, *Phocoena sinus*, from a skull cast up in the Gulf of California. Little is known of the colour pattern of *P. sinus* (Brownell, 1976), but there have been sightings of porpoises believed to belong to this species, where the animal is described as rather less than five feet in length, and of a uniform brown colour dorsally (Norris and McFarland, 1958), as five to six feet long and ' dull lead grey in colour with a slight brownish cast ', and as somewhat over four feet long, and lead grey above grading to white below (observers cited by Norris and Prescott, 1961). The size and colour of our porpoise agree with these observations, but *P. sinus* is considered at present to have a very limited distribution in the Gulf of California (Brownell, 1976).

We therefore prefer to record our porpoise as *Phocoena* sp. until such time as specimens may be obtained.

R. Clarke (1962) called attention to the paucity of our knowledge of the taxonomy and bionomics of the smaller cetaceans of the Southeast Pacific. His remarks are reinforced by this discussion of the small whales, dolphins and porpoises we could not identify in the expedition of 1964.

WHALE MARKING

During the expedition 53 sperm whales and one fin whale were estimated to have been effectively marked. The positions of marking are shown in Fig. 1. A copy of the whale marking records is lodged with the Whale Research Unit, British Antarctic Survey, Cambridge, United Kingdom.

Methods and precautions

The procedures of marking whales (Pl. IV, Fig. 1) and recording the results followed those used in 1958 and 1959 and were similar to those described by R. Clarke and Ruud (1954). Before firing all marks were smeared with an antibiotic ointment to guard against infection of the wound of entry of the mark, as recommended by Ruud, Clarke and Jonsgård (1953) and R. Clarke (1971). To avoid the risk of a mark penetrating to the body cavity of the whale, the marksman aimed at the region of the dorsal fin of whalebone whales (Ruud, Clarke and Jonsgård, 1953), but the aim was directed at the region behind the dorsal fin when marking sperm whales, for reasons explained by R. Clarke (1971). On the voyages of 1958 and 1959 in Chilean and Ecuadorean seas, no whales estimated to be less than 38 ft (11.6 m) in length were marked, because the first author of the present paper considered them too small to be marked without risk of injuring the whale. But few female sperm whales exceed 38 feet, and on the voyage of 1964 we reduced this minimum size for marking to 36 ft (11.0 m) so as to make available the larger female sperm whales and also more of the smaller males. We agree with Clarke (1971) that, unless there is experimental evidence to the contrary from the marking of carcases, a minimum length of 36 feet should be strictly observed for the safe marking of any species of whale where the standard 12-bore *Discovery* mark is employed.

TABLE 9. WHALE MARKS EXPENDED OFF THE COAST OF CHILE IN 1964

Result of shot	Fin	Sei	Sperm	Total	Percent
Hit	1		56*	57*	62
Hit, mark protruding			8	8	9
Possible hit			5	5	5
Ricochet			4	4	4
Miss		4	13	17	18
No verdict				0	0
Wasted				1	1
Total expenditure	1	4	86	92	99

* Three whales marked twice.

Whale marks and their expenditure

The expenditure of whale marks is shown in Table 9. About 25% of the sperm whales sighted were considered to have been effectively marked, and we could have marked many more had we not observed the minimum size for marking of 36 ft.

The blubber of sperm whales is very hard: when marking sperm whales off the coast of Chile in 1958, a large proportion of the marks which scored hits were seen to protrude from the blubber. Whales struck in this way are not considered to be effectively marked, because no mark recorded as protruding has ever been recovered from a whale (with one exception), presumably because the mark eventually falls out from the blubber. Accordingly, for the marking in Ecuadorean seas in 1959, a mark was developed with a slightly more powerful cartridge than that used for whalebone whales. The modified mark proved successful in 1959 (R. Clarke, 1962), and these special marks for sperm whales were also used off Chile in 1964. Of the combined total from 56 hits and eight hits with the mark protruding on sperm whales (Table 9), 13% were hits with the mark protruding which we consider very satisfactory. R. Clarke (1962) gave details of the modification, and we recommend these marks for future use on sperm whales.

Recoveries of whale marks

Up to the time of completing this report, two of the sperm whales marked in 1964 have been recaptured.

Mark no. 23539 was fired into a male sperm whale, estimated to be 49 ft (14.9 m) long, at three miles from Isla Chañaral in 29°01′S, 71°41′W on 30 November 1964, and the whale was in an unclassified school (Table 1, time 0715 to 1020). It was shot on 7 January 1967 in 36°40′S, 73°40′W near Talcahuano where the mark was recovered and the length of the whale recorded as 37 ft. This figure for length must have been a clerical error at the whaling station because we believe that our estimates of the sizes of whales approached for marking were accurate within one foot. The recovery establishes a local displacement of 470 nautical miles southward parallel to the coast in three years (Fig. 4). Although there is no way of knowing the whale's movements in the interval between marking and recovery, this is evidence that sperm whales are indeed moving through the seas adjacent to the coast of central Chile, and that the stock is a local one in the sense that the whales return to the same ground. Perhaps the date of recovery is significant also, because if the whales in successive years were to keep to the same procession of movement with time, then we might well expect a sperm whale which is off Isla Chañaral in November, embarked on a leisurely southward migration combined with feeding, to be off Talcahuano five weeks later in January.

The second recovery is especially interesting, as Brown (1976) has noted. Mark no. 23598 was fired into a male sperm whale, estimated as 40 ft (12.2 m) long, in 29°42′S, 71°37′W where it was one of the great concentration of 90–110 sperm whales (which included harem schools, Table 1) encountered SW of Isla Pájaros on 30 November 1964. The whale was shot in the Bellingshausen Sea

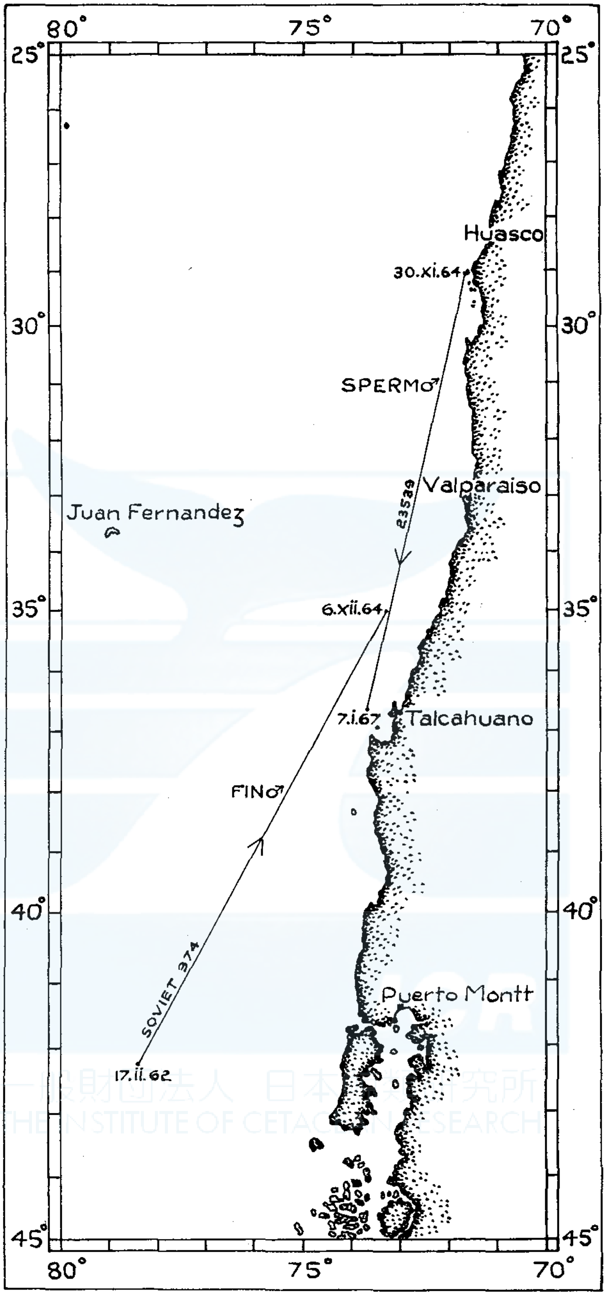

Fig. 4. Recoveries on the coast of Chile of a sperm whale marked in 1964, and of a fin whale bearing a Soviet mark.

in 66°01′S, 83°03′W on 19 December 1973, and it was recorded as 46 ft (14.0 m) long. This recovery after nine years shows a southerly movement of 2,200 nautical miles by the shortest route from sub-tropical latitudes deep into Antarctic Area I (Fig. 5), and is direct evidence from whale marking of the migration into the Antarctic of male sperm whales from the breeding stock of low latitudes. A less extensive penetration into the Antarctic has also been demonstrated from West Australian waters where a sperm whale marked off Albany in 1963 was recovered in 1971 south of Tasmania in 46°31′S, 148°42′E (Brown, 1973). There is one other marking record from elsewhere which shows the return migration: a male sperm whale marked by a Soviet vessel in the Antarctic in the western part of Area III in December 1967 was recovered four and a half months later 2,000

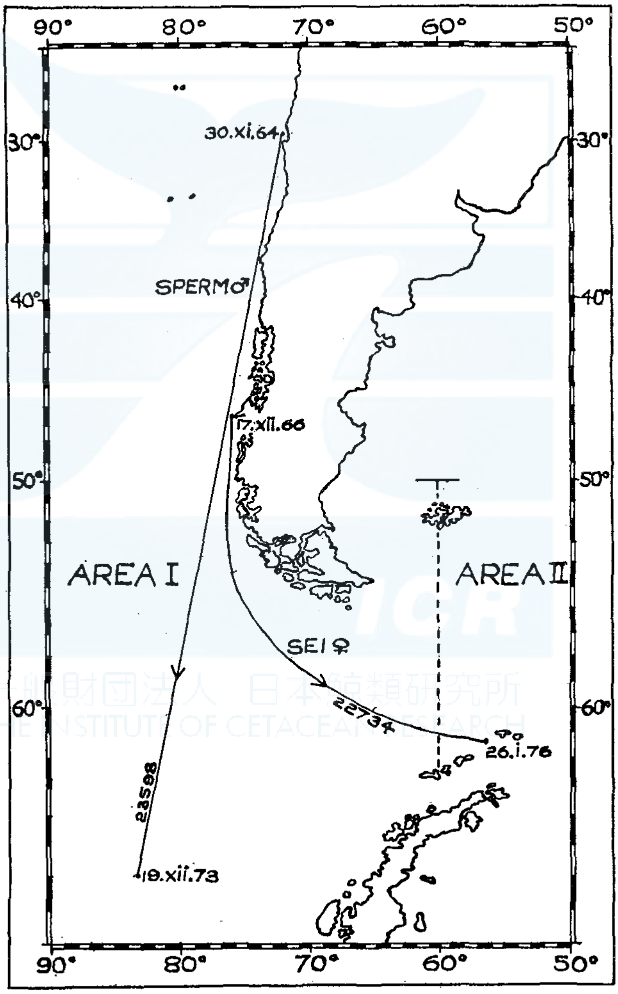

Fig. 5. Recoveries in the Antarctic of a sperm whale marked in 1964 and of a sei whale marked in 1966 off Chile.

nautical miles to the northward in the Indian Ocean off Durban (Best, 1969b).

The recovery of mark no. 23598 is also of interest regarding age determination in sperm whales. Most workers are now agreed that the rate of accumulation of dentinal growth layers in the teeth is one per year (Ohsumi, Kasuya and Nishiwaki, 1963; Best, 1970a; Gambell, 1972) but Berzin (1971) believes that two layers accumulate each year. In Best's mean growth curve for male sperm whales off the west coast of South Africa (1970a, Fig. 5), growth from 40 to 46 ft corresponds with an increase of eight dentinal growth layers, from 21 to 29, so that growth of the whale with mark no. 23598 from 40 ft (estimated) to 46 ft in nine years supports a rate of accumulation of one growth layer each year.

No further marks have been recovered from the voyage of 1964, and there are no additions to the recoveries discussed by R. Clarke (1962) from the voyage off Chile in 1958, whilst so far there have been no recoveries from the voyage of 1959 in Ecuadorean seas. However, we may appropriately discuss here two recoveries from whalebone whales marked on other voyages off the coast of Chile.

We are indebted to Dr M. V. Ivashin of the All-Union Research Institute of Marine Fisheries and Oceanography, Moscow for details of the marking of a fin whale with Soviet mark no. 974 on 17 February 1962 in 42°20'S, 78°23'W. The whale was shot on 6 December 1964 in 35°S, 73°10'W and the mark recovered at Quintay where the whale was recorded as a male 19.8 m (65 ft) long. The minimum displacement was 500 nautical miles after nearly three years (Fig. 4). The recovery is evidence that the same fin whales are moving off the coast of Chile from year to year. Although the recovery gives no information on the actual range of the whale's movements in the interim after marking, it was probably in February 1962 at the rear of the procession of fin whales which was moving past southern Chile into the Antarctic in the summer of 1961/62, because we know, from the recapture in Antarctic Area II of four fin whales from 11 marked off Chile in 1958, that the fin whales off the coast of central Chile in spring are migrants belonging to a stock which moves through Drake Strait to frequent the western part of the Atlantic sector of the Antarctic in summer (R. Clarke, 1962).

The other recovery is from a sei whale marked by one of us (A.A.L.) with two marks, nos 22734 and 22741, off the Taitao Peninsula of southern Chile in 46°32'S, 75°55'W on 17 December 1966, when it was estimated to be 49 ft (14.9 m) long. The marks were recovered (no. 22734 from the whale, no. 22741 from the factory ship deck) in the western part of Antarctic Area II, 61°20'S, 56°22'W, on 26 January 1976, and the whale was recorded as a female, 52 ft (15.9 m) long. The minimum displacement after nine years was about 1,250 nautical miles (Fig. 5). Reporting the recovery, Brown (1977) has emphasised that this movement through Drake Strait into the western Atlantic sector of the Antarctic is directly comparable with that of fin whales marked off Chile in 1958.

The direct evidence from whale marking reviewed here shows that not only fin whales, but also some parts of the sei whale stock and the male sperm whale stock of the Southeast Pacific are exploited on their migrations by coastal whaling from Chile, where regulation is under the Permanent Commission of the South

TABLE 10. FISHING FOR SQUIDS AND FISH BY

Station No.	Date	Position	Duration	Surface Temp. °C	Bait	Casts	
						Depth m	Duration min.
I_{14}	24. xi	33°04′S, 72°28′W	2145–2330	16.1°		50	15
						100	15
I_{15}	25. xi	33°15′S, 75°00′W	2120–2155	16.9°	—	—	—
I_{16}	26. xi	31°20′S, 73°55′W	2110–2255	17.0°		25	5
						50	10
I_{17}	27. xi	30°42′S, 72°00′W	2110–2135	15.6°	Putrid meat	25	2
						50	5
						50	15
I_{18}	28. xi	29°16′S, 71°47′W	2230–2330	15.1°	Putrid meat	50	30
I_{19}	29. xi	28°38′S, 72°00′W	2115–2130	17.0°	—	—	—
I_{20}	1. xii	30°15′S, 72°31′W	2130–2215	17.5°	Fish (Jurel, *Trachurus trachurus*)	25	15
						50	15
I_{21}	2. xii	30°17′S, 75°00′W	2000–2015	18.1°	—	—	—
I_{22}	3. xii	30°27′S, 74°08′W	0345–0600		—	—	—
I_{23}	3–4. xii	31°57′S, 73°10′W	2000/3–0600/4	17.2°		25	15
						50	15
I_{24}	7. xii	34°07′S, 72°17′W	2145–2230	17.2°	None	4	20
I_{25}	8. xii	35°24′S, 73°33′W	2150–2235	17.6°	None	25	15
						50	15
I_{26}	9–10. xii	35°17′S, 75°00′W	2050/9–0200/10	17.3°	—	—	—
I_{27}	10. xii	36°16′S, 74°54′W	2045–2330	16.8°	Meat	50	30
					Garfish	25 50	30

Continued . . .

INDUS XIV OFF THE COAST OF CHILE IN 1964

Squid fishing

Strikes	Captures	No. of strikes and/or captures per hour	Remarks	Other observations
0	0	0		Schools of garfish (*Scomberesox*) passing every 2–3 minutes. Each school contained 50–200 fish.
0	0	0		
—	—	Present	No fishing, but three specimens of *Dosidicus gigas* were washed on deck during the night. Preserved.	Two specimens of *Scomberesox* washed on deck during the night.
0	0	0, but present	Numbers of squids, of 0.4–0.5 m standard length, present at the surface. A large squid, about 2.5 m long, appeared for a moment.	Hand lining for 15 min. at 50 m caught nothing
0	0			
	1	9	A large *D. gigas* of about 1.5 m standard length was captured, but it broke at the surface and only the head was recovered.	Two specimens of *Scomberesox* washed on deck.
2				
0	0			
0	0	0		Six specimens of *Scomberesox* caught in handnet.
—	—	?		Ship stopped only for basic station routine.
0	0	0, but present	Two squids caught by the watch during the night, but later they were lost.	
0	0			
—	—	?		Ship stopped only for basic station routine.
—	—	Present	Two specimens of *D. gigas* caught by the watch during the night. Preserved.	The watch caught with a handnet 37 specimens of *Scomberesox* and 18 myctophids.
0	0	0, but present	Three specimens of *D. gigas* caught by the watch during the night. Preserved.	Hand lining for 30 minutes between 25 and 50 m caught nothing.
0	0			
4	5	27	A great number of squid, hunting *Scomberesox*, surrounded the ship at the surface (1–4 m). They were all 1.0–1.5 m long. The five captures were *D. gigas*. Preserved. The colour changes of one squid were noted.	A single specimen only of *Scomberesox* was caught.
0	0	0	No squids seen at the surface.	Some *Scomberesox* were seen.
0	0			
—	—	?	Because of a heavy swell, no fishing was attempted.	Some *Scomberesox* were washed on deck as the ship rolled. Nine were preserved.
0	0	0	No squids seen at the surface.	One specimen of *Scomberesox* washed on deck.
0	0			

Continued . . .

TABLE 10.

Station No.	Data	Position	Duration	Surface Temp. °C	Bait	Casts Depth m	Casts Duration min.
I_{28}	11. xii	36°35′S, 73°10′W	1510–1530	16.5°	—	—	—
I_{29}	12. xii	35°41′S, 74°52′W	2030–2045	17.1°	Garfish	50	15
I_{30}	14. xii	33°55′S, 75°26′W	2110–2130	17.5°	—	—	—
I_{31}	15. xii	33°55′S, 74°00′W	2100–2315	16.5°	Garfish	25	15
						50	30

Pacific, and in summer in the Antarctic by factory ships operating under regulations of the International Whaling Commission. This increases the urgency for that close cooperation between the Commissions recommended by R. Clarke (1962) after discussing fin whale migrations.

OTHER WORK ON THE VOYAGE

Each night in 1964 when the ship was stopped a brief oceanographical station was worked ; the data and samples have been deposited with the Estación de Biología Marina de Montemar. The routine comprised a surface water sample and surface temperature record, and vertical hauls with phytoplankton net and zooplankton net from 20 m to the surface (Fig. 1, Table 10). The stations were numbered I_{14} to I_{31} in continuation of the similar stations (I_1–I_{13}) worked on the voyage of 1958 (R. Clarke, 1962).

Station I_{28} was worked in the daytime to sample the only patch of discoloured water seen on the voyage (Table 10). There were two occasions when the ship continued sailing through the night, so that we stopped only to work the basic routines of stations I_{19} and I_{21}. At all the remaining 15 night stations we fished under a cargo light for squid with hand lines and for fish with a hand net.

Fish

The only fish seen or caught were myctophids and garfish.

The myctophids were recorded at only one station, I_{22}, and the catch appeared similar to *Myctophum clarkei* de Buen, taken during the voyage of 1958 (R. Clarke, 1962).

The garfish were widely distributed on the track of the voyage, being present at ten of the 15 stations where fishing was conducted. They were sampled at seven of the stations and all the samples have been identified by Dr Walter Fischer as *Scomberesox stolatus* de Buen. This is the *punto fijo* of Chilean seas, formerly confused with *Scomberesox equirostrum* Le Sueur and described, from specimens collected on the voyage of 1958, as a new species by de Buen in 1959. Our unsexed sample

Continued.

Squid fishing				
Strikes	Captures	No. of strikes and/or captures per hour	Remarks	Other observations
—	—	?	No fishing.	Ship stopped to sample a patch of discoloured water, 3–10 m in diameter, of reddish brown colour
0	0	0	No squids seen the surface.	
—	—	?	No fishing. No squids were seen at the surface.	Three specimens of *Scomberesox* washed on deck.
0	0	0	No squids seen at the surface.	
0	0	0		

of 45 individuals from 1964 had a mean length of 32.33±6.39 cm. As on the voyage of 1958, *S. stolatus* was abundant and sometimes present in immense numbers. At station I_{14} schools of 50–200 *Scomberesox* were passing every 2–3 minutes for a period of 105 minutes.

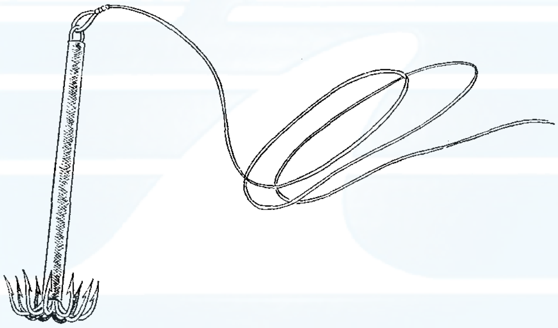

Fig. 6. The *tota* used in fishing for squid from the *INDUS XIV*.

The squid Dosidicus gigas

Table 10 shows the results of fishing for squid. The hand lines were mostly fished at 25 m and 50 m for periods of 15–60 minutes; one cast at 100 m yielded nothing. We used a jig called the *tota* by Chilean squid fishermen (Fig. 6). It is a copper tube, 1.6 cm in diameter and 15 cm long, with about 12 fish hooks protruding in a rosette from one end. The baits used were putrid meat, garfish, and the fish *jurel* (*Trachurus trachurus*), although our best catch, at station I_{24} was made without bait, using the *tota* purely as a jig at 4 m depth. In other seas use of the unbaited jig for squid fishing is widespread (Lane, 1957, p. 132).

Squid were either seen or caught at seven of the 15 night stations. The 14 captures were preserved by injection with 10% formalin (Pl. IV, Fig. 2), and later deposited at Montemar where all were identified as *Docidicus gigas* by Mr Patricio

TABLE 11. RECORDS OF THE HUMBOLDT CURRENT SQUID *DOSIDICUS GIGAS* COLLECTED BY *INDUS XIV* OFF THE COAST OF CHILE IN 1964

Station No.	Sex	1) Total length cm	1) Standard length cm	2) Mantle length cm	2) Width of fins cm	2) Length of fins cm	Sexual maturity	Stomach contents
I_{15}	Male	48	44	26.5	—	—	Imm.	Empty, except for a few fish remains
	Male	47	42	24.5	—	—	Imm.	Full of fish remains
	Male	47	41.3	24	—	—	Imm.	Empty, except for a few fish remains
I_{17}		ca 150		(Only the head recovered. Longest arm 44 cm, tentacles 62 cm)				
I_{22}	Female	130	110	59	45	31	Imm.	Fish remains
	Male	129	110	59	—	—	Mat.	Fish remains
I_{23}	Female	121	103	58	—	—	Imm.	Full of fish remains
	Female	118	100	55	—	—	Imm.	Fish remains
	Female	97	80	47	33	24	Imm.	
I_{24}	Female	141	114	59	—	—	Imm.	Fish remains, and remains of a squid tentacle which was not *D. gigas*
	Female	133	109	58	—	—	Imm.	Empty except for fluid
	Female	121	103	57	—	—	Imm.	Empty
	Male	118	108	55	—	—	Mat.	Remains of squid, possibly *D. gigas*
	Male	116	94	48	37	25	Imm.	Empty

1) Measured fresh

2) Measured after preservation in 10% formol.

García-Tello. We are confident that those we saw at the surface but did not catch were also *D. gigas*, as were those seen or captured on the voyage of 1958 (R. Clarke, 1962). This squid is important in the diet of sperm whales in the Southeast Pacific, and we have already discussed our results on the incidence and abundance of *D. gigas* in relation to the distribution of the sperm whales sighted (p. 144 ff). We give here our observations on the squid itself.

The largest individual seen was about 2.5 m (8 ft 6 in) long and appeared for a moment at the surface at Station I_{16}. The largest hooked was about 1.5 m (5 ft) long but only the head was recovered. Duncan (1941) recorded a capture 9 ft (2.7 m) long, and Professor Gilbert L. Voss, reported by Lane (1957, p. 131), says that *D. gigas* growths to a total length of 12 ft (3.7 m) and mantle length 6 ft (1.8 m). Table 11 records Mr Patricio García-Tello's examination of our captures. On these data males are seen to become sexually mature between 1.16 m and 1.18 m total length, say 1.17 m (mantle length, 0.52 m), whilst females are still immature at 1.41 m (mantle length, 0.59 m). This indicates that the females of *D. gigas* are larger than the males, unless the latter grow more rapidly after sexual maturity.

The fish remains which occurred in eight of the nine stomachs of *D. gigas* which contained food (Table 11) probably included *Scomberesox stolatus*, for we saw the squid feeding voraciously on this fish at Station I_{24}. R. Clarke (1962) also reported them feeding on *S. stolatus* during the voyage of 1958. '*Scomberesox equirostrum*' (*S. stolatus*) was found by de Sylva (1962) in one out of six stomachs containing food in specimens of *D. gigas* caught off northern Chile. The stomach of one of the squids from Station I_{24} contained the remains of squid, possibly *D. gigas* (Table 11). This was to be expected because at Station I_{11} the free-swimming squids were seen to attack their captured fellows as the line was hauled. Duncan (1941) and Wilhelm (1954) have also reported cannibalism in this species.

The captured *D. gigas* showed spectacular colour changes when brought on deck. One specimen at Station I_{24} showed the following changes over the mantle within three minutes of reaching the deck: lead-brown, deep crimson, ochre, dirty cream, brick-red and reddish-brown.

SUMMARY

An account is given of an expedition in the whalecatcher *Indus XIV* to observe and mark whales off the coast of Chile between 28° and 37°S from 24 November to 17 December 1964. This voyage repeated (with a small extension to the southward) the track of an earlier expedition conducted from 21 October to 6 November 1958, and a major object was to compare the abundance of the exploited whale species after a lapse of six years.

In 1964 there were sighted 209–224 great whales, comprising 199–219 sperm whales, four blue whales, one fin whale, one sei whale, and four whales far away, of which three were whalebone whales.

The sighting of four blue whales on the southern part of the track of 1964 prompts a discussion on the presence of the pigmy blue whale, *Balaenoptera musculus brevicauda* as well as the much depleted ' main stock' blue whale *B. m. intermedia* off the coast of Chile.

A drastic reduction in the abundance of fin whales, from 5.1 per 100 nautical miles sailed in 1958 to 0.1 in 1964, is attributed to the effect of Antarctic whaling because whale marks recovered from the voyage of 1958 have established that fin whales off Chile in spring are migrating to the Antarctic. Subsequent intensive fin whaling from Chile in 1964–66 further depleted the stock. Fin whaling in the Antarctic has been prohibited by the International Whaling Commission since 1976, and there is reason for the Permanent Commission of the South Pacific to prohibit the taking of fin whales in Chile and Peru likewise until the stock shall have recovered.

One sei whale was sighted in 1964 as also in 1958. Sei whales and Bryde's whales are both present off Chile, and the possibility of distinguishing them at sea is discussed.

In 1964 there were sighted 11.9 sperm whales per 100 nautical miles sailed compared with 1.7 in 1958. This increase is attributed to a seasonal influx into the area of the breeding stock moving southwards, as shown by the presence in November-December (of 1964) of few solitary males, larger schools, more females and calves and young whales, and a general southerly movement of the whales not feeding, compared with the situation in October-November (of 1958). Thus it is not suggested that the stock had increased between 1958 and 1964, but there was no evidence of a decline.

The distribution of sperm whale schools in relation to surface temperatures in 1958 and 1964 does not support Schubert's conclusion (1951, 1955) that in the Humboldt Current there is an orderly segregation from the coast westward of solitary males in the coldest water, followed successively by bachelor schools and female schools in the warmer water. Solitary males were seen in water of 13.6°–18.7°C, and females in harem schools in water as cold as 14°C, although nursery schools seemed limited to water not colder than 18°C. Limiting temperatures observed for females and calves in other seas are reviewed, and it is concluded that in the southern hemisphere the temperatures at the subtropical convergence are in general those at the limits of female distribution.

Because the large Humboldt Current squid, *Dosidicus gigas*, is known to be important in the diet of sperm whales in the Southeast Pacific, an attempt was made to correlate the distribution and abundance of sperm whales with those of *D. gigas*, as revealed by squid fishing during night stations worked in 1964. No such correlation was observed and possible reasons are suggested. A discussion follows on the fact that in other seas surface-living ommastrephid squid are eaten rarely or not at all by sperm whales.

From the external characters of blackfish observed in 1964, the species is tentatively identified as *Globicephala melaena edwardi* and its general distribution in the Southeast Pacific is reviewed. Distribution and abundance off Chile were very similar in 1958 and 1964, the abundance being 11.0 per 100 nautical miles sailed in 1964 and 13.2 in 1958. Since blackfish are at present unexploited from Chile no change in abundance was to be expected between 1958 and 1964, and these results on blackfish lend confidence to the comparisons of the abundance of other whales on the two voyages. The schooling of blackfish and their habit of mingling with other cetaceans are reviewed. From the results of the voyages of 1958 and 1964 it is recommended that the blackfish resource off Chile should be exploited by a controlled fishery.

Two unconfirmed sightings in 1964 of the southern bottlenosed whale, *Hyperoodon planifrons*, lead to a critical review of sightings in Chilean seas of whales believed to be *H. planifrons*, which can easily be confused with other ziphioid whales at sea.

The appearance at sea is described of an unidentified toothed whale, 4.5–6.0 m (15–20 ft) long, schools of which were encountered twice in 1964. It is possibly of the genus *Pseudorca* or *Grampus*, and agrees with the unidentified, high-finned whale described by Wilson (1905, 1907) from the Antarctic.

Dolphins sighted on four occasions in 1964 were all of the same species. Their appearance is described and they are believed to be *Tursiops* sp. Reports are discussed of other dolphins from Chilean seas.

Porpoises, *Phocoena* sp., were sighted on five occasions in 1964, uncharacteristically far off the coast for this genus. They were like the common porpoise *Phocoena phocoena* but smaller. A discussion on their identity leads to a review of species of *Phocoena* and *Cephalorhynchus* described from the Southeast Pacific, and their synonymy.

One fin whale and 53 sperm whales were marked in 1964. Precautions were taken to avoid injury to the whales when marking them. No whales estimated to be less than 36 ft (11 m) long were marked.

Two sperm whales marked in 1964 have been recovered to date. One marked in 29°01′S, 71°41′W was recovered in 36°40′S, 73°40′W, 470 nautical miles to the southward after three years, showing that sperm whales are indeed moving through the seas adjacent to the coast of central Chile, and that the stock is a local one in the sense that the whales return to the same ground. The second whale was marked in 29°42′S, 71°37′W and recovered nine years later to the southward in Antarctic Area I in 66°01′S, 83°03′W, a minimum displacement of 2,200 nautical miles. This is direct evidence of the migration into the Antarctic of male sperm whales from the breeding stock of low latitudes. Also the estimated length of the whale at marking and the length at recovery support the view that one dentine growth layer accumulates in the teeth each year.

Two recoveries are discussed from other whale marking voyages off Chile since 1958. A Soviet whale mark fired into a fin whale on 17 February 1962 in 42°20′S, 78°23′W was recovered nearly three years later 500 nautical miles to the NNE, in 35°S, 73°10′W, and is evidence that the same fin whales are moving off the coast of Chile from year to year. A sei whale marked in 46°32′S, 75°55′W on 17 December 1966 was recovered in the western part of Antarctic Area II in

61°20′S, 56°22′W after nine years, a minimum displacement of 1,125 nautical miles, and showing a migration route like that of fin whales recovered in the Antarctic from marking off Chile in 1958.

This direct evidence that not only the same fin whales, but also the same sei whales and male sperm whales, are being exploited in the Southeast Pacific and in the Antarctic increases the urgent need for close cooperation between the Permanent Commission of the South Pacific and the International Whaling Commission.

Eighteen brief oceanographical stations (I_{14}–I_{31}) were worked when the ship was stopped at night in 1964. Fishing for squid and fish was conducted at 15 stations. The fish caught were myctophids and the garfish *Scomberesox stolatus*. All the squid were *Dosidicus gigas*, and in 14 specimens the males were sexually mature at total length 1.17 m (mantle length, 0.52 m), whilst the females were still immature at 1.41 m total length (mantle length, 0.59 m). The squid were feeding on *Scomberesox stolatus* and on each other.

RESUMEN

Se informa sobre una expedición en el barco cazador *Indus XIV* para observar y marcar ballenas frente a la costa de Chile entre 28° y 37°S desde el 24 de Noviembre hasta el 17 de Diciembre de 1964. Este viaje repitió (con una pequeña extensión hacia el sur) la ruta de una expedición anterior conducida desde el 21 de Octubre hasta el 6 de Noviembre de 1958; y un objetivo mayor fué comparar la abundancia de las especies de ballenas explotadas después de un lapso de seis años.

En 1964 se avistaron 209–224 ballenas grandes, comprendiendo 199–219 cachalotes, cuatro ballenas azules, una ballena de aleta, una ballena boba, y cuatro ballena lejanas, de las cuales tres fueron ballenas con barbas.

El avistamiento de cuatro ballenas azules en la parte sur de la ruta de 1964 promueve una discusión sobre la presencia de la ballena azul pigmea, *Balaenoptera musculus brevicauda* como también de la muy disminuida ballena azul ‘ existencia principal ’ *Balaenoptera musculus intermedia* frente a la costa de Chile.

Una reducción drástica en la abundancia de ballenas de aleta, de 5.1 por 100 millas navegadas en 1958 a 0.1 en 1964, se atribuye al efecto de la caza Antártica porque marcas de ballenas recuperadas desde el viaje de 1958 han establecido que las ballenas de aleta que se encuentran frente a Chile en la primavera están migrando a la Antártica. Posteriormente una caza intensiva de ballenas de aleta desde Chile en 1964–66 disminuyó aún más la existencia. La caza de ballenas de aleta en la Antártica ha sido prohibida por la Comisión Ballenera Internacional desde 1976, y hay igual razón para que la Comisión Permanente del Pacífico Sur prohiba la captura de ballenas de aleta en Chile y Perú hasta que la existencia se haya recuperado.

Una ballena boba fué avistada en 1964 como también en 1958. Ballenas bobas y ballenas de Bryde existen ambas frente a Chile, y se discute la posibilidad de diferenciarlas en el mar.

En 1964 se avistaron 11.9 cachalotes por 100 millas navegadas comparado con 1.7 en 1958. Este aumento es atribuido a un influjo estacional en el área de la existencia de reproducción moviéndose hacia el sur, como se muestra por la presencia en Noviembre-Diciembre (de 1964) de pocos machos solitarios, de grupos más grandes, de más hembras y crías y de juveniles, y un movimiento general hacia el sur de las ballenas que no estaban alimentándose, comparado con la situación en Octubre-Noviembre (de 1958). Por lo tanto no se sugiere que la existencia de cachalotes había aumentado entre 1958 y 1964, pero tampoco hubo evidencia de una disminución.

La distribución de grupos de cachalotes en relación a las temperaturas superficiales en 1958 y 1964 no apoya la conclusión de Schubert (1951, 1955) que en la Corriente de Humboldt hay una segregación ordenada desde la costa hacia el oeste de machos solitarios en las aguas más frías, seguidos sucesivamente por grupos de machos solteros y grupos de hembras en aguas más templadas. Machos solitarios fueron vistos en aguas de 13.6°–18.7°C, y hembras en grupos harenes en aguas tan frías como 14°C, aunque grupos criaderos (grupos de crianza) aquellas parecían limitados a aguas no mas frías que 18°C. Las temperaturas limitantes observadas para las hembras y crías en otros mares son revisadas, y se concluye que en el hemisferio del sur las temperaturas en la convergencia subtropical son en general encontradas en los límites de distribución de las hembras.

Como se sabe que la jibia grande de la Corriente de Humboldt *Dosidicus gigas*, es importante en la dieta de cachalotes en el Pacífico Sur Oriental, se hizo un intento de correlacionar la distribución y abundancia de cachalotes con aquellas de *Dosidicus gigas*, como estuvieron reveladas por la pesca de jibias durante las estaciones nocturnas trabajadas en 1964. No se encontró tal correlación y posibles razones son sugeridas. Sigue una discusión sobre el hecho que en otros mares las jibias epipelágicas de la familia Ommastrephidae son raramente o nunca comidas por cachalotes.

A partir de los caracteres externos de los calderones observados en 1964, la especie es identificada tentativamente como *Globicephala melaena edwardi* y su distribución general en el Pacífico Sur Oriental es revisada. La distribución y abundancia frente a Chile fueron muy semejantes en 1958 y 1964, siendo la abundancia 11.0 por 100 millas navegadas en 1964 y 13.2 en 1958. Como en la actualidad los calderones no son explotados en Chile, no se esperaba cambios en la abundancia entre 1958 y 1964, y estos resultados sobre el calderón dan confianza a las comparaciones de la abundancia de otras ballenas en los dos viajes. El agrupamiento de los calderones, y su costumbre de mezclarse con otros cetáceos, son revisados. De los resultados de los viajes de 1958 y 1964 se recomienda que la existencia de calderones frente a Chile debe ser explotada por una caza controlada.

Dos avistamientos no confirmados en 1964 de la ballena naríz de botella (graur colderón) *Hyperoodon planifrons*, conducen a una revisión crítica de avistamientos en aguas chilenas de ballenas supuestas ser *Hyperoodon planifrons*, las cuales pueden facilmente ser confundidas en el mar con otras ballenas de la familia Ziphiidae.

Se describe la apariencia en el mar de una ballena con dientes no identificada, 4.5–6.0 m (15–20 pies) de largo, grupos de las cuales fueron encontrados dos veces en 1964. Es posiblemente del género *Pseudorca* o *Grampus*, y está de acuerdo con la ballena de aleta alta no identificada descrita por Wilson (1905, 1907) de la Antártica.

Los delfines avistados en cuatro oportunidades en 1964 fueron todos de la misma especie. Se describe su apariencia y se cree que sean *Tursiops* sp. Informes de otros delfines de los mares chilenos son discutidos.

Marsopas, *Phocoena* sp., fueron avistadas en cinco oportunidades en 1964, extrañamente muy lejos de la costa para este género. Ellas eran parecidas a la marsopa común *Phocoena phocoena* pero más pequeñas. Una discusión sobre su identidad conduce a una revista de las especies de *Phocoena* y *Cephalorhynchus* descritas del Pacífico Sur Oriental, y de sus sinonimias.

Una ballena de aleta y 53 cachalotes fueron marcados en 1964. Se tomaron precauciones para evitar dañar a las ballenas cuando se marcaron. No se marcó ninguna ballena estimada ser menor de 11 m (36 pies) de longitud.

Dos cachalotes marcados en 1964 han sido recuperados hasta la fecha. Uno marcado en 29°01′S, 71°41′W fue recuperado en 36°40′S, 73°40′W, 470 millas naúticas hacia el sur después de tres años, mostrando que los cachalotes están en realidad moviéndose través de los mares adyacentes a la costa de Chile central, y que la existencia es una población local en el sentido que las ballenas regresan a la misma zona. La segunda ballena fué marcada en 29°42′S, 71°37′W y recuperada nueve añosm ás tarde hacia el sur en Area I de la Antártica en 66°01′S, 83°03′W, un desplazamiento mínimo de 2,200 millas náuticas. Esto es evidencia directa de la migración hacia la Antártica de cachalotes machos provenientes de la existencia de reproducción de bajas latitudes. También la longitud estimada de la ballena en la marcación y la longitud al recuperarla soportan el punto de vista que una capa de crecimiento de dentina se acumula en los dientes cada año.

Se discuten dos recuperaciones de otros viajes de marcación frente a Chile desde 1958. Una marca soviética disparada a una ballena de aleta el 17 de Febrero de 1962 en 42°20′S, 78°23′W fué recuperada casi tres años más tarde 500 millas naúticas al NNE, en 35°S, 73°10′W, y es evidencia que las mismas ballenas de aleta se están moviendo frente a la costa de Chile de año a año. Una ballena boba marcada en 46°32′S, 75°55′W el 17 de Diciembre de 1966 fué recuperada en la parte oeste de Area II de la Antártica en 61°20′S, 56°22′W después de nueve años, un desplazamiento mínimo de 1,125 millas, y mostrando una ruta de migración como la de las ballenas de aleta recuperadas en la Antártica de la marcación frente a Chile en 1958.

Esta evidencia directa, que no solo las mismas ballenas de aleta sino también las mismas ballenas bobas y cachalotes machos están siendo explotados en el Pacífico Sur Oriental y en la Antártica, aumenta la urgente necesidad de una cooperación estrecha entre la Comisión Permanente del Pacífico Sur y la Comisión Ballenera Internacional.

Dieciocho breves estaciones oceanográficas (I_{14}–I_{31}) fueron trabajadas cuando el barco estaba parado en las noches en 1964. Pesca de jibias y peces fué conducida en 15 estaciones. Los peces capturados fueron de la familia Myctophidae y el pez aguja (' punto fijo '), *Scomberesox stolatus*. Todas las jibias fueron *Dosidicus gigas*, y en 14 especímenes los machos estuvieron sexualmente maduros a la longitud total de 1.17 m (longitud del manto, 0.52 m) mientras que las hembras fueron aún inmaduras a 1.41 m de longitud total (longitud del manto, 0.59 m). Las jibias estuvieron alimentándose de *Scomberesox stolatus* y de ellas mismas.

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EXPLANATION OF PLATES

PLATE I

Fig. 1. Solitary male sperm whale on 28 November 1964 in 29°16 S, 71°47′W. (Photo: Robert Clarke).

Fig. 2. Harem school of sperm whales on 29 November 1964 in 29°03′S, 71°48′W. (Photo: Robert Clarke).

PLATE II

Fig. 1. Sperm whales, mother and calf from a nursery school, approaching the vessel on 30 November 1964 in 29°35′S, 71°38′W. (Photo: Robert Clarke).

Fig. 2. Blackfish, *Globicephala melaena edwardi*, one of a school of 35–40, on 26 November 1964 in 38°05′S, 74°52′W. The white area behind the dorsal fin may be seen. (Photo: Robert Clarke).

PLATE III

Fig. 1. Unidentified high-finned toothed whales on 24 November 1964 in 33°02′S, 72°11′W. See page 150. (Photo: Robert Clarke).

Fig. 2. Dolphins, believed to be *Tursiops* sp., below water at the bow of the vessel, from a school of eight animals on 27 November 1964 in 31°18′S, 73°41′W. (Photo: Robert Clarke).

PLATE IV

Fig. 1. Marking sperm whales from the whalecatcher *Indus XIV* on 30 November 1964. (Photo: Robert Clarke).

Fig. 2. Measuring and injecting captures of the squid *Dosidicus gigas* on board *Indus XIV* on 8 December 1964. (Photo: Anelio Aguayo L.)

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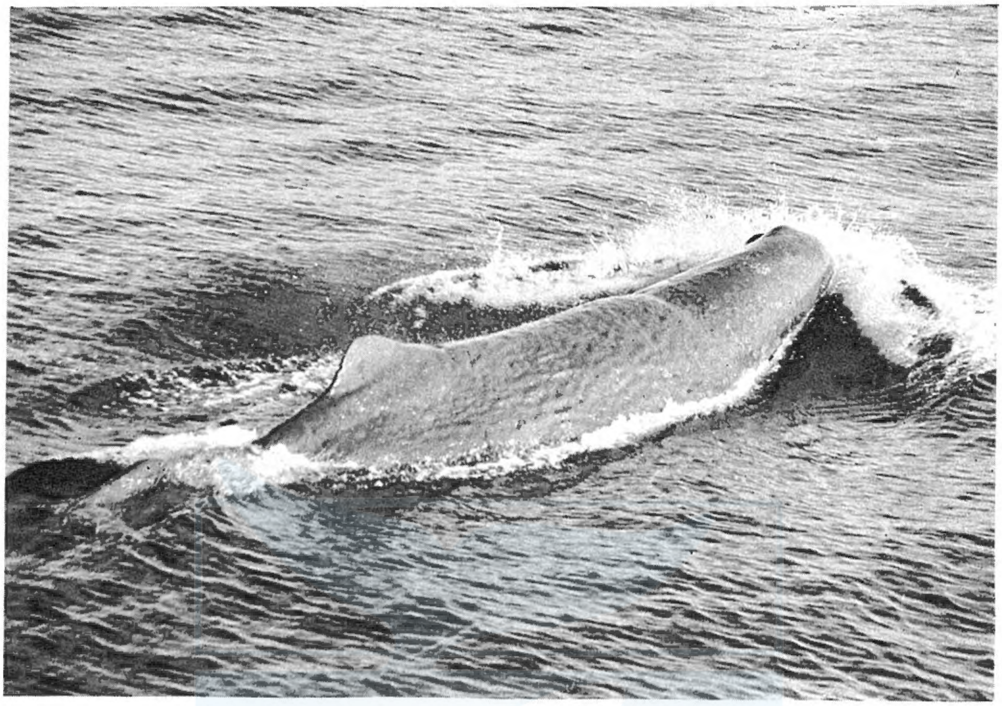

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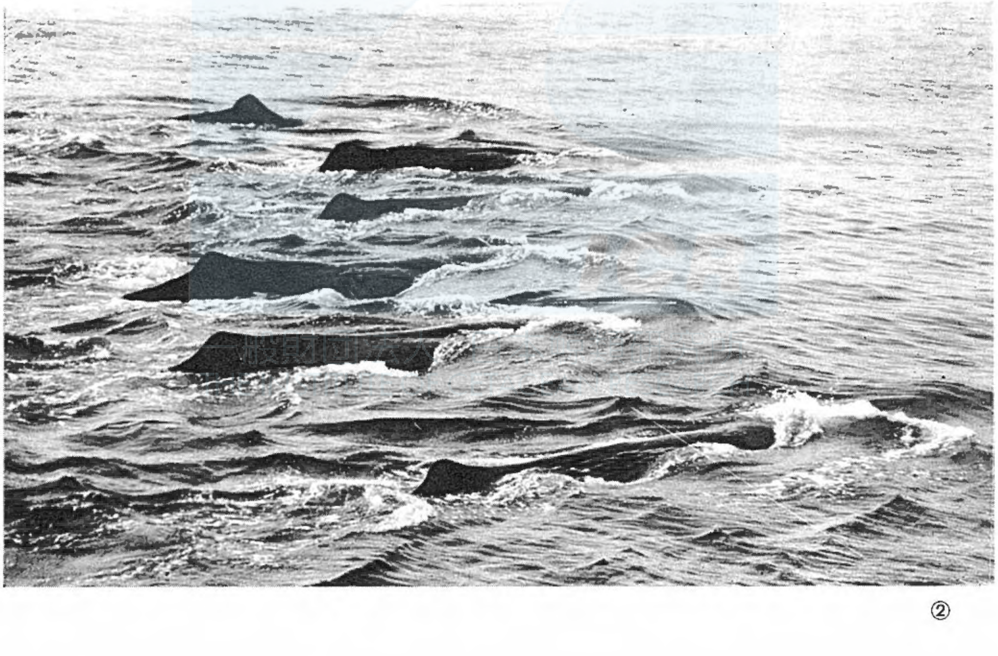

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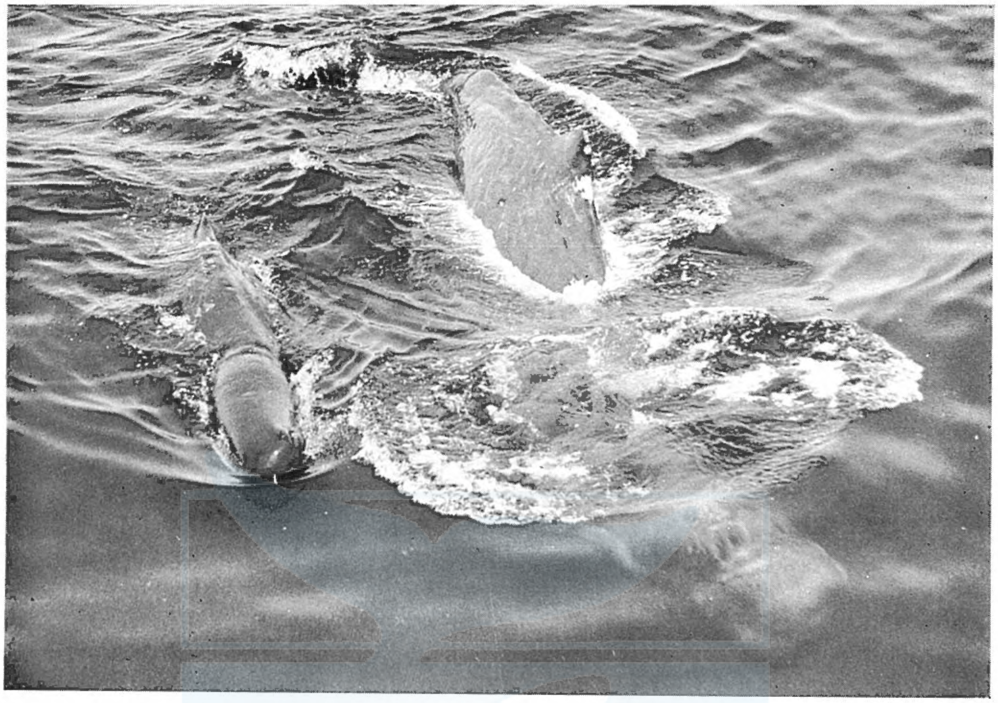

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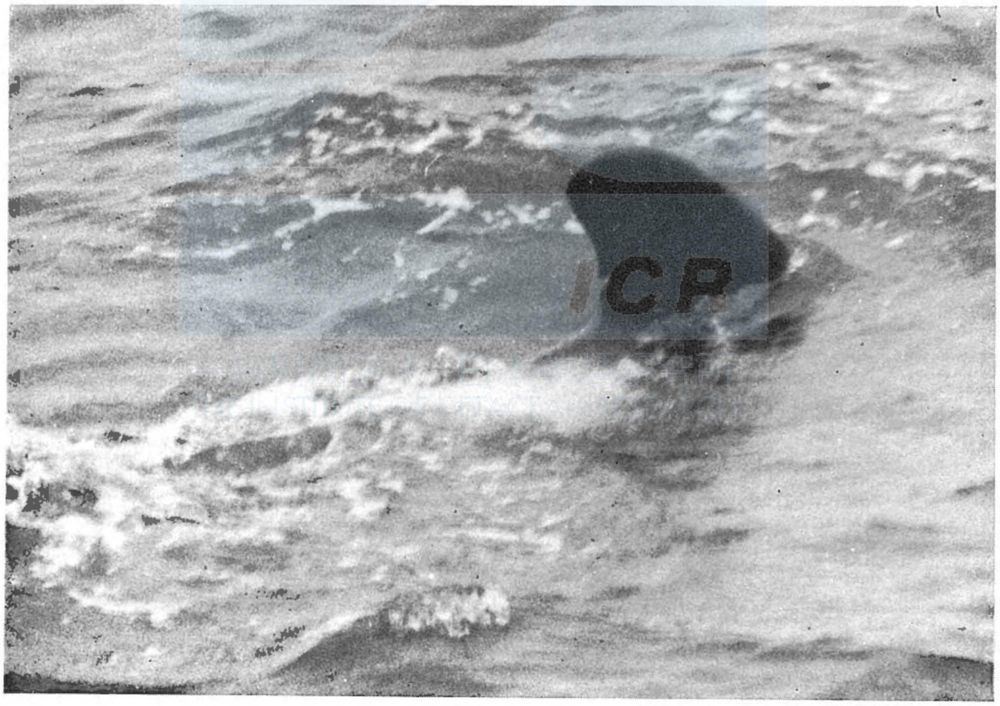

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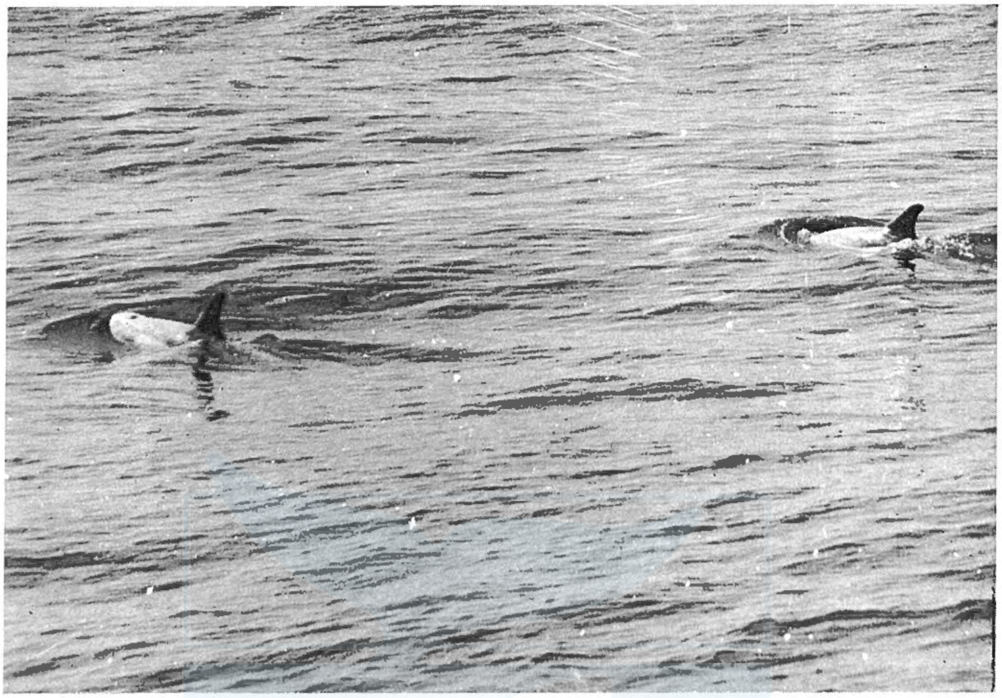

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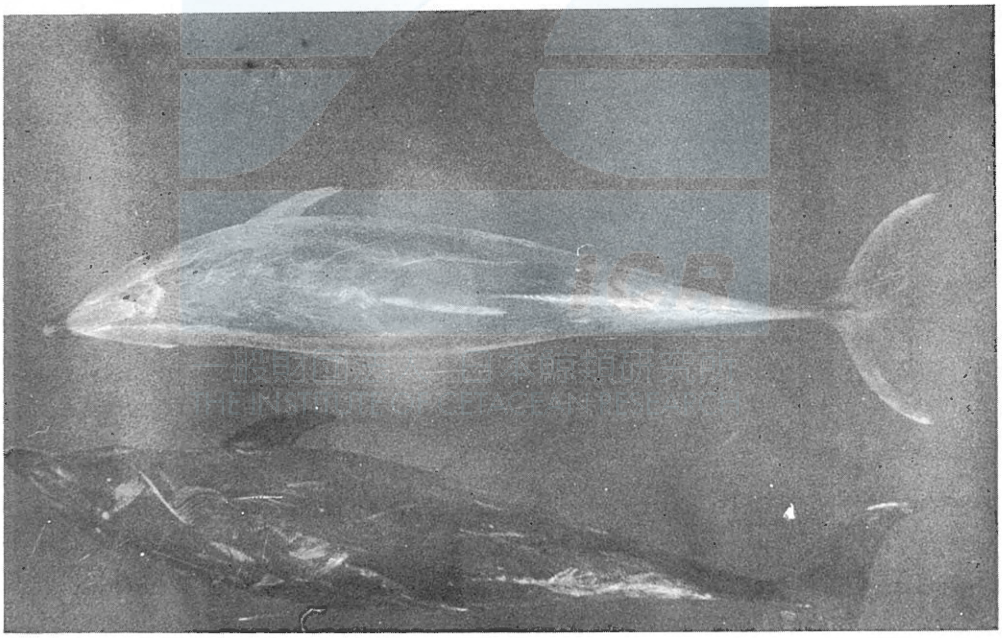

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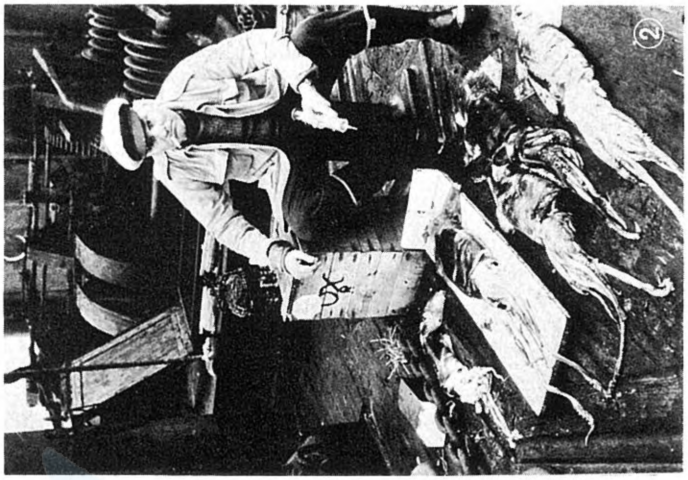

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OBSERVATION OF CETACEA DURING WHALE MARKING CRUISE IN THE WESTERN TROPICAL PACIFIC, 1976

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ABSTRACT

From 20 January to 19 March 1976, the whale marking and sighting were carried out in the western tropical Pacific. During this survey 103 schools of 13 species from 11 genera were sighted, and 15 specimens of 5 species from 4 genera were collected. Observations of these 103 schools were made and the biology of these 15 specimens was studied.

INTRODUCTION

Distribution and biology of cetaceans in the western tropical Pacific have been almost not known till 1972. Recently Masaki (1972) and Wada (1975) carried out the tagging Investigation of cetacea in the western tropical Pacific. In Ogasawara and Mariana Islands Masaki (1972) found *Physeter catodon*, *Balaenoptera borealis*, *B. edeni*, *Stenella coeruleoalba*, *S. attenuata*, *Pseudorca crassidens*, *Globicephala macrorhynchus*, *Delphinus delphis*, *Ziphius cavirostris*. According to Wada (1975) *P. catodon*, *B. edeni*, *S. coeruleoalba*, *S. attenuata*, *G. macrorhynchus* were sighted in the southwest areas of the North Pacific. However, still little is known about thedistribution and biology of cetaceans in these areas. This paper reports biological investigations of cetaceans carried out during winter season in the western tropical Pacific.

MATERIALS AND METHODS

The vessel used was the *Miwa-marn*, 199.68 grosstons and maximum speed 11 knot. It was used from 20 January to 19 March 1976. The cruising course of this survey is shown in Fig. 1. The total cruising and sighting distance were 9,178 and 6,074 nautical miles, respectively. The total time of observation was 631.8 hours. Sightings were usually carried out by three persons at the foremast and two at the upper bridge except for in heavy rain.

Specimens were collected with shot gun and hand harpoon. The specimens were measured, photographed, and made on biological examinations as soon as

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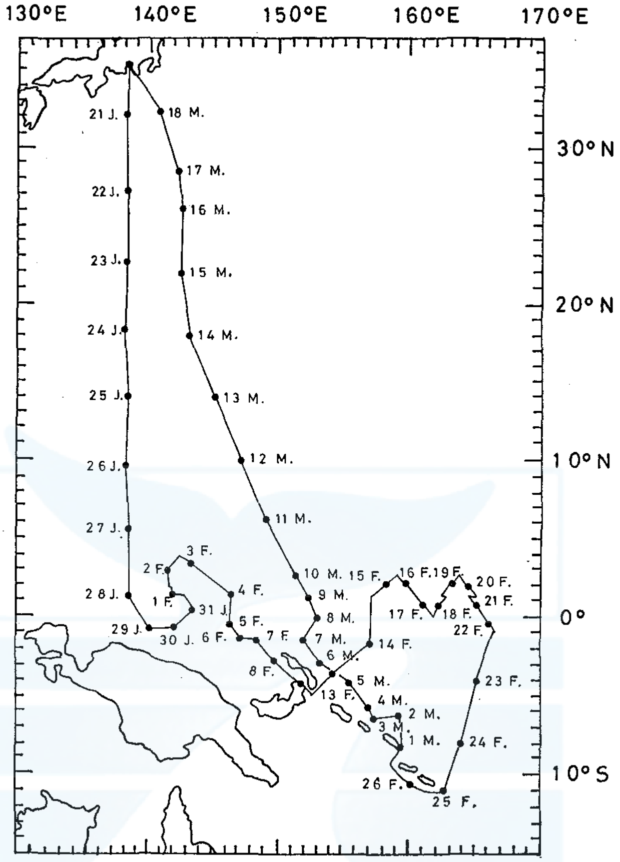

Fig. 1. The cruising course of *Miwa-maru* from 20 January to 19 March 1976. J., F., and M. mean January, February, and March, respectively. Numbers indicate dates.

possible after hauling them aboard the vessel. Testes and ovaries were collected and fixed with 10% formalin solution. In the laboratory testes and ovaries were weighed, the number of corpora counted, and the diameters of Graafian follicles measured. The testes of the specimens were histologically examined.

OBSERVATIONS AND BIOLOGICAL INFORMATIONS

During this survey 103 schools of 13 species from 11 genera were sighted, and 15 dolphins of 5 species from 4 genera were collected. Informations on the distribution, behavior, and biology of these species are given below.

Balaenoptera edeni

Bryde's whales, *Balaenoptera edeni*, are common in the western tropical Pacific (Masaki 1972, Wada 1975). As the research vessel could always approach to

Bryde's whales, it is easy for us to identify the species. Especially it is also possible to distinguish the species from the sei whale, *Balaenoptera borealis*, basing on the three ridges on the snout.

Fifty animals of 25 schools of Bryde's whale, and 4 females with calf in these schools were found (Table 1). Estimated body size of 4 calves, 4 females with calf, and the other animals were 7–8 m, 12–13 m, and 11–13 m, respectively. We could not find subadult animals between 8 and 11 m. According to Masaki (1972) and Wada (1975), they did not also find subadult animals in winter season of the western tropical Pacific. From these data it seems that the subadult of Bryde's whale geographically segregate from the adult in winter season of this area. In order to solve this problem it is necessary to accumulate more data in the future.

Bryde's whales were sighted mostly in the area of 0°–2°N latitude and 142°–144°E longitude, especially around Manus Islands, Solomon Islands, and Nauru Island (Fig. 2). Sea surface temperature at sighting positions ranged from 28.5°C to 30.0°C. School size ranged between 1 and 8 animals, but most of the groups had only one or two whales (Fig. 5). This suggests that Bryde's whales mostly distribute on solitary or pair, and sometime make small school less than 10 animals in winter season of the western tropical Pacific.

Six Bryde's whales of schools (sighting Nos 13, 14, 15, 22, 23, 24) were found together with bonito schools and many sea birds. Especially several animals of the school (sighting No. 14) chased the prey turning sideways with their mouths open and appeared to be feeding. This suggests that Bryde's whales take the prey in winter season. Many remoras (Echeneidae) were found on the back of one adult animal in a school (sighting No. 19).

Physeter catodon

Sperm whale, *Physeter catodon* is common in the western tropical Pacific (Masaki, 1972; Wada, 1975). Twelve schools with a total of 156 sperm whales were found. As shown in Fig. 2, sperm whales were often found around islands. The school size ranged from 1 to 28 animals (Fig. 5). Sea surface temperature at sighting positions ranged from 28.7°C to 29.7°C (Table 1).

Estimated body length of four sperm whales sighted separately (sighting Nos 33, 34, 35, 36) was between 12 and 14 m. These whales were probably solitary adult males. These animals were often observed to dive for 15 to 25 minutes. Four schools had female with calf (Table 1). These females and calves were often found slightly apart from other animals in the school. Estimated body size of these females and calves were 9–10 m and 4–5 m, respectively. Six schools were composed of the subadults or adults, and the school size of these whales was between 8 and 28. In a school (sighting No. 31) there are three groups of the animals. The group composed of 11 adult animals, 5 subadult ones, and 2 calves was placed between two groups, one of which was consisted of 6 adult animals and the other 4 adult ones. One school (sighting No. 38) had eight adult whales and these were found side by side approximately 2–3 m apart. Sperm whales in one

TABLE 1. SIGHTING RECORDS OF CETACEANS DURING THIS SURVEY

Sighting No.	Species	Date	Position	Time	Surface temperature (°C)	School size	Comments
1	*Balaenoptera edeni*	30 I '76	00°54'N, 142°05'E	06: 45	28.8	1	
2	,,	31 I '76	00°16'N, 143°28'E	08: 25	29.2	1	
3	,,	1 II '76	01°35'N, 142°03'E	14: 20	30.0	1	
4	,,	1 II '76	01°40'N, 142°03'E	15: 00	30.0	1	
5	,,	1 II '76	01°43'N, 142°03'E	15: 20	30.0	1	
6	,,	5 II '76	00°55'S, 146°35'E	14: 35	29.0	1	
7	,,	5 II '76	00°57'S, 146°38'E	15: 10	29.0	2	
8	,,	6 II '76	01°05'S, 147°01°E	06: 15	29.0	2	
9	,,	6 II '76	01°16'S, 147°00'E	09: 15	29.0	1	Many remoras attached to the back of this animal.
10	,,	6 II '76	01°21'S, 147°05'E	10: 55	28.8	1	
11	,,	6 II '76	01°22'S, 147°06'E	11: 20	28.8	1	
12	,,	6 II '76	01°27'S, 147°21'E	14: 15	29.0	1	
13	,,	6 II '76	01°23'S, 147°22'E	15: 15	29.0	1	With many seabirds and a school of bonito.
14	,,	6 II '76	01°15'S, 147°28'E	16: 30	29.0	6	With many seabirds and a school of bonito.
15	,,	7 II '76	01°25'S, 148°14'E	09: 10	29.0	1	With many seabirds and a school of bonito.
16	,,	13 II '76	04'08'S, 154°17'E	10: 10	29.2	1	
17	,,	18 II '76	00°04'N, 162°27'E	08: 35	29.1	2	One female with a calf was found.
18	,,	21 II '76	00°55'N, 165°24'E	10: 35	28.5	1	
19	,,	21 II '76	00°47'N, 165°27'E	12: 15	28.7	7	One female with a calf was found.
20	,,	21 II '76	00°37'N, 165°35'E	14: 40	29.0	2	One female with a calf was found.
21	,,	21 II '76	00°30'N, 165°38'E	16: 10	29.0	3	One female with a calf was found.
22	,,	4 III '76	06°06'S, 156°53'E	06: 50	29.6	1	With many seabirds and a school of bonito.
23	,,	4 III '76	06°07'S, 156°56'E	07: 50	29.5	8	With many seabirds and a school of bonito.
24	,,	4 III '76	06°05'S, 156°07'E	10: 55	29.3	2	With many seabirds and a school of bonito.
25	,,	6 III '76	03°16'S, 153°39'E	10: 45	30.2	1	
26	*Physeter catodon*	30 I '76	00°56'S, 142°03'E	08: 00	28.8	18	Four females with a calf were found. Together with two Risso's dolphins.
27	,,	7 II '76	01°24'S, 148°06'E	07: 15	29.0	8	
28	,,	7 II '76	01°34°S, 148°42'E	12: 10	29.2	19	One female with a calf was found.
29	,,	7 II '76	01°50'S, 148°47'E	15: 20	28.8	15	One female with a calf was found.
30	,,	8 II '76	03°16'S, 150°24'E	15: 10	29.7	12	Two females with a calf were found. Many remoras attached to the back of calf.

31	,,	22 II '76	00°44′S, 166°37′E	13:30	28.8	28	
32	,,	24 II '76	08°51′S, 163°50′E	16:00	28.7	16	
33	,,	29 II '76	09°11′S, 159°56′E	17:30	28.8	1	
34	,,	29 II '76	09°11′S, 159°56′E	17:30	28.8	1	
35	,,	29 II '76	09°10′S, 159°57′E	18:35	28.8	1	
36	,,	29 II '76	09°10′S, 159°57′E	18:48	28.8	1	
37	,,	3 III '76	06°14′S, 157°08′E	17:25	29.2	10	
38	,,	10 III '76	02°17′N, 151°34′E	06:20	29.6	26	
39	*Stenella coeruleoalba*	21 I '76	30°47′N, 138°33′E	17:20	18.2	40–50	
40	,,	23 I '76	23°21′N, 138°27′E	09:15	22.4	10–20	
41	,,	5 III '76	04°02′N, 155°41′E	13:35	30.5	400–500	Several females with a calf were found.
42	,,	16 III '76	25°23′N, 143°04′E	07:05	22.6	30–40	Two females with a calf were found.
43	,,	16 III '76	25°56′N, 143°06′E	09:45	22.2	50–60	Three females with a calf were found.
44	,,	16 III '76	26°40′N, 143°07′E	15:05	22.0	40–50	Three females with a calf were found.
45	,,	16 III '76	26°42′N, 143°00′E	17:00	22.0	20–30	
46	,,	17 III '76	28°29′N, 142°30′E	11:10	20.6	100–150	Several females with a calf were found.
47	*Stenella attenuata*	25 I '76	14°50′N, 138°28′E	07:55	27.4	10–20	
48	,,	27 I '76	04°52′N, 138°35′E	16:30	29.1	10–20	Together with a school of *Pseudorca crassidens*.
49	,,	14 II '76	01°09′S, 157°49′E	16:05	29.8	50–60	One specimen (specimen No. 6) was collected.
50	,,	16 II '76	02°20′S, 159°49′E	09:10	29.0	20–30	
51	,,	1 III '76	08°20′S, 160°00′E	11:00	29.1	20–30	One specimen (specimen No. 7) was collected.
52	,,	1 III '76	08°09′S, 160°04′E	13:15	29.4	150–200	Several females with a calf were found.
53	,,	2 III '76	06°37′S, 159°35′E	10:00	29.0	500–600	One specimen (specimen No. 5) was collected. Five females with a calf were found.
54	,,	2 III '76	06°02′S, 159°15′E	16:35	29.5	400–500	One specimen (specimen No. 8) was collected.
55	,,	5 III '76	04°20′S, 155°51′E	10:15	30.1	30–40	Several females with a calf were found.
56	,,	5 III '76	03°48′S, 155°04′E	17:10	30.0	100–150	Serveral females with a calf were found.
57	,,	6 III '76	03°25′S, 153°44′E	09:35	30.2	70–80	
58	,,	6 III '76	03°06′S, 153°31′E	12:15	30.4	50–60	Several females with a calf were found.
59	,,	7 III '76	01°49′S, 151°53′E	10:15	29.8	40–50	
60	,,	16 III '76	26°41′N, 143°07′E	16:40	22.0	100–150	
61	*Stenella longirostris*	2 II '76	03°03′N, 141°57′E	13:35	29.5	40–50	
62	,,	2 II '76	03°11′N, 142°07′E	15:50	29.2	30–40	One specimen (specimen No. 13) was collected.
63	,,	12 II '76	04°55′S, 152°56′E	16:25	29.6	150–200	One specimen (specimen No. 11) was collected.
64	,,	14 II '76	02°09′S, 157°45′E	10:05	29.0	40–50	

Continued . . .

TABLE 1. Continued.

Sighting No.	Species	Date	Position	Time	Surface temperature (°C)	School size	Comments
65	,,	20 II '76	01°18′N, 165°13′E	16: 45	28.7	100–150	Three females with a calf were found.
66	,,	22 II '76	00°52′S, 166°42′E	15: 50	29.1	30–40	One specimen (specimen No. 10) was collected.
67	,,	24 II '76	07°18′S, 164°34′E	07: 00	28.6	150–200	Several females with a calf were found.
68	,,	1 III '76	08°50′S, 159°52′E	07: 35	28.8	30–40	One specimen (specimen No. 15) was collected. Two females with a calf were found.
69	,,	1 III '76	07°53′S, 160°05′E	16: 00	29.5	80–100	Several females with a calf were found.
70	,,	1 III '76	07°52′S, 160°04′E	16: 25	29.5	150–200	Four females with a calf were found.
71	,,	1 III '76	07°41′S, 159°55′E	18: 00	29.5	500–600	One specimen (specimen No. 14) was collected.
72	,,	3 III '76	06°34′S, 158°08′E	09: 20	29.0	50–100	One specimen (specimen No. 9) was collected. Several females with a calf were found.
73	,,	3 III '76	06°31′S, 157°26′E	14: 25	29.9	200–300	One specimen (specimen No. 12) was collected.
74	,,	4 III '76	05°10′S, 156°34′E	18: 10	30.6	20–300	
75	,,	5 III '76	04°54′S, 156°11′E	07: 15	30.0	150–200	Several females with a calf were found.
76	,,	5 III '76	03°48′S, 155°18′E	15: 45	30.6	150–200	Several females with a calf were found.
77	,,	6 III '76	02°55′S, 153°22′E	13: 45	30.4	500–600	
78	,,	9 III '76	00°25′N, 153°09′E	07: 25	29.4	20–30	
79	*Stenella* sp.	31 I '76	00°56′N, 143°30′E	17: 55	30.0	10–20	
80	,,	21 II '76	00°23′N, 165°37′E	18: 20	29.0	10–20	
81	*Tursiops* sp.	7 II '76	01°55′S, 148°53′E	17: 15	28.8	200–300	One specimen (specimen No. 4) was collected.
82	,,	26 II '76	10°33′S, 160°33′E	14: 15	28.4	10–20	
83	*Lagenodelphis hosei*	23 I '76	23°15′N, 138°27′E	10: 00	22.9	200–300	One specimen (specimen No. 1) was collected. Several females with a calf were found.
84	,,	1 II '76	01°33′N, 142°04′E	13: 10	30.0	40–50	One specimen (specimen No. 2) was collected. Several females with a calf were found.
85	,,	2 II '76	03°00′N, 141°55′E	10: 30	29.5	40–50	
86	,,	20 II '76	01°43′N, 164°53′E	12: 10	28.7	400–500	Several females with a calf were found. Together with a school of *Peponocephala electra*.
87	*Peponocephala electra*	20 II '76	01°43′N, 164°53′E	12: 10	28.7	20	One specimen (specimen No. 3) was collected. Together with a school of *Lagenodelphis hosei*.
88	*Pseudorca crassidens*	27 I '76	04°52′N, 138°35′E	16: 30	29.1	10	Together with a school of *Stenella attenuata*.
89	,,	6 III '76	02°37′S, 153°01′E	16: 45	30.8	20–30	Several females with a calf were found.
90	*Orcinus orca*	19 II '76	02°21′N, 164°08′E	15: 15	28.7	9	Two females with a calf were found.
91	*Grampus griseus*	30 I '76	00°56′S, 142°03′E	08: 00	28.8	2	Together with a school of *Physeter catodon*.

92	,,	31 I '76	00°27′N, 143°41′E	10:20	29.7	10
93	,,	31 I '76	00°39′N, 143°42′E	12:50	30.0	10
94	,,	1 II '76	01°20′N, 142°08′E	11:40	30.0	10
95	,,	4 III '76	05°59′S, 157°04′E	11:55	30.2	20–30
96	,,	13 III '76	14°04′N, 144°56′E	13:00	27.6	8
97	*Globicephala macrorhynchus*	30 I '76	00°48′S, 142°14′E	12:40	29.2	9
98	,,	16 III '76	25°58′N, 143°06′E	10:20	22.2	30–40
99	*Feresa attenuata*	6 III '76	02°48′S, 153°16′E	14:50	30.6	150–200
100	*Ziphius cavirostris*	31 I '76	00°54′N, 143°29′E	15:35	29.9	3
101	,,	1 II '76	01°20′N, 142°09′E	11:25	30.0	3
102	,,	19 II '76	01°22′N, 163°04′E	06:30	28.5	1
103	,,	20 II '76	02°06′N, 164°33′E	09:20	28.6	1

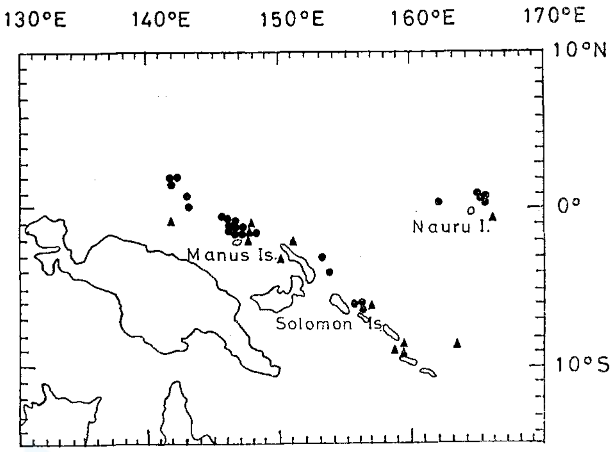

Fig. 2. Sighting records of *Balaenoptera edeni* and *Physeter catodon*. Circles and triangles indicate *B. edeni* and *P. catodon*, respectively.

school (sighting No. 26) were found together with two Risso's dolphins, *Grampus griseus*. Although many remoras were attached on the backs of two calves in one school (sighting No. 27), we did not observe any sucking fish on the backs of the adults or subadults in this school.

Stenella coeruleoalba

Striped dolphin, *Stenella coeruleoalba* is common along the eastern coast of Japan (Miyazaki *et al.*, 1974). Eight schools of striped dolphin were found. Six schools (75%) had less than 100 dolphins (Fig. 5). The maximum school size was estimated to be 400–500 dolphins. Several females with calf were observed in five schools (Table 1). Estimated body lengths of these calves were 110–140 cm. Although several dolphins from two schools (sighting Nos 43 and 46) approached the bow of the vessel, but no dolphin from the other schools approached the bow.

Striped dolphins were found between from 04°02′N to 30°47′N latitude (Fig. 3), and sea surface temperature ranged from 18.2 to 30.5°C (Table 1). Especially 6 schools (75%) were found between 20°N and 30°N latitude. On the other hand, most of spotted dolphins and all of spinner dolphins were found between 10°S and 10°N latitude in this survey as indicated in the latter part of this report. Considering from these data, striped dolphins seem to have larger distribution in the northern Pacific than spotted and spinner dolphins. According to Miyazaki *et al.* (1974), spotted dolphins are found in warmer area than striped dolphins. This supports our result.

Stenella attenuata

Spotted dolphin, *Stenella attenuata* is common in the coast of Japan (Miyazaki *et al.*, 1974), in the tropical Pacific (Dawbin, 1966) and in the eastern Pacific

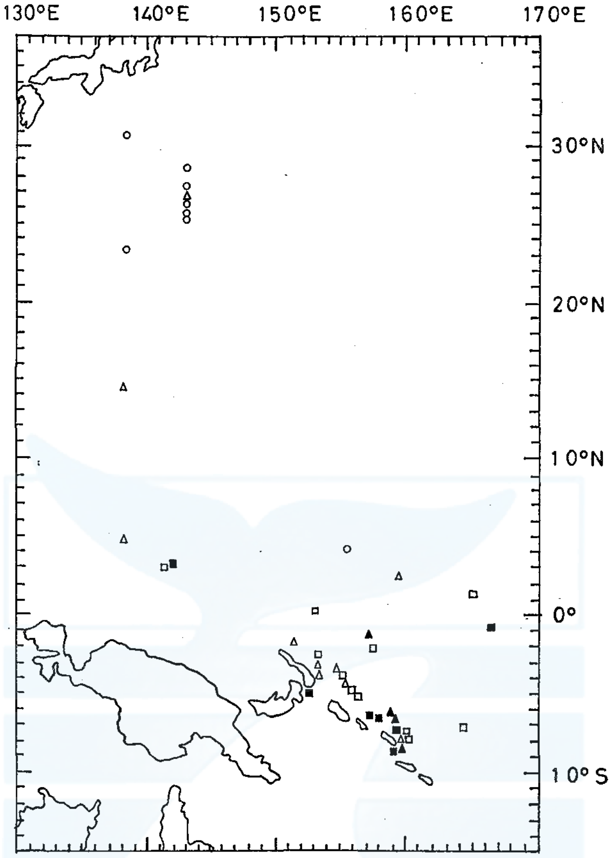

Fig. 3. Sighting and catch records of *Stenella* spp. Circles, triangles, and squares mean *S. coeruleoalba*, *S. attenuata*, and *S. longirostris*, respectively. Open and shaded symbols are sighting and catch records, respectively.

(Perrin, 1975). Perrin (1975) reported that there are at least two races of spotted dolphin in the eastern Pacific.

Fourteen schools of spotted dolphin were found. Nine schools (65%) were less than 100 dolphins (Fig. 5). The maximum school size was estimated at about 500–600 dolphins. Several females with calf were observed in three schools (Table 1). Although some spotted dolphins off the Pacific coast of Japan often approached the bow of ship, in this survey no spotted dolphin did so.

Spotted dolphins were found between from 08°20'S to 26°41'N latitude (Fig. 3), and sea surface temperature ranged from 22.0 to 30.2°C. Between 10°S and 10°N latitude 12 schools (86%) were found. One school of spotted dolphin sighting No. 47) was found between 10°N and 20°N, and another (sighting No. 60) between 20°N and 30°N latitude. On the other hand most of striped dolphin were found between 20°N and 30°N, and all of spinner dolphin were found between 10°S and 10°N latitude in this survey. From these information, it can be

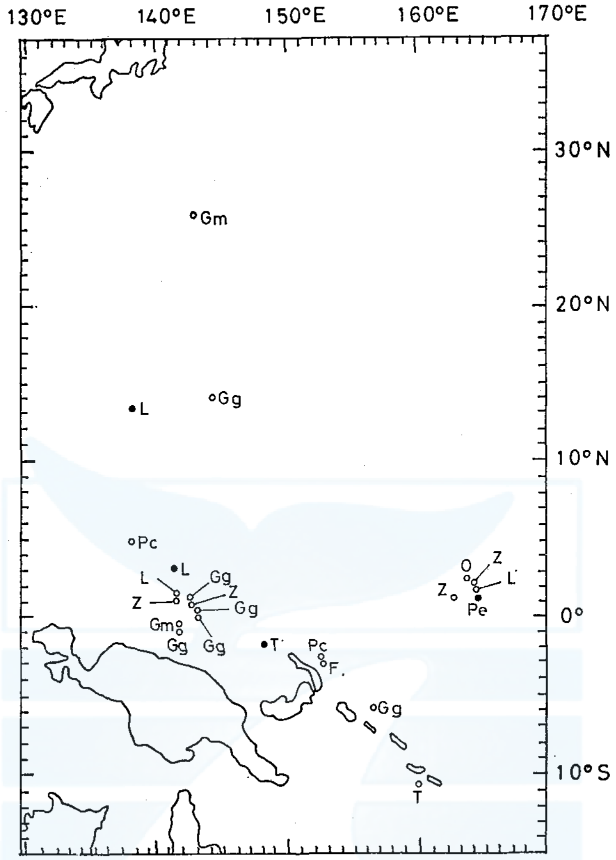

Fig. 4. Sighting (oen circle) and catch (closed circle) records of small cetaceans. Pc., O., Gg., T., L., Pe., Gm., F., and Z mean *Tursiops* sp. *Lagenodelphis hosei*, *Peponocephala electra*, *Pseudorca crassidens*, *Orcinus orca*, *Grampus griseus*, *Globicephala macrorhynchus*, *Feresa attenuata*, and *Ziphius cavirostris*.

said that spotted dolphin may have larger distribution in the western northern Pacific than spinner dolphin.

Four specimens were collected from four different schools (Table 2). These specimens consist of one female and three males. As the left ovary of the female (specimen No. 5) was heavier than the right, and the diameter of Graafian follicles of the left ovary became bigger, the female seems to be in the early stage of ovulation. Two animals (specimen Nos 6 and 7) showed no spermatozoa in the tissue of the testes but one (specimen No. 8) did.

Stenella longirostris

Spinner dolphin, *Stenella longirostris* is common in the eastern Pacific (Perrin, 1975), but little is known about spinner dolphins in the western Pacific.

Eighteen schools of spinner dolphin were found. Half of these schools had

TABLE 2. LIST OF SPECIMENS CAUGHT DURING THIS CRUISE

Specimen No.	Species	Sighting No.	Sex	Body length (cm)	Weight of ovaries (g)		Weight of testes (g)		No. of corpora		Sexual condition	Comments
					L.	R.	L.	R.	L.	R.		
1	*Lagenodelphis hosei*	83	Female	231	3.0	1.3			0–0	0–0	Immature	Diameter of maximum Graafian follicle is 3 mm
2	*Lagenodelphis hosei*	84	Male	183.5			8.6	8.6			Immature	
3	*Peponocephala electra*	87	Female	208	0.9	0.8			0–0	0–0	Immature	
4	*Tursiops* sp.	81	Female	238	3.0	2.7			0–1	0–4	Lactating	
5	*Stenella attenuata*	53	Female	178	1.1	0.4			0–0	0–0	Immature	Diameter of maximum Graafian follicle is 3 mm
6	*Stenella attenuata*	49	Male	173			7.3	7.1			Immature	
7	*Stenella attenuata*	51	Male	176			4.2	4.3			Immature	
8	*Stenella attenuata*	54	Male	215			200	200			Mature	
9	*Stenella longirostris*	72	Female	152	0.2	0.2			0–0	0–0	Immature	
10	*Stenella longirostris*	66	Female	158	0.5	0.5			0–0	0–0	Immature	
11	*Stenella longirostris*	63	Female	167	0.7	0.5			0–0	0–0	Immature	
12	*Stenella longirostris*	73	Female	189	6.4	0.8			1–1	0–0	Pregnant	Body size of the foetus is 75 cm
13	*Stenella longirostris*	62	Female	191	1.3	1.3			0–6	0–3	Resting	
14	*Stenella longirostris*	71	Male	181			320	250			Mature	
15	*Stenella longirostris*	68	Male	187			620	620			Mature	

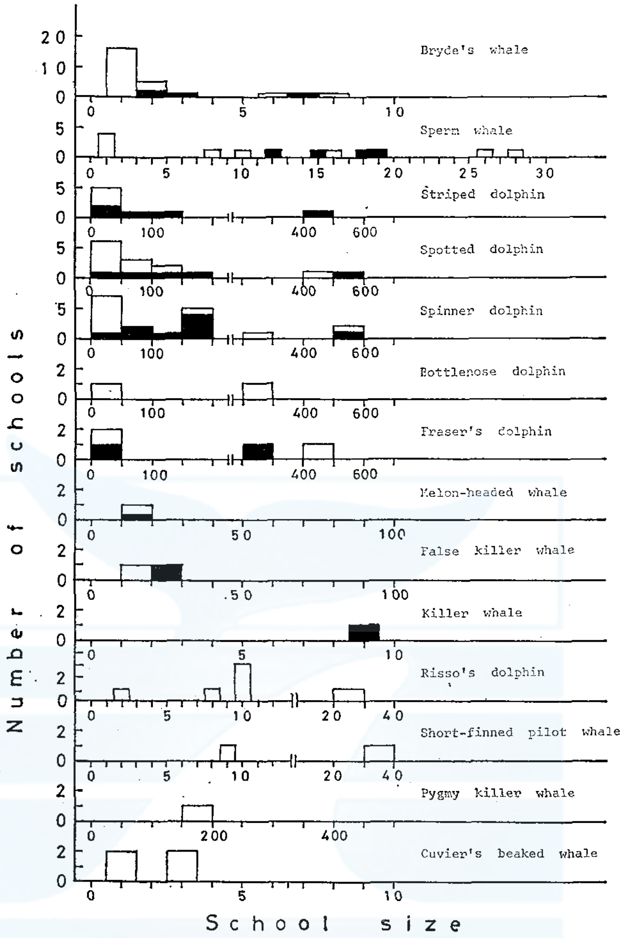

Fig. 5. Frequency of school size in cetaceans. Shaded and open areas are schools with several female and calf and schools without it, respectively.

less than 100 dolphins (Fig. 5). The maximum school size was estimated at about 500 to 600 dolphins. Several females with calf were observed in nine schools (Table 1). No spinner dolphin approached the vessel during this survey.

Spinner dolphins were found between from 08°50'S to 03°11'N latitude (Fig. 3), and sea surface temperature ranged from 28.6°C to 30.6°C. Considering from sighting records of striped, spotted, and spinner dolphins in this survey, spinner dolphin seems to have the most limited distribution in the western north Pacific among these three species of the genus *Stenella*.

Seven specimens were collected from seven different schools (Table 2). These specimens consist of five females and two males. Based on biological examinations of ovaries, mammary gland, and uterus, sexual condition of these females were determined as indicated in Table 2. Pregnant female (specimen No. 12) had a foetus of 75 cm in body length. According to Perrin *et al.* (1977) estimated average length at birth of the spinner dolphin in the eastern Pacific is 77 cm. Therefore, it seems that the foetus collected was probably about term. Two males (specimen Nos 14 and 15) showed spermatozoa in the tissue of the testes.

Stenella sp.

On 31 January a school of approximately 10–20 dolphins, and on 21 February a school of about 10–20 dolphins were found. As these dolphins were found late in the evening, it was impossible to identify the species. However, we thought these dolphins probably to be *Stenella* sp. based on body size, the shape of the snout and the dorsal fin, and their swimming behavior.

Tursiops sp.

On 7 February, a school composed of approximately 200–300 bottlenose dolphins was found (Fig. 4). Sea surface temperature was 28.8°C. Several bottlenose dolphins approached the vessel. A lactating female was collected from them (Table 2). In this animal greyish speckles were characteristically found on the ventral portion between the umbilicus and genital region. Comparing with adult females of *T. gilli* off the Pacific coast of Japan, this animal is shorter in body length and higher in body height, and it appears to be thickset than adult females of *T. gilli*. One open pit was observed on the left lateral portion above the flipper and under the dorsal fin, respectively. Several whale lice were attached to the inside of these two open pits. On 26 February a school composed of about 10–20 bottlenose dolphins were found (Fig. 4). Sea surface temperature was 28.4°C.

Lagenodelphis hosei

Fraser's dolphin, *Lagenodelphis hosei* is rare all over the world. Recently Perrin *et al.* (1973) reported the discovery of the species in tropical and subtropical areas, and Tobayama *et al.* (1973) described specimens from the western North Pacific.

On 23 January a school composed of approximately 200–300 dolphins was found (Fig. 4). This school was consisted of two small schools (100–150 individuals), and several members of one small school approached the bow of the vessel but the other did not. In the small school at least a group of ten, eight, and seven individuals, three groups of six ones, two groups of five ones, and a pair of adult female and calf were observed. The similar school formations is found in *S. coeruleoalba* (Miyazaki and Nishiwaki 1978). One specimen (TK 451) was collected from this school with harpoon. On 1 February a school composed of about 40–50 dolphins with several females with calf were found (Fig. 4). In this school no dolphin approached the bow of the vessel, but one spec imen (TK 452) was captured from the school with shotgun. This specimen showed no spermatozoa in the tissue of the testes. On 2 February a school of about 40–50 dolphins was found (Fig. 4). Any dolphin did not approach the bow of the vessel. No dolphin was captured. On 20 February a school of approximately 400–500 dolphins was found together with a school of *Peponocephala electra* which was composed of about 20 dolphins (Fig. 4). This shows that Fraser's dolphin may rarely mix with other species. Several leaping dolphins were observed, but no dolphin was captured. Sea surface temperature at sighting areas ranged from 22.9°C to 30.0°C.

Peponocephala electra

According to Perrin (1976) and Bryden *et al.* (1977), Melon-headed whale, *Peponocephala electra* appears to be distributed in tropical and warm temperate waters in the world. On 20 February a school composed of approximately 20 dolphins with several females with calf were found together with about 400–500 Fraser's dolphins (Fig. 4). Sea surface temperature was 28.7°C. One immature female was collected from this school (Table 2). In this animal several whale lice attached to the ventral portion between flippers, around the mammary gland and the umbilicus, and under the right eye.

Pseudorca crassidens

On 27 January a school composed of approximately 10–20 false killer whales were found together with about 10–20 spotted dolphins (Fig. 4). Sea surface temperature was 29.1°C. Although a false killer whale was shot and killed with shotgun, the carcass was lost at sea. The estimated body length of this carcass suggests that this animal is subadult one. This school was composed of several groups of two or three animals. Distance between groups ranged from 10 to 50 m. On 6 March a school of approximately 20–30 false killer whales with several pairs of female with calf was found (Fig. 4). Sea surface temperature was 30.8°C.

Orcinus orca

Although the killer whale, *Orcinus orca* is found primarily in polar and temperate regions, the species is sometimes found in the tropical areas. On 19 February a school of 9 killer whales was found (Fig. 4). Sea surface temperature was 28.7°C. Based on body size and shape of the dorsal fin of the animals, and their behavior this school seemed to be composed of 3 adult males, 2 adult or subadult whales, and 2 females with calf. It is noted that three adult males were all found on the outer edge of the school. Estimated body lengths of adult males, adult females, and calves were 7–9 m, 4–6 m, and 2–3 m, respectively.

Grampus griseus

Risso's dolphin, *Grampus griseus* is common in Pacific Ocean, but there are few records of the species in the western tropical Pacific (Dawbin, 1966). Six schools of the species were found. Five schools (85%) had less than 10 animals. The maximum school size was about 20–30 animals. One school (sighting No. 91) was found together with 18 sperm whales, *Physeter catodon*. Rissos's dolphins were found between 20°N and 30°N latitude (Fig. 4) and sea surface temperature ranged from 27.6°C to 30.0°C.

Globicephala macrorhynchus

On 30 January a school of approximately 10 shortfinned pilot whales was found (Fig. 4). Sea surface temperature was 29.2°C. Based on body size and the shape of the dorsal fin, at least two animals of this school seemed to be adult males. On 16 March a school of about 30–40 shortfinned pilot whales was found (Fig. 4). Sea surface temperature was 22.2°C. Judged from body size and the shape of the dorsal fin, it seems that there were some adult males in the school.

Feresa attenuata

On 6 March a school of approximately 150–200 pygmy killer whales was found (Fig. 4). All members of the school were well united in their behaviour. Sea surface temperature was 30.6°C. Although no specimen of the species were collected, these animals were identified as *Feresa attenuata* by the following three reasons. 1) Body size of all animals in the school were about 2.5 m–3.5 m. 2) These animals were of slender bodies with round head and no beak. 3) Their dorsal fins lead edgeslopes backwards, the rear margin is slightly concave, and the tip is pointed.

Ziphius cavirostris

Since Cuvier's beaked whale, *Ziphius cavirostris* is too nervous about the vessel and always dive into the sea for 30–40 minutes before approaching, it is difficult to identify the species by sighting. During their jumping above the sea, however, Cuvier's beaked whales were identified by the body size, the position of the dorsal fin, and the shape of the head.

Cuvier's beaked whales were observed four times (Fig. 4). Two sightings were of single animal and three whales were found in each of the other two pods.

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EXPLANATION OF PLATES

PLATE I

Fig. 1. Bryde's whale, *Balaenoptera edeni*, at sea in 00°55′S, 146°35′E, on February 5, 1976. Note three ridges on the snout.

Fig. 2. A part of school of sperm whales, *Physeter catodon*, at sea in 02°17′N, 151°34′E, showing side by side in the interval of 2–3 m between whales, on March 10, 1976.

Fig. 3. An adult male killer whale, *Orcinus orca*, at sea in 02°21′N, 164°08′E, on February 19, 1976.

Fig. 4. A part of school of Fraser's dolphin, *Lagenodelphis hosei*, at sea in 01°43′N, 164°53′E, on February 20, 1976.

PLATE II

Fig. 1. Lateral view of immature female *Peponocephala electra*, 208 cm long, taken at sea in 01°43′N, 164°53′E, on February 20, 1976.

Fig. 2. Lateral view of the cephalic region of the same specimen.

Fig. 3. Ventral view of the cephalic region of the same specimen.

Fig. 4. Anterior view of the oral region of the same specimen, showing whitish skin on the lip margins and palatine portion.

PLATE III

Fig. 1. Lateral view of lactating female *Tursiops* sp., 238 cm long, taken at sea in 01°55′S, 148°53′E, on February 7, 1976.

Fig. 2. Ventral view of the same specimen, showing greyish speckles on the ventral side.

Fig. 3. Lateral view of the cephalic region of the same specimen.

Fig. 4. Ventral view of the genital region of the same specimen.


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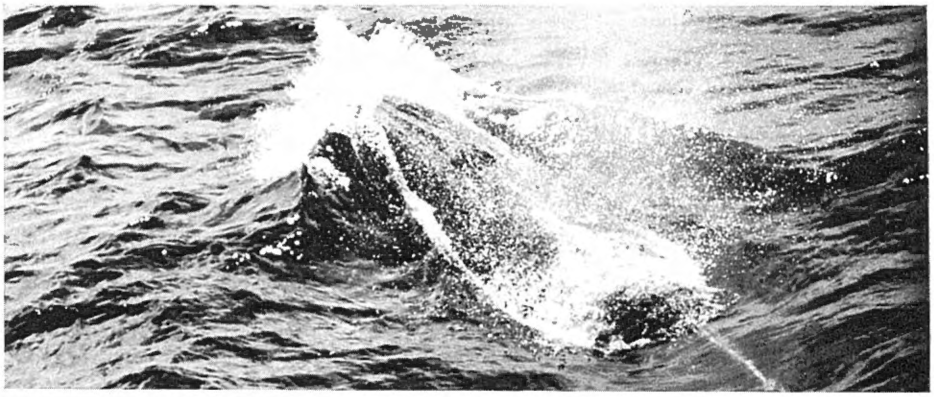

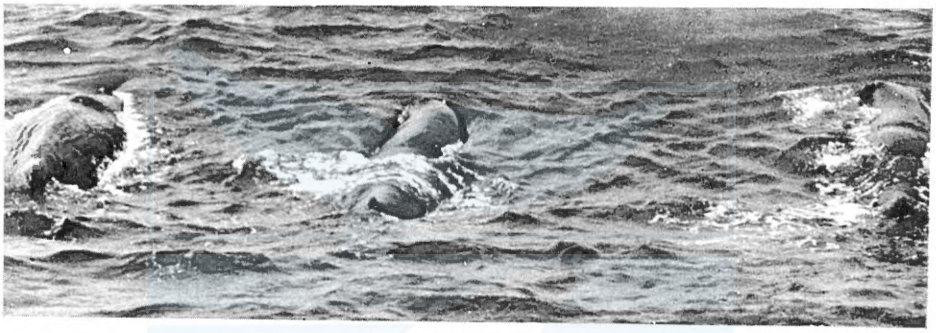

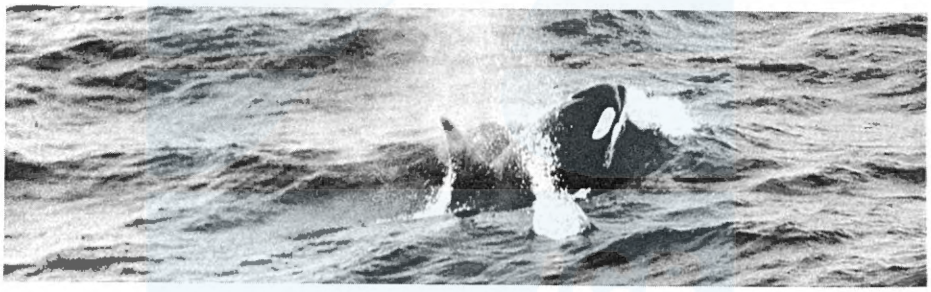


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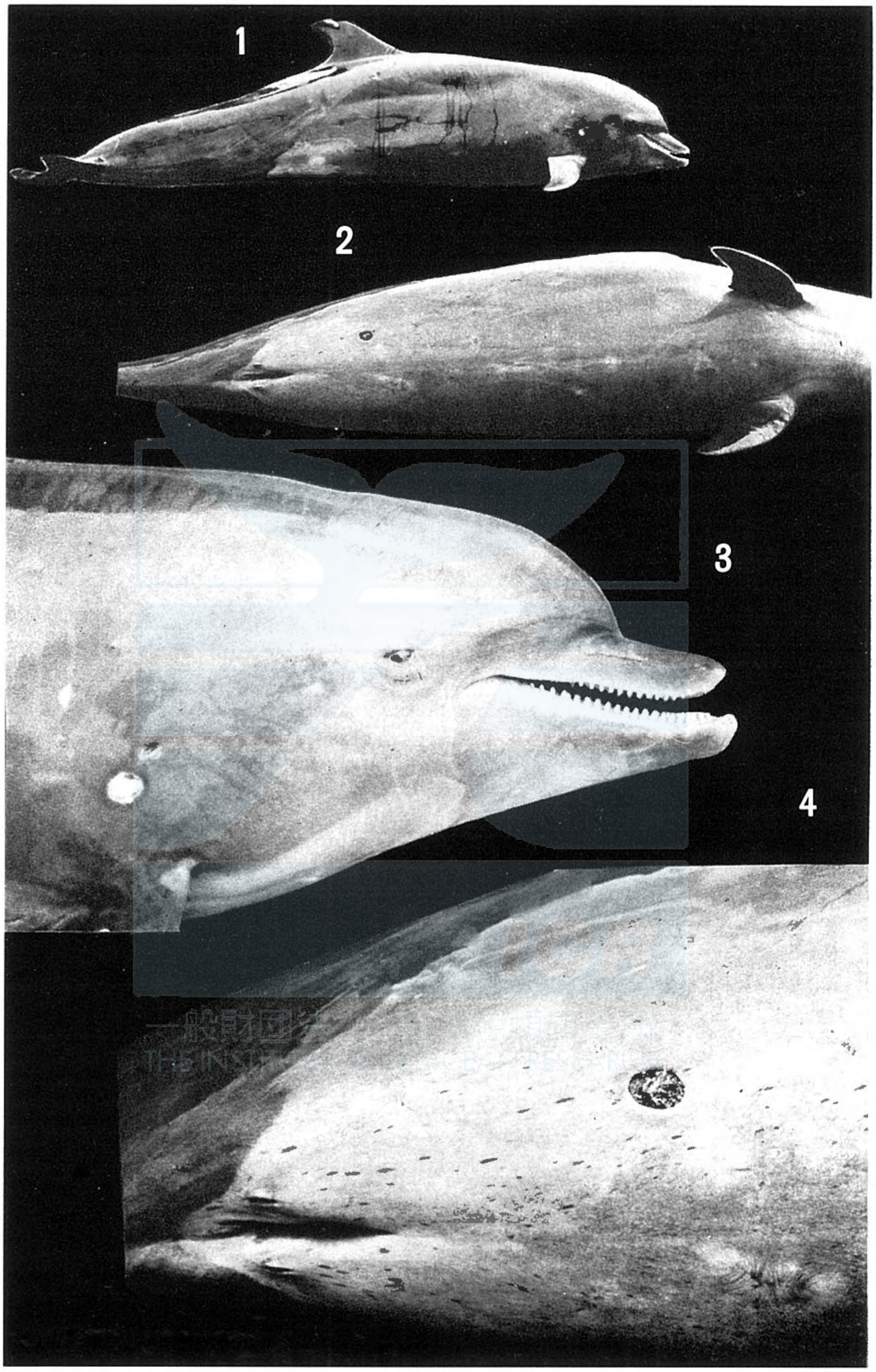
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REPORT ON THE SMALL CETACEANS STRANDED ON THE COASTS OF TIERRA DEL FUEGO*

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ABSTRACT

Little work has been done on the smaller cetaceans of Tierra del Fuego. Data on strandings and new specimens for the following 14 species is presented: *Lagenorhynchus australis*, *Cephalorhynchus commersonii*, *Lissodelphis peronii*, *Globicephala melaena*, *Orcinus orca*, *Phocoena spinipinnis*, *P. dioptrica*, *Tasmacetus shepherdi*, *Berardius arnuxii*, *Mesoplodon layardii*, *M. grayi*, *M. hectori*, *Ziphius cavirostris*, and *Hyperoodon planifrons*. Area characteristics, exploitation and distribution are discussed. This study amplifies the known distribution of some species and increases the number of known specimens of others.

RESUMEN

Hay pocos estudios sobre los cetaceos ménores de Tierra del Fuego. Se presentan datos sobre varamientos y nuevos ejemplares de los siguientes 14 especies: *Lagenorhynchus australis*, *Cephalorhynchus commersonii*, *Lissodelphis peronii*, *Globicephala melaena*, *Orcinus orca*, *Phocoena spinipinnis*, *P. dioptrica*, *Tasmacetus shepherdi*, *Berardius arnuxii*, *Mesoplodon layardii*, *M. grayi*, *M. hectori*, *Ziphius cavirostris* e *Hyperoodon planifrons*. Se proporcionan detalles sobre las caracteristicas de la zona, explotación y distribución. El estudio amplifica la distribución conocida de algunas especies y aumenta el número de ejemplos conocidos de otras especies.

INTRODUCTION

Between the latitude of the southernmost point of New Zealand (47°S) and the main body of the Antarctic continent (70°S), the only land is the southern tip of South America, the Antarctic Peninsula and a few isolated islands. Throughout this immense area of water there is very little traffic. The only ships passing are research vessels going to and from the Antarctic and a few fishing or whaling ships. The only planes are those flying to Antarctic bases. There are few beaches where dead or dying cetaceans can wash up, and the beaches that do exist, facing the west-east currents, are either so rocky that the animals are immediately broken up or so isolated that no one visits them. Thus, the smaller cetaceans of the Southern Ocean are very incompletely known.

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* Prepared for the meeting of the Subcommittee on Small Cetaceans, Scientific Committee, International Whaling Commission, held in London, June 7–9, 1976 (Abstract, Goodall, 1977). Revised and updated, May, 1978.

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Tierra del Fuego, the mass of islands off the southern tip of South America, extends down into the Southern Ocean and breaks the movement of its waters, which must pass between Cape Horn and the Antarctic Peninsula. There is a long history of large whale strandings in Tierra del Fuego (Bridges 1897, Castello and Piñero 1974, local residents pers. comm.) but until very recently practically no one noticed the smaller animals that washed up on the beaches, even though cool climatic conditions prolong the decomposition process.

During expeditions along the beaches looking for botanical specimens, I began picking up a few skulls. On learning of their rarity, expeditions were made especially for stranded cetacean material. It has become apparent that a great many animals strand on the coasts of Tierra del Fuego and that the majority of these have been lost to science. Specimens have been so numerous that most trips have had to be cut short for lack of space in transporting the bones. In one day, on the southwestern beach at Bahía San Sebastián, 88 specimens were collected.

AREA CHARACTERISTICS

The Archipelago of Tierra del Fuego is a maze of intricate channels and islands. The western and southern islands are steep and rocky and any cetaceans stranded there would probably soon be lost. It is impossible to get to that area without using boats. The northern and northeastern parts of the Isla Grande de Tierra del Fuego, however, are flatter and a series of roads allow access to stretches of sandy

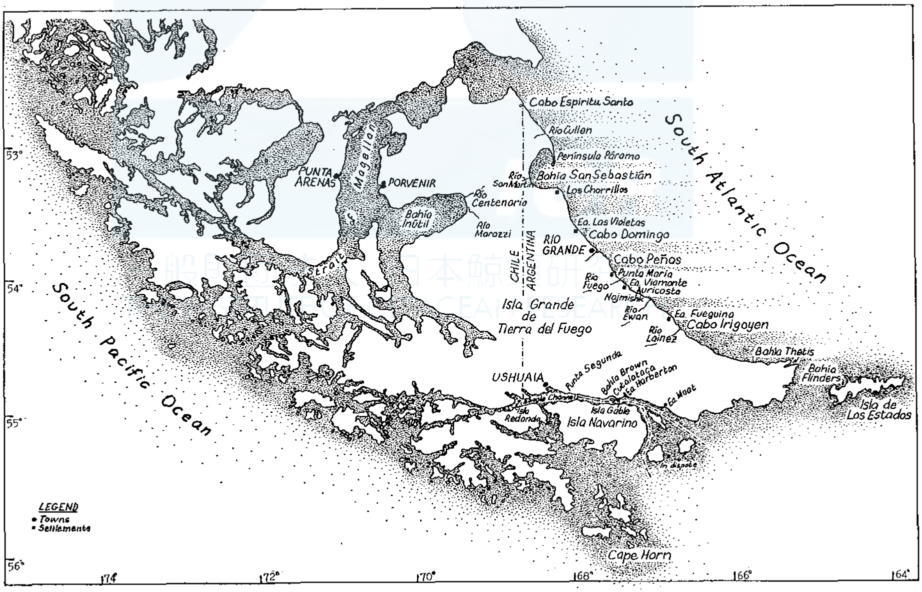

Fig. 1. Map of TIERRA DEL FUEGO showing sites where cetacean specimens were collected.

or stony beaches. It is on these beaches that bones are left by the highest tides.

I have had access only to the Atlantic coast and the eastern Beagle Channel in Argentine Fuegia and eastern Bahía Inútil in the Chilean part. Place names of the areas collected are given in Fig. 1.

There is a large tidal variance on the eastern coast of Tierra del Fuego, from 2.7 m in the Beagle Channel to 9.7 m at Río Grande and a record 15.8 m at Río Gallegos in the Province of Santa Cruz. This tidal range coupled with a fairly flat continental shelf exposes great areas, especially in large, shallow bays such as Bahía San Sebastián. The western and southwestern shores of this bay have produced the greatest amount of stranded material to date. In fact, this area is known to the men of the nearby Argentine border police station as the " cemetery of the whales."

Bahía San Sebastián. This large bay (53°10′S, 68°30′W) opens to the east; the distance across the mouth is 18 km. To the northeast, the bay is partially enclosed by the Península Páramo, a long narrow strip of land composed entirely of sand and Patagonian shingle (smooth round stones). The deepest part of the bay is near the tip of this peninsula, the Punta de Arenas, where the depth varies between 18.3 and 49.4 m (Derrotero Argentino, 1962).

To the southeast of the bay are cliffs 60 ft (18 m) high. Near the mouth of the bay in this section ships load oil from a moored pipeline. Off-shore drilling within the bay is planned for the future.

The whole western coast is an extensive flat beach of sand, clay and mud which, in places, is up to nine km wide. The large tides (the average height is about 10.5 m) and the very gradual slope of the beach combine to make the landing of even small boats almost impossible. This tidal beach area is muddy and slippery most of the year, but during the summer it dries out enough (except during the highest tides) to drive a vehicle from the mouth of the Río San Martín (Fig. 2) north to the northwest corner of the bay, a distance of nearly 40 km. When standing on the beach at low tide, one cannot see the water of the bay.

The winds are predominantly from the southwest and blow strongly throughout the year, although somewhat less in winter. One would think that animals dying within the bay would be blown out to sea, but the greatest amount of stranded material is found in the windward part of the bay. The fishermen claim there is often an E-NE wind on a rising tide, which then changes to SW. No official studies have been made of the currents within the bay, but Capt. H. F. Correa Luna (personal communication 1978), who has for many years captained the boat which connects the loading pipe line to the tankers, says that on the rising tide the currents are generally to the west in the center of the bay, SW in the southern part and NW in the northern. On a falling tide all the currents are to the E, gradually swinging to SE outside the mouth of the bay (Fig. 2). The tide rises and falls rapidly, but without much force, over this wide, gradual slope of mud flats. On the outer coasts where the water is deeper, the force of the falling tide is much greater.

I feel that, apart from the dolphins caught in fishing nets, strandings in this

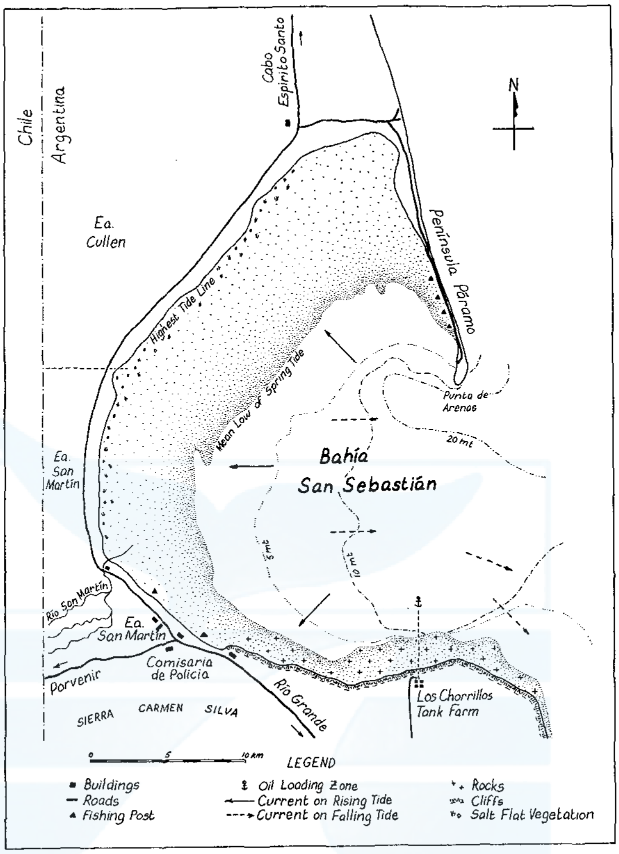

Fig. 2. Bahía San Sebastián showing geographical features, tidal range, water depths and the direction of currents. Data on currents courtesy of Capt. H.F. Correa Luna, 1978.

bay may be accidental, a result of the imperceptibly sloping beach, the rapidity of tidal rise and fall, winds, currents and the slippery, sticky nature of the mud of the tidal zone. The hypothesis of Dudok van Heel (1966) that an animal entering a large shallow area may have difficulty obtaining a good long-range echo and an exit to deep water can only be found by trial and error, seems a definite factor at Bahía San Sebastián. Although no studies have been made of the prey available in the bay, there must be a reason why so many species have been found there. Dudok van Heel's theory that animals concentrating on feeding may miss long distance sonar information and make mistakes in navigation seems an additional possibility.

EXPLOITATION

Although a whaling company operated out of Punta Arenas, Chile, from 1906 to 1916 (Goodall 1975) and whalers from many countries have operated in off-shore waters, there has been no deliberate exploitation of the smaller cetaceans in Fuegian waters until recently when they have been taken for crab bait. Nevertheless, animals have been taken accidentally in fishing nets for many years.

Centolla Net Fishing. There is a large scale fishery for *centolla* or southern king crab (*Lithodes antarctica*) in Punta Arenas, Porvenir and Ushuaia. Tangle nets, 1.30 m high and up to 1000 m in length, have been used for at least 15 years in the Beagle Channel and much longer in the mid-western Strait of Magellan. The nets are taken out in deep bays or channels, set, and left until the following day. *Cephalorhynchus commersonii*, *Lagenorhynchus australis* and *Phocoena spinipinnis* are occasionally taken in these nets.

Centolla Trap Fishing. The prohibition of tangle nets in Argentine Tierra del Fuego since 1976 has forced fishermen to change to crab traps, which require bait. In Argentine Fuegia, the only commercial crab fishing is in the eastern Beagle Channel, where there are few dolphins. The season is from 1 June to 15 December. When nets were used, the season was from October until December. The bait used is normally fish, caught by the crab boats or at San Sebastián by shore fishermen. A few cases of taking sea lions (*Otaria flavescens*) and dolphins have been reported.

In Chilean Fuegia, the season is from 1 July until 31 January and both traps and nets are still used. Fishermen prefer to use dolphin meat as bait in the crab traps. Sielfeld *et al.* (1977a, 1977b) estimated that in order to provide dolphin meat for all the traps during the 1976–77 season, 2,350 dolphins would have had to be killed. The actual number killed is unknown, as the fishermen do not practice it openly. The capture or killing of smaller cetaceans has been prohibited by law in Argentina since 1976 and in Chile since 1977, but no control is yet enforced in either country.

Robalo Net Fishing. Fishing for *robalo* (*Eleginops maclovinus*), *merluza* (*Merluccius australis*) and *pejerrey* (*Austroantherina sp.*) occurs on the Atlantic coast of Tierra del Fuego. This fishing is sometimes done by nets carried along the beach between a boat and men on shore, but the more common method is to attach the net, at low tide, to a row of stakes perpendicular to the shore line, allowing the net to lay on the sand. On the rising tide, floats raise the net and fish feeding in the zone are entangled, along with occasional dolphins.

For many years *robalo* fishing has been done in a small way by local fishermen who camped at places such as the Río Ewan mouth, Cabo San Pablo, Cabo Peñas, Cabo Domingo and Bahía San Sebastián. With the formation of a company during the 1976–77 season, fishing was intensified in Bahía San Sebastián. Three camps were set up, with two long nets at the SW end of the bay and four on the W side of the Península Páramo (see Fig. 2). *Robalo* is most abundant from October through March and it is only in this period that the operation is commercial.

The species accounts which follow show a total of 28 *Cephalorhynchus commersonii*, one *Lagenorhynchus australis* and one *Phocoena dioptrica* caught in *robalo* nets in Argentine Fuegia during the last three years. These represent only animals for which there are specimens. I have data on 15 other captures, but the actual number killed is probably very much higher.

According to the fishermen, some animals return to the sea. Those caught on a rising tide drown, but Commerson's dolphins caught on a falling tide remain alive on the beach and swim off with the next high tide. During low tide, several kilometers of sticky mud separate them from the water's edge. I have no data on *robalo* fishing in Chile.

METHODS

The specimens reported in this paper were obtained by checking the beaches on foot, walking parallel to the coast, paying special attention to the zone above the highest tide line. Along the Beagle Channel where there are few roads, beaches were checked on horseback or, occasionally, by boat. Along the Atlantic coast, it is easier to get near the beach and at times, such as at San Sebastián in summer, to drive directly on the beach. But usually specimens have to be carried out in a backpack. Periodic visits were made to beaches that produced the most specimens.

When the animals were sufficiently fresh, external measurements were taken, along with tracings of appendages, organ weights, samples and stomach contents. The processed specimens are in my collection in Ushuaia or at Estancia Harberton.

The collection up to number RNP 90 was determined by Robert L. Brownell, Jr. and Edward Mitchell in October, 1975, while specimens up to RNP 332 were identified by James G. Mead in February, 1976. Ricardo Praderi studied the collection in November, 1977.

THE SPECIMENS

Since most of these beaches had never been checked for cetacean material, a great quantity of very beach worn bones was found. Few of the early collections were in good condition and many of the skulls were broken or partial. At times, complete sets of vertebrae were found with the skulls, but usually the parts of a single animal were scattered.

In one instance, two uniquely deformed *Phocoena dioptrica* vertebrae, which were found 18 months and 20 km apart, united perfectly.

When the crania were found separately from the post-cranial skeletons, there is obvious overlapping in the collection, which probably contains more specimens than there were animals originally. Care was taken that each cranial collection, at least, represent a distinct animal.

The cool climate of Tierra del Fuego preserves dead animals for a considerable time. Fresh dolphins are often flensed by birds, mainly gulls (*Larus dominicanus*). Fishermen claim that a fresh Commerson's dolphin can be eaten in four or five hours, leaving the head and flukes intact, but with the major part of the vertebral column clean. After this stage, the birds no longer touch the animal, which may then remain on the beach or be taken by the tide. The collection dates given here do not necessarily indicate the stranding date ; most animals had been there a long time.

This paper deals only with general information on the collection. Detailed data on the individual species will be presented later.

Explanation of Tables. Localities (in kilometers) are abbreviated to north and south of a known point. On the west side of Bahía San Sebastián, where most of the specimens were collected, distances are taken north and south of the border between estancias San Martín and Cullen, which is near the middle of the west side of the bay and is marked with a fence.

On the basis of the fusion of the vertebral epiphysis, an indication of age is given. Total fusion, adult; fusion to thoracics, subadult; only caudals fused, immature. This classification does not indicate sexual maturity.

A specimen denoted as "nearly complete" usually lacks only a flipper, scapula, a few caudals or pelvic bones.

Other abbreviations: R, right; L, left; Ea., estancia or ranch; v, vertebrae; r, ribs; imm., immature; v. imm., very immature; subad., subadult; *=caught in *robolo* nets; #=caught in *centolla* nets.

The initials RNP are used for the cetacean collection to differentiate from RNPG, used for my botanical collection. C & G specimens were those collected by H. P. Castello and R.N.P. Goodall in 1974.

FAMILY DELPHINIDAE

Lagenorhynchus australis (Peale 1848)

Peale's dolphin, Blackchin dolphin, Delfín Austral

This is a coastal species known from northern Chile around Cape Horn to the Patagonian coast in Argentina (Brownell 1974, Aguayo 1975). Brownell (1974), summarizing the known records of this dolphin, shows a number of sight records but no specimens from the Tierra del Fuego area. Aguayo (1975) states that the Norris expedition on the R.V. *Hero* in 1968 collected nine specimens between the Golfo de Arauco and Cape Horn. Praderi (1977) gives information on seven museum specimens.

Although I have not had much opportunity to see dolphins in their natural habitat, my experience is that Peale's dolphin is very common throughout the channels and bays of Tierra del Fuego, but more numerous in the southern part, such as the Beagle Channel, while *Cephalorhynchus commersonii* is more numerous in the Strait of Magellan. Local residents confirm this impression. Peale's dolphin is regularly seen by fishermen and often rides the bow wave of boats.

In spite of this being one of the most common species seen in Fuegian waters, there have been relatively few strandings (Table 1). Perhaps the preference of Peale's dolphin for fiords and deep bays means that sick or dead animals would be broken up on the rocky beaches of southern Fuegia.

The Tierra del Fuego collection includes one complete and two nearly complete skeletons, four good craniums, two very incomplete craniums and two single mandibles.

Specimen 649, a female, was caught in *robalo* nets and retrieved by the fishermen, who covered the carcass with sacks to protect it from the birds until we returned one month later. Although it was in an advanced state of decomposition, we were able to discern the color pattern.

The other two nearly complete skeletons had already been flensed by birds when found.

Peale's dolphin, since it is common in the channels and is inclined to play around boats, is one of the species harpooned for *centolla* bait (Torres 1977). Many have probably been captured in the last two years (Sielfeld *et al.* 1977a, 1977b) but I know personally of only two instances. The skull of an animal harpooned near Puerto Williams in the eastern Beagle Channel on 15 Jan. 1977 is deposited in the Museo Martín Gusinde in Puerto Williams, and another was seen by the crew of the R.V. *Hero* aboard a crab boat in the western Beagle Channel in July, 1977 (T. D. Goodall, personal communication).

The craniums in Table 1 exhibit differences in overall size and cranial width, with specimens 179, 193 and 535 being the smallest, 269 and 649 intermediate and 287 and 291 the largest. Since there are very few differences between the skulls of *Lagenorhynchus australis* and *L. cruciger* (Fraser and Noble 1968), all will provisionally be included in *Lagenorhynchus australis* until further comparisons can be made.

Cephalorhynchus commersonii (Lacépède, 1804)
Commerson's dolphin, Tonina overa

This species, considered one of the most striking in the world, occurs from

TABLE 1. SPECIMENS OF *LAGENORHYNCHUS AUSTRALIS* STRANDED ON TIERRA DEL FUEGO

RNP no.	Locality	Date	Details
		NEARLY COMPLETE SKELETONS	
179	Estancia Moat	xi. 1975	Nearly complete (Col. J. Lawrence)
269	Ea. San Martín	28. i. 1976	Nearly complete
649	Península Páramo	28. i. 1978	Complete ♀ *
		CRANIAL MATERIAL	
193	Ea. San Martín 4 N	28. i. 1976	Cranium, fair; L mandible
287	San Sebastián 3 S	13. ii. 1976	Cranium, large, fair
291	San Sebastián 7.5 S	13. ii. 1976	Cranium, large, fair
439	Punta María N	3. iii. 1977	Incomplete cranium
535	Río San Martín 6 N	30. v. 1977	Incomplete cranium
544	Río Cullen S	1. vi. 1977	R mandible
545	Río Cullen S	1. vi. 1977	Incomplete cranium
547	Río Cullen S	1. vi. 1977	L mandible, smaller than 544
		POST CRANIAL MATERIAL	
161	Península Páramo	21. xii. 1975	16 vertebrae
418	Península Páramo	15. ii. 1977	2 teeth, 11 r, 21 v.
422	Península Páramo	15. ii. 1977	4 vertebrae
423	Península Páramo	15. ii. 1977	4 ribs, 5 vertebrae
476	Cabo Irigoyen	6. iii. 1977	3 caudals
554	Río Cullen S	1. vi. 1977	13 vertebrae

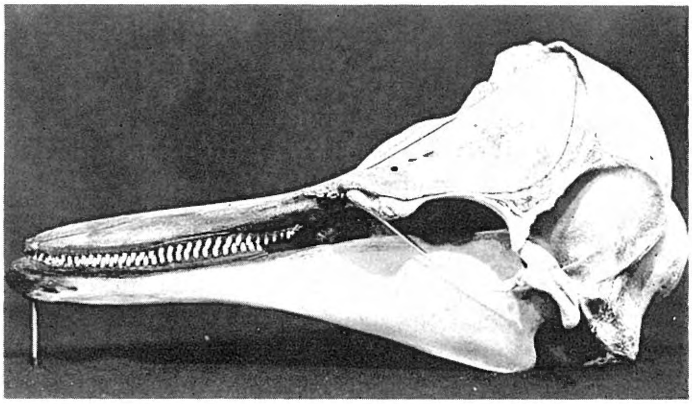

Fig. 3. *Lagenorhynchus australis*, lateral view of an immature female (RNP 649) caught by *robalo* fishermen on the Península Páramo in December, 1977. (Photo T. D. Goodall)

Peninsula Valdés, Argentina, to the Strait of Magellan and Tierra del Fuego, the Falkland (Malvinas) Islands, South Georgia and Kerguelen Island (Brownell 1974, Aguayo 1975, Rice 1977).

Brownell (1974) shows only two specimens of indefinite locality from Tierra del Fuego and one from the Strait of Magellan. Norris (1968) captured two more specimens in the Strait of Magellan in 1968. Sightings have been made in the Beagle Channel and south of Cape Horn (Olrog 1950, Aguayo 1975). Strange (1972) considered this the most common dolphin off the Falkland (Malvinas) Islands.

The opinion of local residents that the Commerson's dolphin is more common in the northern part of Tierra del Fuego than in the southern seems to be confirmed by the collections, most of which are from Bahía San Sebastián (Table 2).

Since this is a coastal species (Brownell 1974), one would assume that it would be one of the most likely to be victim to accidental exploitation. J. G. Mead (in Mitchell 1975) found that the Commerson's dolphin was taken incidental to *centolla* fishing north of Río Gallegos. He estimated the number taken as less than 20 per year and perhaps 100 per year on the whole coast.

The specimens from Tierra del Fuego show a heavy accidental catch. During the 1977–78 season, when fishermen at San Sebastián started saving skeletons for me, eleven fresh animals and 20 skeletons flensed by birds were collected. Three of these were caught in *centolla* nets and 28 in *robalo* nets. This does not represent the full catch, as some caught in *robalo* nets were sent to Ushuaia for crab bait, some lived until the following high tide and were able to swim away, and some carcasses left out on the bay near the nets floated away. The catch in Chilean Fuegia is probably much higher still. Fishermen at Bahía Inútil, using only two of the many boats in the area, estimated a catch of 20–30 per year in their *centolla* nets.

Of the animals of known sex caught by fishermen, there were twice as many males (thirteen) as females (six). Based on fusion of the epiphysis, six very immature, 12 immature, two subadult and 12 adult or very old animals were caught, appearing to be a fairly relative sample of the local population. Several of the " immature " specimens showed adult total lengths.

During the first week of December, 1977, two pregnant females were caught at the Península Páramo. One dolphin was born on the beach and the other was removed by the fishermen after the mother died. Both were sent to Ushuaia for crab bait. When I checked with the company, they had already been used. These two records, confirmed by several fishermen and the director of the *centolla* factory, along with that of the dolphin (RNP 634) with a near term fetus caught on 12 Dec. 1977, indicate that *Cephalorhynchus commersonii* calve in early summer.

Three other records of Commerson's dolphin, not given in Table 2, can be mentioned. On 16 Oct. 1972, fishermen left a small female (112 cm) on the beach in Ushuaia. The animal was not preserved, but measurements and drawings were recorded.

A Commerson's dolphin, caught by *robalo* fishermen on 21 May 1976 at Río Grande, has been mounted and is on display in the Museo Salesiano, Río Grande.

On 28 Jan. 1978, we saw a Commerson carcass, partially flensed by birds, beside a net on the Péninsula Páramo, but could not reach it because of the deep mud. The pigmentation pattern was clearly recognizable.

Lissodelphis peronii (Lacépède, 1804)

Southern right whale dolphin, Delfín liso

This dolphin, mainly on the basis of sightings, seems to be widely distributed around the world in the southern hemisphere (Brownell 1974, Aguayo 1975, Mitchell 1975). Gaskin (1968) recorded many sightings but no strandings for New Zealand.

The known sightings and stranding records for the species are shown by

TABLE 2. NEW SPECIMENS OF *CEPHALORHYNCHUS COMMERSONII* FROM TIERRA DEL FUEGO

RNP no.	Location	Date	Details	Sex	Maturity
			NEARLY COMPLETE SKELETONS		
75	Bahía Inútil	24. ii. 1975	Nearly complete ?		v. imm.
81	Cabo Peñas S	31. vii. 1975	Nearly complete ?		subad.
395	Cabo Peñas S	16. i. 1977	Nearly complete *		v. imm.
398	Cabo Peñas S	16. i. 1977	Nearly complete *		imm.
399	Cabo Peñas S	16. i. 1977	Nearly complete *		imm.
414	San Sebastián S	13. ii. 1977	Nearly complete *		imm.
415	San Sebastián S	13. ii. 1977	Nearly complete *	♂	imm.
497	Río Lainez	5. iii. 1977	Nearly complete *		imm.
574	Bahía Inútil	26. vii. 1977	Complete, fresh #	♂	imm.
575	Bahía Inútil	26. vii. 1977	Nr. complete, fresh #	♀	v. imm.
576	Punta Arenas	29. vii. 1977	Complete, fresh #	♂	imm.

Continued . .

TABLE 2. Continued.

RNP no.	Location	Date	Details		Sex	Maturity
577	San Sebastián S	30. xi. 1977	Complete, fresh	*	♀	v. imm.
578	Ea. San Martín N	5. xi. 1977	Nearly complete	*		adult
595	Península Páramo	24. xi. 1977	Complete, fresh	*	♂	adult
596	San Sebastián S	28. xi. 1977	Complete	*	♂	v. imm.
619	San Sebastián S	11. xii. 1977	Complete, fresh	*	♂	imm.
620	San Sebastián S	11. xii. 1977	Complete, fresh	*	♂	adult
623	San Sebastián S	11. xii. 1977	Nearly complete	*		adult
632	Península Páramo	12. xii. 1977	Complete	*	♂	imm.
633	Península Páramo	12. xii. 1977	Complete	*	♀	v. imm.
634	Península Páramo	12. xii. 1977	Complete, pregnant	*	♀	adult
635	Península Páramo	12. xii. 1977	Entire in formol	*	♂	fetus of 634
636	San Sebastián	20. xii. 1977	Complete, fresh	*	♂	adult
637	San Sebastián	20. xii. 1977	Complete, fresh	*	♂	adult
645	Península Páramo	12. xii. 1977	Nearly complete	*		subad.
646	Península Páramo	28. i. 1978	Nearly complete	*		imm.
647	Península Páramo	28. i. 1978	Nearly complete	*	♂	adult
648	Península Páramo	28. i. 1978	Nearly complete	*	♂	adult
650	Península Páramo	28. i. 1978	Nearly complete	*		imm.
651	Península Páramo	28. i. 1978	Nearly complete	*		adult
652	Península Páramo	28. i. 1978	Nearly complete	*	♀	imm.
653	Península Páramo	28. i. 1978	Complete	*	♀	adult
655	Península Páramo	28. i. 1978	Nearly complete	*		adult
			CRANIAL MATERIAL			
7	Cabo Domingo	27. ix. 1975	Cranium, incomplete; 1 v.			
14	Río Fuego N	30. ix. 1975	Cranium, incomplete; L mandible			
19	Río Fuego N	30. ix. 1975	Cranium, fair			
20	Río Fuego N	30. ix. 1975	Cranium, fair			
22	Río Fuego N	30. ix. 1975	Cranium, incomplete, poor			
23	Río Fuego N	30. ix. 1975	Cranium, incomplete, poor			
24	Río Fuego mouth	30. ix. 1975	Cranium, incomplete, poor			
40	Ea. San Martín N	12. v. 1975	Cranium, poor			(Col. J. Tico)
43	Ea. Viamonte	12. iv. 1974	Cranium, v. poor			(C & G 1)
44	Ea. Viamonte SE	12. iv. 1974	Cranium, poor			(C & G 2)
45	Ea. Viamonte	12. iv. 1974	Cranium, v. poor			(C & G 3)
49	Ea. Viamonte SE	12. iv. 1974	Cranium, v. poor			(C & G 5)
52	Ea. Viamonte SE	12. iv. 1974	Cranium, good			(C & G 8)
54	Península Páramo	13. iv. 1974	Cranium, v. poor			(C & G 10)
55	Península Páramo	1970	Cranium, fair (Col. N. O'Byrne)			(C & G 11)
57	Ea. Viamonte	1971	Cranium, good			imm. (C & G 13)
63	Península Páramo	4. vii. 1974	Complete skull, good			v. imm.
64	Península Páramo	4. vii. 1974	Cranium, v. poor			
68	Cabo Peñas SE	5. vii. 1974	Cranium, v. poor			
72	Punta María N	5. vii. 1974	Cranium, poor			
79	Punta María SE	39. vii. 1975	Cranium, v. poor			
80	Punta María SE	31. vii. 1975	Cranium, v. poor			
134	Ea. Las Violetas	19. xii. 1975	Complete skull, good			v. imm.
139	Cabo Espiritu Santo	20. xii. 1975	Cranium, good			

Continued . . .

TABLE 2. Continued.

RNP no.	Location	Date	Details	Maturity
140	Cabo Espiritu Santo	20. xii. 1975	Cranium, v. poor	
150	Península Páramo	21. xii. 1975	L. mandible	
155	Península Páramo	21. xii. 1975	Cranium, v. poor	
156	Península Páramo	21. xii. 1975	Cranium, poor	
161a	Península Páramo	21.xii. 1975	R mandible	
166	Península Páramo	21. xii. 1975	Cranium, v. poor	
186	Ea. San Martín 4 N	28. i. 1976	Cranium, fair, oil covered	
192	Ea. San Martín N	28. i. 1976	Cranium, fair	
212	Ea. San Martín 4 N	28. i. 1976	Cranium, poor	
217	Ea. San Martín 4 N	28. i. 1976	Cranium, poor	
250	Ea. San Martín 6 N	28. i. 1976	Cranium, v. poor	
260	Ea. San Martín 6–7 N	28. i. 1976	Cranium, v. poor	
294	San Sebastián 7.6 S	13. ii. 1976	Cranium, fair	
295	San Sebastián 4 S	13. ii. 1976	Cranium, poor	
321	San Sebastián 7.5 S	13. ii. 1976	Cranium, good	
322	San Sebastián 12.8 S	13. ii. 1976	Cranium, fair	
323	San Sebastián 13 S	13. ii. 1976	Cranium, fair	
359	Río San Martín S	21. xi. 1976	Cranium, v. poor	
396	Cabo Peñas S	16. i. 1977	Mandibles, teeth	
407	Cabo Peñas S	16. i. 1977	Cranium, v. poor	
417	Península Páramo	15. ii. 1977	Cranium, poor	
420	Península Páramo	15. ii. 1977	Cranium, v. poor	
442	Punta María 7 N	3. iii. 1977	Cranium, poor	
450a	Punta María 1 N	3. iii. 1977	Cranium, v. poor	
458	Punta María S	4. iii. 1977	Cranium, v. poor	
508	San Martín N	8. iv. 1977	Cranium, v. poor	
514	Río Grande S	9. iv. 1977	Cranium, v. poor	
528	Los Chorrillos 4 N	29. v. 1977	Cranium, poor; R mandible	
565	Bahía Inútil E	25. vii. 1977	Cranium, fair	imm.
569	Bahía Inútil E	25. vii. 1977	Cranium, L mandible, v. good	v. imm
591	Ea. San Martín 3 N	21. xi. 1977	Cranium, v. poor	
598	San Sebastián S	28. xi. 1977	L mandible, good	
603	San Sebastián S	28. xi. 1977	Cranium, v. poor	
627	Río San Martín 3 N	11. xii. 1977	Cranium, v. poor	
POST CRANIAL MATERIAL				
16	Río Fuego N	30. iv. 1975	13 vertebrae	
69	Punta María NW	5. vii. 1974	27 vertebrae	
165	Península Páramo	21. xii. 1975	15 vertebrae	
300	San Sebastián 13 S	13. ii. 1976	Sternum, 15 r, 59 v.	adult
397	Cabo Peñas S	16. i. 1977	12 r. 46 v.	imm.
474	Río Lainez SE	5. iii. 1977	12 vertebrae	
475	Cabo Irigoyen	6. iii. 1977	Cervicals	
496	Cabo Peñas S	3. iii. 1977	Cervicals	v. imm.
526	Los Chorrillos N	29. v. 1977	33 vertebrae	adult
549	Río Cullen S	1. vi. 1977	27 vertebrae	imm.
560/562	Río Marazzi	25. vii. 1977	47 vertebrae	adult
570	Río Marazzi	25. vii. 1977	Almost complete	adult
593	Península Páramo	21. xi. 1977	6 ribs, 19 vertebrae	

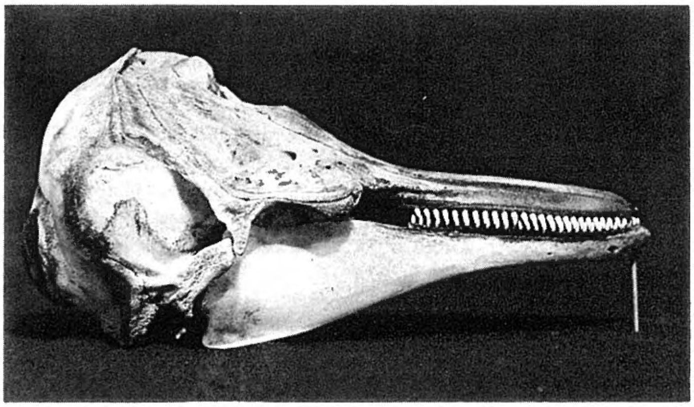

Fig. 4. *Cephalorhynchus commersonii,* lateral view of an adult male (RNP 636) caught in *robalo* nets at Bahía San Sebastián in December, 1977. (Photo T. D. Goodall)

Brownell (1974), who gives a total of only seven specimens, six from southern South America and one from Tasmania. Of those from South American waters, four were collected well off shore and two were found at Bahía Thetis, Tierra del Fuego. Aguayo (1975) records a live animal caught by fishermen at Concón, Chile, which was later released.

The collection now reported includes four nearly complete skeletons, 17 cranial specimens and eight groups of isolated vertebrae.

The four nearly complete specimens were found in a mummified state on the mud flats and had been partially flensed by birds. The tips of the flippers and of the upper jaw of RNP 656 had been eaten, probably by a fox (*Dusicyon griseus*).

TABLE 3. TIERRA DEL FUEGO SPECIMENS OF *LISSODELPHIS PERONII*

RNP no.	Location	Date	Details
		SKELETONS	
288	San Sebastián 6 S	13. ii. 1976	Nearly complete skeleton
656	San Sebastián N	29. i. 1978	Nearly complete skeleton
676	Río San Martín 2 N	15. iv. 1978	Nearly complete skeleton
677	Río San Martín 2 N	15. iv. 1978	Nearly complete skeleton
		CRANIAL MATERIAL	
51	Ea. Viamonte	12. iv. 1974	Cranium, good, (C & G 7)
58	Bahía Thetis	xi. 1969	Cranium, good
109	Isla Gable	20. xi. 1975	Cranium, R mandible, 10 r, 5 v (Col. R. Scotti)
168	Cutalataca, Ea. Harberton	27. ii. 1975	Cranium, 2 ribs
218	Ea. San Martín 4 N	28. i. 1976	Mandibles, incomplete
233	Ea. San Martín 4 N	28. i. 1976	Cranium, R mandible, 3 r, 2 v
237	Ea. San Martín 3 N	28. i. 1976	Cranium, incomplete
255	Ea. San Martín 6 N	28. i. 1976	Cranium, incomplete
265	Ea. San Martín 6 N	28. i. 1976	Cranium, incomplete

Continued . . .

TABLE 3. Continued.

PNR no.	Location	Date	Details
266	Ea. San Martín 6 N	28. i. 1976	R mandible
352	Río San Martín S	21. xi. 1976	Cranium, incomplete
367	Río San Martín S	21. xi. 1976	Cranium, incomplete
369	Río San Martín S	21. xi. 1976	Cranium, incomplete
607	San Sebastián S	28. xi. 1977	Cranium, excellent; 4 v
629	Río San Martín 3 N	11. xii. 1977	Cranium, incomplete
631	Río San Martín 3 N	11. xii. 1977	Cranium, fair
679	San Sebastián 2 S	15. iv. 1978	Cranium, good
		POST CRANIAL MATERIAL	
104	Ea. Viamonte	12. ix. 1974	5 vertebrae (2 cervicals)
124	Ea. Las Violetas	18. xii. 1975	5 ribs, 10 vertebrae
183	Ea. Harberton	1972	Sternum, 9 vertebrae
257	Ea. San Martin 6 N	28. i. 1976	15 vertebrae
340	Auricosta, Ea. Viamonte	14. xi. 1976	2 vertebrae
362	Río San Martín	21. xi. 1976	Cervicals
365	Río San Martín	21. xi. 1976	3 vertebrae
430	Cabo Peñas	16. ii. 1977	4 vertebrae

Fig. 5. *Lissodelphis peronii*, specimen RNP 656 as found on the mud flat of northern Bahía San Sebastián in January, 1978. (Photo RNP)

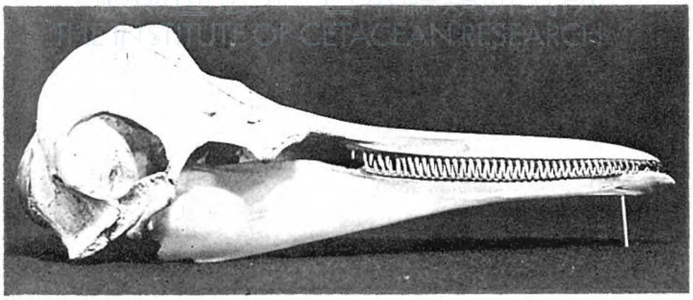

Fig. 6. *Lissodelphis peronii*, lateral view of specimen RNP 288 from Bahía San Sebastián, February, 1976. (Photo T. D. Goodall)

The eleven cranial specimens from the Río San Martín area, all beach worn, may represent a mass stranding.

Most sightings of the southern right whale dolphin have been well offshore (Brownell 1974) and it has generally been considered pelagic (Mitchell 1975) or pelagic and coastal (Aguayo 1975). The collections from Bahía San Sebastián and the two specimens found well within the Beagle Channel (Cutalátaca and Gable Island), indicate that it may occasionally inhabit shallow waters.

Globicephala melaena (Traill 1809)
Long-finned pilot whale, Piloto, Calderon

The long-finned pilot whale is common throughout the Southern Ocean north of the Antarctic Convergence but associated with cold currents. There is a distinct population in the North Atlantic Ocean. Specimens are known from all shores of the southern continents and larger islands (Mitchell 1975, Brownell 1974). Brownell (1974) cites 13 specimens from southern waters, including one from Isla de los Estados. Piñero and Castello (1975) summarize South Atlantic mass strandings from Uruguay, the Falkland (Malvinas) Islands and Bahía Blanca, Argentina. The only specimens they cite from Tierra del Fuego were parts of eleven animals collected by Norris from Isla Navarino in 1968.

Pilot whale strandings are common on Tierra del Fuego beaches. Strandings from which specimens were collected (worn material was not collected) are given in Table 4. Skeletons which were left on the beach to be collected later, because of their weight and state of decomposition, are indicated in parenthesis.

In December, 1966, two pilot whales (RNP 1 and 2) were found stuck in the mud of the First West Creek, Estancia Harberton. Although they lived for two days, there was no way to free them. Both skeletons (434 and 410 cm long respectively) are preserved at Estancia Harberton.

Several other Fuegian strandings of pilot whales are known. Eleven animals stranded south of the Estancia Viamonte houses in 1928 or 1929 (T. L. Bridges, personal communication). RNP numbers 21, 27 and 31 may represent part of this stranding, since bones are shifted northward by the rising tide.

On 7 November, 1971, while on a botanical expedition aboard the R.V. *Hero* to Isla de los Estados, T. R. Dudley and I saw and photographed a mass stranding of nine pilot whales in Bahía Flinders. Because of their semi-decomposed condition, no specimens were collected.

One pilot whale cranium, without data, is on exhibit at the Museo Salesiano in Río Grande, and there are others in Fuegian private homes.

The specimens collected at Cabo Irigoyen and Estancia Fueguina (Table 4) represent cranial material from 17 animals. These were part of a mass killing by depth charges of 27 adult and 12 young pilot whales in 1972. The animals came ashore at Estancia Irigoyen, then washed north beyond Cabo Irigoyen and on to Estancia Fueguina (Nemesio Menéndez, personal communication, 1977).

TABLE 4. TIERRA DEL FUEGO STRANDINGS OF *GLOBICEPHALA MELAENA* SPECIMENS IN PARENTHESIS WERE NUMBERED ON THE BEACH

RNP no.	Locality	Date	Collected	Still on beach
	NEARLY COMPLETE SKELETONS			
1	Estancia Harberton	xi. 1966	Complete ♂	
2	Estancia Harberton	xi. 1966	Complete ♀	
432	Cabo Peñas S	17. ii. 1977	L flipper	(complete)
433	Cabo Peñas S	17. ii. 1977		(complete ♂)
523	Bahía Brown	25. iv. 1977	Complete ♀ imm., deformed spine	
610	San Sebastián S	28. xi. 1977	Complete	
	CRANIAL MATERIAL			
21	Río Fuego N	30. ix. 1975	Cranium, good	
27	Río Fuego N	30. ix. 1975	Cranium, beach worn	
31	Río Fuego N	30. ix. 1975	Mandible	
62	Península Páramo	4. vii. 1974	Cranium, good, large	
67	Cabo Peñas S	5. vii. 1974	Mandible	
76	Ea. Fueguina	25. v. 1975	Cranium, good; few vertebrae	
77	Ea. Fueguina	27. v. 1975	Cranium, 1 mandible, ribs	
175	San Sebastián N	21. xii. 1975	Cranium, incomplete	
280	San Sebastián 18 N	13. ii. 1976	Cranium, incomplete	
284	San Sebastián 18 N	13. ii. 1976	Cranium, good; 19 v, 16 r	
335	Ea. Viamonte	12. iv. 1974	Mandible	
343	Ea. San Martín S	21. xi. 1976	Mandible	
477	Cabo Irigoyen N	6. iii. 1977	2 teeth, 1 earbone	
478	Cabo Irigoyen N	6. iii. 1977	1 tooth	(large ♂, complete)
479	Cabo Irigoyen N	6. iii. 1977	1 earbone	(small, nearly complete)
480	Cabo Irigoyen N	6. iii. 1977	Half earbone	(skull)
481	Cabo Iriogyen N	6. iii. 1977	Photographs	(large, complete)
482	Cabo Irigoyen N	6. iii. 1977	Cranium, medium sized	
483	Cabo Irigoyen N	6. iii. 1977	Mandible, scapula	(skeleton buried)
484	Cabo Irigoyen N	6. iii. 1977	Mandible	(skeleton)
485	Cabo Irigoyen N	6. iii. 1977	Cranium, small	
486	Cabo Irigoyen N	6. iii. 1977	Cranium, medium	
487	Cabo Irigoyen N	6. iii. 1977	Mandible	
488	Cabo Irigoyen N	6. iii. 1977	Cranium, partial skeleton, v. imm.	
489	Cabo Irigoyen N	6. iii. 1977	Cranium, medium	
490	Cabo Irigoyen N	6. iii. 1977	Cranium, med. lg.; 2 v	
491	Cabo Irigoyen N	6. iii. 1977	Cranium, medium	
571	Río Centenario, B. Inútil	25. vii. 1977	Cranium, v. large	
572	Río Centenario, B. Inútil	25. vii. 1977	Cranium, medium	
573	Río Centenario, B. Inútil	25. vii. 1977	Cranium, medium large	
	POST CANIAL MATERIAL			
381	Najmishk, Ea. Viamonte	19. xii. 1976	Several vertebrae	
408	Cabo Peñas SE	16. i. 1977	Scapula, flipper	(may belong to 432)
416	Península Páramo	15. ii. 1977	Cervicals	
473	Río Lainez	5. iii. 1977	Cervicals, 5 vertebrae	
617	Punta Maria SE	10. xii. 1977	Cervicals, 11 thoracics, 9 ribs	
644	Río Ewan SE	1. i. 1978	Six vertebrae	

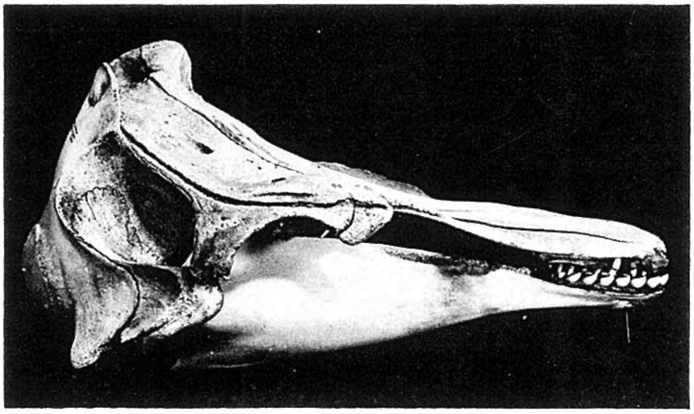

Fig. 7. *Globicephala melaena*, lateral view of an immature female (RNP 523) with a deformed spine found at Bahía Brown in April, 1977. (Photo I. S. Cameron)

Orcinus orca (Linnaeus, 1758)

Killer whale, Orca

Killer whales are found in all oceans, but are most abundant in cold waters of both hemispheres (Brownell 1974, Mitchell 1975, Rice 1977). Although common, very few specimens are known from the southern hemisphere (below 35°S). Gaskin (1968) records various strandings for New Zealand, but listed only four specimens. Brownell (1974) shows five specimens, including three of those cited by Gaskin.

Strandings of killer whales are common on Fuegian beaches. Because of their size and state of decomposition (usually still held together by very hard, dry meat and skin), most of the specimens listed below (Table 5) have been numbered and left on the beach. Certain bones have been collected as they come loose.

Fig. 8. View of one (RNP 674) of four *Orcinus orca* stranded on the mud flats in late 1972. Photograph of mummified carcass taken 13. ii. 1976. (Photo RNP)

Fig. 9. *Orcinus orca* (RNP 303), one of fifteen stranded along the vegetation line at southwestern Bahía San Sebastián. (Photo RNP)

TABLE 5. STRANDINGS OF *ORCINUS ORCA*. SPECIMENS IN PARENTHESIS HAVE NOT YET BEEN COLLECTED, BUT WERE NUMBERED ON THE BEACH

RNP no.	Locality	Date	Collected	Still on beach
137	Ea. San Martín SE	13. iv. 1974	Scapula, ribs	(nearly complete)
185	Ea. San Martín N	28. i. 1976	Cranium, mandibles, ears, some vert.	
256	Ea. San Martín 6 N	28. i. 1976	Cranium, incomplete	
289	San Sebastián S	13. ii. 1976		(complete)
290	San Sebastián S	13. ii. 1976		(good skull)
293	San Sebastián S	13. ii. 1976	Earbones	(complete, large)
303	San Sebastián 13 S	13. ii. 1976	1 earbone, 1 tooth	(complete)
304	San Sebastián 13.5 S	13. ii. 1976		(mostly complete)
305	San Sebastián 13.6 S	13. ii. 1976	Discs 4	(mostly complete)
306	San Sebastián 13.6 S	13. ii. 1976		(♂ complete, v. large)
307	San Sebastián 13.7 S	13. ii. 1976	Discs	(complete)
308	San Sebastián 13.7 S	13. ii. 1976	1 earbone	(complete)
309	San Sebastián 13.8 S	13. ii. 1976	1 earbone, 2 teeth	(complete)
310	San Sebastián 14 S	13. ii. 1976	1/2 earbone, 12 teeth LR	(nearly comp.)
311	San Sebastián 14.5 S	13. ii. 1976		(nearly complete)
312	San Sebastián 14.7 S	13. ii. 1976	1/2 earbone, 1 pelvic	(complete, small)
563	Río Marazzi,	25. vii. 1977	Cervicals	
612	San Sebastián N	21. xii. 1975	Scapula	(♂ complete, mummified)
662	San Sebastián 15 S	13. ii. 1976		(small, complete)
663	Río San Martín S	21. xi. 1976		(complete)
672	San Sebastián N	21. xii. 1975		(♀ complete, mummified)
673	San Sebastián N	21. xii. 1975		(♂ complete, mummified)
674	San Sebastián N	21. xii. 1975		(♂ complete, mummified)

Four killer whales (RNP 612, 672, 673 and 674) were stranded together on the San Sebastián mud flats in November, 1972. I first saw them in 1975 and have visited the location several times a year since then (Fig. 8). These animals are about one km out from shore on the mud and have been " mummified " by the salt water which reaches them on the very highest tides. The skin and meat have gradually decayed away on the under side, leaving the skeleton with an upper tough, lichen encrusted covering.

Along the outer edge of vegetation bordering the salt flats at the west side of Bahía San Sebastián, a series of 15 nearly complete orca skeletons are spread over a distance of about eight kilometers (Fig. 9). All are about the same stage of decomposition, almost surely representing a mass stranding, probably a little earlier than the four " mummified " whales farther north. Many of these have been damaged by people chopping at the jaws, trying to remove the teeth.

FAMILY PHOCOENIDAE

Phocoena spinipinnis Burmeister, 1865

Burmeister's porpoise, Black porpoise, Marsopa espinosa

Fraser (1948) calls this porpoise a rarely occuring species. Aguayo (1975) shows its distribution in Chile as reaching south to Valdivia (40°S). It seems to be fairly common in northern Chile and Peru, where it is taken for food (Mitchell 1975, Anonymous 1975). On the Atlantic coast, this porpoise has been cited for Uruguay (Praderi 1971, Pilleri and Gihr 1972, 1974) and southward to Patagonia (Praderi 1971). Rice (1977) summarizes, " East coast of South America from Uruguay to Patagonia ; west coast from Paita, Peru, to Valdivia, Chile."

Pilleri and Gihr (1972) illustrated the species as occurring all the way from Uruguay around Cape Horn to Peru, but Brownell and Praderi (1975) rightly felt that this was not valid, since no sightings nor specimens for the species existed as far south as the Strait of Magellan. They thought that the Atlantic and Pacific populations might be isolated.

Few museum specimens are known of this species. Praderi (1971) mentions only eight. The specimens represented in Table 6 are the southernmost known and the first from the Cape Horn area.

Specimens 110 and 111 were taken in *centolla* nets. On 3 Dec. 1975, another

TABLE 6. NEW SPECIMENS OF *PHOCOENA SPINIPINNIS* FROM TIERRA DEL FUEGO

RNP no.	Locality	Date	Details	Maturity
		NEARLY COMPLETE SKELETONS		
110	Isla Redonda, Canal Beagle	2. xii. 1975	Complete #	imm.
111	Canal Beagle	4. xii. 1975	Complete #	imm.
167	Punta Segunda, Canal Beagle	24. xii. 1975	Nearly complete # ?	subad.
		CRANIAL MATERIAL		
451	Punta María 2 N	3. iii. 1977	Cranium, fair, small	
546	Río Cullen S	1. iv. 1977	Cranium, poor	v. imm.
		POST CRANIAL MATERIAL		
551	Río Cullen S	1. vi. 1977	4 thoracics	adult
375	Río San Martín 3 S	21. xi. 1976	17 vertebrae, 7 ribs	
458	Punta María N	3. iii. 1977	2 vertebrae	imm.

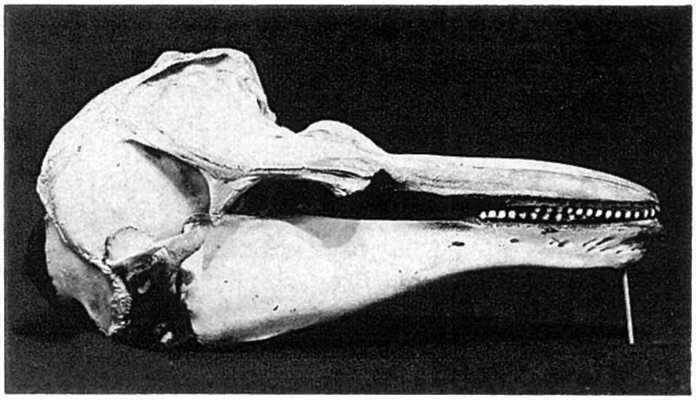

Fig. 10. *Phocoena spinipinnis*, lateral view of specimen RNP 111, caught in *centolla* nets in the Beagle Channel in December, 1976. (Photo T. D. Goodall)

Burmeister's porpoise was caught in the nets in Lapataia Bay, Beagle Channel. The fishermen, who threw it overboard, estimated it to be about 160 cm in length.

Specimen 167 was found on the beach to the east of Ushuaia ; it also may have been caught in crab nets. Although very fresh, it had been eaten by dogs and the sex could not be determined.

The collection of these specimens in Tierra del Fuego indicates that *Phocoena spinipinnis* may occur continuously around southern South America from Uruguay to Peru. Further studies are needed in the area south of 40°S.

Phocoena dioptrica Lahille, 1912

Spectacled porpoise, Marsopa de anteojos

Praderi (1971) and Brownell (1975), who gave the most complete accounts of this species, listed only ten specimens (one a fetus) and one stranding observation, all from the western South Atlantic. The type specimen presumably has been lost. The collection of a skull in January, 1974, from New Zealand (Baker 1977, Cawthorne 1977) greatly extended the known distribution.

The range of this cetacean can now be considered to include the western South Atlantic coast from Uruguay to Tierra del Fuego, the Falkland (Malvinas) Islands, South Georgia and New Zealand (Baker 1977).

The species has been sighted alive only near New Zealand (M. Cawthorn, personal communication 1977) although a possible sighting has been reported from Kerguelen (Frost and Best 1976), which could indicate a circum polar distribution around off shore islands.

This work presents eleven fairly complete skeletons, 76 complete or partial skulls and 25 groups of vertebrae. A further 29 post-cranial specimens from the collection, containing from one to 44 vertebrae, have not been included.

Total lengths are available for only six of the eleven most complete specimens. Due to the state of decomposition, pigmentation was discernable on only four occasions (RNP 412, 413, 658 and 670). Specimen 670 was fresh and has been preserved entire in formol. Dorsal fin tracings were taken from five animals.

Two specimens, RNP 413 and 670, probably unweaned animals since dentition had not erupted, were found in mid-February and late March. The only other reproductive data known for the species was that of two pregnant females with near term fetuses obtained in late July and mid-August (Brownell 1975). The finding of two suckling animals in late summer seems to confirm that young may be born in late winter or early spring.

Only one of the specimens (RNP 412) was definitely known to have been taken accidentally (in a *robalo* net). Specimen 413 was presumably its calf and probably died after the mother was caught. Both were found in advanced stages of decomposition.

Another specimen (670) had been deliberately wounded and its mother could not be found. It lived for three hours and observations were made of it swimming in Harberton Bay. No other specimen has been collected alive (Anonymous 1975). This is the only specimen from southern Tierra del Fuego.

In view of these numerous beach collections, *Phocoena dioptrica* appears to be the small cetacean most common in the waters off northeastern Tierra del Fuego, yet there are no published observations of live animals in this area (Brownell 1974). The collection of the majority of these specimens from Bahía San Sebastián and one from the Beagle Channel seem to indicate that it is an inshore species.

TABLE 7. SPECIMENS OF *PHOCOENA DIOPTRICA* FOUND ON TIERRA DEL FUEGO BEACHES

RNP no.	Locality	Date	Details	Maturity
		NEARLY COMPLETE SKELETONS		
82	Cabo Peñas S	31. vii. 1975	Nearly complete	imm.
298	San Sebastián 10 S	13. ii. 1976	Nearly complete	imm.
299	San Sebastián 12.8 S	13. ii. 1976	Nearly complete	imm.
412	Ea. San Martín S	13. ii. 1977	Complete ♀ *	imm.
413	Ea. San Martín N	13. ii. 1977	Complete ♂	v. imm.
443	Punta María 5–6 NW	3. iii. 1977	Fairly complete	subad.
533	Ea. San Martín S	30. v. 1977	Nearly complete	imm.
536	Río San Martín 7 N	31. v. 1977	Nearly complete	imm.
625	Río San Martín 3 N	11. xii. 1977	Nearly complete	v. imm.
658	Ea. San Martín N	29. i. 1978	Complete	adult
670	Puerto Harberton	25. iii. 1978	Complete, fresh entire in formol	v. imm.
		CRANIAL MATERIAL		
11	Ea. Viamonte	30. ix. 1975	Cranium, incomplete	
17	Río Fuego N	30. ix. 1975	Cranium, incomplete	
33	Río San Martín	12. v. 1975	Cranium, fair	(Col. J. Tico)
34	Río San Martín	12. v. 1975	Cranium, good	(Col. J. Tico)
35	Río San Martín	12. v. 1975	Cranium, incomplete	(Col. J. Tico)
36	Río San Martín	12. v. 1975	Cranium, good	(Col. J. Tico)
37	Río San Martín	12. v. 1975	Cranium, incomplete	(Col. J. Tico)
38	Río San Martín	12. v. 1975	Cranium, good	(Col. J. Tico)

Continued . . .

TABLE 7. Continued.

RNP no.	Locality	Data	Details	Maturity
39	Río San Martín	12. v. 1975	Cranium, mandibles, earbones	(Col. J. Tico)
48	Ea. Viamonte 2 SE	12. iv. 1974	Cranium, incomplete	(C & G 4)
50	Ea. Viamonte 2 SE	12. iv. 1974	Cranium, fair	(C & G 6)
65	Cabo Peñas SE	5. vii. 1974	Cranium, 36 v., ribs	adult
70	Punta María NW	5. vii. 1974	Cranium, incomplete	
71	Punta María NW	5. vii. 1974	Cranium, incomplete	
85	Cabo Peñas SE	31. vii. 1975	Cranium, good; mandibles	
117	Cabo Peñas SE	18. xii. 1975	Cranium, incomplete	
118	Cabo Peñas SE	18. xii. 1975	Cranium, incomplete	
123	Ea. Las Violetas	18. xii. 1975	Cranium, fair; mandibles broken	
141	Cabo Espiritu Santo	20. xii. 1975	Cranium, very incomplete	
176	San Sebastián N	21. xii. 1975	Cranium, poor	
191	Ea. San Martín N	28. i. 1976	Cranium, crushed	
194	Ea. San Martín 4 N	28. i. 1976	Cranium, fair; R mandible; 2 r	
195	Ea. San Martín 4 N	28. i. 1976	Cranium, fair; 18 r, 21 v	
198	Ea. San Martín 4 N	28. i. 1976	Cranium, incomplete	
204	Ea. San Martín N	28. i. 1976	Cranium, fair; 2 v.	imm.
206	Ea. San Martín 4–5 N	28. i. 1976	Cranium, fair	
221	Ea. San Martín 4–5 N	28. i. 1976	Cranium, very incomplete	
224	Ea. San Martín 4–5 N	28. i. 1976	Cranium, poor	
225	Ea. San Martín 4–5 N	28. i. 1976	Cranium, fair	
234	Ea. San Martín 4–5 N	28. i. 1976	Cranium, fair	
239	Ea. San Martín 3–4 N	28. i. 1976	Cranium, v. incomplete; 3 r, 2 v	
251	Ea. San Martín 6 N	28. i. 1976	Cranium, v. incomplete; 2 v	
262	Ea. San Martín 6 N	28. i. 1976	Left mandible	
263	Ea. San Martín 6 N	28. i. 1976	Left mandible	
267	Ea. San Martín 6 N	28. i. 1976	Cranium, fair; earbone, hyoids, 33 v, 2 chevrons	imm.
297	San Sebastián 7.5 S	13. ii. 1976	Cranium, good	
302	San Sebastián 16.3 S	13. ii. 1976	Cranium, v. incomp.; sternum, 18 r, 50 v.	
316	San Sebastián 16.3 S	13. ii. 1976	Cranium, v. incomplete	
317	San Sebastián 16.4 S	13. ii. 1976	Cranium, v. incomplete	
318	San Sebastián 16.4 S	13. ii. 1976	Cranium, incomplete; 19 r, 28 v.	imm.
319	San Sebastián 16.5 S	13. ii. 1976	Cranium, good	
324	San Sebastián 14.5 S	13. ii. 1976	Cranium, good	
325	San Sebastián 14.7 S	13. ii. 1976	Cranium, good	
349	Río San Martín S	21. xi. 1976	Cranium, poor	
350	Río San Martín S	21. xi. 1976	Cranium, fair	
351	Río San Martín S	21. xi. 1976	Cranium, fair	
361	Río San Martín S	21. xi. 1976	Cranium, v. incomplete	
376	Río San Martín 2 S	21. xi. 1976	Mandibles, 23 r, 35 v.	imm.
401	Cabo Peñas SE	16. i. 1977	Cranium, poor	
403	Cabo Peñas SE	16. i. 1977	Cranium, good; 1 earbone; 3 r, 4 v.	adult
411	San Sebastián N	13. ii. 1977	Cranium, v. incomplete	
429	Cabo Peñas SE	16. ii. 1977	Cranium, good; mandibles, 22 r, 31 v	imm.
440	Punta María 7.5 NW	3. iii. 1977	Cranium, fair; 1 r, 5 v.	imm.
441	Punta María 7.5 NW	3. iii. 1977	Cranium, v. incomplete	
445a	Punta María 5–6 NW	3. iii. 1977	Cranium, v. incomplete, 2 r, 1 v	

Continued . . .

TABLE 7. Continued.

RNP no.	Locality	Date	Details	Maturity
445b	Punta María 5–6 NW	3. iii. 1977	Cranium, v. incomplete	
449	Punta María 3 N	3. iii. 1977	Cranium, v. incomplete	
455	Punta María 1 N	3. iii. 1977	Cranium, good	small
459	Punta María S	4. iii. 1977	Cranium, fair; 7 r, 33 v.	imm.
460	Punta María S	4. iii. 1977	Cranium, fair; 12 r, 32 v.	adult
463	Punta María S	4. iii. 1977	Cranium, v. incomplete, cervicals	
464	Punta María S	4. iii. 1977	Cranium, fair	adult
465	Punta María S	4. iii. 1977	Cranium, fair	
469	Punta María S	4. iii. 1977	Cranium, fair; R mand., sternum, 26 r, 50 v.	imm.
505	Los Chorrillos N	8. iv. 1977	Cranium, fair	
525	Los Chorrillos 4 N	29. v. 1977	Cranium, good; mandibles, 1 ear, 19 r, 14 v, st. ribs	imm.
539	Río San Martín 7 N	31. v. 1977	Cranium, v. incomplete	
583	San Sebastián 2 S	21. ix. 1977	Cranium, good	
586	San Sebastián N	21. ix. 1977	Cranium, fair, small	
592	Península Páramo	21. ix. 1977	Cranium, poor	
599	San Sebastián S	28. xi. 1977	Cranium, very good	
600	San Sebastián S	28. xi. 1977	Cranium, good	
604	San Sebastián S	28. xi. 1977	R mandible	
609	San Sebastián S	28. xi. 1977	Cranium, good; L mand.; 19 r, 27 v.	adult
628	Río San Martín 3 N	11. xii. 1977	Cranium, fair	
639	Río Ewan N	1. i. 1978	Cranium, poor	
POST CRANIAL MATERIAL (* = includes cervicals)				
10	Cabo Domingo S	27. ix. 1975	Fairly complete *	adult
18	Río Fuego N	30. ix. 1975	Fairly complete *	adult
41	San Sebastián S	12. v. 1975	Fairly complete*	adult (Col. J. Tico)
46	Ea. Viamonte SE	12. iv. 1974	5 ribs, 25 vertebrae *	adult (C & G 3 b)
47	Ea. Viamonte SE	12. iv. 1974	10 vertebrae	adult (C & G 3 c)
59	San Sebastián	3. vii. 1974	9 r, 36 v *	adult
66	Cabo Peñas SE	5. vii. 1974	19 vertebrae, worn	adult
83	Cabo Peñas SE	31. vii. 1975	Sternum, 3 r, 33 v *	imm.
84	Cabo Peñas SE	31. vii. 1975	13 vertebrae *	adult
125	Ea. Las Violetas	18. xii. 1975	11 r, 22 vertebrae *	
131	Ea. Las Violetas	18. xii. 1975	Sternum, 27 r, 36 v *	imm.
146	Cabo Espiritu Santo	20. xii. 1975	27 r, 22 v *	adult
174	San Sebastián N	21. xii. 1975	1 r, 58 v *, chevrons	adult
205	Ea. San Martín 4–5 N	28. i. 1976	9 r, 25 vertebrae	adult
230	Ea. San Martín 5 N	28. i. 1976	Cervicals	
232	Ea. San Martín 3–4 N	28. i. 1976	1 rib, 8 vertebrae *	
292	Río San Martín S	13. ii. 1976	26 vertebrae *	adult
358	Río San Martín S	21. xi. 1976	6 ribs, 20 vertebrae	subadult
363/364	Río San Martín S	21. xi. 1976	7 ribs, 16 vertebrae *	imm.
405	Cabo Peñas SE	16. i. 1977	8 ribs, 20 vertebrae *	adult
431	Cabo Peñas SE	16. ii. 1977	Fairly complete	
438	Punta María 7 NW	3. iii. 1977	24 vertebrae	imm.
448	Punta María 3–4 NW	3. iii. 1977	20 ribs, 33 vert. *	imm.
494/495	Punta María 3–4 NW	3. iii. 1977	15 vertebrae *	imm.
513	Cabo Domingo S	9. iv. 1977	7 r, 46 chevrons tracing dorsal fin. ♂	adult

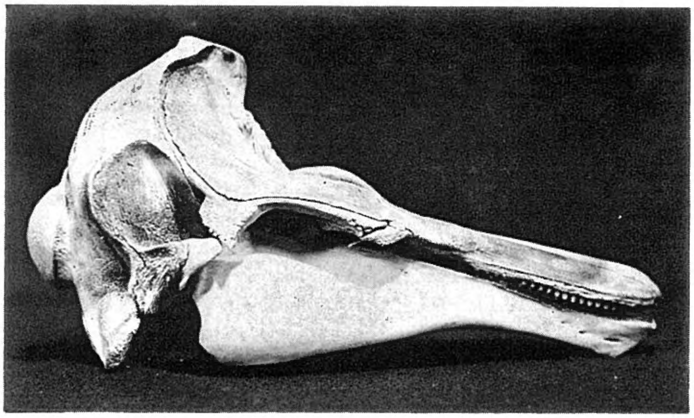

Fig. 11. *Phocoena dioptrica*, lateral view of RNP 536, collected on the mud flats of Bahía San Sebastián in May, 1977. (Photo T. D. Goodall)

FAMILY ZIPHIIDAE

Tasmacetus shepherdi Oliver, 1937

Shepherd's beaked whale, Tasman whale

This rare whale is known from eight stranded specimens (Mitchell 1975, Anonymous 1975). Six specimens are known from mainland New Zealand, Steward and Chatham Islands (Oliver 1937, Gaskin 1968), one from Península Valdés, Argentina (Mead and Payne 1975) and a photographed but not collected stranding on the Islas Juan Fernandez, Chile (Brownell *et al.* 1976).

The collection of two specimens on Tierra del Fuego extends the known distribution southward and furthers the assumption (Anonymous 1975) that the species is circumpolar.

TABLE 8. NEW SPECIMENS OF *TASMACETUS SHEPHERDI*

RNP no.	Locality	Date	Details
457	Punta María S	4. iii. 1977	Cervicals
582	Punta María S	6. xi. 1977	Cranium, incomplete, very worn
666	Isla Gable NE	9. iv. 1977	Photographs of cranium
		15. iii. 1978	Mandible borrowed from restaurant
		9. iv. 1978	Col. cervicals, 18 v, scapula, 2 ribs, part of sternum, humerus, 2 radii, from Gable Is.

The collections in Table 8 were made in unusual circumstances. Cranium RNP 582 was found leaning against a new fence 200 m from the beach. Cervicals RNP 457 appear to belong to this cranium as they were found on the same beach and match the condyles. Both have the same degree of beach damage.

In April, 1977, a very worn cranium was photographed at the Prefectura Maritima Station on Gable Island. In March, 1978, a set of mandibles that had been decorating the wall of an Ushuaia restaurant for two years were examined

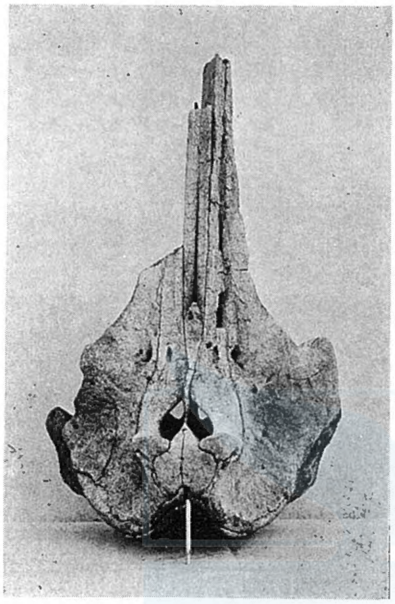

Fig. 12. *Tasmacetus shepherdi*, dorsal aspect of RNP 582, a very beach worn cranium found at Punta Maria in November, 1977. (Photo I.S. Cameron)

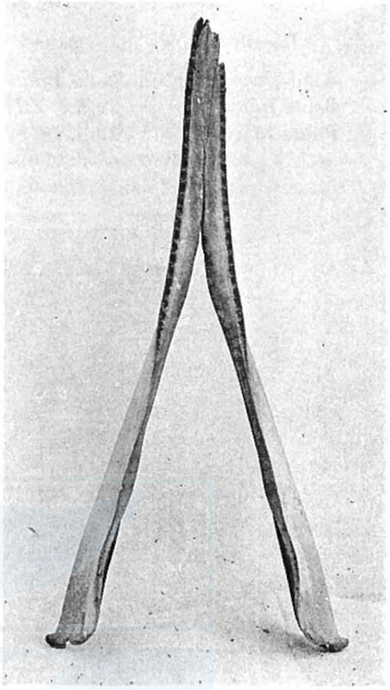

Fig. 13. *Tasmacetus shepherdi*, dorsal aspect of mandibles of RNP 666, stranded on Gable Island, ca. 1974. These mandibles were displayed in an Ushuaia restaurant for several years. (Photo I.S. Cameron)

and found to be those of a *Tasmacetus* (RNP 666). The measurements agree very closely with those given by Oliver (1937). Further inquiry yielded an approximate date (1974) and the site of collection; a trip was made to retrieve that which remained (cervicals, 18 additional vertebrae, right scapula, two ribs, two radii, one humerus and a section of sternum). It was confirmed that the cranium and mandible came from the same animal. I have been unable to obtain the cranium for study.

Berardius arnuxii Duvernoy, 1851

Arnoux's beaked whale

Brownell (1974) gives the distribution of this whale as South Australia, New Zealand, South Africa, Argentina, the Falklands (Malvinas), South Georgia, the South Shetlands and the Antarctic Peninsula, showing a total of 14 specimens. McCann (1975) records more specimens, mainly from New Zealand. The only specimen known from the continental coasts of the western South Atlantic is from the Río de la Plata, Argentina (Marelli 1920). There are no former records from Tierra del Fuego.

TABLE 9. NEW SPECIMENS OF *BERARDIUS ARNUXII*

RNP no.	Locality	Date	Details
472	Río Lainez	5. iii. 1977	Cervicals
566	Bahía Inútil	25. vii. 1977	Cervicals
693	Punta María 6 N	3. iii. 1977	Photographs of very incomplete cranium. Specimen collected 14. v. 1978

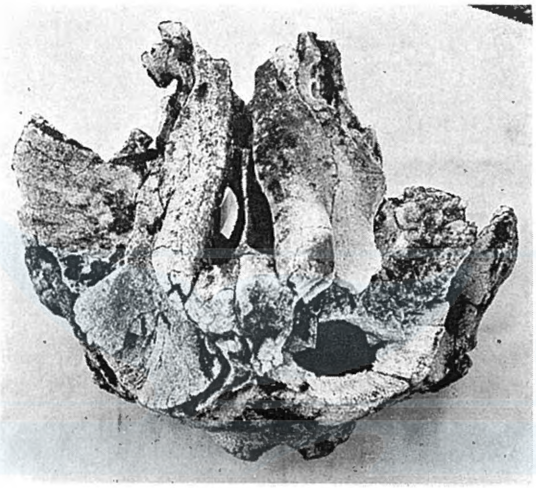

Fig. 14. *Berardius arnuxii*, dorsal aspect of a very incomplete and beach damaged cranium, RNP 693, found north of Punta Maria in March, 1977. (Photo I.S. Cameron)

The new specimens from Tierra del Fuego are two groups of cervical vertebrae and a very worn, incomplete cranium. Specimen 566 from the Río Marazzi, Inútil, has the centrae and neural arches of the first three cervicals fused and the fourth fused by the neural arch. The first three cervicals of number 472 are fused.

The partial cranium, RNP 693, was photographed on the beach in March, 1977, but because of weight it was not collected until May, 1978.

Mesoplodon layardii (Gray, 1865)

Strap-toothed whale, Layard's beaked whale

This species is known from New Zealand, southern Australia, South Africa, the Falkland (Malvinas) Islands (Turner 1880, Fraser 1948, Rice 1977) and from Uruguay (Praderi 1972). Gaskin (1968) records 19 specimens from New Zealand. Until now there was no record from Tierra del Fuego.

Five new crania were found on Tierra del Fuego, four from Bahía San Sebastián and one from the Beagle Channel. Unfortunately, no complete mandibles were found. Specimen RNP 61 was stranded between April and July, 1974. The body had been burnt and only 14 vertebrae and the cranium were recovered.

Ziphioid vertebrae are frequently scattered on the beaches, but positive

TABLE 10. NEW SPECIMENS OF *MESOPLODON LAYARDII*

RNP no.	Locality	Date	Details	Maturity
61	Península Páramo	4. vii. 1975	Cranium, good; cervicals, 14 v, burned	immature ♂ ?
74	Bahía Brown	31. xii. 1975	Cranium, good; 7 v.	adult ♀ ?
313	San Sebastián, 15 S	13. ii. 1976	Cranium, v. incomplete, 5 v.	
326	San Sebastián 10 S	13. ii. 1976	Cranium, v. good, 10 v.	adult ♀ ?
659	Ea. San Martín N	29. i. 1978	Cranium, v. incomplete	

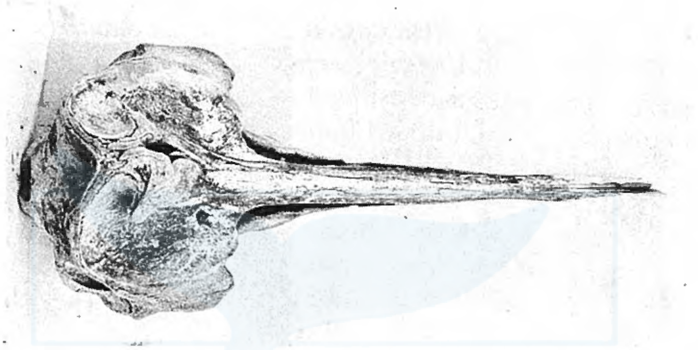

Fig. 15. *Mesoplodon layardii*, dorsal aspect of cranium of RNP 326 found at San Sebastián in February, 1976. (Photo I.S. Cameron)

identification is difficult due to beach damage.

Mesoplodon grayi von Haast, 1876

Gray's beaked whale, Scamperdown whale

Rice (1977) cited Gray's beaked whale from South Africa, South Australia, New Zealand, Chatham Island, and Argentina, as well as one record from the Netherlands. The species appears to be most common near New Zealand (Gaskin 1968).

The western South Atlantic specimens are all from Argentina; Quequen, Monte Hermoso and Miramar in the Province of Buenos Aires (Urquiola *et al.* 1970) and Chubut (Moreno 1895). There are no former records from Tierra del Fuego.

New records for this species (Table 11) include one nearly complete skeleton, three crania and one group of thoracic vertebrae.

Specimen RNP 270 is nearly complete (lacking scapulae and flippers). It was an adult animal with a total length of 516 cm. The total length of the skeleton is 463 cm. The teeth were visible in the lower jaw, indicating a male, and there were 15 vestigial teeth embedded in the flesh of the upper left and nine in the upper right jaw. The animal was in a very decomposed condition when found.

The other three crania are incomplete; two of them are very beach worn.

TABLE 11. NEW SPECIMENS OF *MESOPLODON GRAYI*

RNP no.	Locality	Date	Details	Maturity
270	Ea. San Martín	28. i. 1976	Nearly complete skeleton. Lacks scapulae & flippers.	adult
271	Los Chorrillos	1975	6 thoracics	adult
328	San Sebastián 15 S	13. iii. 1976	Cranium, very incomplete	
378	Río San Martín S	21. xi. 1977	Cranium, incomplete; part of R mandible, 1 tooth, some v.	imm.
379	Río San Martín S	21. xi. 1977	Cranium, very incomplete	

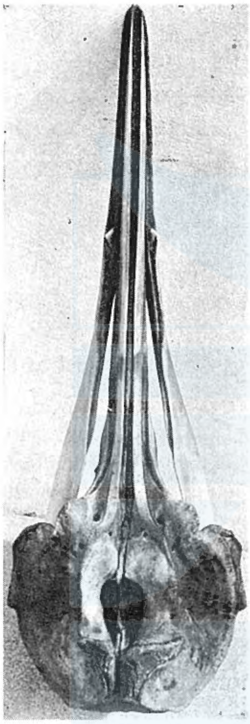

Fig. 16. *Mesoplodon grayi*, dorsal aspect of skull of RNP 270 found in front of Estancia San Martín in January, 1976. (Photo T. D. Goodall)

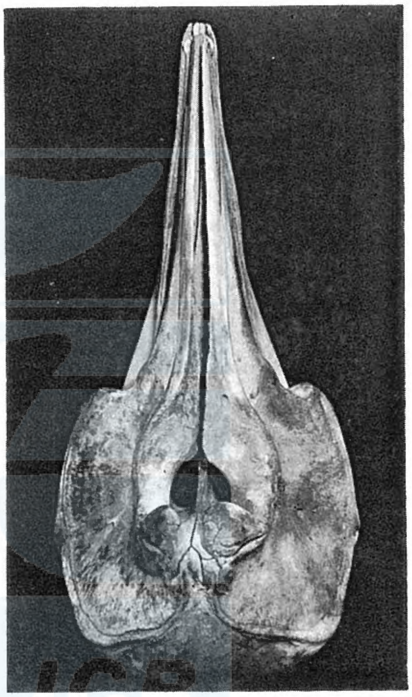

Fig. 17. *Mesoplodon hectori*, dorsal view of cranium and mandibles of RNP 172, found in December, 1975, on the mud flats of western Bahía San Sebastián. (Photo T. D. Goodall)

Mesoplodon hectori (Gray, 1871)
Hector's beaked whale

Hector's beaked whale is known only from Tasmania, New Zealand, the Falkland (Malvinas) Islands and South Africa (Rice 1977). In the literature there are only six specimens published (Ross 1970). The only specimen known from American waters is that from the Malvinas (Fraser 1950, Hamilton 1952).

RNP 172 becomes the seventh known animal of this species and the first

TABLE 12. NEW SPECIMEN OF *MESOPLODON HECTORI*

RNP no.	Locality	Date	Details	Maturity
172	San Sebastián N	21. xii. 1975	Nearly complete skeleton. Lacks scapulae and flippers.	imm.

from Tierra del Fuego, in addition to being the southernmost specimen yet found.

When found on the west side of the San Sebastián mud flats on 21 December, 1975, this animal was well decomposed. The head and rib cage were taken at that time, while the rest of the animal was collected in February, 1976. This specimen is of a young animal and is complete except for the scapulae, flippers and part of the sternum. The neural spines of three vertebrae are damaged. None of the vertebrae are anchylosed, but two well-developed teeth are present, indicating that it was a male. The total length of the skeleton is 281 cm.

Ziphius cavirostris G. Cuvier, 1823

Cuvier's beaked whale, Ballena picuda de Cuvier

This whale is cosmopolitan, occurring in all oceans, except at high latitudes. A number of specimens are known from around the world, as far south as Tierra del Fuego (Anonymous 1975, Mitchell 1975, Gaskin 1968).

Eight new records are reported in Table 13 from Tierra del Fuego.

An adult male Cuvier's beaked whale (RNP 3) was stranded entire at the First West Creek, Estancia Harberton, in September, 1967. The cause of death was unknown. The pigmentation pattern was visible and the body was covered with parallel scratches. With the exception of the blubber, birds showed little interest in it, although one wintery day nearly a year after stranding, six condors (*Vultur gryphus*) were seen sitting on it. This specimen took five years to decay. Both teeth were present on stranding, but one disappeared before it could be collected. The nearly complete skeleton is preserved at Harberton.

Number 327 is a male skull in excellent condition. One tooth was missing. The other six skulls are incomplete and very beach worn. The male specimens were so classified because of the pronounced " basining " of the cranium. Specimen 138 is a complete vertebral column without a skull.

TABLE 13. NEW SPECIMENS OF *ZIPHIUS CAVIROSTRIS*

RNP no.	Locality	Date	Details	Maturity
3	Ea. Harberton	24. ix. 1967	Nearly complete skeleton ♂	adult
60	San Sebastián 4 N	3. vii. 1974	Cranium, incomplete ♀	
73	Punta María N	5. vii. 1974	Cranium, incomplete ♀	
138	San Sebastián N	19. xii. 1975	Complete axial skeleton, except scapulae and flippers	imm.
177	San Sebastián 5 N	21. xii. 1975	Cranium, incomplete ♂	
327	San Sebastián 16 S	13. ii. 1976	Cranium, mandibles, 1 tooth, ear bones good ♂	
377	Río San Martín S	21. xi. 1976	Cranium, incomplete ♀	
638	San Sebastián 5 N	12. xii. 1977	Piece of cranium, worn ♀	
696	Punta María 10 N	14. v. 1978	Cranium, broken ♂	

Hyperoodon planifrons Flower, 1882

Southern bottlenose whale, Ballena pico de botella

The southern bottlenose is widely distributed in the southern hemisphere. Specimens are known from New Zealand, Australia, South Africa, the South Atlantic Islands and off the coast of Antarctica (Brownell 1974, Rice 1977).

In South America the species is known for southern Brazil, Argentina (Gianuca and Castello 1976), the Falkland (Malvinas) Islands (Hamilton 1952), South Georgia and the South Orkney Islands (Fraser 1945), and the Chilean coast (Clarke 1962). None were known from Tierra del Fuego until the following speci-

TABLE 14. NEW SPECIMENS OF *HYPEROODON PLANIFRONS*

RNP no.	Locality	Date	Details
4	Cutalataca, Ea. Harberton	xi. 1967	Cranium, fair
382	Najmishk, Ea. Viamonte	19. xii. 1976	Cranium, very incomplete
584	San Sebastián N	21. xi. 1977	Cranium, very incomplete
585	San Sebastián N	21. xi. 1977	Cranium, mandibles; fairly complete, but worn and broken
630	San Sebastián	11. xii. 1977	Cervicals (7 fused)

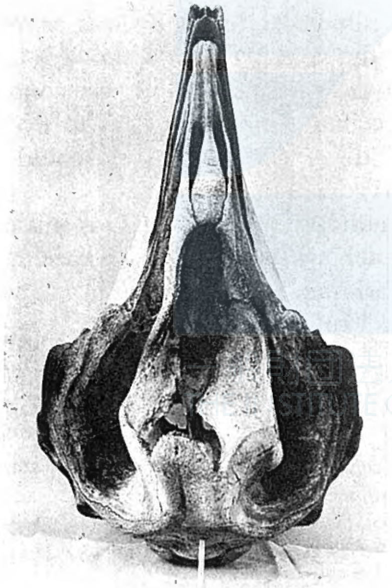

Fig. 18. *Ziphius cavirostris,* dorsal aspect of skull of RNP 327 found at Bahía San Sebastián in February, 1976. (Photo I.S. Cameron)

Fig. 19. *Hyperoodon planifrons,* dorsal aspect of cranium of RNP 4, found at Cutalátaca, Estancia Harberton, in the Paso Guaraní of the Beagle Channel in November, 1967. (Photo I.S. Cameron)

mens were found.

Four crania and a group of seven fused cervicals represent the collection in Tierra del Fuego. Only one of the crania, found at Estancia Harberton on the Beagle Channel, is in fair condition. The others are very broken and beach worn. Specimens 382 and 585 were buried in sand and mud, respectively, and crumbled extensively on removal. The latter specimen has mandibles but no teeth; the mandibles have also disintegrated on drying. No fresh specimens were found.

DISCUSSION

Because of the enormous amounts of water and few inhabited areas, the small cetaceans of the Southern Ocean are little known. Museum specimens of southern whales and dolphins are few, and even less were known from Tierra del Fuego, where little previous work has been done.

Recent combing of the beaches has produced large quantities of new cetacean material. The area where most specimens were found was Bahía San Sebastián, but all beaches sampled offered a few specimens. Only a small portion of available beaches were checked. Southern Patagonia and Tierra del Fuego offer extensive beaches, many of which have never been surveyed.

Since most of the specimens had been on the beach for long periods, I have little information on the seasonality of strandings, but a systematic checking of beaches should yield new data. The slow rate of decay makes it difficult to judge the length of time the animals have been on the beach.

Eight of the fourteen species (*Orcinus orca*, *Phocoena spinipinnis*, *Tasmacetus shepherdi*, *Berardius arnuxii*, *Mesoplodon layardii*, *M. grayi*, *M. hectori* and *Hyperoodon planifrons*) had not been previously collected on Tierra del Fuego, although most of them were known for the general area.

It is strange that deepwater species such as *Lissodelphis peronii*, *Tasmacetus shepherdi*, *Mesoplodon layardii*, and *Hyperoodon planifrons* should be found in the relatively shallow waters north of Gable Island in the Beagle Channel and the very shallow waters of Bahía San Sebastián. Mitchell and Kozicki (1975) mention that *Hyperoodon ampullatus* is known to stray into fiords and rivers during migrations and then strand. This may be the case here.

In number of cranial specimens (91) *Cephalorhynchus commersonii* was the species most often collected, but this total includes a large number (at least 31) which were taken in fishing nets. The species most numerous in strandings was *Phocoena dioptrica* (88 cranial and many post cranial collections), which was thought to be one of the rarest cetaceans. More study on these and other species occuring in the area is needed.

Means should be found to protect the southern dolphins from deliberate exploitation for crab bait and accidental capture in fish nets. Little is known of the populations of the two species most affected, *Lagenorhynchus australis* in the channels and *Cephalorhynchus commersonii* in the Strait of Magellan, its bays and the Atlantic coast, but it is doubtful if either are able to withstand much exploitation.

My future plans include periodic surveys of the beaches which have yielded the most material, exploration of new beaches, and more study of the dolphins captured incidentally during *robalo* fishing at Bahía San Sebastián.

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FRASER'S DOLPHIN, *LAGENODELPHIS HOSEI* IN THE WESTERN NORTH PACIFIC

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ABSTRACT

During whale marking cruise from 20 January to 19 March 1976, 4 schools of *Lagenodelphis hosei* were sighted and two specimens were collected in the western tropical Pacific. The coloration and other external characters, skeletal measurements, and life history data of those two specimens are reported. Suggested distribution of the species is also noted in brief.

INTRODUCTION

The Fraser's dolphin (*Lagenodelphis hosei*) was named by F. C. Fraser in 1956. His examination was made on a skeleton collected by C. Hose in 1895 on a sea beach in Sarawak (Fraser 1956). Until 1972 there is no further records of the species. Perrin *et al.* (1973) reported external and skeletal characters of the specimens they collected from the eastern Pacific, south Africa, and Australia. Tobayama *et al.* (1973) described the external and skeletal characteristics, as well as the stomach content of the specimen collected from the western North Pacific. In this paper are reported the sighting and catch records of Fraser's dolphins, and the external and skeletal characteristics of two specimens captured in the western North Pacific.

MATERIALS AND METHODS

From 20 January to 19 March 1976, whale marking and sighting cruise was made by the *Miwa-maru* (199.68 grosstons, maximum speed 11 knot) in the western tropical Pacific. This cruise was conducted by Far Seas Fisheries Research Laboratory. In this survey four schools of Fraser's dolphin were sighted (Table 1) and two specimens of the species were collected (Table 2). These two specimens were photographed and examined alive or immediately after the death on board. They were frozen and brought to the laboratory. The skeletons of the two specimens were prepared for osteological study and measured there. Sexual organs were collected from both specimens and fixed in 10% formalin solution on board. The testes (TK 452) were histologically examined and the ovaries (TK 451) were

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TABLE 1. RECORDS OF SPORADIC CATCH OF *LAGENODELPHIS HOSEI*

No.	Date			Position	Body length (cm)	Body weight (kg)	Sex	Sexual condition	Author	Comments
1	—	—	1895	Sea beach in Sarawak	—	—	—	physically mature	Fraser, 1956	Holotype BMNH, 1895.5.9.1 collected in British Museum
2	31	X	1969	Kaohsiung (22°37′N, 120°17′E)	—	—	—	calf	Tobayama *et al.* 1973	HCY 69/10 (TKO 310) collected in Ocean Research Institute, Univ. of Tokyo
3	27	I	1971	05°00′N, 95°45′W	226	—	♂	unknown	Perrin *et al.* 1973	LK 22
4	27	I	1971	05°00′N, 95°45′W	110.2	19.3	♂	calf	Perrin *et al.* 1973	LR 23 (USNM 39079) collected in US National Museum
5	17	II	1971	30°47′S, 30°58′E	236	164	♀	pregnant	Perrin *et al.* 1973	PBB 71/3 (SAM 36322) collected in South Africa Museum
6	19	II	1971	30°09′S, 32°20′E	264	209	♂	physically mature	Perrin *et al.* 1973	PBB 71/4 (SAM 36323) collected in South Africa Museum
7	1	III	1971	30°10′S, 153°10′E	226	—	♀	adult	Perrin *et al.* 1973	
8	17	II	1972	29°33′S, 32°12′S	225.9	130	♀	subadult	Perrin *et al.* 1973	PBB 72/2 (PEM 1517/93) collected in Port Elizabeth Museum
9	20	V	1972	05°00′N, 122°22′W	—	—	—	—	Perrin *et al.* 1973	Three more dolphins (all females) were captured in a set net on yellow fin tuna
10	25	V	1972	Kamogawa (35°06′N, 140°06′E)	235	129	♂	physically mature	Tobayama *et al.* 1973	KSW 72/5 (TKO 3—) collected in Ocean Research Institute, Univ. of Tokyo
11	23	I	1976	23°15′N, 138°27′E	231	—	♀	immature	Present data	TK 451, collected in Ocean Research Institute, Univ. of Tokyo
12	1	II	1976	01°33′N, 142°04′E	183.5	—	♂	immature	Present data	TK 452, collected in Ocean Research Institute, Univ. of Tokyo

TABLE 2. SIGHTING RECORDS OF *LAGENODELPHIS HOSEI*

No.	Date			Position	Time	Surface temperature (°C)	School size	Author	Comments
1	11	VII	1966	0°, 165°W	—	—	400	Perrin *et al.* 1973	—
2	23	I	1976	23°15′N, 138°27′E	10: 00	22.9	200–300	Present data	One specimen (TK 451) collected from this school
3	1	II	1976	01°33′N, 142°04′E	13: 10	30.0	40–50	Present data	One specimen (TK 452) collected from this school
4	2	II	1976	03°00′N, 141°55′E	10: 30	29.5	40–50	Present data	—
5	20	II	1976	01°43′N, 164°53′E	12: 10	28.7	400–500	Present data	—

examined in detail at the laboratory.

CATCH AND SIGHTING RECORDS

Catch records of twelve Fraser's dolphins ever reported are shown in Table 1. From this table it can be said that the female *L. hosei* may attain sexual maturity at around 225–235 cm in body length. The data that the specimen TK 451 may situate in the early stage of ovulation (see page 236) appears to support above result. The five sighting records of *L. hosei* (Table 2) show that the species is gregarious and is distributed in warmer waters. Summing up all catch and sighting records of Fraser's dolphins, the species were found between 40°N and 40°S in the Pacific and Indian Oceans (Fig. 1). This result supports the suggestion of Perrin *et al.* (1973) that the species may continuously distribute in tropical high-seas of the Pacific and Indian Oceans.

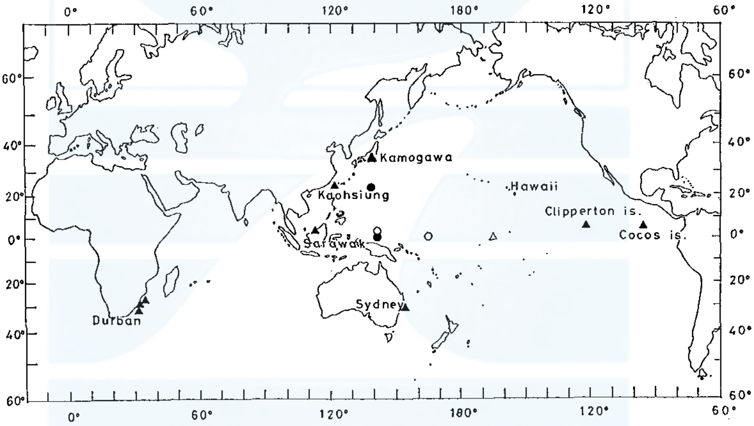

Fig. 1. Recorded occurrences of *Lagenodelphis hosei*. Circles represent new records. Triangles are previously published records. Black symbols are specimen localities; white ones are sighted localities.

COLORATION

A single greyish yellow lateral stripe which extends from above the eye to the genital area is very characteristic in Fraser's dolphin. This stripe is broader and darker in one specimen TK 451 than in another specimen TK 452. The width of this stripe in the specimen TK 451 was 5.5 cm on the midway between the eye and the genital area. The flipper stripe has double structure. In the specimen TK 451 the upper stripe is 4.0 cm in width on the midway and the lower is 3.5 cm. Eye patch, eye stripe, blowhole stripe, lip patch, and beak blaze, termed by Mitchell (1970), were observed in two animals TK 451 and TK 452, and these color was darker in the specimen TK 451 than in the specimen TK 452. Accord-

TABLE 3. EXTERNAL MEASUREMENTS OF

	Measurement	Eastern Pacific specimens		South
		LR 22 —	LR 23 (USNM396079)	PBB 7 1/4 (SAM36322)
1	Total length	226 cm (100%)	110.2 cm (100%)	236 cm (100%)
2	Tip of upper jaw to centre of eye	—	17.7(16.1)	33(14.0)
3	Tip of upper jaw to apex of melon	4.5(2.0)	1.8(1.6)	4.5(1.9)
4	Length of gape	—	14.3(13.0)	27.5(11.7)
5	Tip of upper jaw to external auditory meatus	—	21.1(19.1)	—
6	Centre of eye to angle of gape	—	4.0(3.6)	5.5(2.3)
7	Centre of eye to centre of blowhole	—	11.0(10.0)	21(8.9)
8	Tip of upper jaw to blowhole	—	16.5(15.0)	33.5(14.2)
9	Tip of upper jaw to anterior insertion of flipper	—	24.5(22.2)	46(19.5)
10	Tip of upper jaw to tip of dorsal fin	—	61.0(55.4)	133(56.4)
11	Tip of upper jaw to umbilicus	—	51.5(46.7)	110(46.6)
12	Tip of upper jaw to centre of genital aperture	—	71.3(64.7)	165(69.9)
13	Tip of upper jaw to centre of anus	—	78.8(71.5)	175(74.2)
14	Projection of lower jaw beyond upper	—	0	0.3
15	Girth at axilla	—	61.7(56.0)	110(46.6)
16	Maximum girth	—	—	132(55.9)
17	Girth at anus	—	37.9(34.4)	70(29.7)
18	Width of blowhole	—	2.0	2.5
19	Length of flipper, to anterior insertion	25.1(11.1)	15.2(13.8)	27(11.4)
20	Length of flipper, to axilla	18.8(8.3)	10.5(9.3)	19.5(8.3)
21	Width of flipper	6.6(2.9)	4.8(4.4)	8(3.4)
22	Height of dorsal fin	17.8(7.9)	7.6(6.9)	17(7.2)
23	Span of flukes, tip to tip	49.5(21.9)	22.8(20.7)	57(24.1)
24	Width of fluke, from notch to neraest point on anterior border	—	7.7(7.0)	13(5.5)

ing to Perrin *et al.* (1973) a light patch in the center of the dorsal fin was observed in the large eastern Pacific specimen (male, 226 cm in body length), but this patch was not observed in our two specimens. There were four definite black spots on the beak, and these spots were bilaterally symmetrical on the midway of the beak. The dorsum above the lateral stripe is dark greyish black, and the dorasl fin and both sides of the flippers and tail flukes are similarly coloured. Ventrum is white tinged with pink. This colour is very conspicuous in the leaping dolphin. Ventral views of the genital areas of the two specimens TK 451 and TK 425 reveal the sexual dimorphism in coloration (Plates IV and V).

BODY PROPORTION

Body proportion of nine specimens are given in Table 3. The ratio of the length of head region to body length appears to decrease with growth and to be larger in the female than in the male, as may be seen from Table 3. The measurements concerning the positions of umbilicus and genital aperture show the sexual dimorphism. In the male, umbilicus situated slightly anteriorly than in the female. The distance between umbilicus and genial aperture is larger in the female than

NINE SPECIMENS OF *LAGENODELPHIS HOSEI*

African specimens		Australian specimen	Western Pacific specimens		
PBB 7 1/4 (SAM36323)	PBB 7 2/2 (PEM1517/93)		KSW 7 2/5 (TDO3—)	(TK 451)	(TK 452)
264 cm (100%)	225.9 cm (100%)	226 cm (100%)	235 cm (100%)	231 cm (100%)	183.5 cm (100%)
33(12.5)	33.1(14.7)	29.5(13.1)	28.0(11.9)	31.0(13.4)	28.5(15.5)
3(1.1)	4.8(2.1)	3.5(1.5)	3.0(1.3)	2.6(1.1)	4.0(2.2)
27(10.2)	28.0(12.4)	24(10.6)	24.0(10.2)	27.0(11.7)	23.0(12.5)
39(14.8)	38.2(16.9)	34.5(15.3)	33.5(14.2)	37.5(16.2)	33.5(18.3)
6(2.3)	6.0(2.7)	4.4(1.9)	—	—	—
23(8.7)	19.7(8.7)	17.6(7.8)	—	—	—
28(10.6)	30.9(13.7)	28.6(12.7)	31.0(13.2)	32.0(13.9)	27.0(14.7)
43(16.3)	45.8(20.3)	42.0(18.6)	41.0(17.4)	—	40.5(22.1)
132(50.0)	118.4(52.4)	—	103.3(43.9)	127.0(55.0)	93.5(51.0)
116(43.9)	106.9(47.3)	—	108.0(45.9)	109.0(47.2)	88.0(48.0)
170(64.4)	157.2(69.6)	—	156.5(66.5)	159.0(68.8)	21.0(65.9)
189(71.6)	187.7(83.0)	—	169.5(72.1)	165.0(71.4)	133.5(72.8)
1	0.6	0.4	1.0	0.8	0.5
—	106.9(47.3)	—	106.9(45.4)	—	—
—	116.5(51.6)	—	116.3(49.5)	124.0(53.7)	94.0(51.2)
92(34.8)	70.0(31.0)	—	74.2(31.5)	70.5(30.5)	51.5(28.1)
4	2.5	2.4	2.5	—	—
28.8(10.9)	26.7(11.8)	25.5(11.3)	L26.0(11.1)	29.0(12.6)	23.5(12.8)
21.5(8.1)	20.0(8.9)	17.3(7.7)	L17.5(7.4)	21.0(9.1)	16.5(9.0)
9.4(3.6)	8.3(3.7)	8.1(3.6)	L8.4(3.6)	9.0(3.9)	8.0(4.4)
22(8.3)	15.9(7.0)	15.0(6.6)	17.5(7.4)	17.0(7.4)	11.5(6.3)
59(22.3)	50.9(22.5)	47.0(20.8)	53.0(22.6)	53.0(22.9)	38.0(20.7)
14.2(5.4)	13.4(5.9)	12.6(5.6)	L15.2(6.5)	—	—

in the male, but the distance between genital aperture and anus is reverse. The size of flipper corresponding to body length seems to decrease with growth, and to be larger in the female than in the male. On the other hand, the height of dorsal fin appears to become higher with growth, and to be higher in the male than in the female corresponding to body length.

LIFE HISTORY DATA

Several teeth collected from the centre of tooth row of two specimens TK 451 and TK 452 were prepared by the method of Kasuya (1976), and examined under the microscope (×40 to× 400) using low intensity transmitted light. The numbers of laminations observed were as follows: Specimen TK 451, 11 in the dentine and 11 in the cementum; Specimen TK 452, 4 in the dentine and 4 in the cementum.

The stomach of the animal TK 451 contained the fishes, the shrimps, and the squids, but that of the animal TK 452 had nothing.

During the preparation for the skull in the specimen TK 451 several tens nematodes were observed in ear cavity, but in the specimen TK 452 no nematodes was found.

The testis weights of the specimen TK 452 were 8.6 g in the left and 8.6 g in the right. Histological examination of the left testis showed no spermatozoa in the tissue. Therefore the male TK 452 was determined to be immature. In the specimen TK 451 no corpora was observed in both ovaries. The weights of ovaries were 3.0 g in the left and 1.3 g in the right. The largest Graafian follicle was observed in the left ovary and its size was 3 mm in diameter. As the left ovary of the specimen was heavier than the right and the diameter of Graafian follicle of the left ovary became bigger, the immature female TK 451 seemed to be in the stage of approaching first ovulation.

OSTEOLOGY

Skull: The dimensions of the seven skulls of Fraser's dolphin are given in Table 4. The widths of the snout and skull seem to be broader in the male than in the female, as may be seen from Table 4. The premaxillae of the two specimens TK 451 and TK 452 are not fused. In both specimens it is characteristic that rostrum is flat, and the width of premaxillae is almost not variable throughout the rostrum length.

Axial skeleton: The vertebral formulae of the specimens TK 451 and TK

TABLE 4. SKELETAL MEASUREMENTS AND MERISTICS

		South African
Measurement or count	Sarawak specimen (holotype BMNH 1895.5.9.1)	PBB 7 1/3 (SAM 36322) ♀ 236
Condylobasal length	413 mm (100%)	429 mm (100%)
Length of rostrum	226(54.7)	240(55.9)
Width of rostrum at base	121(28.3) (53.5% of rost. ln.)	119(27.7) (49.6% of rost. ln.)
Width of rostrum at midlength	71(17.2)	71(16.6)
Width of rostrum 60 mm anterior to antorbital notches	85(20.5)	86(20.0)
Least supraorbital width	202(48.8)	202(47.1)
Preorbital width	207(50.1)	207(48.3)
Postorbital width	230(55.7)	229(53.4)
Zygomatic width	225(54.5)	225(52.4)
Parietal width	170(41.2)	161(37.5)
Maximum width of premaxillae	82(19.9)	78(18.2)
Length of upper left tooth row	194(46.9)	193(45.0)
Length of lower left tooth row	193(46.7)	198(46.2)
Length of left ramus	350(84.7)	367(85.5)
Coronoid height of left ramus	70(16.9)	65(15.2)
Length of symphysis	36(8.7)	37(8.6)
Number of teeth	ca. 43 | 44 40 | 42	40 | 42 39 | 39
Total number of vertebrae	80±2	78
Vertebral formula	C7D15L21C37±2	C7D16L21C34

452 are C7 (first 2 fused)+D15+L21+Ca35=78, and C7 (first 2 fused)+D15+L20+Ca36=78, respectively. The atlas and axis are fused together in both specimens. All epiphyses of cervical vertebrae are fused to their centra in both specimens, but epiphyses of vertebrae from D1 to Ca16 in the specimen TK 451 and from D1 to Ca19 in the specimen TK 452 are not fused. Figure 3 shows the change of the greatest height, the greatest breadth, and the length of vertebrae in three specimens. The greatest height appears to reach the maximum at around lumbar 7–9, and becomes larger in all the vertebrae with body length. The greatest breadth seems to attain at the maximum in around the last dorasl, and increases in dorsal, lumbar and anterior part of caudal vertebrae with body length. The lengths of dorsal, lumbar, and caudal vertebrae increase with body length but those of cervical do not. The length of vertebrae appears to attain at maximum around dorsal 8–13, and have the second peak in the around middle part of caudal vertebrae. The atlas shows higher value than the other cervical bones in both the greatest height and breadth. Both height and breadth of centrum increase with serial number, and appear to reach the maximum around at caudal 24 and 18, respectively (Fig. 3).

In the specimen TK 451 there are 15 pairs of ribs. The first four pairs of ribs possess two heads (Table 5). As the ribs of the specimen TK 452 were broken it is impossible to describe here.

OF SEVEN SPECIMENS OF *LAGENODELPHIS HOSEI*

specimens	Western Pacific specimens			
PBB 7 1/4 (SAM 36323) ♂ 264	KSW 7 2/5 (TKO 3—) ♂ 235	HCY 6 9/10 (TKO 310) —	(TK 451) ♀ 231	(TK 452) ♂ 183.5
440 mm (100%)	423 mm (100%)	415 mm (100%)	430 mm (100%)	386 mm (100%)
241(54.8)	235(55.5)	232(56.1)	240(55.8)	212(54.9)
130(29.5)	128(30.2)	113(27.0)	131(30.5)	106(27.5)
(53.9% of rost. ln.)	(54.5% of rost. ln.)	(48.7% of rost. ln.)	(54.6% of rost. ln.)	(50.0% of rost. ln.)
80(18.2)	77(18.2)	62(14.9)	78(18.1)	59(15.3)
101(23.0)	91(21.5)	78(18.8)	91(21.2)	71(18.4)
218(49.5)	209(49.4)	195(47.0)	208(48.4)	179(46.4)
223(50.7)	213(50.3)	197(47.5)	214(49.8)	184(47.7)
247(56.1)	234(55.3)	210(50.0)	237(55.1)	204(52.8)
240(54.5)	229(54.1)	broken	230(53.5)	199(51.6)
177(40.2)	190(44.9)	161(38.8)	203(47.2)	172(44.6)
83(18.9)	70(16.5)	74(17.8)	83(19.3)	67(17.4)
213(48.4)	199(47.0)	203(48.9)	201(46.7)	185(47.9)
207(47.0)	192(45.3)	208(50.1)	212(49.3)	185(47.9)
375(85.2)	broken	357(86.0)	373(86.7)	331(85.8)
71(16.1)	70(16.5)	65(15.6)	69(16.0)	60(15.5)
31(7.0)	32(7.5)	41(9.9)	—	—
42 | 42	40 | 42	41 | 39	39 | 39	39 | 39
41 | 40	37+ | 40	41 | 42	41 | 41	40 | 40
78±1	81		78	78
C7D16L+C55±1	C7D15L20C39		C7D15L21C35	C7D15L20C36

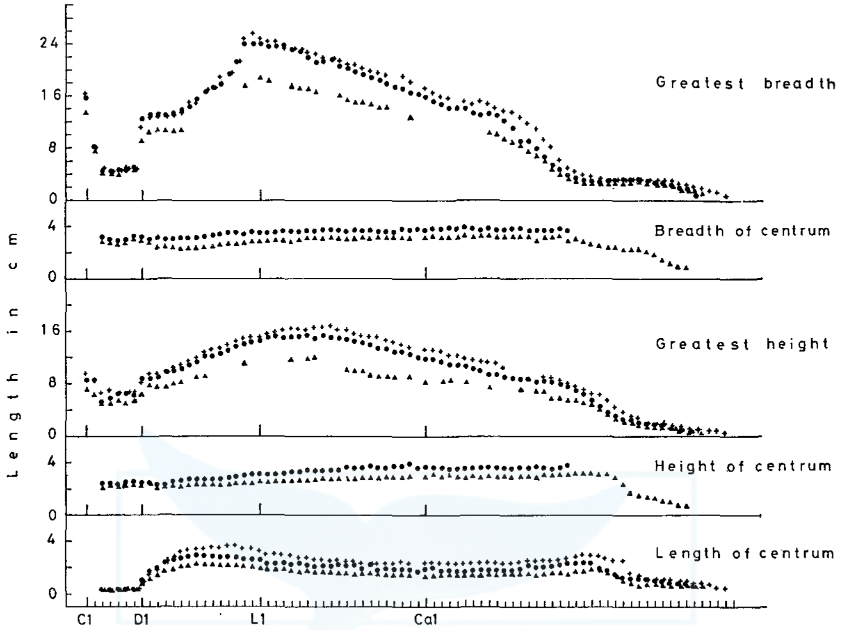

Fig. 2. Comparison of size of each vertebra in three specimens of *Lagenodelphis hosei*. Closed circle indicates the specimen (TK 451), closed triangle the specimen (TK 452), and double crosses the Kamogawa specimen (cited from Tobayama *et al.* 1973).

TABLE 5. DIMENSIONS OF LEFT RIBS OF *LAGENODELPHIS HOSEI*

Specimen TK 451			Specimen TK 452		
No. of ribs	Straight length (mm)	Breadth at middle (mm)	No. of ribs	Straight length (mm)	Breadth at middle (mm)
1	132*	22	1	124*	17
2	188*	18	2	164*	13
3	241*	14	3	—	12
4	276*	13	4	212*	11
5	296	13	5	—	11
6	308	12	6	222	11
7	312	12	7	212	10
8	315	11	8	222	10
9	313	11	9	—	9
10	306	11	10	—	8
11	300	11	11	—	10
12	291	12	12	—	8
13	285	11	13	—	7
14	280	9	14	—	5
15	252	5	15	—	—

* Ribs with two heads

TABLE 6. DIMENSION OF OTHER BONES OF *LAGENODELPHIS HOSEI* (in mm)

	Specimen TK 451	Specimen TK 452
ATLAS		
Greatest width of articulating surface	86	79
Height (from internal anterodorsal margin of neural canal to bottom of anterior face of body)	54	52
Length of lateral process (from margin of anterior articulaing surface to farthest point at end of process)	36	28
Greatest length of neural spine	31	23
STERNUM		
Greatest width of manubrium	115	68
Length of manubrium along midline	74	59
Depth of anterior notch of manubrium	43	29
SCAPULA		
Height (from posterior margin of glenoid fossa to coracovertebral angle)	141	97
Length (from posterior margin of glenoid fossa to glenovertebral angle)	139	85
Greatest length of coracoid process (from anterior margin of glenoid fossa)	43	26
Greatest width of coracoid process	31	21
Greatest width of metacromion process (from apex of ventral curvature to vertebral apex)	47	32

The measurements of atlas, sternum, and scapulae are shown in Table 6.

ACKNOWLEDGMENTS

We want to express our gratitude to the captain and other crew of the *Miwa-maru* for their cooperation, and to Drs S. Ohsumi, Y. Fukuda and I. Ikeda of the Far Seas Fisheries Research Laboratory for giving us chance for this study. We are indebted to Dr T. Kasuya of Ocean Research Institute of Tokyo University for allowing us to examine specimens in his care. Professor M. Nishiwaki of Department of Marine Sciences, University of the Ryukyus is also deeply acknowledged for his advice throughout this study.

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APPENDIX TABLE MEASUREMENTS OF VERTEBRAE OF *LAGENODELPHIS HOSEI* (in mm)

SPECIMEN TK451

Serial no.	Vertebral no.	Greatest breadth	Greatest height	Centrum			Neural canal		Degree of* fusion of epiphyses
				Breadth	Height	Length	Breadth	Height	
1	C 1	15.9	8.6	—	—	—	3.9	3.4	A
2	2	8.1	8.6	—	—	—	3.1	—	A
3	3	4.5	5.3	3.2	2.4	0.2	2.5	2.8	A
4	4	4.4	5.7	3.0	2.4	0.3	2.4	2.6	A
5	5	4.7	6.4	2.9	2.3	0.3	2.5	2.4	A
6	6	4.7	6.4	3.0	2.5	0.3	2.7	2.4	A
7	7	5.1	6.2	3.2	2.5	0.3	2.9	2.3	A
8	D 1	12.2	8.8	3.2	2.4	1.1	3.9	2.3	C
9	2	13.1	8.8	3.0	2.4	1.7	3.8	2.6	C
10	3	13.0	9.0	3.1	2.3	2.0	3.8	3.0	C
11	4	12.9	9.8	3.0	2.3	2.4	3.8	3.2	C
12	5	13.3	9.9	3.0	2.5	2.6	3.7	3.4	C
13	6	13.9	10.3	3.1	2.6	2.7	3.7	3.4	C
14	7	14.6	10.9	3.1	2.7	2.8	3.5	3.3	C
15	8	15.6	11.4	3.1	2.7	2.9	3.1	3.2	C
16	9	16.5	12.1	3.2	2.7	2.9	2.8	3.0	C
17	10	17.1	12.2	3.3	2.7	2.9	2.5	2.9	C
18	11	17.8	12.7	3.4	2.7	2.8	2.4	2.9	C
19	12	19.4	13.2	3.5	2.8	2.8	2.4	2.8	C
20	13	21.1	13.7	3.5	2.9	2.8	2.2	2.6	C
21	14	23.7	14.0	3.4	3.0	2.6	2.0	2.6	C
22	15	23.7	14.4	3.6	3.1	2.6	1.8	2.6	C
23	L 1	23.7	14.7	3.5	3.1	2.6	1.9	2.5	C
24	2	23.4	15.1	3.5	3.1	2.3	1.8	2.6	C
25	3	23.4	15.2	3.5	3.1	2.3	1.7	2.6	C
26	4	23.7	15.0	3.6	3.2	2.4	1.8	2.6	C
27	5	22.9	15.2	3.6	3.3	2.3	1.7	2.6	C
28	6	22.4	15.2	3.6	3.3	2.3	1.6	2.7	C
29	7	21.8	15.3	3.6	3.4	2.2	1.5	2.6	C
30	8	21.1	14.9	3.6	3.4	2.0	1.4	2.5	C
31	9	21.2	15.3	3.7	3.4	2.1	1.4	2.7	C
32	10	21.7	15.0	3.7	3.4	2.1	1.4	2.7	C
33	11	20.6	14.8	3.7	3.4	2.2	1.3	2.3	C
34	12	20.0	14.6	3.6	3.6	2.1	1.3	2.4	C
35	13	19.5	14.4	3.7	3.6	2.2	1.2	2.5	C
36	14	19.2	14.1	3.6	3.6	1.9	1.2	2.5	C
37	15	18.6	13.9	3.7	3.7	2.2	1.2	2.5	C
38	16	18.2	13.6	3.6	3.6	1.8	1.2	2.2	C
39	17	17.7	13.3	3.6	3.6	1.9	1.1	2.1	C
40	18	17.4	13.0	3.6	3.7	1.9	1.1	2.1	C
41	19	17.0	12.9	3.8	3.7	1.8	1.1	2.1	C
42	20	16.5	12.4	3.7	3.9	1.8	1.0	2.1	C

Continued . . .

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* A indicates complete fusion of epiphyses, C no fusion of epiphyses, B intermidiate stage between A and C.

APPENDIX TABLE Continued.

Serial no.	Vertebral no.	Greatest breadth	Greatest height	Centrum			Neural canal		Degree of* fusion of epiphyses
				Breadth	Height	Length	Breadth	Height	
43	21	16.1	12.0	3.8	3.6	1.6	1.0	2.0	C
44	Ca 1	15.8	11.9	3.7	3.7	1.9	0.8	1.9	C
45	2	15.1	11.8	3.8	3.6	2.0	0.8	1.9	C
46	3	14.7	11.4	3.8	3.6	1.7	0.8	1.8	C
47	4	14.1	10.9	3.9	3.5	1.8	0.8	1.8	C
48	5	14.0	10.7	3.8	3.5	1.7	0.7	1.6	C
49	6	14.0	10.7	3.9	3.5	1.7	0.7	1.6	C
50	7	13.2	10.3	3.8	3.6	1.8	0.7	1.5	C
51	8	12.9	10.0	3.7	3.6	1.8	0.6	1.3	C
52	9	13.1	9.5	3.8	3.6	1.8	0.5	1.2	C
53	10	12.9	9.4	3.7	3.6	1.8	0.5	1.2	C
54	11	12.1	9.1	3.7	3.6	1.8	0.5	1.1	C
55	12	11.0	8.9	3.8	3.5	1.8	0.4	1.0	C
56	13	8.9	8.6	3.8	3.6	1.9	0.4	1.0	C
57	14	8.8	8.5	3.7	3.6	2.2	0.3	1.0	C
58	15	7.7	8.3	3.7	3.7	2.0	0.3	0.8	C
59	16	6.5	8.3	3.7	3.6	2.1	0.3	0.8	C
60	17	5.3	8.1	3.7	3.5	2.1	0.3	0.7	B
61	18	4.3	7.8	3.8	3.6	2.2	0.3	0.6	B
62	19	3.9	7.4	3.7	3.8	2.3	—	—	B
63	20	3.2	6.9	—	—	2.3	—	—	B
64	21	3.0	6.2	—	—	2.3	—	—	A
65	22	2.9	5.5	—	—	2.3	—	—	A
66	23	2.9	4.5	—	—	1.9	—	—	A
67	24	3.0	3.6	—	—	1.7	—	—	A
68	25	3.1	3.2	—	—	1.4	—	—	A
69	26	3.3	2.5	—	—	1.2	—	—	A
70	27	3.3	2.4	—	—	1.1	—	—	A
71	28	3.3	2.0	—	—	1.1	—	—	A
72	29	3.0	1.9	—	—	1.1	—	—	A
73	30	2.8	1.7	—	—	1.0	—	—	A
74	31	2.5	1.5	—	—	0.9	—	—	A
75	32	2.2	1.2	—	—	0.8	—	—	A
76	33	2.0	1.0	—	—	0.7	—	—	A
77	34	1.6	0.7	—	—	0.7	—	—	A
78	35	0.7	0.5	—	—	0.7	—	—	A

SPECIMEN TK452

Serial no.	Vertebral no.	Greatest breadth	Greatest height	Centrum			Neural canal		Degree of* fusion of epiphyses
				Breadth	Height	Length	Breadth	Height	
1	C 1	13.6	7.3	—	—	—	3.8	3.3	A
2	2	7.5	6.3	—	—	—	2.9	2.7	A
3	3	4.1	5.3	2.8	2.0	0.3	2.4	2.7	A
4	4	4.1	5.1	2.8	2.2	0.3	2.3	2.6	A
5	5	3.9	5.5	2.6	2.2	0.3	2.4	2.5	A
6	6	5.1	5.2	2.8	2.2	0.4	3.1	2.2	A
7	7	4.4	5.7	3.1	2.3	0.3	2.7	2.3	A
8	D 1	9.1	6.1	2.9	2.3	0.8	3.7	2.4	C
9	2	10.3	7.8	2.8	2.4	1.1	3.7	2.2	C

Continued. . .

APPENDIX TABLE Continued.

Serial no.	Vertebral no.	Greatest breadth	Greatest height	Centrum			Neural canal		Degree of* fusion of epiphyses
				Breadth	Height	Length	Breadth	Height	
10	3	10.6	7.5	2.4	2.1	1.4	3.6	2.5	C
11	4	10.5	7.5	2.4	2.1	1.7	3.5	2.7	C
12	5	10.5	7.9	2.3	2.1	1.8	3.4	2.9	C
13	6	10.7	8.2	2.3	2.1	2.0	3.4	2.9	C
14	7	—	—	2.3	2.2	2.1	3.3	3.0	C
15	8	—	9.0	2.3	2.3	2.2	3.1	2.9	C
16	9	—	9.3	2.4	2.3	2.2	2.8	2.9	C
17	10	—	—	2.4	2.3	2.2	2.5	2.7	C
18	11	—	—	2.6	2.3	2.1	2.2	2.9	C
19	12	—	—	2.6	2.3	2.1	2.0	2.7	C
20	13	—	—	2.6	2.4	2.1	1.9	2.7	C
21	14	17.6	11.0	2.7	2.4	2.0	1.8	2.7	C
22	15	—	—	2.8	2.4	2.0	1.7	2.7	C
23	L 1	18.4	—	2.8	2.5	1.9	1.6	2.6	C
24	2	18.2	—	2.8	2.5	1.8	1.6	2.8	C
25	3	—	—	2.9	2.5	1.8	1.4	2.7	C
26	4	—	—	2.9	2.6	1.9	1.5	2.6	C
27	5	17.3	11.7	2.9	2.6	1.7	1.4	2.7	C
28	6	17.2	—	2.9	2.6	1.6	1.3	2.6	C
29	7	17.0	11.8	3.0	2.6	1.7	1.3	2.7	C
30	8	16.5	11.8	3.0	2.6	1.6	1.2	2.5	C
31	9	—	—	3.0	2.7	1.6	1.1	—	C
32	10	—	—	3.1	2.7	1.6	1.1	2.5	C
33	11	15.9	—	3.0	2.7	1.5	1.1	2.5	C
34	12	15.2	10.0	3.0	2.7	1.5	1.0	2.3	C
35	13	14.8	9.7	3.0	2.7	1.4	0.9	2.2	C
36	14	14.8	9.9	3.1	2.8	1.5	1.1	2.3	C
37	15	14.5	9.3	3.0	2.8	1.5	0.9	2.3	C
38	16	14.0	9.2	3.0	2.8	1.4	0.8	2.0	C
39	17	14.0	9.2	3.1	2.9	1.4	0.8	2.1	C
40	18	—	9.1	3.1	2.9	1.4	0.8	2.0	C
41	19	—	—	3.1	2.9	1.4	0.7	2.1	C
42	20	12.4	9.2	3.1	2.9	1.4	0.7	1.9	C
43	Ca 1	—	8.2	3.1	2.9	1.3	0.6	1.9	C
44	2	—	—	3.2	3.0	1.3	0.7	1.7	C
45	3	—	8.3	3.1	2.9	1.4	0.6	1.6	C
46	4	—	8.4	3.1	3.0	1.4	0.6	1.6	C
47	5	—	—	3.1	2.8	1.4	0.6	1.4	C
48	6	—	8.1	3.2	2.8	1.3	0.6	1.5	C
49	7	—	—	3.1	2.9	1.3	0.6	1.5	C
50	8	—	—	3.2	2.8	1.3	0.5	1.2	C
51	9	10.0	7.5	3.2	2.9	1.4	0.5	1.2	C
52	10	9.9	—	3.1	2.8	1.3	0.5	1.1	C
53	11	9.4	—	3.1	2.9	1.4	0.4	0.9	C
54	12	8.8	—	3.1	2.8	1.4	0.3	0.8	C
55	13	8.2	7.0	3.1	2.9	1.4	0.3	0.7	C
56	14	7.5	—	3.1	2.9	1.4	0.3	0.7	C

Continued . . .

APPENDIX TABLE Continued.

Serial no.	Vertebral no.	Greatest breadth	Greatest height	Centrum			Neural canal		Degree of* fusion of epiphyses
				Breadth	Height	Length	Breadth	Height	
57	15	6.8	6.5	2.8	2.8	1.3	0.3	0.7	C
58	16	5.9	6.5	3.1	3.0	1.4	0.2	0.6	C
59	17	4.9	5.9	3.1	3.0	1.5	0.2	0.5	C
60	18	3.9	5.9	3.1	3.0	1.5	0.2	0.4	C
61	19	3.4	5.6	2.8	3.0	1.4	0.2	0.4	C
62	20	3.2	5.5	3.0	3.0	1.6	0.2	0.4	B
63	21	2.8	5.0	2.8	3.1	1.6	0.2	0.4	B
64	22	2.6	4.4	2.6	3.1	1.8	0.1	0.2	B
65	23	2.5	4.0	2.5	3.0	1.8	0.2	0.2	B
66	24	2.5	3.5	2.4	3.0	1.5	0.1	0.1	B
67	25	2.4	2.9	2.4	2.8	1.4	—	—	A
68	26	2.4	2.5	2.2	2.3	1.0	—	—	A
69	27	2.5	2.1	2.2	1.6	0.7	—	—	A
70	28	2.6	1.6	2.2	1.4	0.5	—	—	A
71	29	2.5	1.4	2.0	1.3	0.6	—	—	A
72	30	2.6	1.3	1.8	1.2	0.7	—	—	A
73	31	2.3	1.3	1.4	1.0	0.6	—	—	A
74	32	2.0	1.1	1.1	0.9	0.6	—	—	A
75	33	1.8	1.0	0.9	0.7	0.6	—	—	A
76	34	1.6	0.8	0.8	0.6	0.7	—	—	A
77	35	1.6	0.8	—	—	0.6	—	—	A
78	36	1.2	0.5	—	—	0.5	—	—	A

EXPLANATION OF PLATES

PLATE I

Fig. 1. Dorsal view of skull of specimen TK 451.
Fig. 2. Ventral view of skull of specimen TK 451.
Fig. 3. Lateral view of skull of specimen TK 451.
Fig. 4. Posterior view of skull of specimen TK 451.

PLATE II

Fig. 1. Dorsal view of skull of specimen TK 452.
Fig. 2. Ventral view of skull of specimen TK 452.
Fig. 3. Lateral view of skull of specimen TK 452.
Fig. 4. Posterior view of skull of specimen TK 452.

PLATE III

Fig. 1. Lateral view of specimen TK 452.
Fig. 2. Ventral view of specimen TK 452.
Fig. 3. Dorsal view of specimen TK 452.
Fig. 4. Anterior view of the cephalic region of specimen TK 452.
Fig. 5. Lateral view of the cephalic region of specimen TK 452.

PLATE IV

Fig. 1. Ventral view of the cephalic region of specimen TK 452.
Fig. 2. Ventral view of the genital region of specimen TK 452.
Fig. 3. Lateral view of the dorsal fin of specimen TK 452.
Fig. 4. Dorsal view of the cephalic region of specimen TK 452.
Fig. 5. Dorsal view of the caudal region of specimen TK 452.

PLATE V

Fig. 1. Lateral view of specimen TK 451.
Fig. 2. Lateral view of the cephalic region of specimen TK 451.
Fig. 3. Ventral view of the genital region of specimen TK 451.
Fig. 4. A part of the school of *Lagenodelphis hosei* sighted at 03°00′N, 141°55′E, on 2 February 1976.


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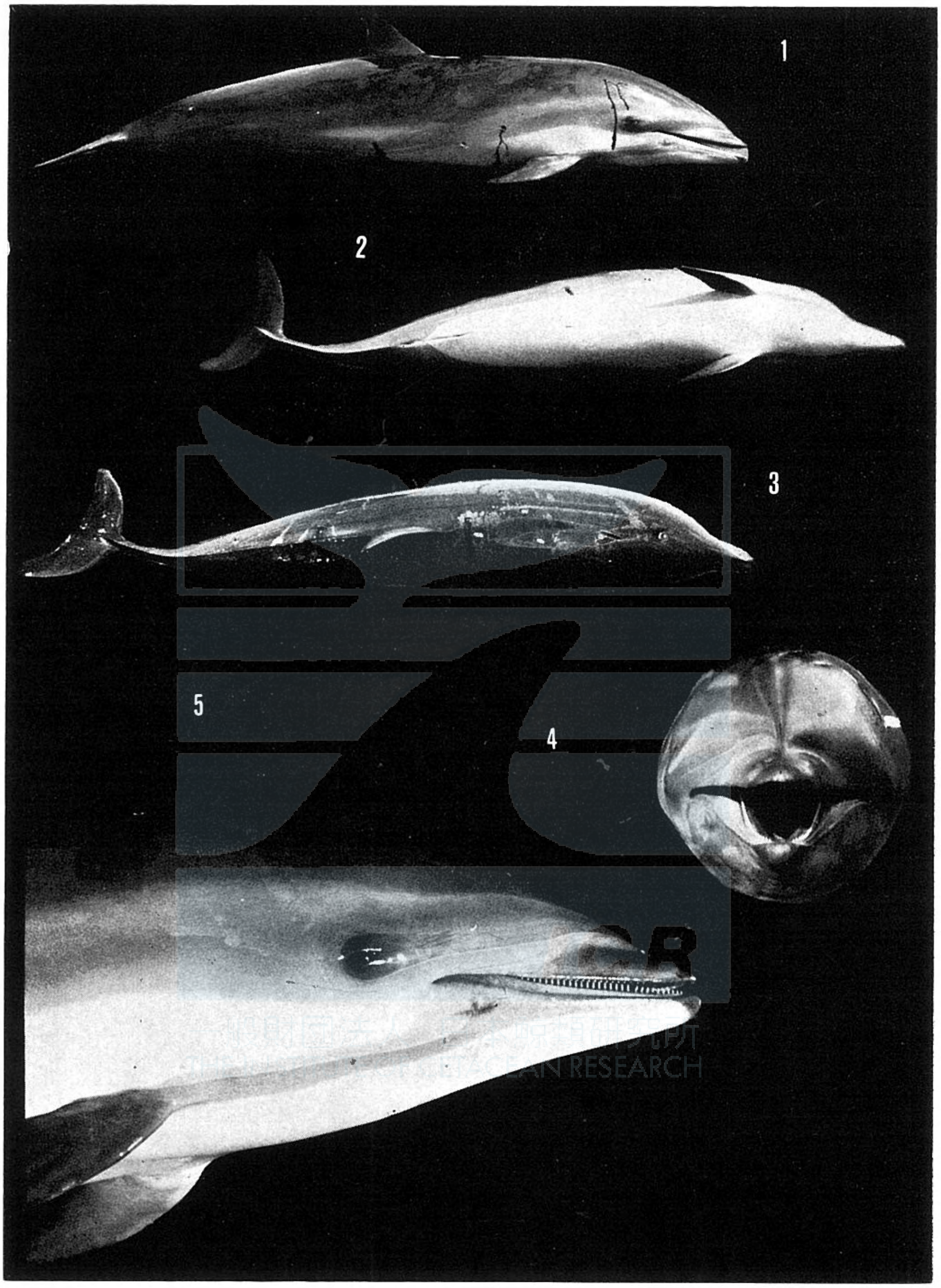
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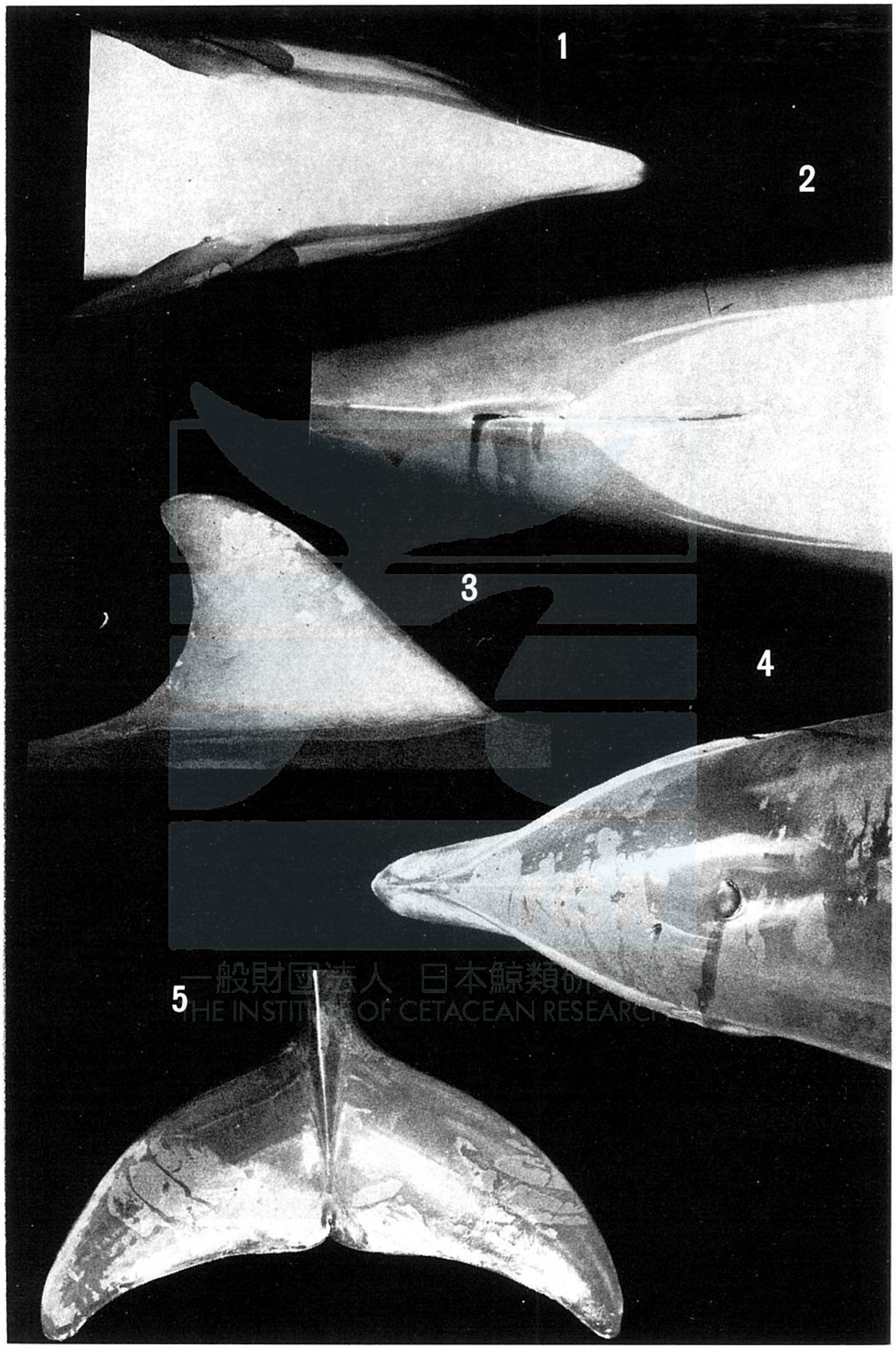
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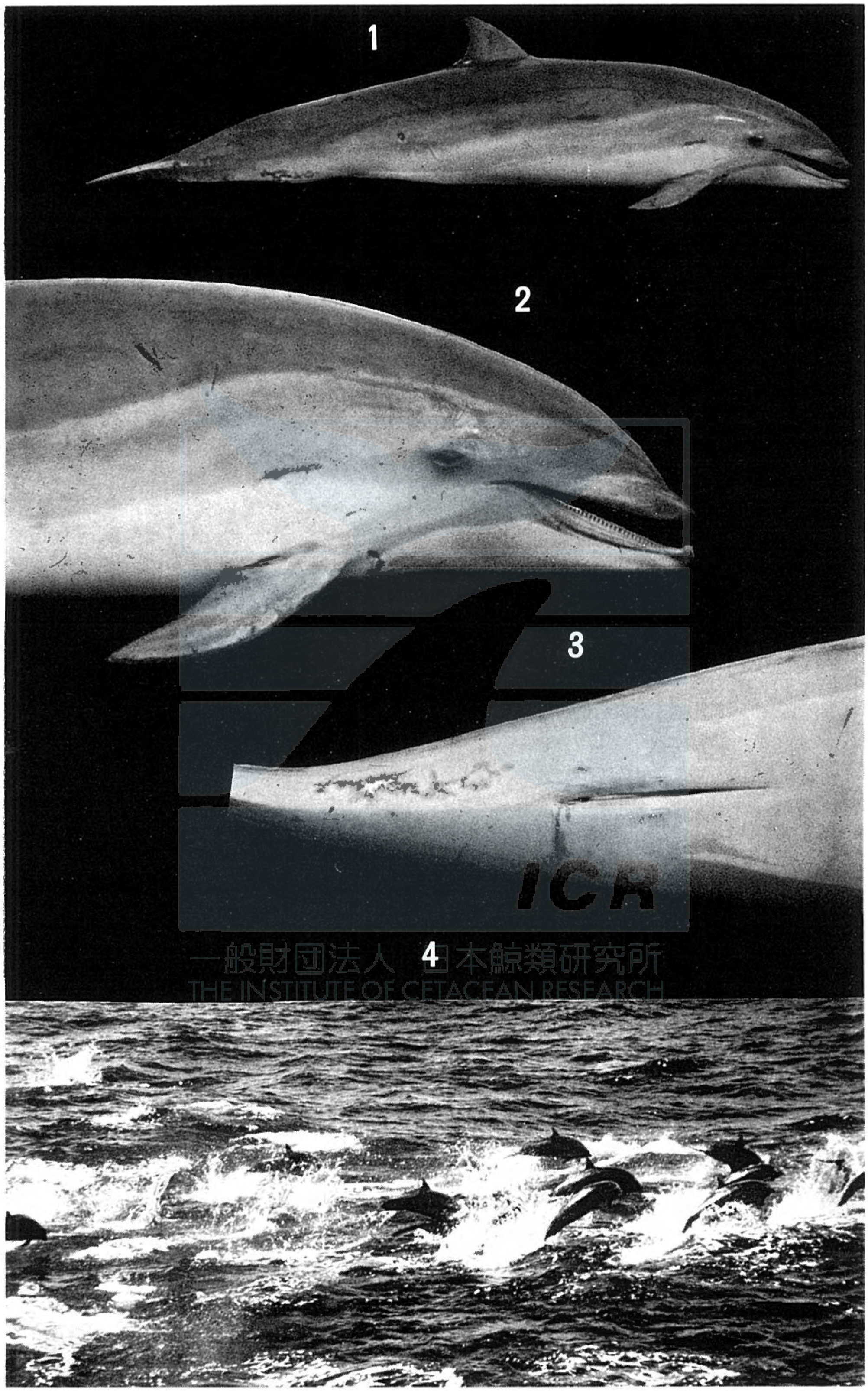
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HUMPBACK WHALES OBSERVED WITHIN THE CONTINENTAL SHELF WATERS OF THE EASTERN BERING SEA

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Humpback whales, *Megaptera novaeangliae*, have been protected in more than recent 10 years according to the Regulation of the International Whaling Commission. The recent observations of humpback whales have been increasing by many sighting surveys (Ohsumi and Masaki, 1973: Herman and Antinoja, 1977: Wolman and Jurasz, 1977: Christensen, 1977). Especially in the North Pacific, more than three hundred humpback whales have been observed in the subtropical waters around Hawaiian Islands (Herman and Antinoja, 1977: Wolman and Jurasz, 1977), and Herman and Antinoja (1977) reported about 200–250 animals around Hawaiian Islands in 1976 but few record has been reported from the summer feeding ground of the North Pacific.

In the cruise of the Research Vessel *Hakuho-Maru* of the Ocean Research Institute, University of Tokyo, in the Bering Sea in 1975, about 30 humpback whales were observed in the Alaskan continental shelf off Nunivak Island. On 11 July 1975, *Hakuho-Maru* was cruising at the position, 58°57′N and 166°00′W in the shelf waters, where school of 5 humpback whales were seen at first at 12-30 o'clock noon. Following this school, other three schools of 5 humpback whales appeared at 12-35, and two schools of 3 humpback whales were seen successively, while the *Hakuho-Maru* still cruising to the north-west direction. The position and moving direction of humpback whales are illustrated in Fig. 1.

These humpback whales have been observed to feed on swarming of euphausiids such as *Thysanoessa raschii* which distribute in these area of low water temperature and salinity (Nemoto, 1962: Fukuchi, 1977), or other swarming fish in this shallow water. There were also many sea bird *Puffinus griseus* and some *Rissa triductyla* were found around the same waters with humpback whales. *Puffinus griseus* individuals fed actively on plankton and a few *Rissa triductyla* were flying about above the water.

Humpback whales have been observed and caught mainly along the shelf waters of continental shelf and edge of islands shelf (Townsend, 1935: Nishiwaki, 1966) in the North Pacific. Humpback whales also congregate around the Aleutian Islands in the summer season where they feed on swarming euphausiids and some heavy swarms of fish such as Alaskan pollack (Nemoto, 1959). However, it has been rather rare to be found within the continental shelf, although humpback whales are considered to be " Ocean and marginal sea denizen " (Nemoto, 1959).

Sometimes humpback whales have been caught within the shelf waters in Arctic Polar Sea and Davis Straight and Barents Sea of the North Atlantic. Recent

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observation of the humpback whales in the Atlantic shows that rather many humpback whales have been found in Barents Sea along the edge of island shelf (Christensen, 1977). He considered the increase of number of humpback whales seen in the Northeast Atlantic in recent years indicate that the abundancy of this species is increasing in that area.

The observation of humpback whales in the North Pacific in recent years, however, shows that they are mainly found in the shelf edge of islands in the mid ocean in winter time. According to Ohsumi and Masaki, some 59 humpback whales were found in winter time of the year in 1972 and 1973 in their whale sighting and marking cruise mainly in the waters around Hawaiian Islands (Ohsumi and Masaki, 1973). Wolman and Jurasz (1977) also reported three hundred seventy three humpback whales in Hawaiian waters, and these large number of sightings of humpback whales are suggesting that the population of humpback whales are increasing.

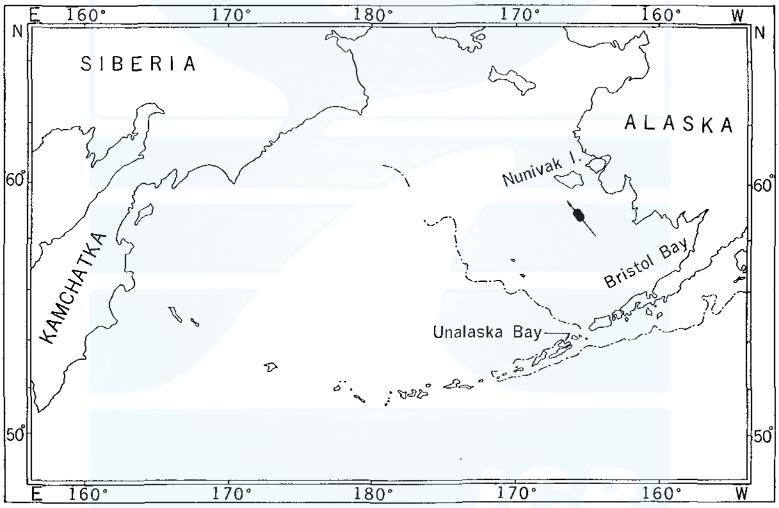

Fig. 1. The position and swimming direction of humpback whales found in the *Huakho-Maru* cruise in 1975 in the Bering Sea.

On the other hand, sighting of humpback whales in the summer feeding ground is not so numerous in the North Pacific. Humpback whales have been caught in the marginal sea such as Okhotsk Sea and Yellow Sea in the former years, but few observation was recorded in the uppermost Bristol Bay according to the fisheries peoples. One humpback whale was reported to be entangled in deep sea cable in the Alaskan waters (Heezen, 1957 by personal communication from Gilmore 1955), but precise information was not given. Considering the diving depth of humpback whales is shallower than the sperm whales, this whale might be entangled in the shelf waters along the Alaskan continent.

The finding of summer feeding schools of humpback whales in shelf waters in the North Pacific is also considered as the indication of the recovery of the number of this species too.

Herman and Antinoja (1977) find only 35% of whales have all black pectoral fins and other whales are white pectoral fins. They consider that Hawaiian humpback whales are different population from those observed in the feeding areas near southeast Alaska and even from whales near Kamtchatka in the upper western Pacific.

Wolman and Jurasz (1977) also consider that humpback whales seen in Hawaiian waters by their vessel census in 1976 possibly differ from those distributing in the Southeastern Alaska. The most distinctive feature of Hawaiian humpback is also white dorsal flipper. One or two humpback whales observed to jump in the continental shelf waters of Alaskan continent in our cruise in 1975 do not have white dorsal flipper, however, it needs more observation on this point to separate these two groups of humpback whales. Another marking results of humpback whales also show that some humpback whales hit in the Eastern Alaskan Islands were captured in the Okinawa Island (Nishiwaki, 1966). But, it is not conclusive, because no whaling had been operated in Hawaiian waters at that time.

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STRANDING OF A BLACK RIGHT WHALE AT KUMOMI, SOUTHWESTERN COAST OF IZU PENINSULA

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On 15 April 1977 a black right whale was stranded on the coast of Kumomi, southwestern coast of Izu peninsula (Fig. 1). We received the information of this stranding at about 2000 hours of that day and went there in haste. After arriving the town of Kumomi and while we were on the way to the beach where the whale stranded we heard several moans of animal, which was sounded as if they were emitted from bottom of a manhole.

After arriving the beach we saw the whale in the shallow water of the beach and still alive. The sound we heard on the way were the respiration sound which were produced while outgoing air passes through the blowholes. We are quite familiar with respiration sounds of dolphins kept in our aquarium, but this sound was quite different from these and very impressive.

The whale went agrounded on the shallow bottom of the beach, nosing the head towards the beach and moving its tail flukes very gently (Fig. 2). On the previous day it was announced by press that a whale came quite close to the beach of Numazu city (see Fig. 1). We thought this was the same whale and it moved from there down to here along the coast and finally stranded. There is an evidence, however, to think that the whale was pursued by several fishing boots on the way.

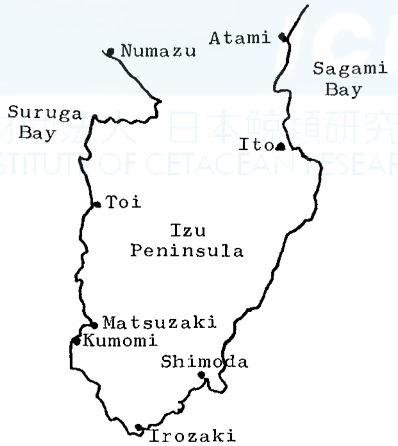

Fig. 1. Location of Kumomi and Numazu (see text).

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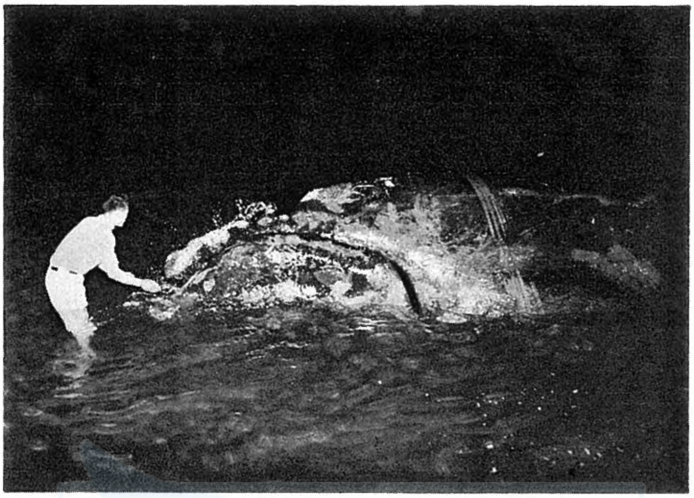

Fig. 2. The black right whale stranded at Kumomi.

TABLE 1. BODY PROPORTION OF THE BLACK RIGHT WHALE STRANDED ON 15 APRIL 1977 AT KUMOMI, IZU PENINSULA

	Measurements	Length in cm	% against total length
1.	Total length	1,150	100
2.	Tip of snout to center of eye	270	23.5
3.	Tip of snout to blowholes	225	19.6
4.	Tip of snout to angle of gape	277	24.0
5.	Tip of snout to anterior insertion of flipper	297	25.8
6.	Tip of snout to tip of flipper	410	35.7
7.	Center of eye to center of ear	60	5.2
8.	Notch of flukes to center of anus	290	25.2
9.	Notch of flukes to center of umbilicus	480	41.7
10.	Flipper, tip to anterior insertion	204	17.7
11.	Flipper, tip to posterior insertion	175	15.2
12.	Flipper, greatest width	118	10.3
13.	Tail flukes, total spread	415	36.1
14.	Tail flukes, tip to notch	210	18.3
15.	Tail flukes, anterior insertion to notch	240	20.9
16.	Tail flukes, anterior insertion to tip	105	9.1

The whale was left whole the night as it was, because there was no means to move the whale.

On the following day we heard that the whale died early in the morning. We went to Kumomi again in a hope to obtain whole of the skull and other bones for osteological specimen. But this was not possible because people of Kumomi had already decided other way of treating. We made some observation of the whale and measured body proportions which are shown in Table 1.

In Fig. 3 arrangements of the bonnet and other carosities are shown. These

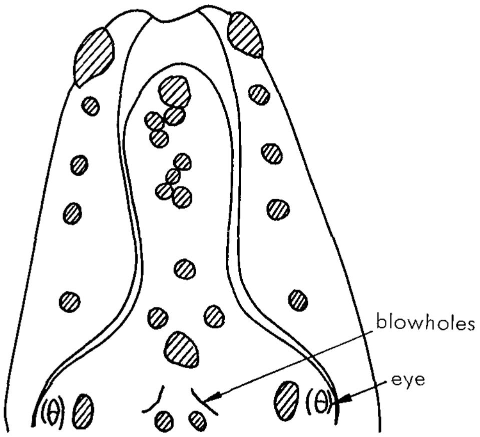

Fig. 3. Arrangement of bonnet and other carosities of the black right whale stranded at Kumomi.

are very hard in structure and like miniature of ranges of mountains, each top being pointing. Cyamids were infested heavily on these carosities. Further there present bristles in the region of bonnet and other carosities as well as a number was noted on the surface of mandibles.

This whale was a young male of 11.5 m in length and all black in color and no white patch was observed on ventral surface of the body.

This whale was dismembered on the third day and when we arrived there the treating was already begun and went rather hurriedly. We only could make some observations. The sex of the whale was ascertained by the presence of a long and slender penis of 110 cm in length. Thickness of blubber was measured at several points around anus and the average thickness of these was 20 cm. The color of baleen plates was grayish black and they numbered 227 on one side. We could not examine internal organs nor stomach contents.


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COMPARISON OF EARLY DEVELOPMENT OF STERNUM AND CLAVICLE IN STRIPED DOLPHIN AND IN HUMPBACK WHALE

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ABSTRACT

The morphogenesis of the sternum and the clavicle in whales was studied for the first time. The mode of development of these structures shows considerable differences between the toothed whales (Odontoceti) and the whalebone whales (Mysticeti). The toothed whales are, in this case, similar to all other mammals. Their sternum originates from three different embryonal elements. During development of the embryo a rudimentary clavicle is to be found in the shouldergirdle. The whalebone whales, on the other hand, differ from this mode of development. Their sternum originates from only two embryonal elements and there is no clavicle at all. The third sternum element cannot even be found as a rudimentary element, which is unique among mammals. The significance of these findings are discussed.

INTRODUCTION

The development of the sternum and shouldergirdle in man as well as in terrestrial mammals has been dealt with in quite a few papers (Ruge, 1880 ; Eggeling, 1904, 1906 ; Müller, 1906 ; Gladstone and Wakeley, 1932 ; Reiter, 1942 ; Chen, 1952, 1953 and others). According to the latest findings in this area (Klima, 1968, 1973, 1975) the sternum originates, during embryogenesis, from three different elements : 1. an unpaired ventrocranial element of the interclavicle, 2. a paired lateral element of the coracoid plates and 3. a paired lateral element of the sternal bands. These three elements always participate in the morphogenesis of the shouldergirdle and sternum in Monotremata as well as in Marsupialia and Placentalia. Apart from this these elements may behave rather different during the further course of ontogeny. They may be included in the interclavicle, the coracoid bones or the sternum. The sternum may be divided into the manubrium and sternebrae or not. In addition to this the breast-shoulder-apparatus may be large or small. But these three elements mentioned here represent a constant factor that is obviously determined genetically and has been found in the ontogeny of every mammal studied so far.

At present we know nothing about the morphogenesis of the sternum in whales. Although a few cetacean embryos have been studied (Eschricht 1849, Turner 1870, Kükenthal 1914, Schulte 1916, Slijper 1936), all of them, however, were too large to find out anything about the mode of the development of the sternum. Even the smallest of them, an embryo of *Balaena mysticetus* of about 10 cm length, studied by Eschricht and Reinhardt (1849), and an embryo of *Balaenoptera acutorostrata* of 10.5 cm studied by De Burlet (1917), had finished the morphogenesis of the sternum, that already had the typical form and location as is seen in adult animals. Besides, it would be of special significance to know the mode of development of the greatly reduced and transformed sternum of whalebone whales, whether it coincides with the pattern of all mammals, or whether it deviates from this scheme. In fact accurate examinations of the ossification process of the sternum in the whales are lacking so far. Some observations concerning this problem are being published at the moment (Krauss-Hoeft, 1978).

I had the opportunity to study two very favourable morphogenetic stages, one was a representative of the toothed whales (*Stenella coeruleoalba*), the other a representative of the whalebone whales (*Megaptera novaeangliae*). They allowed an exact observation of the mode of development of the sternum and of the clavicle in whales. The results can by all means be considered characteristic for both groups of whales, Odontoceti and Mysticeti, as the sternum of each group develops according to an uniform scheme. Considerable differences within the two suborders are not to be expected.

MATERIAL AND METHODS

The material of embryos examined belongs to the collections of the Department of Anatomy, Faculty of Medicine, University of Tokyo, Hongo, Tokyo. I was able to evaluate two important developmental stages out of several serial sections of the striped dolphin (*Stenella coeruleoalba*). More information about this material can be found in the paper by Kamiya and Pirlot (1974). From the serial sections of the humpback whale (*Megaptera novaeangliae*) two stages were also suitable for the purpose of my research. The material used is summarized in the following table:

	Body length:	Plane of section:
Stenella coeruleoalba	17 mm	longitudinal
Stenella coeruleoalba	35 mm	longitudinal
Megaptera novaeangliae	21 mm	transversal
Megaptera novaeangliae	37 mm	transversal

All of the embryos were made into celloidin slides in the customary histologic fashion, the sections being between 20 and 25 μ were stained with hematoxilin-eosin. I have made a graphic reconstruction of both a *Stenella* and a *Megaptera* embryo (Figs 2 and 7).

The osteological material of adult animals includes sterna of *Stenella coeruleoalba*, several further representatives of the family Delphinidae, and next to *Megaptera novaeangliae* further representatives of the family Balaenopteridae. This material came from the following collections: Institut voor Taxonomische Zoölogie, Amsterdam; Universitetets Zoologiske Museum, Kobenhavn; Rijksmuseum van Natuurlijke Historie, Leiden; British Museum (Natural History), London;

National Science Museum (Natural History Institute), Tokyo; Ocean Research Institute, University of Tokyo, Tokyo; The Whales Research Institute, Tokyo; Tokyo University of Fisheries, Tokyo; Museum National d'Histoire Naturelle, Paris.

A selection from this material is shown in the Figs 1 and 5 with a note of their origin. Two figures of the sternum of the blue whale (*Balaenoptera musculus*) were taken from the publications by White (1919) and Miller (1924).

RESULTS

Stenella coeruleoalba

The sternum of *Stenella* has the same basic shape as the sternum of all mem-

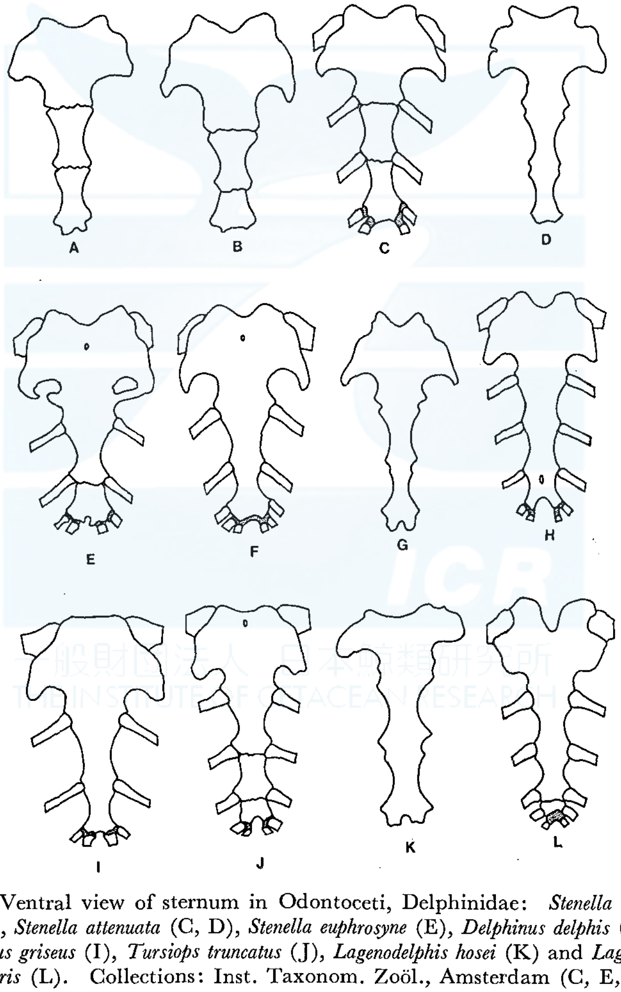

Fig. 1. Ventral view of sternum in Odontoceti, Delphinidae: *Stenella coeruleoalba* (A, B), *Stenella attenuata* (C, D), *Stenella euphrosyne* (E), *Delphinus delphis* (F, G, H), *Grampus griseus* (I), *Tursiops truncatus* (J), *Lagenodelphis hosei* (K) and *Lagenorhynchus albirostris* (L). Collections: Inst. Taxonom. Zoöl., Amsterdam (C, E, F, H, J); Rijksmus. Nat. Hist., Leiden (B, I, L); British Mus. Nat. Hist., London (D, G); Ocean Res. Inst., Tokyo (A).

bers of the Delphinidae (Fig. 1). It is divided into a manubrium and two to three sternebrae.

The manubrium lies between the first and second pair of ribs. It is flattened dorsoventrally and rather broad laterally. It has a wide pointed projection on both sides towards the back. This projection can, in some cases, melt into a wide plate with the central part of the manubrium. Of the caudal margin of the plate there can be found closed window openings or half open notches (Fig. 1E). The wide cranial end of the manubrium is slightly dented in the middle. Near to the dent there may be one small hole. The thin caudal end has a slightly waved edge, that borders on the first sternebra.

The sternebrae are very flattened out dorsoventrally and their diaphysis is thinner than their epiphysis. The division into sternebrae is obviously only to be found in young animals. They develop out of bone cores, that are located between

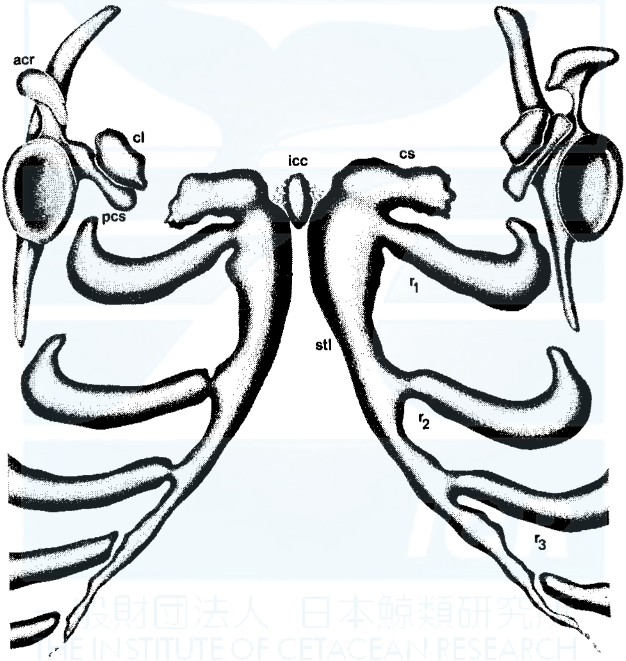

Fig. 2. *Stenella coeruleoalba*, embryo of 35 mm body length. Graphic reconstruction of the anlage of sternum and shouldergirdle in ventral view.

acr	Acromion
cl	Clavicle
cs	Paired lateral element of the coracoid plates (=Coracoidscapularplatte)
ht.........	Heart
icc	Unpaired ventrocranial element of the interclavicle (=Pars chondralis interclaviculae)
pcs	Processus coracoideus scapulae
$r_{1,2,3}$......	$\text{Ribs}_{1,2,3}$
stl.........	Paired lateral element of the sternal bands (=Sternalleiste)

successive rib connections (Krauss-Hoeft, 1978). Whith age they melt together, as the manubrium does, into a uniform and completely ossified sternum. The number of sternebrae varies between two and three ; in some exceptional cases there can even be four. This is coherent with the number of true ribs, that are incorporated into the sternum. Usually there are four to five, but there can be six or even seven pairs of true or vertebrosternal ribs. The connection of the last pairs of ribs to the sternum shows great inconsistency, probably the consequence of a regressive development, that one can see in the caudal region of the sternum in almost all mammals. In the Delphinidae, as, by the way, in all the Odontoceti, this regressive development has gone so far that the Processus xiphoideus has disappeared completely.

In contrast to most mammals there is no connection of the sternum with the shouldergirdle by means of the clavicle. The clavicle is completely reduced.

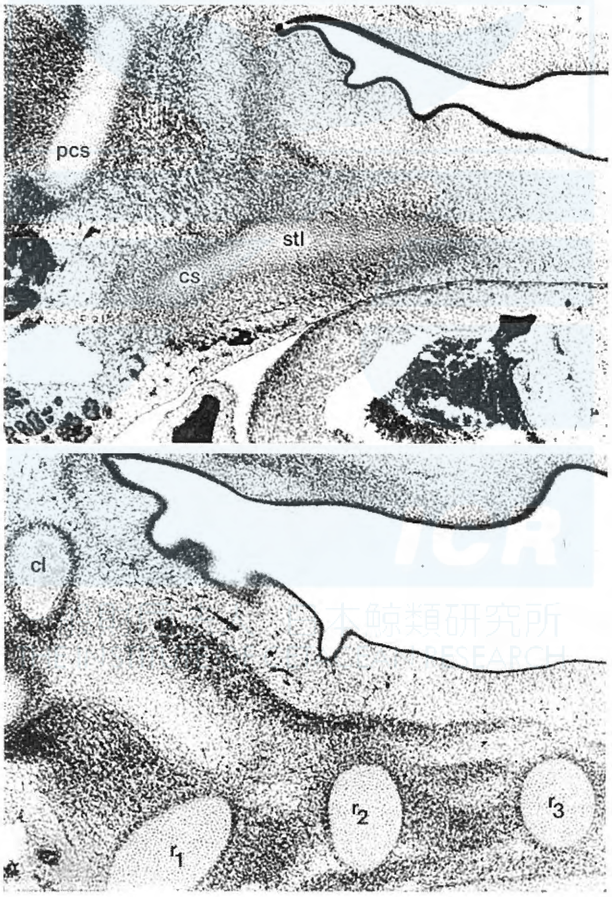

Fig. 3. *Stenella coeruleoalba*, embryo of 35 mm body length. Longitudinal section of the anlage of sternum (cs and stl) and clavicle (cl). For abbreviations see Fig. 2.

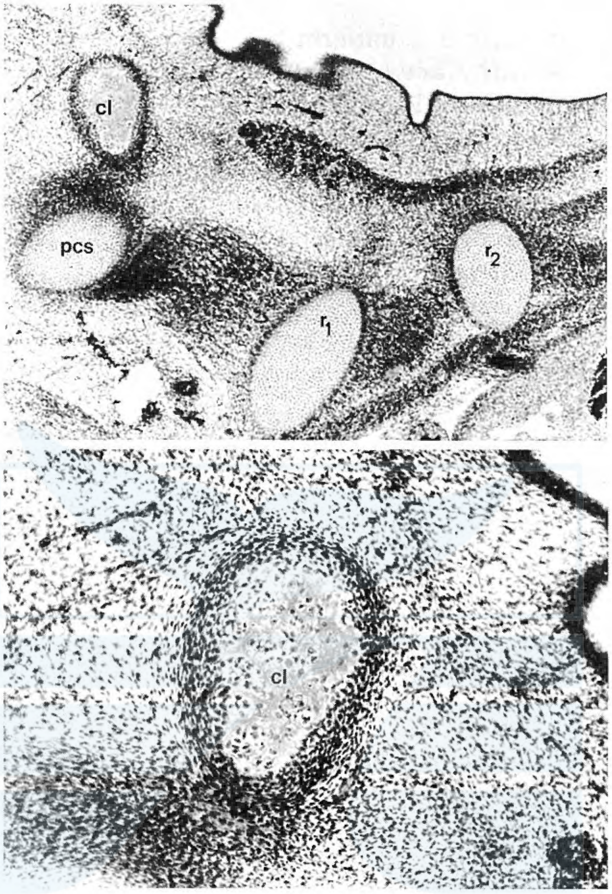

Fig. 4. *Stenella coeruleoalba*, embryo of 35 mm body length. Longitudinal section demonstrating the anlage of clavicle (cl). For abbreviations see Fig. 2.

The *Stenella* embryo of 17 mm has a thin strip of dense mesenchyme on each side of its body ventral of the rib ends. The dense mesenchyme extends from the first to the fourth pair of ribs. Both strips still lay far apart from each other, the cranial ends, however, come closer to the median line than the caudal ends. Details cannot be recognized. As far as the location is concerned these structures are unpaired lateral elements of sternal bands that can be seen in analogous stages of development in all other mammals.

In the *Stenella* embryo of 35 mm (Figs 2 and 3) the cranial ends of both of the sternal bands have moved closer to each other and are fusing in the median line. They extend from the first to the fifth pair of ribs. The cranial parts continue laterally each as an additional element. Both elements extend in the direction of the Processus coracoideus of the scapula but do not unite with it. They are paired craniolateral elements of coracoid plates such as one can see in the ontogeny of many other mammals. In the median line, in front and between the two sternal bands is located the third embryonal anlage, an unpaired ventrocranial element of interclavicle, or the so-called Pars chondralis interclaviculae of the Monotremata (Klima, 1973), an ancestral rudiment occurring in all mammals.

Between the sternum anlage and the Acromion scapulae there is on both sides an isolated desmal ossified element, that is equivalent to a rudimentary clavicle (Figs 2 and 4).

Megaptera novaeangliae

The sternum of the adult *Megaptera* is made of one piece. There is no division in manubrium and sternebrae in any phase of the ontogenesis. The sternum only comes in contact with the first pair of ribs; the other ones are floating ribs with free ends. These characteristics not only pertain to *Megaptera*, but to all members of the family Balaenopteridae and actually are peculiar to all Mysticeti.

The shape of the sternum of each species, however, is very different. It also varies a lot even within one species (Fig. 5). In *Megaptera* I have found sterna that one could call triangular, heart-shaped, trilobate or U-shaped. Each of these sterna, it makes no difference of which shape, pushes itself between the first pair of ribs with the thinner caudal end (Figs 5E, F, G). Thus the larger part of the sternum is located on the front margin of the ribs. This position is typical for the sterna of the Balaenopteridae. In many prepared skeletons, however, the sternum has subsequently been falsely placed in the middle between the first pair of ribs or even in back of it. Such an incorrect position of the sternum in *Megaptera* can be found for example in a paper by Rudolphi (1829, recently taken over by Arvy and Pilleri, 1977). Eschricht (1849) already pointed out many mistakes that have been made in this regard.

In *Megaptera* as in all other Mysticeti the scapula is the only part of the shouldergirdle that is left. It is located relatively far away from the sternum, much further dorsolaterally than in the Odontoceti. A clavicle is not present.

In the *Megaptera* embryo of 21 mm, that can be compared with the 17 mm *Stenella* stage, the ribs are still far apart in the body wall on both sides of the pericardium (Fig. 6). Near to the ventral ends of the first ribs there is an indistinct dense mesenchyme zone. It is relatively small and confined to the area of the first pair of ribs only. The significance of this mesenchyme zone is uncertain. It could correspond to the later visible paired craniolateral elements of coracoid plates. The paired lateral elements of sternal bands as well as the clavicle are not developed.

In the *Megaptera* embryo of 37 mm (Figs 7 and 8), that can be compared with 35 mm *Stenella* stage, the ribs have already pushed themselves far ventrally. With them, they have taken the mesenchyme zones towards the median plane. These take up the space between and in front of the first pair of ribs, histologically already consisting of young cartilaginous tissue. They begin to fuse in the median plane. This tissue stays distinct from the rib anlage and spreads craniolaterally, analogous to the paired craniolateral elements of coracoid plates in *Stenella*. I think that these elements are identical, too. The paired lateral elements of sternal bands,

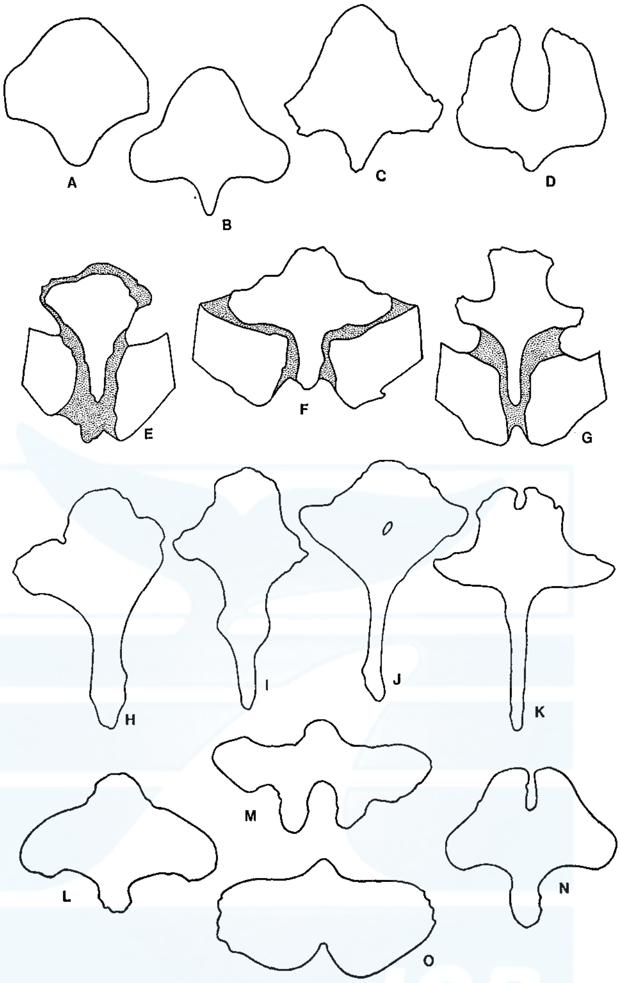

Fig. 5. Ventral view of sternum in Mysticeti, Balaenopteridae: *Megaptera novaeangliae* (A, B, C, D, F), *Balaenoptera acutorostrata* (E, G, H, I, J, K) and *Balaenoptera musculus* (L, M, N, O). Collections: Inst. Taxonom. Zoöl., Amsterdam (H, I); Univ. Zool. Mus., Kobenhavn (C, E, L); Rijksmus. Nat. Hist., Leiden (G); British Mus. Nat. Hist., London (A, B, O); Mus. National Hist. Nat., Paris (D); Nat. Sci. Mus., Tokyo (J); Whales Res. Inst., Tokyo (K); (M) after Waite, 1919; (N) after Miller, 1924.

out of which all other mammals as well as *Stenella* build up the largest part of the sternum, do not exist in *Megaptera*. On the other hand one can see between the cranial ends of the coracoid plates an unpaired ventrocranial element of interclavicle, histologically consisting of condensed mesenchyme, not very sharply delineated from the surrounding tissue.

In a similar case in the sternum of an embryo of *Balaenoptera acutorostrata* of

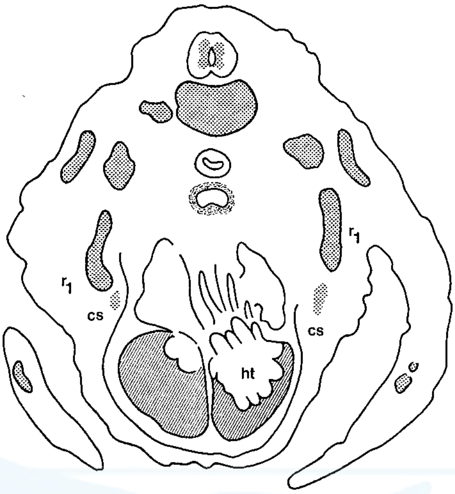

Fig. 6. *Megaptera novaeangliae*, embryo of 17 mm body length. Transversal section at the level of heart (ht). For abbreviations see Fig. 2.

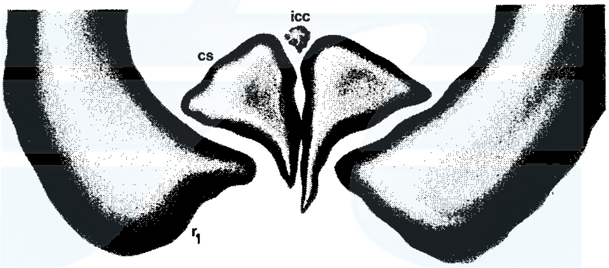

Fig. 7. *Megaptera novaeangliae*, embryo of 37 mm body length. Graphic reconstruction of the anlage of sternum in ventral view. For abbreviations see Fig. 2.

10.5 cm length, shown by De Burlet (1917), the elements mentioned had already fused. There still are to be distinguished one rounded central process between two rounded lateral processes. This central process develops, without doubt, from the unpaired element of the interclavicle. Should the element of the interclavicle not be present, the result would probably be an U-shaped sternum, as I was able to establish in the specimen of *Megaptera* out of the Paris collection (the later sternum was presented earlier in the following papers of Gervais, 1871 ; Lessertisseur and Saban, 1967 ; Arvy and Pilleri, 1977).

DISCUSSION

General considerations

Even the comparison of the sternum and shouldergirdle in adult animals

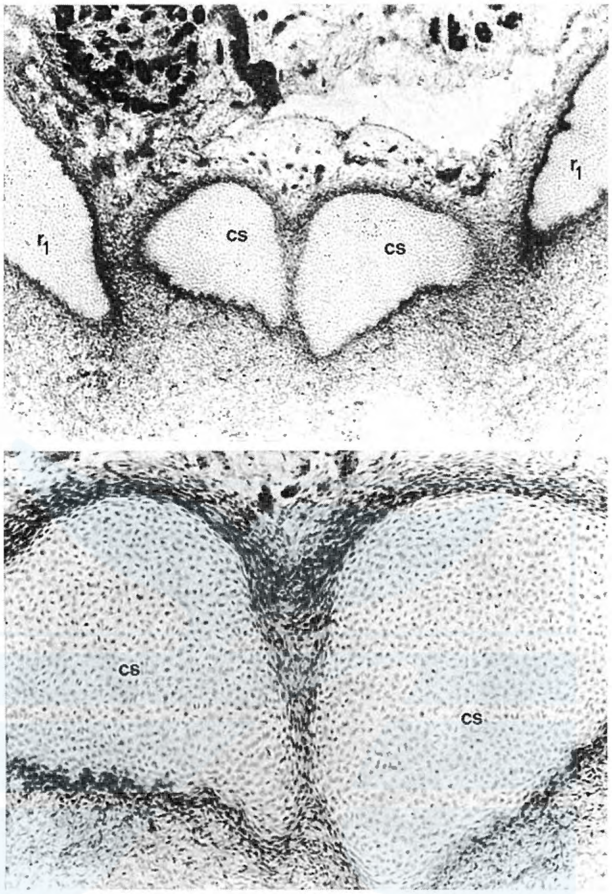

Fig. 8. *Megaptera novaeangliae*, embryo of 37 mm body length. Transversal section of the anlage of sternum (cs). For abbreviations see Fig. 2.

shows considerable differences between both suborders of Cetacea, the Odontoceti and the Mysticeti. These differences become even more apparent when the early development is examined. The morphogenesis of the sternal complex of the Odontoceti is similar to that of all other placental mammals, while the morphogenesis of the Mysticeti, on the other hand differs greatly from this pattern. Herein both groups obviously have been submitted to completely different evolutionary trends. The Mysticeti have reduced the sternal complex to a very great extent. In this regard the Mysticeti are a unique group within the mammalia.

The shape of the sternum

The sternum of adult Odontoceti shows many typical characteristics of sterna of terrestrial mammals. It is divided into a manubrium and several sternebrae that usually melt into a compact piece in old age. Normally the sternum is longer than wide and closes off the ventral portion of the chest. The number of true ribs varies to a great extent. Most Odontoceti have four to five pairs of true ribs, some species have only three, but some are known to have seven or eight pairs of true ribs. These numbers usually vary within one and the same species. These circumstances also occur in most terrestrial mammals. In Odontoceti the caudal end of the sternum is a bit more reduced. The Processus xiphoideus is completely absent.

The sternum of adult Mysticeti consists of one single piece of bone that is located in front and between the first pair of ribs and has a relatively loose connective tissue link. All of the remaining ribs have completely loose ends on the ventral side of the thorax. A division of the sternum in manubrium und sternebrae is not to be seen. The sternum is usually wider than long and it is often triangular, heart-shaped, cross-shaped or U-shaped. Although the different species of Mysticeti show the same shape of the sternum, its morphological variability is so great that it can hardly be used as a criterion for the separation of species. This was recognized by Omura and published in numerous papers (Omura 1957, 1972, 1975). Contrary to some authors, who for instance thought that the sternum of *Balaenoptera* was of taxonomic importance, Omura (1957) writes: " . . . the sternum is to be regarded as a rudimentary organ and subject to individual variation largely, it is thought to have less taxonomic value ". This statement is, without doubt, valid for all Mysticeti.

The size of the sternum

There is not only a considerable difference in the shape but also in the size of the sternum of Odontoceti and Mysticeti. It stands to reason that not the absolute but rather the relative size of the sternum must be considered. Arvy and Pilleri (1977) are correct, when they write: " . . . the adjective ' small ' can hardly be applied to sternums of . . . 41×36 cm (*Eubalaena glacialis*) . . . 49×67.5 cm (*Balaenoptera acutorostrata*) or 47×60 cm (*Balaenoptera musculus*) ". But this " truth " is in no reasonable relation to the actual circumstances. In spite of its enormous size, the sternum of the Mysticeti is actually, when compared with the rest of the skeleton, the smallest that can be found in mammals. I have started some measurements on these grounds (the studies are not yet completed) and have been able to find the following relationships: the relative size of the sternum or the length of the sternum in percent (%) of the length of the whole skeleton is usually between 7 and 14% in most Odontoceti, the genera *Platanista* and *Inia* are closer to the lower percentage, whereas the genera *Berardius* and *Ziphius* are near to the higher percentage. For *Stenella* I found a percentage of 10.1. *Physeter* obviously differs from all the other Odontoceti; with a percentage of 4.8. It is closer to the relative size of the Mysticeti sternum that is between 1.4 and 3.5%. *Balaenoptera* is towards the lower percentage whereas *Eubalaena* is closer to 3.5%. For *Megaptera* I found 2.2% relative sternum length.

The early development of the sternum and the clavicle

The reduction of the sternal complex of the Mysticeti takes place in an early period of embryogenesis. In this case it does not manifest itself as a secondary differentiation of an existing structure. Rather we have to do with a reduction that goes as far as a complete absence of an embryonal element. As written in detail in the introduction, the sternum of terrestrial mammals originates from three different elements. This is also the case in the Odontoceti. On the other hand the Mysticeti do not even have an anlage of the paired sternal bands. The reduction of this element has obviously moved below the threshold of morphogenesis. It is astonishing that this is just the element that is most important for the development of the sternum of all other mammals, not only for the caudal half of the manubrium but also for all of the sternebrae or the whole corpus, respectively. It is also the largest element. Phylogenetically it is the youngest and most " modern " element that still plays a small role in the development of the sternal complex in Monotremata but increasingly determines the development of the sternum of Marsupialia and Placentalia. In these cases it substitutes the two older, ancestral or " primitive " elements, the interclavicle and the coracoid plates. It is remarkable that just these two ancestral elements mentioned above remain in the Mysticeti, as if they were established firmer and more " conservative " in

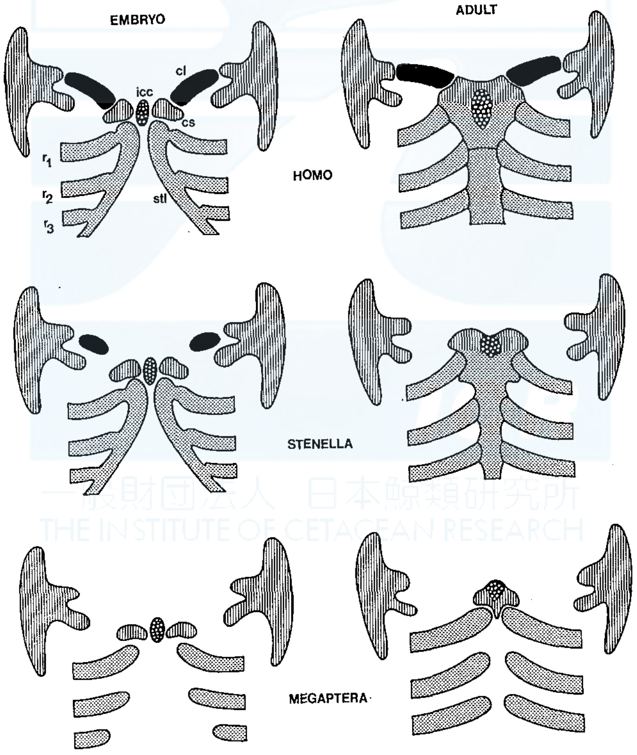

Fig. 9. Comparison of the development of sternum and shouldergirdle in terrestrial mammals (*Homo*), in toothed whales (*Stenella*) and in whalebone whales (*Megaptera*). For abbreviations see Fig. 2.

the genetic code as the " modern " element of sternal bands. The sternum that develops from these elements is only a rudimentary structure without any greater functional significance. The further trend in the development of the Mysticeti is probably towards a complete reduction of the sternum. According to its location the sternum of recent Mysticeti corresponds to the anterior resp. cranial part of the manubrium, in the development of which take part laterally the elements of the coracoid plates, and medially the element of the interclavicle.

The members of the Odontoceti as well as of the Mysticeti do not have a clavicle as adult. This is also the case in some terrestrial mammals. However, they have a clavicle at least temporarily during the genesis of the embryo. A rudimentary clavicle is also obvious in the Odontoceti during the embryogenesis, as has been proved in this paper for *Stenella*. No rudimentary clavicle can be found in *Megaptera*, which, as I think, can be considered a rule for all Mysticeti. This total reduction is in complete correspondence with the extensive reduction of the sternum.

Monophyly or Polyphyly ?

The question of monophyly or polyphyly of the Cetacea is a theme that has often been discussed vehemently. Final evidence for one or the other hypothesis cannot be found at present.

The Cetacea have to be derived from terrestrial mammals. As common ancestors ancient insectivora come into account from which not only the Ungulata, but also the +Creodonta have evolved. Among the +Creodonta it were probably the +Mesonychidae from which the +Archaeoceti originated as the first ancestors of the whales that were adapted to aquatic life. This happened at the end of the Cretaceous period, in other words about 70 million years ago.

As to the hypothesis of a monophyletic derivation, the Odontoceti as well as the Mysticeti would originate from the +Archaeoceti. This hypothesis is supported by the development of the very specialized auditory ossicles, that is supposed to be almost identical in the three cetacean suborders (Van Valen, 1968) as well as the correspondence in the karyotype and the structure of the chromosomes in Odontoceti and Mysticeti (Arnason, 1969, 1974 and Kulu, 1972). The striking differences are, according to this hypothesis, secondary and brought about by different dietary specialization.

The supporters of diphyletic or polyphyletic derivation of Cetacea have the opinion that the living Odontoceti and Mysticeti do not stem from one and the same root, or that the +Archaeoceti represent a completely independent group, respectively. All correspondences in morphology would be, as far as this hypothesis is concerned, convergent functional adaptations to aquatic life (Slijper, 1962; Yablokov, 1964 and others). Summarizing accounts on the problem of monophyly and polyphyly of Cetacea recently can be found in Gaskin (1976) and Oelschläger (1978).

The results in this paper on the early development of the sternal complex can give us some ideas as to the question of monophyly and polyphyly of Cetacea.

However, it cannot give any final answer. At first glance the great difference between Odontoceti and Mysticeti in the mode of development seems to point to polyphyly. How far these differences reach back into the phylogenetic past can hardly be determined. For such a determination one would need to know the possible speed of the regressive development of the single sternal elements. As we do not know this speed we have to compare the situation in Cetacea with analogous cases in other mammals. For instance different groups of mammals have completely lost their teeth. The best known example of a reduction of skeletal elements is that of the regressive development of the clavicle. The sternum is, however, neither to be compared with dentin structures nor with desmal bone. It originates from a chondral base and for this reason can only be compared with a chondral element of the skeleton. A genuine analogy for the reduction of the sternum in Cetacea is for instance the reduction of the finger bones in Ungulata, or the complete reduction of the hind limbs as well as of the pelvis of Odontoceti and Mysticeti. The reduction of the structures just mentioned took place in a comparable, if not shorter period of time than the 70 million years that were necessary to bring forth the recent Cetacea. It could be quite possible, that the reduction of the sternum of the Mysticeti also took place in this period of time. For this reason a monophyletic development of the Cetacea cannot be excluded.

Still there are several unsolved problems in this field. All structures mentioned above are not reduced completely. They appear, at least for a short span of time during embryogenesis, as relics of tissue. This is not true for the sternal bands in Mysticeti. In all of the examples mentioned we are able to give a functional explanation for the reduction of the organ concerned. We consider the loss of teeth an extreme dietary specialization, the reduction of the clavicle to be caused by a change in the mode of locomotion of the front extremities, the diminution of finger bones as an adaptation to faster running. The loss of the hind limbs as well as of the pelvic girdle has to be considered a consequence of the transition from a terrestrial to an aquatic habitat and, in correlation with this, of the takeover of the locomotory function by the trunk-tail-apparatus. There is no plausible explanation for the reduction of sternal apparatus in Mysticeti or for its persistence in the Odontoceti. Neither the mode of locomotion nor the breathing mechanism, the size of the body, the depth of diving or any other imaginable factors show any correlation that could give a plausible answer.

CONCLUSION

The sternum as well as the shouldergirdle of whales are reduced to a great extent. Compared with terrestrial, four-legged mammals the reduction of this apparatus is, however, advanced not to the same extent in the toothed whales (for example *Stenella*) as in the whalebone whales (for example *Megaptera*). The toothed whales conform in general with terrestrial mammals, which also manifests itself in the development of the embryo. All of the three embryonal elements, which are typical for terrestrial mammals and out of which the sternum originates, also occur in toothed whales. They are 1. an unpaired ventrocranial element of interclavicle, 2. paired craniolateral elements of coracoid plates, and 3. paired lateral elements of sternal bands. The complete sternum anlage of the embryo extends from the first to the fifth pair of ribs. A rudimentary clavicle is obvious. In whalebone whales on the other hand the sternum originates from only two primordial elements. Even at an early stage their extension is very small; the whole anlage fills only the small cleft between the first pair of ribs. The paired lateral elements of sternal bands are completely missing. Thus the embryonal element, that plays the largest role in the development of the sternum in all Marsupialia and Placentalia, and that phylogenetically is the youngest and most " modern " of all, is absent. On the other hand the oldest and most " primitive " elements, the interclavicle and the coracoid plates are present. Not even a rudimentary clavicle is to be found. No constructive connections, that would explain the different modes of development of whalebone whales and the toothed whales as a functional adaptation could be found. With regard to the embryogenesis of the sternum and the shouldergirdle, the toothed whales and the whalebone whales have obviously evolved in separate directions. Monophyly of both groups is nevertheless not to be excluded.

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PRELIMINARY REPORT ON MORPHOLOGICAL STUDY OF PELVIC BONES OF THE MINKE WHALE FROM THE ANTARCTIC

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ABSTRACT

In the 1976-77 season a total of 51 pairs of the pelvic bone of the minke whale from the Antarctic has been collected for morphological study. These suggested some doubt on sexual dimorphism of bones, which was affirmed in the North Atlantic population. The size of bones is thought to be smaller than in the North Atlantic. The most interesting point, however, is the presence of ossified remnant of the femur in some specimens. Final conclusion is defered for future, because more samples have been collected in the 1977-78 season and these are still in the course of study.

INTRODUCTION

Pelvic bones of baleen whales are two slender elongated bones embedded in muscle on either side of the genital aperture and nearly parallel to the body axis. In studying skull and postcranial bones of the minke whale from the Antarctic I noticed some morphological difference of pelvic bones between whales from the Antarctic and those from the North Pacific (Omura, 1975). This difference was in the position of the lateral tubercle or promontory, and in the former specimen the tubercle situated towards the middle of the bone, whereas in the latter specimen in more posterior position. In these two specimens bones are nearly straight, but in the third specimen which was examined in the following year pelvic bones are curved inwards and in this specimen the lateral tubercles situated posteriorly (Omura, 1976).

In order to investigate the scope of variation in shape of pelvic bones I have asked Kyodo Hogei Co., a whaling company operating pelagic whaling, to collect pelvic bones from the minke whale in the 1976–77 Antarctic season, from each 10 whales from different areas of operation. Thus a total of 51 pairs of pelvic bones were collected from different five areas and these samples are the basis of this report. Almost all of the samples are from males and samples from femeles have been collected in the 1977–78 season, though they are not included in this study.

Concerning the name of this bone Arvy (1976) feels that it is time to discard the ‘ pelves ’, the ‘ pelvic bones ’, the ‘ ischia ’ and ‘ ilia ’ of the cetacea for the only logical appellation of abdominal bones. But I have still sticked to the traditional name ‘ pelvic bones ’ in this paper.

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MATERIAL

Pelvic bones were collected by *Nisshin Maru No. 3* and *Tonan Maru No. 2* expeditions, by crew of the factory ships during treating of whales, and they were stored in refrigeration chamber, attached with identification tag of the whale. Catch position and other particulars of whales from which pelvic bones were collected are shown in Appendix Table in detail, together with measurements of bones.

As shown in Fig. 1 pelvic benes were collected from five different areas of operation, defined by the International Whaling Commission. Further in each area collections were made within a short period of several days (see Appendix Table) and in small squares shown by hatched lines in Fig. 1. Accordingly it may be assumed that pelvic bones collected from the same square represent the same population of the minke whale, though it is not known yet how many populations of the minke whale exist in the whole Antarctic.

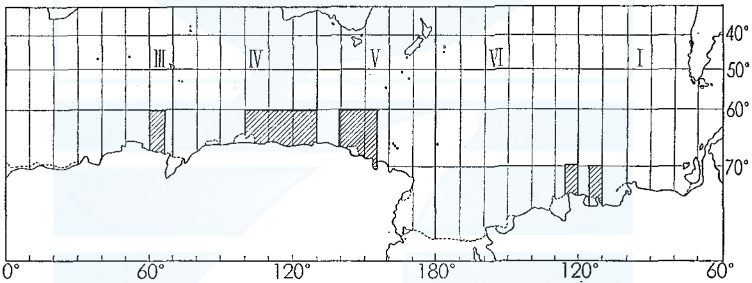

Fig. 1. Chart showing postitions where pelvic bones were collected in the 1976–77 season. Roman numerals denote whaling statistical areas, and hatched small squares in each area show locality where samples were collected.

After arriving our laboratory these bones were boiled for several hours, after each pair was contained in a small bag made of cotton cloth in order to secure remnant of femur, if any. Then each bag was opened and all of the surrounding tissues were removed, and then bones were boiled again. Finally these bones were dried by direct sun.

RESULTS AND DISCUSSION

Heyerdahl jr. (1973) found sexual dimorphism in pelvic bones of the minke whale from the North Atlantic, those of the female having the shape of a knife while those of the male look like drum sticks. Among 51 pairs of pelvic bones collected from the minke whale from the Antarctic only one pair was reported as sampled from a female and all others from male, as seen in Appendix Table. All photographs of these bones are shown in Plates I–V. This female is 76T0193 and 9.0 m in length and the pelvic bones are shown in Pl. III Fig. 10. As seen from this photograph these bones are short and wide, and lateral promontories are well developed. Both bones are very flat and the ratio of thickness of bones against their width across the promontory are 0.20 and 0.21 respectively. These values are somewhat smaller than those obtained by Heyerdahl jr. (1973), though the general shape resembles to his female specimen.

In other specimens there are rather wide range of variation in the shape of pelvic bones. Some are like drum stick, but some are not. These difference in shape are dependent on the development of the lateral promontory. In the typical ' drum stick ' type no promontory is observed (Pl. I, Figs 4, 8, 10; Pl. II, Figs 3, 5, 6; Pl. III, Figs 2, 5, 6; Pl. IV, Figs 7, 9; Pl. V, Figs 8, 10). In the most developed specimen of promontory they are Y-shaped in general (Pl. II, Fig. 2; Pl. III, Fig. 4; Pl. IV, Fig. 1; Pl. V, Fig. 5). In these specimens sexual dimorphism can not be noticed in shape alone.

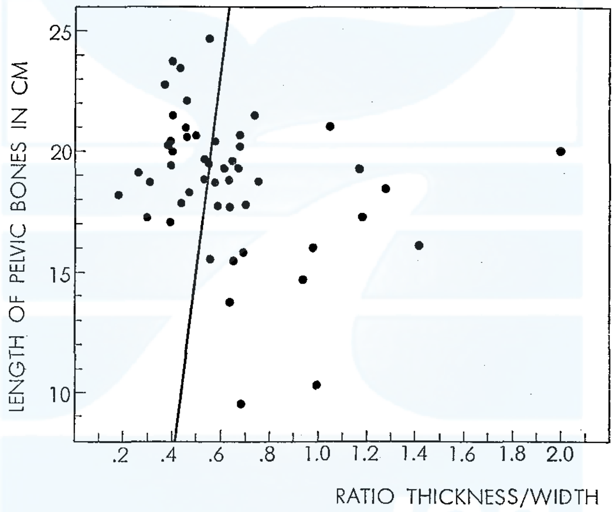

Fig. 2. Relation between lengths of pelvic bones and ratios of thickness/width across the promontory in minke whales from the Antarctic. The straight line in the figure is the regression line obtained by Heyerdahl jr. (1973) for minke whale from the North Atlantic.

As stated already these samples were collected by crew of the factory ships during the course of treatment of whale carcasses. On the flensing deck many carcasses are processed consecutively, and it is rather difficult to identify whale number exactly without special caution. At this moment I can not say any more on this matter and should wait further collection of materials, especially from females.

Among intermediate type of ' drum stick ' and ' Y-shape ' there are also some variations. In Fig. 2 are shown the ratio of thickness/width against their lengths. In this case the average value of measurements within each pair have been used.

The straight line in the figure is the regression line obtained by Heyerdahl jr. (1973) from pelvic bones of the male minke whales from the North Atlantic. His conclusion is that the female bones tend to maintain their proportions while the male bones diverge towards a rounder shape (with growth of the body). In Fig. 2 no such regression line be drawn, because dotts are scattered very widely. I haven't collected pelvic bones from whales shorter than 8 m in length. This is because that in immature animals ossification of bone is not completed and cartilages are remaining towards both ends. In order to simplify the matter I have asked crew of the expeditions to collect bones from animals of 8 m or over in length, because average body length at which sexual maturity is attained is 7.2 m for males and 8.0 m for females (Ohsumi and Masaki, 1975). I haven't measured the degree of ossification of the pelvic bones on the X-ray photographs, and in fact I have noticed while boiling the bones that cartilages are still remaining in some specimens at their extremities, but they are short and do not affect greatly.

In Fig. 3 are shown the relationship between the length of the pelvic bones and length of the whales from which bones were extracted. The straight line shown in the figure is the regression line obtained by Heyerdahl jr. (1973), and

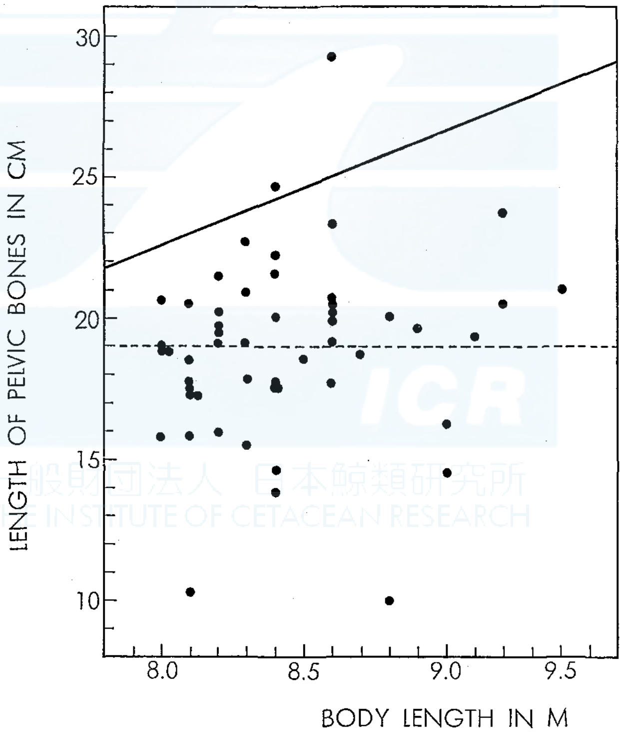

Fig. 3. Relation between lengths of pelvic bones and body lengths in minke whales from the Antarctic. The straight line in the figure is the regression line obtained by Hyerdahl jr. (1973) for minke whale from the North Atlantic and the dotted line 19 cm or minimum length of mature animals in the North Atlantic.

the dotted line was drawn at 19 cm. There is a discrepancy in measuring the length of the bone, because Heyerdahl jr. measured the total length, including those of cartilages, but I have only measured the ossified bones. But this difference in length is not great in the matured animals. Even taking into consideration of this fact it seems that the pelvic bones are shorter in the minke whale in the Antarctic than in the North Atlantic. In the matured minke whales from the North Atlantic pelvic bones are 19 cm or more (Fig. 9 of Heyerdahl jr., 1973), but this does not apply to minke whales from the Antarctic, and they are below the regression line drawn by Heyerdahl jr., with only two exceptions.

The most interesting point in this study is the presence of the remnants of femur in 13 specimens or 25% of the total animals investigated. These are ossified small bones and they are generally like candies or bulbs in shape. Measurements of these bones are also shown in Appendix Table. Burmeister (1867) described the pelvis of his specimen of *Balaenoptera bonaerensis* ' No vestige of an attachment of another bone to any part of its surface is visible; and it is the same with the European species, according to the observation of Eschricht and Reinhardt '. The existence of the femur in the minke whale had long been denied by other authors too (e.g. Hosokawa 1951), but Heyerdahl jr. (1973) discovered a nodule of cartilage anterior and lateral to the promontory in one of the 32 X-ray photographs. This specimen is from a 25-foot (7.5 m) female, possibly an immature whale judged from Fig. 4 of his paper.

TABLE 1. PRESENCE OF FEMUR IN THE PELVIC BONE OF THE MINKE WHALE FROM THE ANTARCTIC

Area	III	IV	V	VI	I	Total
Total number collected	11	10	10	10	10	51
in which femur attached	6	2	2	2	1	13
% femur attached	55	20	20	20	10	25

In the present samples the occurrence of the femur is biassed according to areas where they were sampled, as shown in Table 1. From this table it is suggested that there is difference in occurrence of the femur bone according to different populations, those in the area III showing big value than others. But I hesitate to draw any conclusion at this moment on this and other problems. Also in the 1977–78 season a number of pelvic bones of the minke whale has been collected, mostly from females, but they arrived the laboratory quite recently and now in the course of preparation for study.

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Sincere thanks are due to the crew of *Nisshin Maru No. 3* and *Tonan Maru No. 2*, who collected samples of the pelvic bone with much care and trouble.

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APPENDIX TABLE. CATCH PARTICULARS OF THE MINKE WHALE FROM WHICH PELVIC BONES WERE SAMPLED AND MEASUREMENTS OF BONES (1976–77 SEASON)

Whale no.	Date of catch	Sex	Body length m	Position of catch		Area	Measurements in mm							
							One side				Another side			
				Lat.	Long.		Length	Width*	Thick-ness*	Femur**	Length	Width*	Thick-ness*	Femur**
76N0026	18 Nov. '76	♂	8.2	61°-56'S	106°-21'E	IV	202	27	19	none	202	27	19	none
76N0027	,, ,, ,,	,,	8.1	,, ,, S	,, ,, E	,,	172	46	13	41, 18, 19	173	43	41	41, 18, 17
76N0029	19 ,, ,,	,,	8.6	61°-43'S	110°-07'E	,,	193	37	21	none	202	43	21	none
76N0075	,, ,, ,,	,,	8.6	,, ,, S	,, ,, E	,,	290	21	29	none	296	23	22	none
76N0119	21 ,, ,,	,,	8.4	62°-43'S	115°-56'E	,,	221	40	17	none	222	35	17	none
76N0378	25 ,, ,,	,,	8.6	64°-01'S	125°-53'E	,,	199	42	17	none	205	43	16	none
76N0390	26 ,, ,,	,,	8.4	63°-59'S	122°-39'E	,,	199	47	19	none	201	43	17	none
76N0391	,, ,, ,,	,,	8.8	,, ,, S	,, ,, E	,,	194	13	27	none	205	15	29	none
76N0692	30 ,, ,,	,,	8.6	64°-19'S	126°-11'E	,,	206	53	20	24, 18, 13	202	53	21	missed?
76N0727	2 Dec. ,,	,,	9.0	64°-09'S	127°-29'E	,,	161	24	30	none	162	21	33	none
76N0974	8 Feb. '77	,,	8.2	66°-44'S	61°-17'E	III	156	25	28	none	163	24	20	none
76N0980	,, ,, ,,	,,	8.4	,, ,, S	,, ,, E	,,	166	45	18	32, 22, 18	184	52	20	34, 23, 19
76N0983	,, ,, ,,	,,	8.8	,, ,, S	,, ,, E	,,	104	20	13	none	94	19	13	none
76N0984	,, ,, ,,	,,	8.1	,, ,, S	,, ,, E	,,	174	28	36	none	172	29	31	none
76N0987	,, ,, ,,	,,	8.0	,, ,, S	,, ,, E	,,	163	27	18	none	153	24	17	none
76N0988	,, ,, ,,	,,	8.1	,, ,, S	,, ,, E	,,	158	25	14	none	150	24	17	none
76N0993	,, ,, ,,	,,	8.4	,, ,, S	,, ,, E	,,	256	37	20	34, 22, 22	236	35	20	53, 22, 20
76N1424	13 ,, ,,	,,	8.4	66°-55'S	62°-05'E	,,	143	39	28	21, 19, 14	132	36	20	22, 21, 15
76N1425	,, ,, ,,	,,	8.6	,, ,, S	,, ,, E	,,	170	36	22	34, 22, 19	185	33	19	35, 23, 18
76N1427	,, ,, ,,	,,	8.3	,, ,, S	,, ,, E	,,	232	38	15	26, 16, 12	222	41	14	34, 18, 17
76N1433	,, ,, ,,	,,	8.6	,, ,, S	,, ,, E	,,	206	50	23	33, 22, 19	209	52	24	32, 24, 18
76T0025	15 Nov. '76	,,	9.1	63°-19'S	153°-04'E	V	196	28	20	none	190	33	21	none
76T0081	16 ,, ,,	,,	8.2	63°-26'S	151°-17'E	,,	194	30	18	none	189	29	18	none
76T0082	,, ,, ,,	,,	8.4	,, ,, S	,, ,, E	,,	196	40	15	29, 20, 18	236	38	16	26, 22, 17
76T0083	,, ,, ,,	,,	8.7	,, ,, S	,, ,, E	,,	187	62	20	46, 29, 26	187	64	20	45, 29, 26
76T0128	17 ,, ,,	,,	9.4	63°-47'S	148°-47'E	,,	212	30	28	none	207	25	29	none
76T0193	18 ,, ,,	♀	9.0	64°-06'S	147°-01'E	,,	145	56	12	none	145	60	12	none
76T0221	19 ,, ,,	♂	8.4	64°-13'S	141°-48'E	,,	153	23	22	none	140	21	19	none

Continued . . .

APPENDIX TABLE. Continued.

Whale no.	Date of catch	Sex	Body length m	Position of catch		Area	Measurements in mm							
							One side				Another side			
				Lat.	Long.		Length	Width*	Thickness*	Femur**	Length	Width*	Thickness*	Femur**
76T0222	19 Nov. '76	♂	9.2	64°-13'S	141°-48'E	V	236	40	16	none	238	43	17	none
76T0299	21 ,, ,,	„	8.2	64°-27'S	139°-26'E	„	213	35	22	none	217	27	23	none
76T0300	,, ,, ,,	„	8.5	,, ,, S	,, ,, E	„	190	24	34	none	180	28	32	none
76T0766	16 Feb. '77	„	8.6	70°-20'S	114°-21'W	I	189	54	15	none	193	53	15	none
76T0767	,, ,, ,,	„	8.1	,, ,, S	,, ,, W	„	127	37	30	none	80	27	32	none
76T0774	,, ,, ,,	„	8.2	,, ,, S	,, ,, W	„	199	46	18	none	190	45	18	none
76T0819	17 ,, ,,	„	8.1	70°-18'S	115°-31'W	„	172	37	18	none	173	38	17	none
76T0827	,, ,, ,,	„	8.4	,, ,, S	,, ,, W	„	181	31	14	none	174	33	14	none
76T0863	,, ,, ,,	„	8.1	,, ,, S	,, ,, W	„	181	33	21	none	189	40	21	none
76T0871	18 ,, ,,	„	8.3	71°-01'S	114°-57'W	„	201	37	18	none	217	36	15	none
76T0907	19 ,, ,,	„	8.3	70°-54'S	112°-12'W	„	190	35	27	none	166	42	26	none
76T0908	,, ,, ,,	„	8.0	,, ,, S	,, ,, W	„	190	25	15	none	186	23	15	none
76T0914	,, ,, ,,	„	8.0	,, ,, S	,, ,, W	„	189	25	20	missed?	186	28	20	18, 11, 9
76T1094	23 ,, ,,	„	8.0	70°-45'S	121°-21'W	VI	186	41	19	19, 13, 13	190	35	21	19, 11, 10
76T1106	23 Feb. '77	„	8.3	70°-45'S	121°-21'W	VI	149	29	19	none	161	36	16	none
76T1129	,, ,, ,,	„	8.2	,, ,, S	,, ,, W	„	198	34	17	none	193	30	18	none
76T1130	,, ,, ,,	„	9.2	,, ,, S	,, ,, W	„	206	40	21	49, 32, 22	203	39	24	50, 37, 24
76T1139	24 ,, ,,	„	8.3	70°-44'S	124°-36'W	„	188	68	18	none	194	70	18	none
76T1164	,, ,, ,,	„	8.9	,, ,, S	,, ,, W	„	194	34	21	none	199	34	22	none
76T1165	,, ,, ,,	„	8.5	,, ,, S	,, ,, W	„	235	38	19	none	231	43	16	none
76T1171	,, ,, ,,	„	8.1	,, ,, S	,, ,, W	„	202	32	20	none	209	31	23	none
76T1172	,, ,, ,,	„	8.0	,, ,, S	,, ,, W	„	207	33	17	none	205	37	17	none
76T1177	,, ,, ,,	„	8.1	,, ,, S	,, ,, W	„	175	31	15	none	180	27	21	none

* Measured across promontory.

** Three dimentions.

EXPLANATION OF PLATES

PLATE I

Pelvic bones of the minke whale collected in area IV.

Fig. 1.	76N0026	Fig. 6.	76N0378
Fig. 2.	76N0027	Fig. 7.	76N0390
Fig. 3.	76N0029	Fig. 8.	76N0391
Fig. 4.	76N0075	Fig. 9.	76N0692
Fig. 5.	76N0119	Fig. 10.	76N0727

PLATE II

Pelvic bones of the minke whale collected in area III.

Fig. 1.	76N0974	Fig. 7.	76N0993
Fig. 2.	76N0980	Fig. 8.	76N1424
Fig. 3.	76N0983	Fig. 9.	76N1425
Fig. 4.	76N0984	Fig. 10.	76N1427
Fig. 5.	76N0987	Fig. 11.	76N1433
Fig. 6.	76N0988		

PLATE III

Pelvic bones of the minke whale collected in area V.

Fig. 1.	76T0025	Fig. 6.	76T0221
Fig. 2.	76T0081	Fig. 7.	76T0222
Fig. 3.	76T0082	Fig. 8.	76T0299
Fig. 4.	76T0083	Fig. 9.	76T0300
Fig. 5.	76T0128	Fig. 10.	76T0193

PLATE IV

Pelvic bones of the minke whale collected in area I.

Fig. 1.	76T0766	Fig. 6.	76T0863
Fig. 2.	76T0767	Fig. 7.	76T0871
Fig. 3.	76T0774	Fig. 8.	76T0907
Fig. 4.	76T0819	Fig. 9.	76T0908
Fig. 5.	76T0827	Fig. 10.	76T0914

PLATE V

Pelvic bones of the minke whale collected in area VI.

Fig. 1.	76T1094	Fig. 6.	76T1164
Fig. 2.	76T1106	Fig. 7.	76T1165
Fig. 3.	76T1129	Fig. 8.	76T1171
Fig. 4.	76T1130	Fig. 9.	76T1172
Fig. 5.	76T1139	Fig. 10.	76T1177


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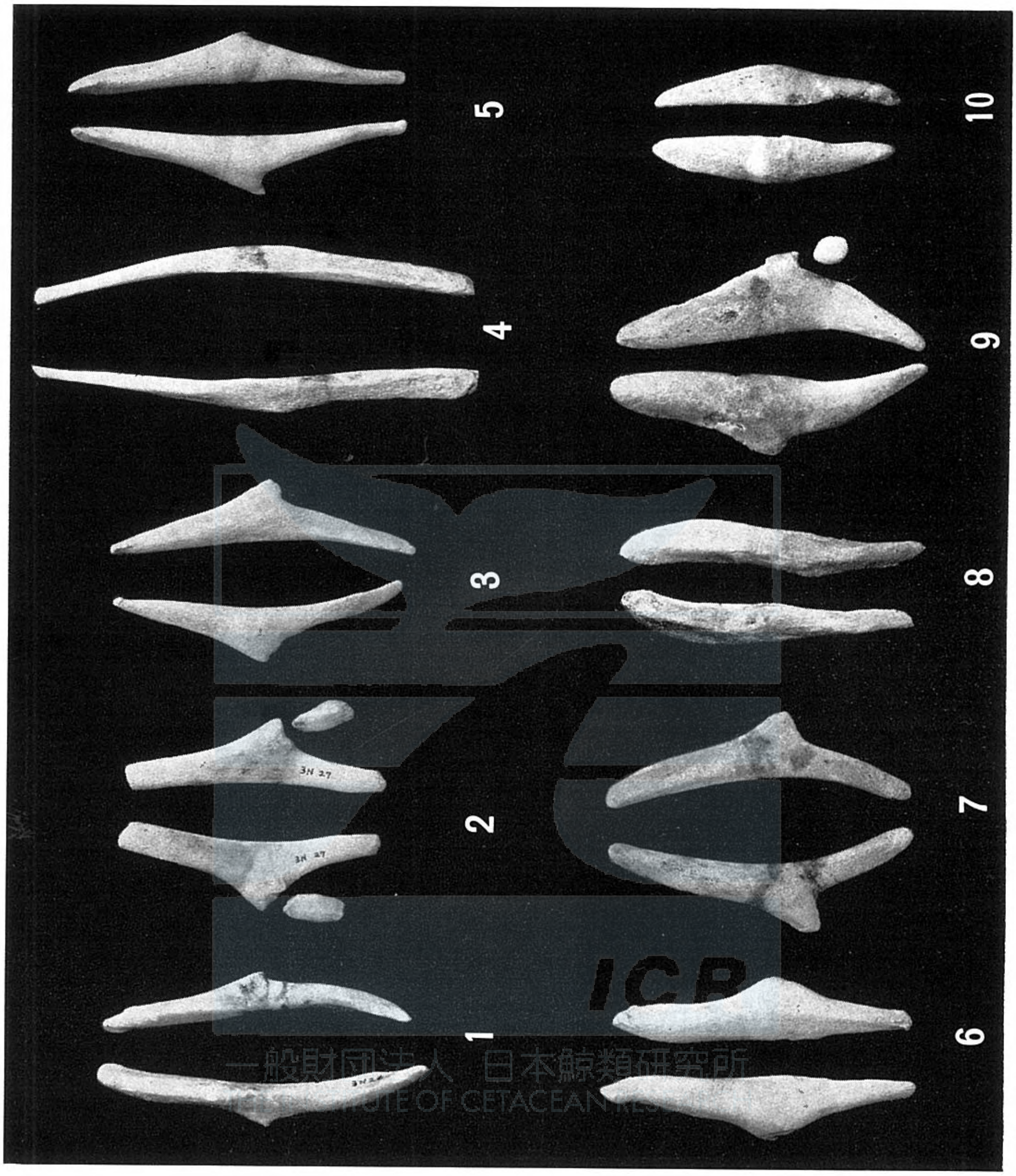
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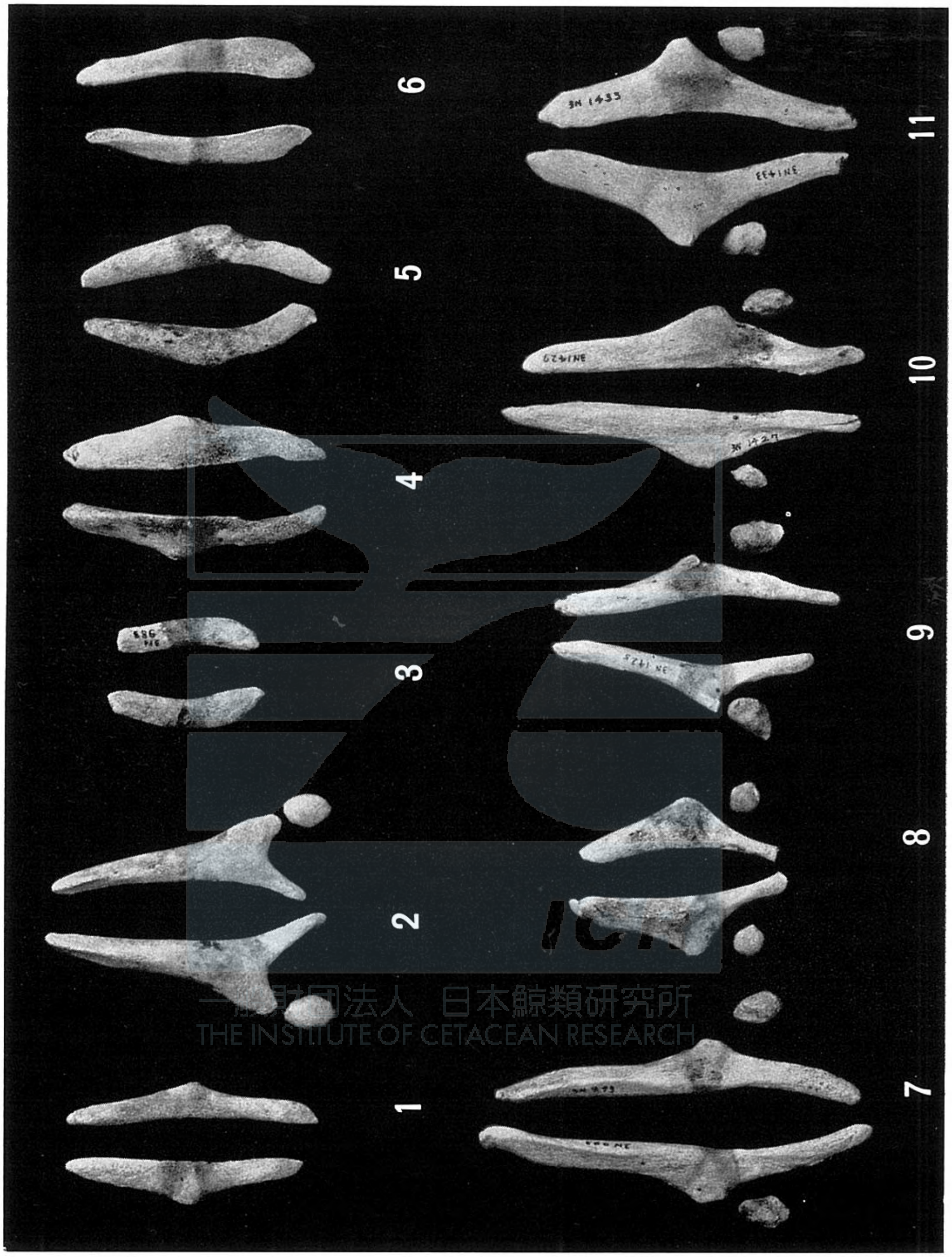
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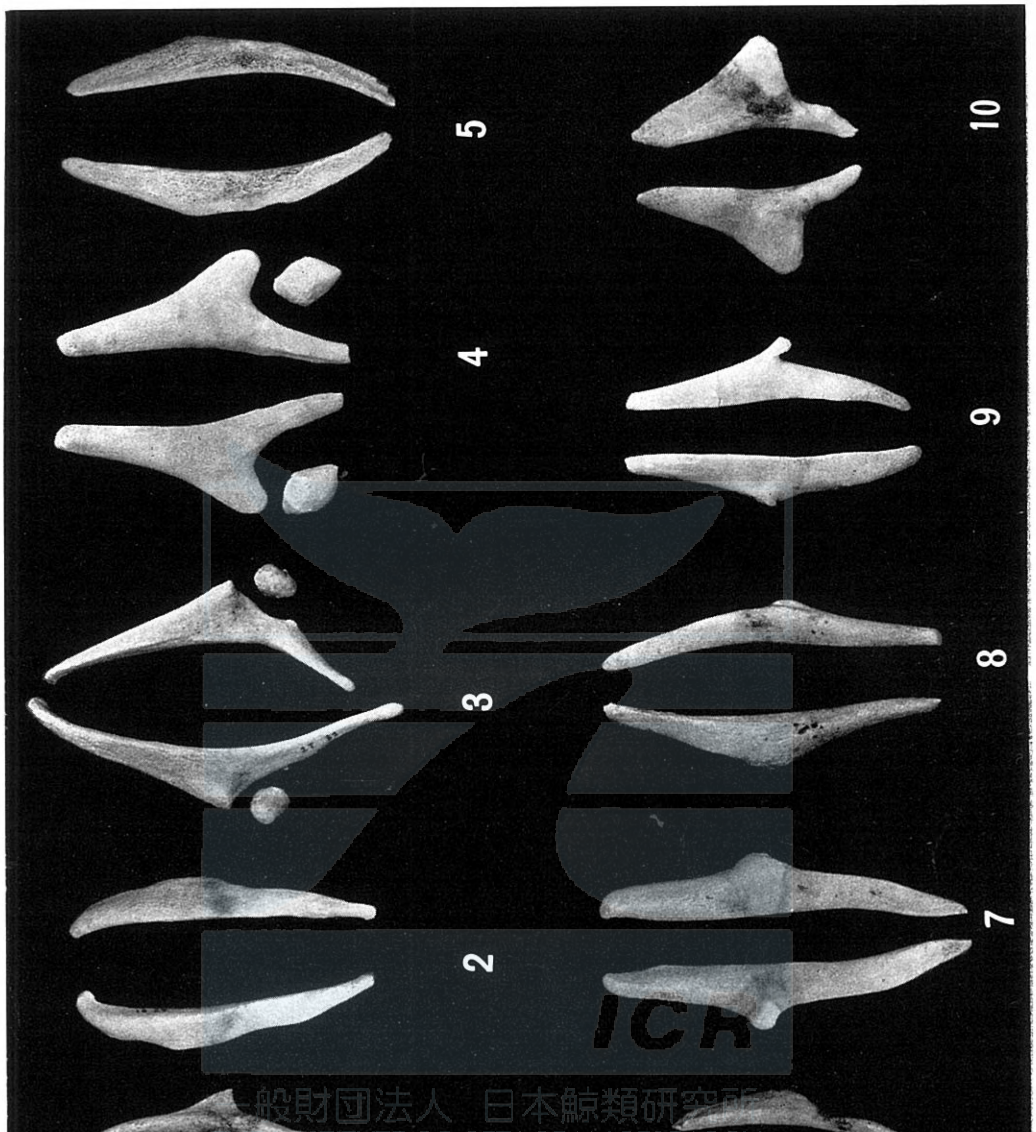
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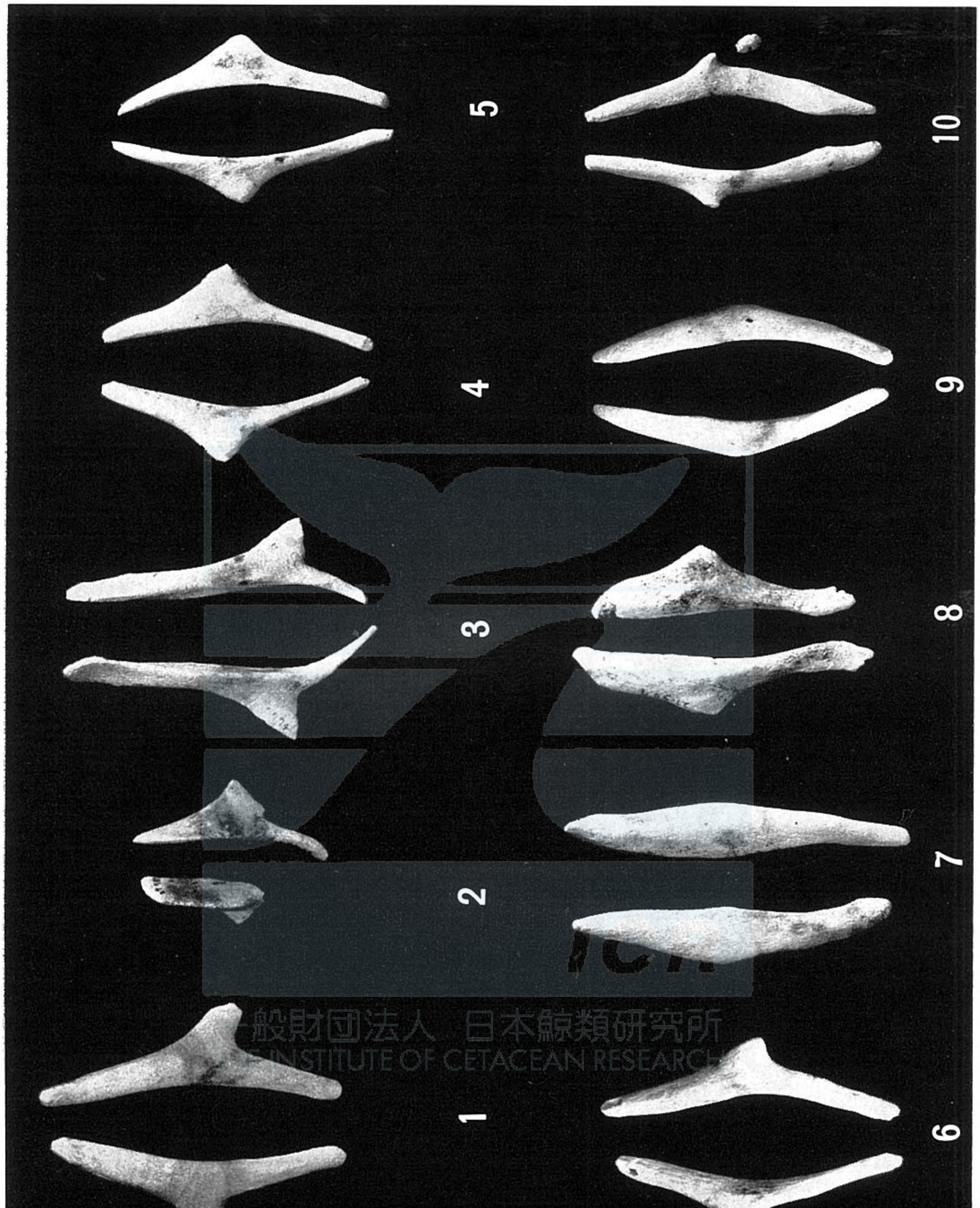
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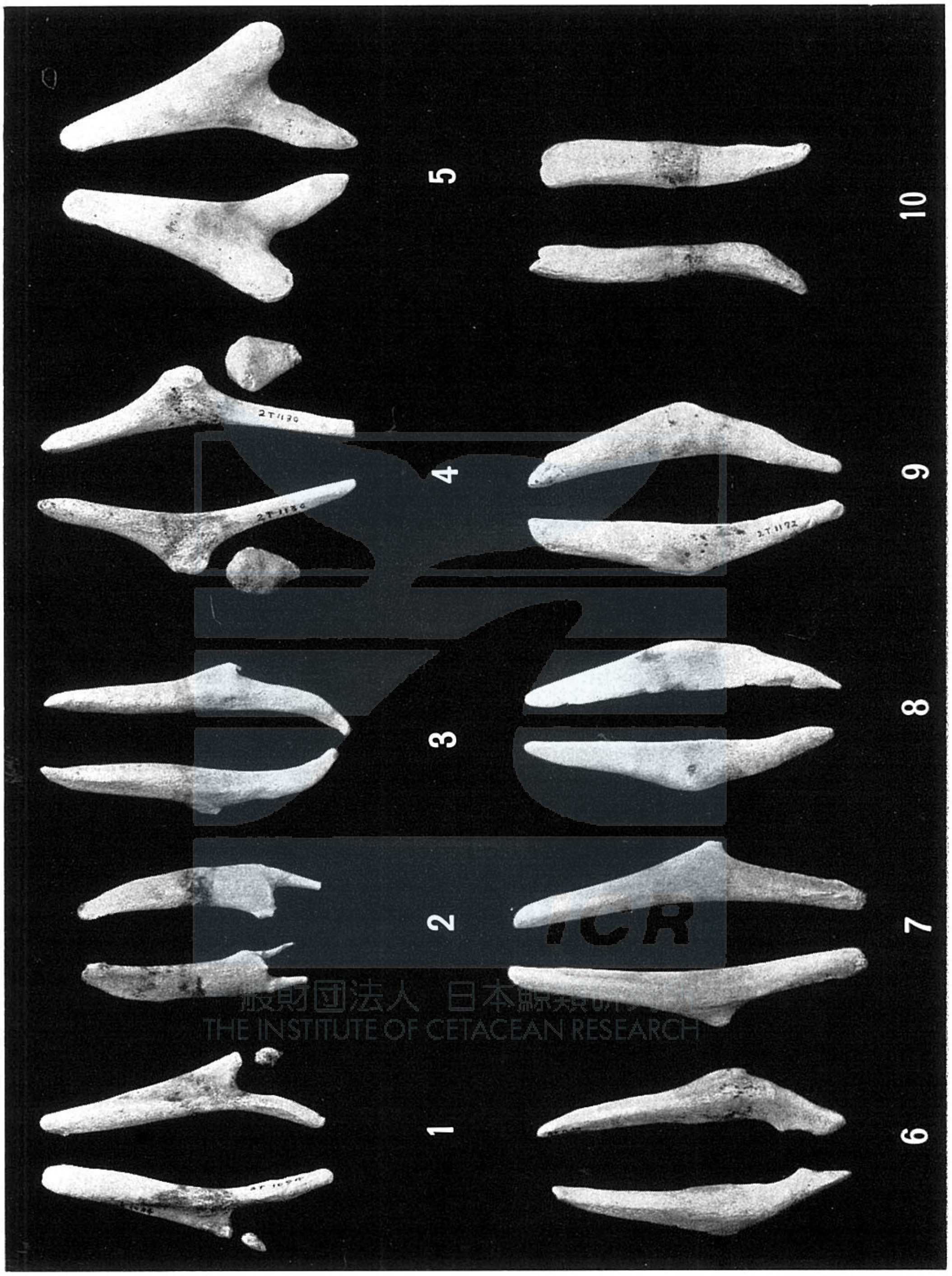
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A NOTE ON THE PARATHYROID GLANDS OF GANGES SUSU

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The parathyroid glands in man are small structures, each about the size of a match-head, and are loosely attached behind the rostral and caudal ends of the thyroid. Usually there are four, two on each side. The parathyroid glands are said to be concerned with the regulation of calcium and phosphorus metabolism. Although the role of the parathyroid glands in Cetacea should be as important as in land mammals, very few studies have been made on cetacean parathyroid gland.

Schulte (1916) pointed out a small glandular mass, which appears to have been the parathyroids in the macroscopic dissection of a 37.5 cm foetus of sei whale. Hosokawa (1955) detected a structure which was considered the anlage of the parathyroid on the lateral side of the fourth branchial pouch in a microscopical observation of a 12 mm striped dolphin foetus. In large-sized adult whales, Slijper (1962) described grey or pinkish parathyroid glands of fin whales, located on both posterior sides of the thyroid ; measuring 7 cm longitudinally and 4 cm transversally, and weighing 10–130 g with individual variations. Pilleri and Gihr (1969) reported two parathyroid glands on the dorsal side of the thyroid in gross anatomical observations of a Risso's dolphin.

The abovementioned previous reports were not studies of the parathyroids themselves, but were merely additional observations of the thyroid. No histological observation on the parathyroid glands of Cetacea has yet been reported. We wish to clarify the accurate structure of the cetacean parathyroid glands, and to compare it with those of other mammals with consideration of living environment. As a first step, the parathyroid glands of the fresh water Ganges susu and the salt water striped dolphin have been compared in this brief note.

Five Ganges susu, *Platanista gangetica* (body length from 105.5 cm to 118 cm) were used for this study. The specimens were examined macroscopically at the site of collection. Two fresh specimens (113 cm and 118 cm) among the five were prepared for histological observation. Six striped dolphins, *Stenella coeruleoalba*, from the late prenatal to adult stages, were examined for comparison and for a developmental study of the parathyroid glands.

The thoracic wall of a Ganges susu (body length, 118 cm) was incised to remove the heart. Figure 1 shows the heart and structures adjacent to the heart viewed from the ventro-rostral aspect. The thyroid gland appeared as a large dark brown mass measuring 31 mm (transverse diameter)×16 mm (longitudinal

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diameter)×8 mm (thickness) and weighing 3 g. After removal of the fibrous capsule covering the thyroid gland, numerous indentations were found on its surface. The carotid artery was adjacent to both the inferior and lateral edges of the thyroid. The thymus was light yellow and consisted of several large lobes, and was situated from the rostral part of the heart to rostro-lateral part of the thyroid. The thymus was abundant in interlobular connective tissue. Each lobe of the thymus was subdivided into lobules connecting to form a rosary around the blood vessel as an axis. Small tissue masses of various shapes were scattered around the thyroid, thymus and trachea. These massess were distinguishable microscopically into three kinds of structures ; the thymus, lymphatic tissue and parathyroid. Two parathyroids were found in a Ganges susu, body length 113 cm, one each on the right and left sides of the thyroid at the rostral end. In a 118 cm susu, three parathyroids were observed ; one at the right rostral end of the thyroid, and one each at the rostral end of the right and left thymus. The largest of these parathyroids was flat and oval-shaped, measuring 14×6×2 mm and weighing 0.1 g. No parathyroids were found on the posterior side of the thyroids.

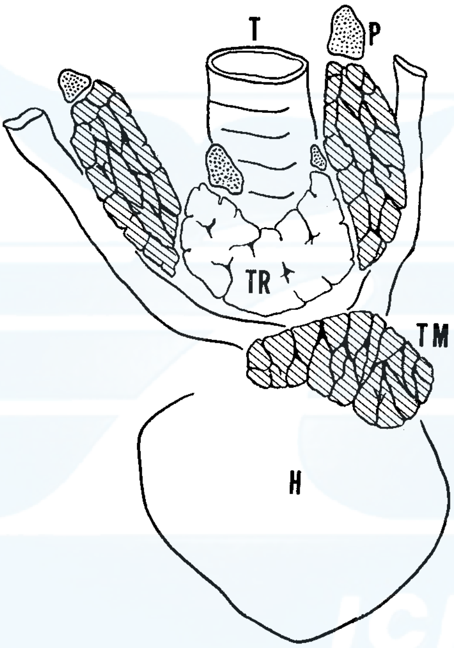

Fig. 1. The position of parathyroid glands of *Platanista gangetica*. The diagram indicates the position of the parathyroids of a 113 cm specimen added to those of a 118 cm one. (H) heart; (P) parathyroid; (T) trachea; (TM) thymus; (TR) thyroid.

In the six striped dolphins observed most parathyroids were located around thr rostral ends of the right and left lobes of the thymus on both sides of the trachea.

The parathyroids were variable in number ; two glands in one case, three in three cases, and four in two cases. It is likely that the relationship between the parathyroid and thymus is more intimate in the striped dolphin than in the Ganges susu.

The fibrous tissue of the capsule of the parathyroids of the dolphins observed entered the parenchyma accompanyed by blood vessels, and divided it into numerous lobules. One of the characteristics of the parathyroid gland of dolphins is a great abundance of interlobular connective tissue finely dividing the glandular tissue. In some regions parathyroids contained heterotopic thymus tissue. The parenchymatous cells of the parathyroid were polygonal, about 10 μm in diameter, and had round nuclei. The parenchymatous cells of the parathyroid of the Ganges susu and striped dolphin consisted of only chromophobic chief cells. Acidophilic cells that are seen in man and some mammals could not be found.

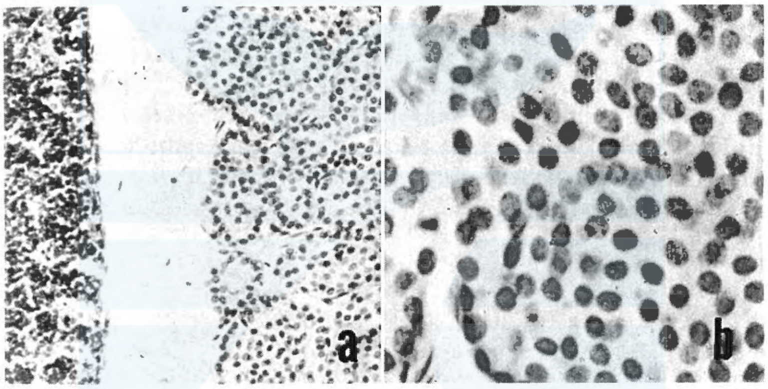

Fig. 2. a: Low magnification photomicrograph of section of thymus (left) and parathyroid gland (left) of a *Platanista gangetica* (body length, 113 cm). H-E stain. ×70. b: Photomicrograph of the parathyroid of *Platanista gangetica*. Only one chromophobic chief cell is shown in this field. H-E stain. ×400.

The epithelium of the dorsal wall of the third and fourth pharyngeal pouches differentiates into parathyroid tissue, while that of the ventral region of the third pouch forms the primordium of the thymus. With further development of the thymus and prarthyroid tissues, the thymus migrates in a caudal and medial direction, pulling the parathyroid tissue with it, moving to its final position in the thorax. In other mammals the parathyroid tissue of the third and fourth pouches finally comes to rest on the dorsal surface of the thyroid gland. However, the parathyroid glands of the dolphins observed did not lie on the dorsal surface of the thyroid but were found near the thymus. It has been said that the parathyroid glands are highly variable in number and location in mammals. This was confirmed in the dolphins we observed. Although the relationship between the parathyroid and the thymus in the observed dolphins seems to be closer than that in other mammls, further comparative observations of Cetacea are necessary to clarify whether this is dependent on interspecific or individual differences.

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TASTE BUDS IN THE PITS AT THE POSTERIOR DORSUM OF THE TONGUE OF *STENELLA COERULEOALBA*

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ABSTRACT

There are five to eight pits that form a V-shaped row opening anteriad at the posterior dorsum of the tongue of *Stenella coeruleoalba*. The pits have five to ten warty projections protruding from their bottoms. Epithelium covering the projections is markedly thinner than that of the dorsum. Taste buds resembling those of other mammals can be found in the epithelium of the projections and in that of the thinned side wall of the pits of young dolphins. However, taste buds are considerably few in number. They cannot be observed in adults.

INTRODUCTION

It is not known whether Cetacea possess a gustatory sense because taste buds have not been identified in all cetacean species. Yablokov (1961 ; 1972) has suggested that depressions located on the V-shaped line on the root of the odontocete tongue might act as chemoreceptors. Sokolov and Volkova (1971) investigated the tongues of *Stenella coeruleoalba*, *Phocoena phocoena*, *Tursiops truncatus*, and *Delphinus delphis*, but they failed to find taste buds. Neither could Sokolov and Kuznetzov (1971) find taste buds in *Lagenorhynchus acutus*, *Tursiops truncatus*, and *Phocoena phocoena*. However, these authors suggested that the dolphins must have a gustatory sense according to examinations in which specimens responded well to several chemical substances dissolved in sea water. Recently, taste buds have been observed within the epithelium of the papillae of the pits located on the root of the tongues in *Delphinus delphis* and *Tursiops truncatus* (Suchowskaja, 1972) and in *T. truncatus* (Donaldson, 1977). We have found taste buds, which resemble those of the gustatory cells in other mammals, lying in the epithelium of the pits in *Stenella coeruleoalba*. The follwoing brief report on this dolphin should help to disseminate knowledge of the gustatory sense of Cetacea.

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MATERIALS AND METHODS

The materials examined were taken from fetal, young and adult stages of the striped dolphin, *Stenella coeruleoalba* (body length 60, 98, 115, 150, about 200, 237, and 238 cm), collected off the Pacific coast of Izu peninsula in Japan. Materials were fixed in 10% formalin solution at the site of collection and sent to our laboratory. After macroscopical observations, pieces corresponding to the pits were embedded in paraffin or celloidin. Serial sections were made and then stained with hematoxylin and eosin. Typical sections were selected for photomicrography.

OBSERVATIONS AND DISCUSSION

The dorsum of the tongue of *Stenella coeruleoalba*, as shown in Fig. 1, exhibits a V-shaped row with five to eight pits opening anteriad at the posterior about one-fourth of the whole length of the tongue (from apex to the epiglottis). Sokolov and Volkova (1971) observed three to nine in this dolphin. The angle of the V is about 100° in adults, and is somewhat blunter in younger specimens. No pits exist on the mid line, and their number is not always the same on both sides. The shape of the opening of the pits is round in the early stage becoming long and narrow, and trench-like in adults. In the adult, the pit is approximately 2 to 8 mm in length, 1 to 2 mm in width and 1 to 1.5 mm in depth. The size, shape,

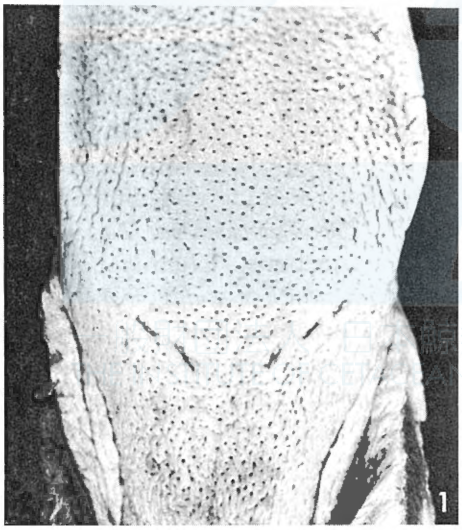

Fig. 1. The posterior dorsum of the tongue of *Stenella coeruleoalba* (body length, 238 cm) viewed from the dorsal aspect. Five pits are present forming a V-shaped row. Lingual glands are well developed except around the circumference of the pits, and gland orifices are clearly visible as black spots on the dorsum. ×1.1.

Fig. 2. Dorsal view of the one of the pits of the 150 cm calf. Warty projections are clearly visible in the pit. ×20.

and number of the pits vary considerably from specimen to specimen in the *Stenella* observed. The pits may be variable in appearance in the same species in other dolphins as illustrated by the following description in *Tursiops truncatus*: three to nine fossae (Sokolov and Volkova, 1971); small cavities (Suchowskaja, 1972); distinct cavities rather than a groove (Caldwell and Caldwell, 1972); an 8 to 12 mm long continuing groove on the left and three shorter sections on the right (Donaldson, 1977). These seem to be due to individual differences and the degree of development. In *Delphinapterus leucas*, five shallow, oval hollows were demonstrated at the corresponding region by Yablokov (1972). Therefore, the appearance of the pits also seem to differ in interspecies. However, in the observed cases of Platanistidae (*Platanista*, *Pontoporia* and *Inia*), no pits could be found in that region (Yamasaki *et al.*, 1976a).

As shown in Fig. 2, there are five to ten warty projections, conical in shape, protruding from the bottoms of the pits in the 115 and 150 cm calves. However, there are only one or two projections in each small pit. They are approximately 0.3 to 0.8 mm in diameter at their bases and about 0.3 to 0.6 mm in height. The upper limit of the projections never reaches the surface of the tongue. The projections are remarkably visible in the young stage, and in the adult they become rather indistinguishable besides being often hard to observe from the dorsal aspect because of the elongation and narrowing of the pit orifice. Aggregations of lymphocytes are present in places in the lamina propria of the pits. It is likely that the projections correspond to conical-shaped papillae in the *Tursiops truncatus* observed by Donaldson (1977) and possibly to the ' globular bodies ' in *Delphinapterus leucas* described by Sonntag (1922).

Pits can already be recognized in a 60 cm fetus. Since the developmental degree of each pit varies considerably, various stages of development of the pits can be observed in a 98 cm fetus. At first, a hollow develops in the area corresponding to the future pit and breaks away from the circumference. It then sinks and the broken blocks, which are covered by thin epithelium, form warty projections.

Lingual glands, sero-mucous in nature, are well developed from the mid part of the dorsum of the tongue to the epiglottis in the 115 cm calf and they are extremely well developed in the adult. The glands open on the dorsal surface, except for the circumference adjacent to the pit orifice. The galnds also open at the bottom of the pit around projections almost with no gland ducts. In some projections the glands open at their tips with a short duct. The glands are not always well-developed at the bottom of the pit as compared with those of the rest of the tongue. Sokolov and Volkova (1971) used the term ' fossa ' for the opening of the lingual glands seen on the dorsum and also used this term in considering the pit to be a deeper and larger fossa. Donaldson (1977) has suggested that the pits may be derived from the gland ducts, based on the observation of the marsupial tongue (Kubota *et al.*, 1963). In the abovementioned observation of the fetal tongues of the *Stenella*, we could not clarify whether the pits are derived from lingual gland ducts. Further studies on this subject will be made in the near future.

The dorsum of the tongue of the calves observed is covered by a thick stratified squamous epithelium, approximately 600 μm or more in thickness, of which the superficial layer shows a tendency toward cornification but without complete disappearance of nuclei. The epithelium thins remarkably at the inside of the pit (projection, its side wall and bottom), and measures 40 to 100 μm (Fig. 3a). Papillae of connective tissue of the dorsum are well developed but those on the inside of the pit are not. Taste buds resembling those of other mammals can be clearly observed lying in the epithelium of the projection and the side wall of the pit in the 115 cm and 150 cm specimens (Fig. 3b). Taste buds are always present within the thin part (40 to 50 μm) of the epithelium. Some projections of the 115 cm specimen are covered by a layer consisting of two or three elongate cells without an upper stratified squamous epithelial layer. No taste buds are present in these areas. Taste buds extend from the basement membrane almost to the epithelial surface. An outer taste pore and two kinds of cells, taste and supporting, can be recognized. The long axis of the buds is approximately 40 to 45 μm in length, and about 30 to 40 μm across. In the specimen of approximately 200 cm body length, taste buds, about 20 to 30 μm in diameter, are located in the lower one-third of the epithelium without an outer taste pore. Cells forming the buds are rather irregular in arrangement, probably due to degeneration. These findings are similar in appearance to those observed by Donaldson (1977) in the adult

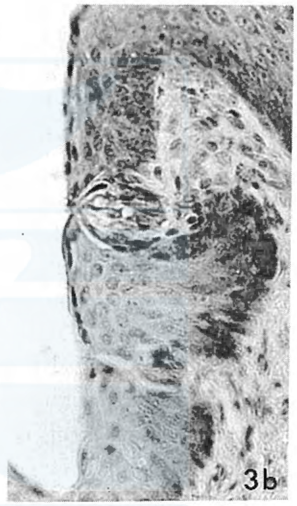

Fig. 3a. Photomicrograph of a vertical section of one of the pits of the 150 cm calf. The epithelium covering the projections and the side wall of the pits is remarkably thinner than that of the dorsum. Two taste buds (arrow) are observed in the thin epithelium. Lingual glands open at the bottom of the pit. ×25.

Fig. 3b. A view of the part indicated by the arrow in Fig. 3a under higher magnification. Taste buds lie in the thin part of the epithelium. The outer taste pore can be seen in the upper taste bud. ×325.

Tursiops truncatus. We suppose that larger taste buds having an outer taste pore will be found in the younger *Tursiops*. Taste buds could not be found in the specimens of the adult *Stenella* (237 and 238 cm). In the 98 cm fetus, the part corresponding to the pits is covered with thin epithelium (20 to 40 μm, about one-tenth of the thickness of that of the dorsum), and is on almost the same level as the tongue surface. A few primordial taste buds, similar to those of fetal fur seals observed by Kubota (1968), could be found within this area. Features of the pits, warty projections, and taste buds in the *Stenella* we observed are essentially similar to those of the *Tursiops* and *Delphinus* reported by Suchowskaja (1972), although the author used other terms of reference*.

Although taste buds in the *Stenella* can be clearly observed in the pits of the young stage (115 cm and 150 cm), they are considerably few in number, and may degenerate with age. This may be one reason that taste buds have not been found in Cetacea since examinations have been done only on few sections or in adults. There is a possibility of finding taste buds in other cetacean tongues when detailed observations are done on all parts of the pits with consideration of age. There are no descriptions concerning the body length of the *Tursiops* and *Delphinus* in Suchowskaja's article (1972). The examination on the time sequence of taste buds will be expected in other odontocetes.

Pit-formation may precede the appearance of the taste buds because typical taste buds have not been observed in the developing stages of the pits of fetuses. Since the calves of the *Stenella* start feeding on solid food at the age of about 0.5 year, at a body length of about 140 cm (Kasuya, 1972), it seems that there is some relations between feeding time and the formation of the taste buds. Adult dolphins may depend upon some other senses, possibly cultivated with age, for taking food if taste buds are realy nonexistent in adults. Donaldson (1977) also supposed that young dolphins might first learn which fish to eat by taste and gradually these acceptable-tasting fish might come to be recognized by appearance.

Sokolov and Volkova (1971) have stated that papillary projections along the anterolateral margin of the tongue in Odontocete evidently have a receptor function. However, these projections of the *Stenella* have no taste buds and nerve fiber bundles are inconspicuous. Therefore, we have considered the projections to be structures with a mechanical function for suckling rather than as a sensitive part of the tongue (Yamasaki *et al.*, 1976b ; 1978).

Absence of lingual papillae is another characteristic of the cetacean tongue. Of course, there are no vallate papillae seen in other mammals. Donaldson (1977) thinks that the linguopharyngeal groove (corresponding to what we call a pit) might be a variation of the circumvallate papilla. The pits, at least in position, may correspond to the vallate papillae of other mammals. The tast buds in mammals, for example in man, usually lie within the thinner side surface epithelium of the foliate and circumvallate papillae. The dorsum of the tongue of dolphins has a much thicker epithelium than that of other mammals. The epithelium cover-

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* Suchowskaja called the warty projections and the taste buds as 'taste buds' and 'gustatory papillae', respectively.

ing the inside of the pits is markedly thinner than that of the dorsum of the tongue. This fact may be the reason that the existence of the taste buds is only limited to the pits.

Generally, in other mammals, there is a V-shaped sulcus terminalis just behind the vallate papillae by which the tongue is divided into the body and root. No sulcus terminalis and no trace of the foramen caecum there can be seen on the dolphin's tongue. It should be adequate to consider that the body and the root of the tongue meet at the point of the V-shaped row with pits, although it is necessary that embryological observations (*e.g.* as for the location of the dividing line between the first and second pharyngeal arches) and examinations of the innervation be made. In Platanistidae, as mentioned above, no V-shaped mark can be seen on the dorsum of the tongue, and taste buds are lacking in all parts of the tongue (Yamasaki *et al.*, 1976a). Further observations are expected concerning the gustatory sense of Platanistidae.

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ON THE BALEEN FILTER AREA IN THE SOUTH PACIFIC BRYDE'S WHALES

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ABSTRACT

The baleen filter area of the South Pacific Bryde's whale was examined, and found that the total filter area in terms of square meters was 1.43–1.99 (Av. 1.75) in male, 1.19–2.40 (Av. 1.95) in female, while it was 1.04–1.92 (Av. 1.64) in male, 1.10–2.44 (Av. 2.02) in female in the North Pacific animals. The averaged filter area per unit body length (m^2/m body length) of being combined both sexes was 0.136 in the South Pacific animals while it was 0.145 in the North Pacific animals. It was indicated that the South Pacific animals are smallest in the filter area of Bryde's whale ever examined, and they are possibly separated from the North Pacific populations occurring in both northern pelagic and coastal waters.

INTRODUCTION

It has been known that Bryde's whales in the North Pacific show a polymorphic, a considerable variety on both the whole structure and shape of filtering apparatus, and details of baleen plates (Kawamura and Satake, 1976 ; Omura, 1977). Although Kawamura and Satake (1976) did not find any conclusive morphological differences among a possible localized populations except one supposition that there seems to exist two or three characteristic groups of animals in the North Pacific region. The differences which made them be separated were the shape of baleen plates such as the width *versus* length quotient and the total filter area, which may roughly correspond to those ' offshore ' and ' inshore ' types found in the South African waters (Best, 1977). Two of them possibly mingle with each other in the waters off Sanriku, northern Japan. The baleen plates of the Bryde's whales occurring in the pelagic waters of the North Pacific are relatively slender with finer bristles than the animals usually occur in the waters around Bonin Islands and in the East China Sea region, *i.e.*, the filtering apparatus in the former animal is structured more alike to that of sei whale while the latter two are more alike a ' traditional ' Bryde's whale treated in the previous reports (Omura *et al.* 1952 ; Kawamura and Satake, 1976, Figs 8, 10 and Table 8). Since filtering apparatus in baleen whales is supposed to be an organ closely related to feeding strategies by an inter- and/or intra-specific relationships under various state of feeding environments (e.g. Kawamura, 1974), possible morphological changes acquired through the adapation for the existence might be found. It seems, therefore, to be an interest to examine and compare the filter area of Bryde's whales came from various localities with a

Sci. Rep. Whales Res. Inst.,
No. 30, 1978, 291–300.

hope to find characteristics by each local population since there exist very few information concerning the identity of Bryde's whale populations throughout the warmer waters over the world.

MATERIAL AND METHOD

The material dealt with in this report was obtained from the animals caught under the scheme of special permission in the tropical South Pacific between New Zealand and Fiji Islands during 1976/77 season (Ohsumi, 1977) (Fig. 1). Their food was consisted exclusively of euphausiids, *Euphausia diomedae*, *E. recurva* and *Thysanoessa gregaria*, and the general feeding habits have been reported previously (Kawamura, 1977), where he discussed considerable nutritional availability for baleen whales even in the tropical seas. The filtering apparatus and some related measurements for a total of 22 out of 113 animals caught by the *Tonan Maru No. 2* operation in the waters mentioned above were measured by the ship's personnel. The measurements obtained were: 1) length of a row of baleen plates along both palatal ridge and gum level, 2) spread of baleen rows between both sides at their widest position, 3) distance from anterior end of baleen row to the largest baleen plates, and 4) length of baleen plates including minor plates along the meshed filter surface by an interval of every 30 cm so as to be calculated the whole inside filter area by reappearing the unfold filter shape. The particulars of measurements concerned were given in Appendix Table 1 along with the proportions against body length. Data and figures for the North Pacific Bryde's whales used in this report were quoted

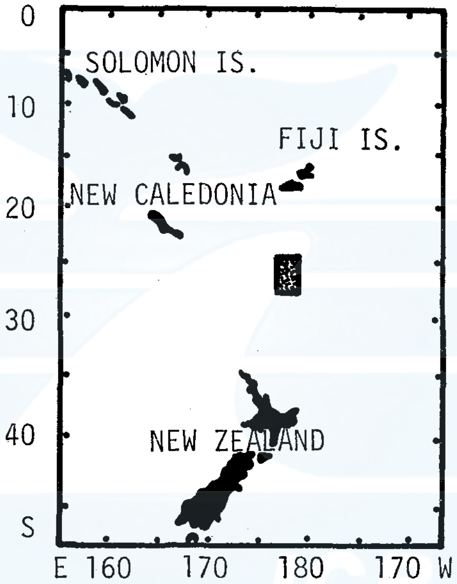

Fig. 1. Sea area of catch for the Bryde's whales, 30 October–5 November, 1976.

from Kawamura and Satake (1976).

RESULT AND DISCUSSION

In order to examine the shape of oral cavity in horizontal plane two dimensions were figured (Fig. 2). The length of a row of baleen plates along gum level keeps fairly constant and proportional growth with the length of palatal ridge. As far as these figures are concerned, there found no significant differences in this relationships between the North Pacific and South Pacific animals. However, when we see the quotient for maximum spread between both sides of baleen rows *versus* length of palatal ridge, it is observed on the whole that the South Pacific animals show a trend of more prominent oval shaped oral cavity or more larger hunging angle in baleen row (Fig. 3). The hanging angle (θ) for the North Pacific animals ranged 43°–56° (Kawamura and Satake, 1976, Table 3), and the South Pacific animal seems to be angled more largely in the overall filter shape. In this connection, it is noteworthy that there were two males whose relative spread of baleen row was more than a half of its across along the principal axis. No definite defferences were observed in this relationships between both sexes.

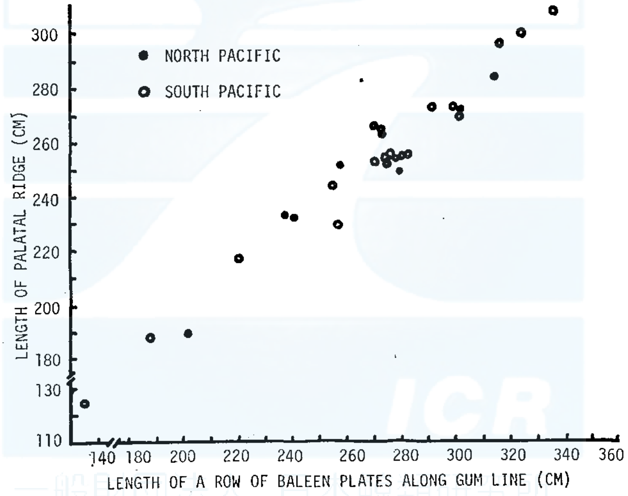

Fig. 2. Two dimensions related to the shape of oral cavity in horizontal plane.

The filter area for the North Pacific animals develops proportionally with their body length in the animals of larger than 11 m, while it was significantly small in the younger animals (Kawamura and Satake, 1976, Fig. 9). Concerning this discontinuous developmental figures, Kawamura and Satake (1976) suggested a possible rapid development of filtering apparatus around weaning period. On the other hand, the filter area for the South Pacific animals showed fairely constant development (Fig. 4). It is, however, observed that the filter area in many South Pacific animals was in the midst of both outside and inside filter area for the North

Pacific animals.

Comparing these figures, it was clearly noticed that the absolute values for the filter area in the South Pacific animals were appreciably smaller, say, 0.2–0.3 m², than that known in the North Pacific ones. To make smooth the variations possibly due to the different composition of body length between northern and southern populations, the filter area per unit of body length was calculated (Fig. 5). The values expressed by square meters of filter area per 1 m body length again showed a clearly smaller relative filter area in the South Pacific animals, and this trend may become more clearer especially in the animals larger than 12.5 m, *i.e.*, the larger the animal, the smaller relative filter area per unit of body length.

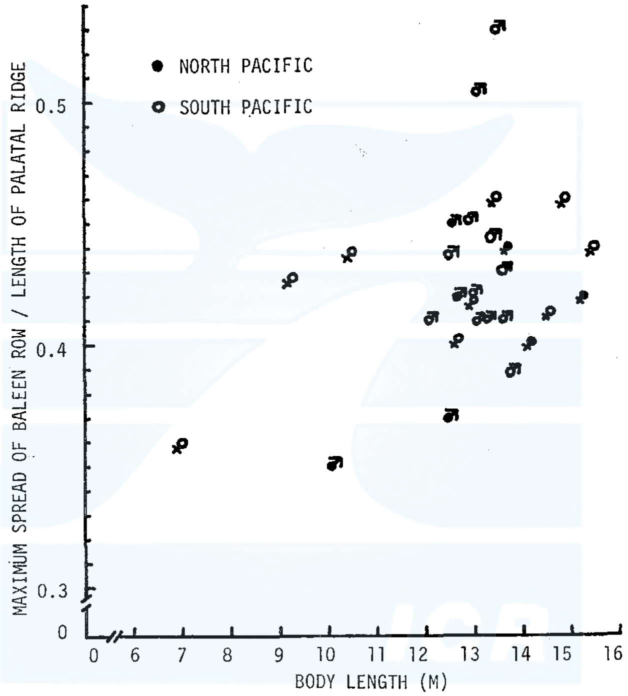

Fig. 3. Quotient between the spread of both baleen rows and the length of oral cavity. An oval shape of baleen rows in their horizontal arrangements is more prominent in the South Pacific animal than that of the North Pacific, which suggests a possible larger trend in hunging angle of each baleen plate in the South Pacific animal than the North Pacific.

The averaged relative filter area for both the North and South Pacific animals was 0.145 and 0.136 (m²/m body length) respectively. Two instances of relative small filter area (0.046 and 0.094 m²/m body length for Nos 79 and 80 in Appendix Table 1) though not by far the extent found in the North Pacific animals, may again make us confirm a very rapid development of filtering apparatus around weaning period.

Although the number of animals and/or materials examined to date is still very few, it seems to be clear that the development of filter area in the South Pacific Bryde's whales may relatively be poorer by the magnitudes of 6.2–10.3% smaller than the North Pacific animals in terms of relative filter area per unit of body length. Comparing the total filter area for Bryde's whales with that of another baleen whale species by interporating the data onto Fig. 8-6 by Kawamura (Kawamura, 1974), it is observed that the Bryde's whales are intermediately characterized between sei and fin whales, and the figures for the former animals may correspond to that of humpback and minke whales. The general food habits of baleen whales (e.g. Nemoto and Kawamura, 1977) may well describe the result due to these characteristics in the structure of feeding apparatus.

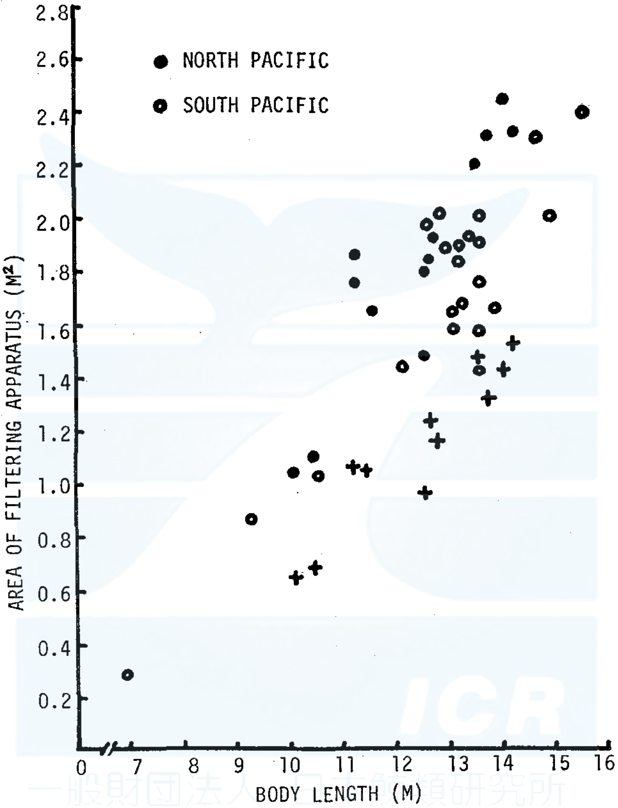

Fig. 4. Total filter area for both the North Pacific and the South Pacific Bryde's whales. An outer surface filter area for the North Pacific animal is shown by the cross.

So far as the result from 120 Bryde's whales in the South Pacific and the Coral Sea, and 105 animals in the Indian Ocean are concerned, they fed solely upon euphausiids, *Euphausia diomedeae*, *E. recurva*, and *Thysanoessa gregaria* (Kawamura, 1977), while the 'offshore' form Bryde's whales in the South African waters has

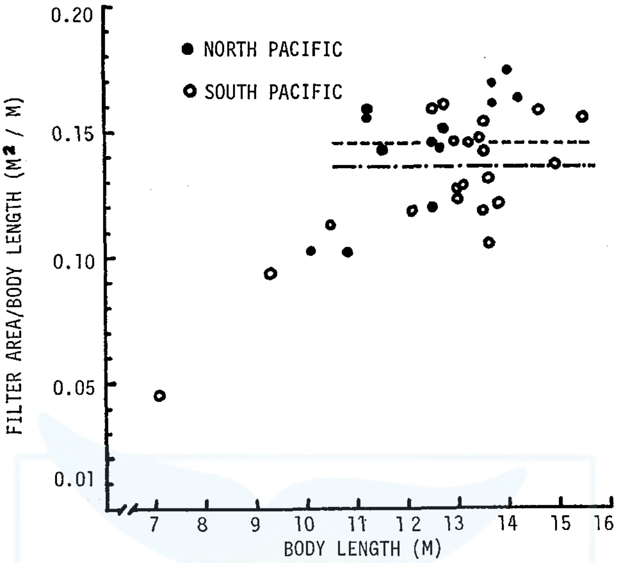

Fig. 5. Filter area per unit of body length shows an appreciably more poorer developments of filtering apparatus in the South Pacific Bryde's whales than in the North Pacific animals. Averages for both the North Pacific and the South Pacific animals were 0.145 (N=13, broken line) and 0.136 (N=20, chain line) respectively. The unusual and relatively smaller figures for two young animals (see Nos 79 and 80 animals in Appendix Table 1) were excluded in taking an average.

been reported to feed mainly upon *Euphausia lucens*, *E. recurva*, *Nyctiphanes capensis*, *Thysanoessa gregaria* and several species of micronektonic fish (Best, 1977). To see the dominancy of *E. recurva* in the stomach of fin, sei, humpback and pygmy blue whales in addition to Bryde's whales at Durban (Bannister and Baker, 1967), *E. recurva* may be considered to play an important role in the nutritional ecology of baleen whales widely over the warmer sea region. The coincidence with the food habits in both above mentioned Bryde's whale populations may suggests that the animals in the South Pacific are very similar to ' offshore ' form, and they must be similar ' form ' to the animals occurring in the waters of Bonin Islands and southern coastal regions. However, the former animals are possibly be separated morphologically from those occur in the pelagic North Pacific although Ohsumi (1977) thinks the latter can also be reffered to the ' offshore ' form. On the other hand, Nemoto and Kawamura (1977) gives a figure in the order of selection of food by baleen whales as 88.9% of Bryde's whales fed upon euphausiids and the rest 11.1% was composed of fish diet. This may suggests the animal to be similar to ' offshore ' form. However, the food item of baleen whales itself is so variable with the change of feeding ground under the multi-specific structure such as the North Pacific (see Kawamura, 1973; Nemoto and Kawamura, 1977), and hardly be determined by the morphological character alone. The clear difference in the size and shape of North Pacific pelagic form from those in the southern coastal waters of Japan indicates the former animals, if not entirely, could be separated from the latter as well as the South Pacific Bryde's whales which also could be separated from the northern population by their appreciably smaller filter area.

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APPENDIX TABLE 1. Measurements on filtering apparatus for the South Pacific Bryde's whales caught

1.	8	15	45	59	60	62	68	71	72	73	74
2.	30 X	30 X	31 X	1 XI	1 XI	2 XI	2 XI	2 XI	2 XI	2 XI	2 XI
3.	25–06	23–32	24–49	24–32	25–00	24–42	24–38	24–49	24–45	24–49	24–48
	177–34	177–50	177–48	177–19	177–40	177–18	177–27	177–24	177–25	177–26	177–18
4.	M	M	M	F	M	F	M	F	F	M	M
5.	13.4	13.2	13.6	15.5	13.0	13.0	12.1	13.5	14.9	13.1	12.5
6.	Nil	Nil	Nil	Eu+	Eu++++	Eu+++	Eu+++	Eu+++	Eu++	Nil	Eu+++
7.	—	—	—	None	—	108 (M)	—	None	None	—	—
8.	4.0	3.5	4.0	5.0	4.5	4.0	3.5	4.0	5.0	3.5	4.5
9.	278	300	276	336	273	274	255	273	316	276	274
	20.75	**22.73**	**19.85**	**21.68**	**21.00**	**21.08**	**21.07**	**20.22**	**21.21**	**21.07**	**21.92**
10.	255	273	267	319	265	255	244	243	294	254	252
	19.03	**20.68**	**20.58**	**20.38**	**19.62**	**20.17**	**20.07**	**19.48**	**19.73**	**19.39**	**20.16**
11.	112	112	140	110	107	99	99	120	136	103	110
	8.36	**8.48**	**9.03**	**8.46**	**8.23**	**8.18**	**8.18**	**8.89**	**9.12**	**7.86**	**8.80**
12.	187	195	218	180	159	155	155	208	246	195	165
	13.96	**14.77**	**14.06**	**13.85**	**12.23**	**12.81**	**12.81**	**15.41**	**16.51**	**14.89**	**13.20**
13.	1.97	1.92	1.79	2.40	1.65	1.59	1.44	2.08	2.04	1.67	1.99
14.	0.15	0.15	0.15	0.13	0.12	0.12	0.12	0.15	0.14	0.13	0.16

Key to the numbers, 1 to 14, in the appendix table

1. Ser. No.
2. Date of catch (day/month)
3. Position of catch (south latitude and east longitude)
4. Sex
5. Body length of animal (m)
6. Stomach contents
7. Body length of foetus (sex)
8. Thickness of blubber (cm)
9. Length, row of baleen plates along gum level (cm)
10. Length, row of baleen plates along palatal ridge (cm)
11. Maximum spread of filtering apparatus across both baleen rows (cm)
12. Length, anterior end of baleen row to largest baleen plates (cm)
13. Total area of filtering apparatus (m^2)*
14. Total area of filtering apparatus/Body length (m^2/m body length)

* Total inside surface filter area corresponds to ' Si ' given in Kawamura and Satake (1976, Appendix II and Fig. 8)

by the *Tonan Maru No. 2* fleet in 1976. Percentage proportions to the body length is given in bold faces.

75	76	77	79	80	86	87	88	93	95	104
2 XI	2 XI	3 XI	3 XI	3 XI	3 XI	3 XI	3 XI	3 XI	3 XI	4 XI
24–30	24–47	24–50	24–45	24–49	25–02	25–08	25–08	24–52	24–37	25–35
177–39	177–15	177–22	177–28	177–26	177–15	177–11	177–11	178–08	178–04	178–30
F	M	M	F	F	M	M	M	F	M	F
10.5	13.8	13.5	7.1	9.3	13.1	13.5	13.6	14.6	12.9	12.7
Eu+	Eu++	Eu+	Nil	Eu+	Eu+	Nil	Eu++	Eu+	Eu+	Eu+
None	—	—	None	None	—	—	—	None	—	None
4.0	4.5	3.5	3.5	3.0	4.0	4.5	4.5	5.5	4.5	3.5
220	291	273	135	189	258	282	270	322	280	302
20.95	**21.09**	**20.22**	**19.29**	**20.32**	**19.69**	**20.89**	**19.85**	**22.05**	**21.71**	**23.78**
219	273	—	125	187	230	255	253	300	255	270
20.86	**19.78**	—	**17.86**	**20.11**	**17.56**	**18.89**	**18.60**	**20.54**	**19.77**	**21.26**
96	106	107	45	80	116	135	103	124	115	110
9.14	**7.68**	**7.93**	**6.43**	**8.60**	**8.85**	**10.00**	**7.57**	**8.49**	**8.91**	**8.66**
150	190	188	80	118	177	193	185	230	169	210
14.29	**13.77**	**13.93**	**11.43**	**12.69**	**13.51**	**14.29**	**13.60**	**15.75**	**13.10**	**16.54**
1.19	1.67	1.59	0.33	0.88	1.83	1.92	1.43	2.33	1.89	2.03
0.11	0.12	0.12	0.05	0.09	0.14	0.14	0.11	0.16	0.15	0.16

APPENDIX TABLE 2. Comparison of proportions and filter area between the North Pacific and South Pacific Bryde's whales. Averaged figure is given in parenthesis.

Locality	North Pacific* (Japan, coastal)	South Pacific** (Pelagic)
Period of catch	24 VII–3 VIII 1976	30 X–4 XI 1976
No. of animal examined, male	7	13
” ” female	6	9
Body length, male	10.1–12.7(11.87)	12.1–13.8(13.18)
” ” female	10.8–14.2(12.93)	10.5–15.5(13.53)
Length, row of baleen plates along gum level, male	19.20–22.14(20.65)	19.69–22.73(20.91)
” ” female	17.59–22.11(20.96)	20.22–23.78(21.57)
Length, row of baleen plates along palatal ridge, male	18.64–20.35(19.50)	17.56–20.38(19.50)
” ” female	19.93–20.07(20.00)	19.48–21.26(20.30)
Maximum spread of filtering apparatus across both baleen rows, male	6.53–8.88(7.88)	7.57–10.00(8.40)
” ” female	8.02–8.76(8.41)	8.23–9.14(8.79)
Length, anterior end of baleen row to largest baleen plates, male	9.91–12.96(11.22)	12.81–14.89(13.79)
” ” female	10.83–11.88(11.36)	12.23–16.54(14.97)
Total filter area, male	1.04–1.92(1.64)	1.43–1.99(1.75)
” ” female	1.10–2.44(2.02)	1.19–2.40(1.95)
Total filter area/Body length, male	0.103–0.156(0.137)	0.105–0.159(0.133)
” ” female	0.102–0.174(0.154)	0.113–0.160(0.143)

* Based on data by Kawamura and Satake (1976)

** Figures for those unusually smaller animals (Nos 79 and 80, see Appendix table 1) were excluded from the calculation on right column.

ON THE AGE CHARACTERISTICS AND ANATOMY OF THE TUSK OF *DUGONG DUGON*

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ABSTRACT

This study is based on 15 samples obtained at Celebes, Luzon, Mulgrave, and Thursday Islands. The dentinal growth layers in the larger tusk, possiblly the permanent 1st upper incisor, are the most useful for age determination unless the tusk is erupted and abraded. Cemental layers and the circular ridge on the surface of the tusk are usefull to a lesser degree. The formation cycle is suspected as annual from comparison with the growth of reared animals. The female seems to attain sexual maturity at about 10 years of age, and live for 45 years. Special pattern of distribution of enamel on the tusk is described.

INTRODUCTION

The dugong, *Dugong dugon* (Müller 1776), is one of the sirenian species decreasing in numbers at the various places of its habitat, but a considerable number is still being exploited or killed incidentally in some regions (Bertram and Bertram 1968, Colin and Bertram 1970, Allen *et al.* 1976, Jones 1976). The basic biological information needed for conservation are still insufficient (Heinsohn 1972), and the establishment of a method of age determination is one of the most important studies.

Scheffer (1970) was the first to describe the growth layers in the dentine of the tusk and suggest a possible use for age determination. He distinguished two kinds of layers, namely the coarse and fine layers, and assigned them as representing lunar and daily cycles respectively. Recently Mitchell (1976 and 1978) indicated the possibility of annual or biannual formation of the former layer.

The present study aims to describe the anatomy of the tusk, to improve the method of observing the growth layers, and to have some considerations on the accumulation rate of the growth layers.

MATERIALS AND METHOD

The present study is based on the tusks of 15 individuals. The specimen Toba-2, the youngest, was imported by the Toba Aquarium, and a tusk was presented for

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TABLE 1. LIST OF MATERIALS

1. No. of sample	Toba-2	RMM002	RMM001	Kamiya-1	Kamiya-2	TK389-1	TK389-2
2. Capture, date	—, May, '77	26, Aug., '75	25, July, '75	20, May, '78	20, May, '78	—	—
3. Capture, place	Luzon I.	Celebes I.	Celebes I.	Mulgrave I.	Mulgrave I.	—	—
4. Death, date	—, May, '77	21, Oct., '75	20, Oct., '75	20, May, '78	20, May, '78	—	—
5. Death, place	Luzon I.	Okinawa[1]	Okinawa[1]	Mulgrave I.	Mulgrave I.	Thursday I.[2]	Thursday I.[2]
6. Sex	♂	♀	♀	♂	♂	♀	♂
7. Body length (cm)	169.7	204.0	254.0	191.0	207.0	—	—
8. Body weight (kg)	80.1	—	—	—	—	—	—
9. Maturity	Immature	Immature	Adult	—	—	—	—
10. Straight length of tusk (mm)	37.2	94.9	172.5	88.8	119.5	210.3	164.8
11. No. of growth ridges	3	8	19	11	—	—	—
12. No. of dentinal layers[3]	2 (1.5 cycles)	7	18	10	21+	45	—
13. No. of regular layers[3]	2	7	10	8	10+	11	—
14. Last layer (coarse)	Thin stainable	Thick stainable	Thick stainable	Thick unstainable	Thick unstainable	Thin unstainable	— —
15. Eruption	No	No	No	No	Yes	No	Yes

1) Arrived at Okinawa on 29, Sept., 1975. 2) Picked up on the beach. 3) Coarse postnatal dentinal layers.

this study. The two females, RMM001 and 002, were kept alive for about 20 days at the Okinawa Ocean Exposition, and the skeletons were presented to the University of the Ryukyus. Other two tusks with body length were provided by T. Kamiya who was presented the tusks by an islander of Mulgrave Island. The nine tusks without biological data (8 females and one male) were picked up by Nishiwaki on Thursday Island. Another female tusk was purchased by Nishiwaki on Celebes Island. The sex of animals without biological data was decided by the eruption and size of the tusks. The tusks which are too small to determine the sex are not included. Some of these samples, including the oldest, are shown in Table 1 and Fig. 1.

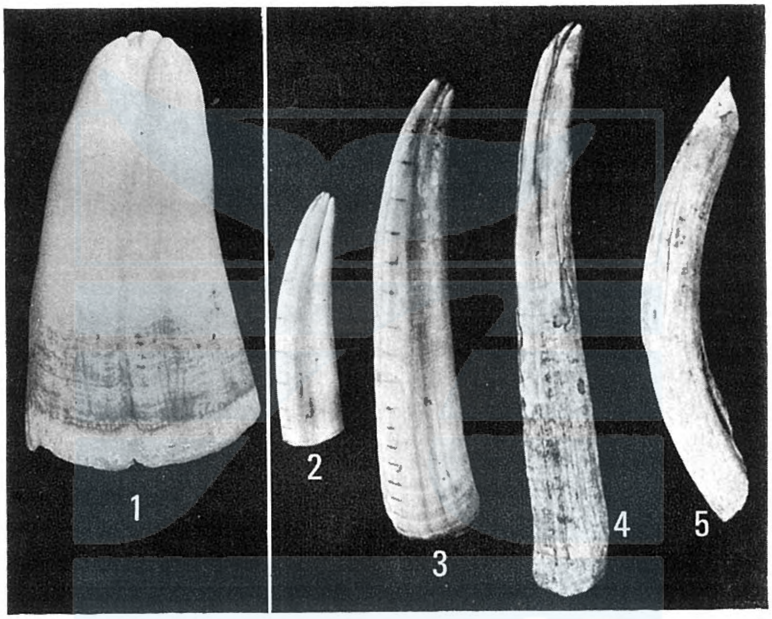

Fig. 1. The tusks of *dugong dugon* used in the present study.
1: Toba-2, 2: RMM002, 3: RMM001, 4: TK389-1, 5: TK389-2.

The body length of the animal was measured on a straight line connecting the anterior tip of the upper lip and the bottom of the tail notch. The maturity was studied by Dr T. Kamiya of the Faculty of Medical Science, University of Tokyo. Among the three specimens with biological data, only RMM001 is sexually mature with several corpora albicantia in the ovaries. RMM002 had neither corpus nor follicle in the ovaries.

Preparation of the tusk was made following the method used for the teeth of some odontoceti (Kasuya 1976, Kasuya 1977). One or two longitudinal sections of a thickness between 1.0 mm and 2.0 mm were taken from each tusk using a saw with a diamond blade. One side of the section was polished with grinder and whet stones until the center of the tusk was exposed, and the surface was glued on a piece of clear plastic plate (1 mm in thickness) with quick adhesive synthetic resin (cyanoacrylate resin). Then the other side was polished in the same way and a ground section of a thickness between 50 μm and 60 μm was prepared. If the tooth section is glued on a plate which is so rigid that is not bent by the swell of the tusk during polishing in water, the preparation will separate from the plate.

Some of the thin ground sections were decalcified in 5% formic acid for a few hours, stained with Mayer's haematoxylin for 30 minutes, and mounted with permanent mounting medium. The small tusk or the small pieces of tusks were ground thinner (20 to 30 μm) before decalcification and staining, and used for the detailed observations of the structure of the tusk. The half cut ground sections are also used for a limited purpose.

RESULT

Structure of the tusk

Since there is found a small rudimental tusk beneath the gum at the mesial side of the large tusk, the larger tusks listed in Table 1 will possibly correspond to the permanent first upper incisors (Peyer 1968). The size of the rudimental tusk, or the probable deciduous first upper incisor, is about 40 mm in length and 5.5 mm in diameter in the specimen RMM002, and slightly smaller in older RMM001. There was a feature indicating the resorption of the dental tissue at the distal end of the deciduous tusks of Kamiya-1, RMM001, and RMM002. This tusk is present on a young male Toba-2, but absent on the skulls with erupted large tusks (Pl. 4, Fig. 7). Possibly the deciduous tusk will be, in males, resorbed or lost soon after the eruption of the permanent tusk. Though the growth layers are present in this rudimental tusk (Pl. II, Fig. 4), they are not investigated in the present study because the layers near the tip are lost by erosion. All the following analyses are made on the larger tusks or the probable permanent first incisors.

The tip of the unerupted tusk has several points separated by grooves as if there are several cusps (Pls I and II). The enamel layer of a thickness varying from place to place from 130 μm to 350 μm covers the entire surface of the fetal dentine. However, it is rudimental, except for the ventro-mesial part, on the surface of the first and second postnatal dentinal growth layers of the long cycle mentioned later, and is completely absent on the tooth formed afterward. On the ventro-mesial surface of the tusk, the enamel layer is deposited on the entire length of tusk (Pl. IV, Figs 5 and 6). This restricted distribution of the enamel means that when the erupted tusk is abraded into a chisel shape (Pl. IV, Fig. 7 and Marsh *et al.* 1978 Fig. 3)the cutting edge is reinforced and sharpened with enamel.

The cementum covers almost the entire external surface of the older tusk, but is thin or partially lacking on the enamel surface at the distal tip of the tusk of young individuals.

Dentinal growth layer

When the thin ground section is observed under transmitted light, there is found a clear translucent line near the tip of the tusk (Pl. II, Fig. 3 and Pl. III, Fig. 3). This will be the neonatal line. This neonatal line appears less clearly as an unstainable layer on the decalcified and stained section. The thickness of the fetal dentine ranges from 0.36 mm to 0.52 mm with a mean of 0.39 mm (n=4).

In the postnatal dentine, there are observed under transmitted light two kinds of growth layers, namely the coarse long cycle and fine short cycle layers. They correspond to the coarse and fine layers described by Scheffer (1970). Since the opaque layer reflects the light, it appears as a white layer under the reflected light, the translucent layer appears dark (Table 2). The opaque dentinal layer appears as a stainable layer on the decalcified and stained preparation (see the last layer in different preparations in Plates). The latter feature is same as that of *Tursiops truncatus* (Sergeant 1959) and of the fur seal (Kasuya unpublished), but opposite to the dentine of the spotted and striped dolphins (Kasuya 1976) or the nature of the skeletal and tooth layers of some other mammals (Klevezal and Kleinenberg 1967). Though the coarse growth layers are clearer on the decalcified and stained section, the thin ground section is usable for the purpose of age determination. Possibly even the half cut logitudinal ground preparations are also suitable (Mitchell 1976, 1978).

TABLE 2. COMPARISON OF THE NATURE OF THE COARSE DENTINAL GROWTH LAYERS AND THE MORPHOLOGY OF TUSK

Reflected light	White	Dark
Transmitted light	Opaque	Translucent
Haematoxylin	Stainable	Unstainable
Pulp cavity	Wide	Narrow

The pulp cavity opens wide when the stainable or opaque dentine is accumulated, and becomes narrow when the dentine of the opposite phase is deposited (Pl. IV, Fig. 4). Accordingly the circular ridge on the external surface of the tusk correspond to the phase when the accumulation of stainable dentine ends and that of the unstainable dentine starts, and the circular grooves to the opposite phase. Possibly the growth of the tusk will be slower in the period when the unstainable dentine is deposited. The number of the external ridges coincides, in young animals, with that of the stainable layers counted including the fetal dentine (Table 1).

The thickness of the coarse growth layer is between 2.6 mm and 3.6 mm in the the young dentine of, and between 0.5 mm and 1.0 mm in the dentine of the older age. The number of the fine growth layers in one accumulation cycle of the coarse layer ranges between 10 and 15 layers in most of the coarse layers (Pl. IV, Figs 3 and 4). However, when the extremely fine layers are counted, the number is in some part of the tusk can be 30 or more as indicated by Scheffer (1970). An improvement of the method of reading the fine layers is needed for detailed study

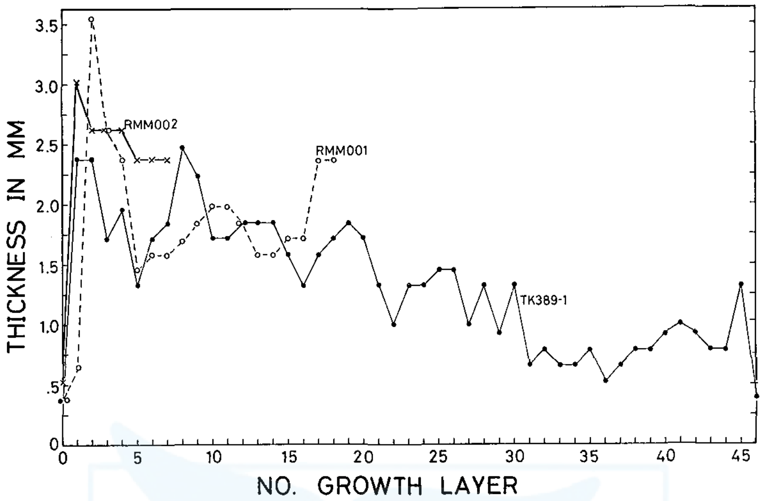

Fig. 2. The thickness of the coarse dentinal layers in the tusk of the dugong. The thickness is measured between the centers of the opaque layers. The thickness of fetal dentine is plotted on no. 0 layer, and the first and the last postnatal layers can be of incomplete thickness.

of their accumulation rate.

Cemental growth layer

There exist faint growth layers in the cementum, which can be observed on decalcified and stained sections. Though the cementum is not deposited on the tusk of Toba-2, there are observed about 16 stainable layers on RMM001 (Pl. II, Fig. 2). This suggest that the accumulation rate of the cemental growth layer is same with the coarse growth layer in dentine but the deposition of the cementum starts 1 or 2 years after birth (assuming annual deposition of the coarse dentinal layer).

DISCUSSION

Heinsohn (1972) studied the growth of the dugong based on large number of samples killed incidentally by shark control nets. There was found no difference in body size between sexes. He considered that calves are born at Townsville in August and September at a length of about 1.1 m. They start grazing before 3 months of age, but accompany their mothers for more than one year. The mean body length at the attainment of sexual maturity was calculated as 2.53 m (male) and 2.58 m (female). By plotting the body lengths on the date of catch moved back and forth into different years, he constructed a hypothetical growth curve, which suggests that the calves attain the length of about 1.8 m in one year, 2.3 to 2.4 m in two years, and 2.5 to 2.7 m in 3 years. However, Mitchell (1976) considered, based on the skull length at the attainment of sexual maturity obtained by Spain and Heinsohn (1974) and on the relationship between the age and skull length she obtained, that the sexual maturity is attained at the age of 10 growth layers, or presumably at 10 or 5 years, depending on the hypotheses of the annual or biannual formation of the layer. A direct estimation of the growth rate of the species is given by Jones (1976) based on the two individuals kept in captivity at Mandapan Camp. This estimate gives a growth rate much slower than that of Heinsohn (1972).

In the present study the annual growth rate of the species is calculated from the 4 known age individuals by assuming various formation cycle of the layer, the neonatal length of 1.1 m, and continuous growth from the smallest to the largest individual. Though the 169.7 cm male, Toba-2, has two opaque layers in the tusk, both of the 1st and 2nd (the last) postnatal layers are thin and is considered as incomplete. Since the sum of the thickness of the two layers is only 4.60 mm, or 154% of the mean of the thickest first or second layers of other 3 individuals, its age was assumed as 1.5 accumulation cycles.

The natural environmental changes which affect the deposition of dentine in the tusk could be daily, lunar and annual cycles (Scheffer 1970). However, as in the case of the sperm whale, there can exist a situation where two parallel minor layers composing one annual layer are counted separately and the accumulation

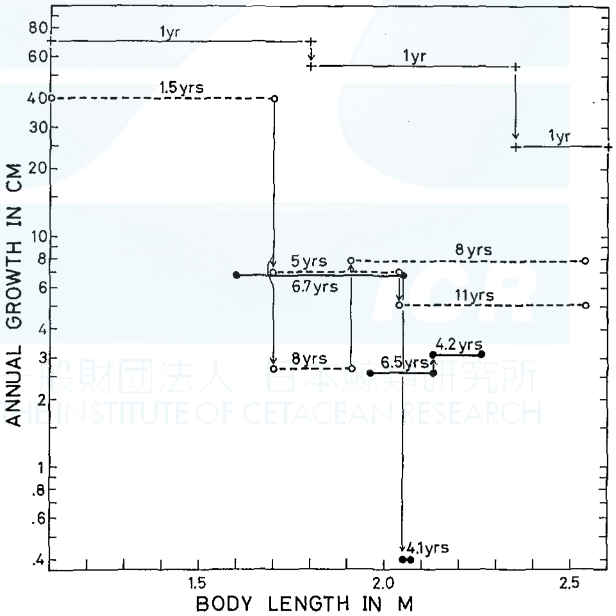

Fig. 3. Mean annual growth rate of the dugong. Closed circle and thick solid line indicate the growth in captivity (Jones 1976), open circle and dotted line the growth rates calculated from the growth layers (annual accumulation), and cross and thin solid line the growth rates estimated by Heinsohn (1972).

rate is considered as biannual (Klevezal and Kleinenberg 1967). As shown in Fig. 3, the growth rates calculated on the assumption of an annual formation of the coarse growth layer coincide with those of the captive individuals reported by Jones (1976). The assumption of the biannual or monthly formation of the coarse growth layer gives worse coincidence. This suggests that the formation of the coarse dentinal layer is annual. This result and seasonal change of the nature of the last incomplete layer (Table 1) suggest that the stainable dentine is deposited, in the equatorial and northern tropical waters, in the season from June to October.

It was indicated that there are usually observed 10 to 15 fine layers in one cycle of the coarse dentinal layer. Since the deposition of the latter is estimated as annual that of the former can be suspected as representing the lunar cycle or endogenous rhythm of about one month as *Berardius* (Kasuya 1977). There is observed, on RMM001 and 002, a sharp unstainable dentine near the pulp cavity, and 2 or 3 fine stainable layers are deposited inside of it (Pl. IV, Figs. 1 to 4). The extraordinary unstainable layer could be formed by physiological change of the animals soon after capture. The number of the fine layers formed after it coincides approximately with the length of life in captivity in months. This is another suggestion of the presence of about 30 days cycle in the deposition of the dentine.

Sexual maturity of the female is, in the present materials, attained by the age of 17 coarse layers but not attained at the age of 7 layers. In the latter individual, RMM002, all the seven dentinal layers show a simple regular feature. However, such regular layers are restricted, in the adut female RMM001, to earlier 10 layers, and the growth layers accumulated after this age show more irregular looking with conspicuous accessory layers between them (Pl. I). The number of the regular layers of 10 females and 1 male ranges from 8 to 12 with the mean at 9.7 layers. It is often observed on the maxillary tooth of the sperm whale that the dentinal growth layers are regular in the immature stage and it changes, in the dentine formed after the age at sexual maturity, into irregular feature with conspicuous accessory layers (for the structure of the tooth layer see Ohsumi *et al.* 1963). This is in the strong resemblance with the dentinal growth layers of the dugong tusk. Accordingly it is suspected that the sexual maturity of the female dugong will be attained at about 10 coarse growth layers, or presumably at about 10 years of age.

ACKNOWLEDGMENTS

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EXPLANATION OF PLATES

PLATE I

Thin ground section of the tusk RMM001, photographed under transmitted light. Circle indicates the coarse postnatal opaque layer, and the open circle the 10th layer.

Fig. 1. A whole view of the section.

Fig. 2. Distal part of the section.

Fig. 3. Proximal part of the section.

PLATE II

Fig. 1. Decalcified and stained section of the tusk RMM001, proximal portion of the same tusk shown in Pl. I. Circle indicates coarse stainable layer in dentine.

Fig. 2. Decalcified and stained section of a part of cementum of RMM001, taken from the position corresponding to the first postnatal dentinal layer. Circle indicates the stainable growth layer, C cementum, and D dentine.

Fig. 3. Thin ground section of the tusk Toba-2. Cross indicates enamel layer, open circle the neonatal layer in the dentine, closed circle postnatal coarse opaque layer in the dentine. This photograph is taken inserting the tooth section into the negative holder of an enlarger, and the translucent layer is shown dark.

Fig. 4. Thin ground section of the deciduous first upper incisor of RMM002. The distal end (top) is resorbed. C indicates cementum, and D dentine. Photograph is taken in a same way as Fig. 3.

PLATE III

Fig. 1. Thin ground section of the tusk TK389-1, the distal portion. Photographed under transmitted light.

Fig. 2. The proximal portion of the same section.

Fig. 3. Thin ground section of the tusk RMM002. Photographed under transmitted light. For Symbols see Pl. II, Fig. 3.

PLATE IV

Fig. 1. Decalcified and stained section of the proximal portion of the tusk RMM 002, showing the fine dentinal growth layers. C indicates cementum, D dentine, and P pulp cavity. The open circle indicates the position of the strong unstainable layer possibly representing the dentine deposited soon after the capture.

Fig. 2. Decalcified and stained section of the proximal portion of the tusk RMM-001. For the explanations see Fig. 1.

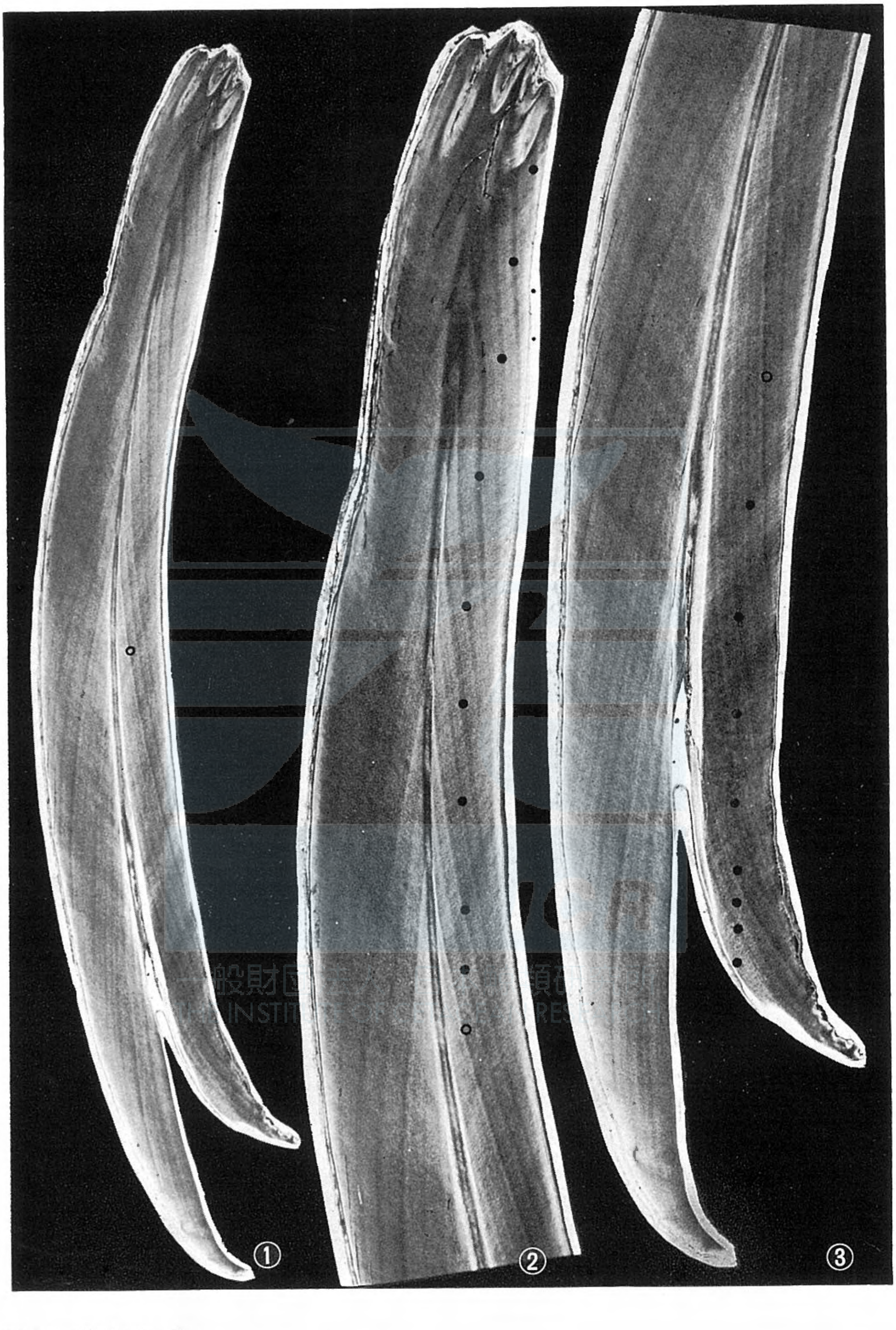
Fig. 3. Lower magnification of the preparation shown in Fig. 1. C indicates cementum, P pulp cavity, and open circle the coarse stainable dentinal layer. About 12 or 13 fine layers are observed in one cycle of the coarse layer.

Fig. 4. Lower magnification of the preparation shown in Fig. 2. E indicates the cast of decalcified enamel. For further explanations see Fig. 3.

Fig. 5. Thin transverse ground section of the tusk TK389-2, taken from the cervix. Photographed under transmitted light. C indicates cementum, D dentine, and E enamel.

Fig. 6. Thin transverse ground section of the tusk RMM001, taken from the mid-length of the tusk. The distribution of the cementum (C), dentine (D), and enamel (E) is indicated.

Fig. 7. Antero-dorsal view of the tusk of a probable male dugong, showing the pointed tip of the tusk.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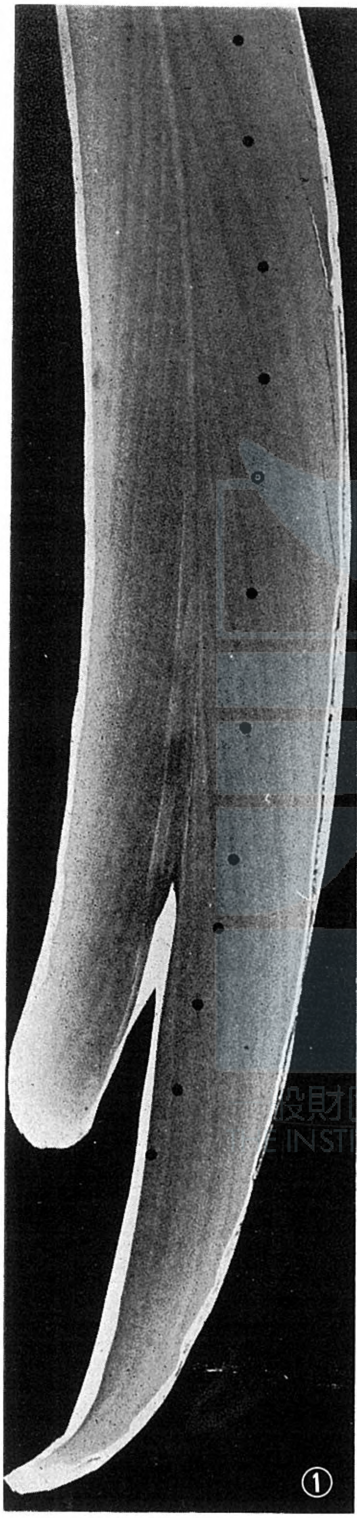

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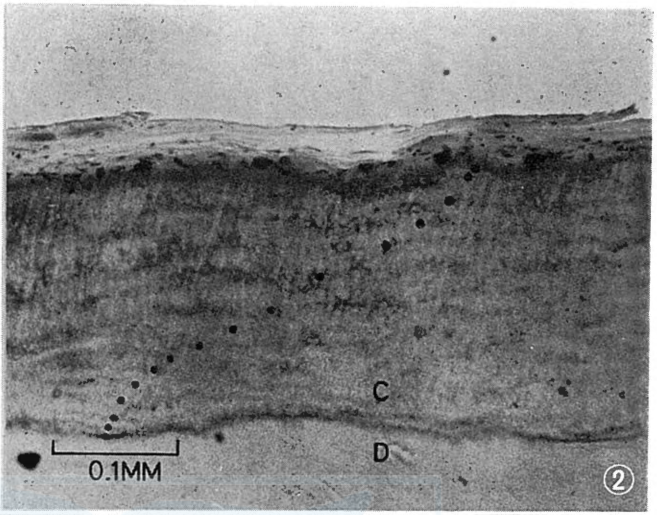

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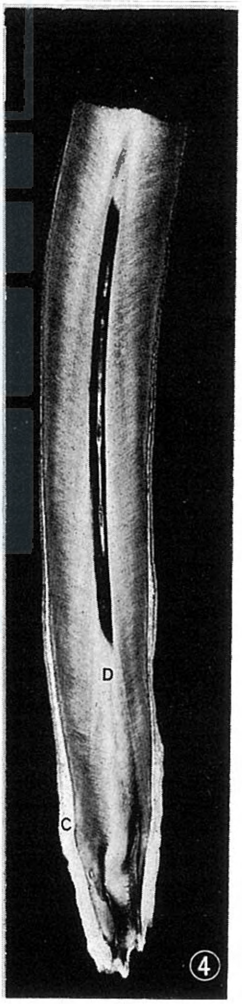

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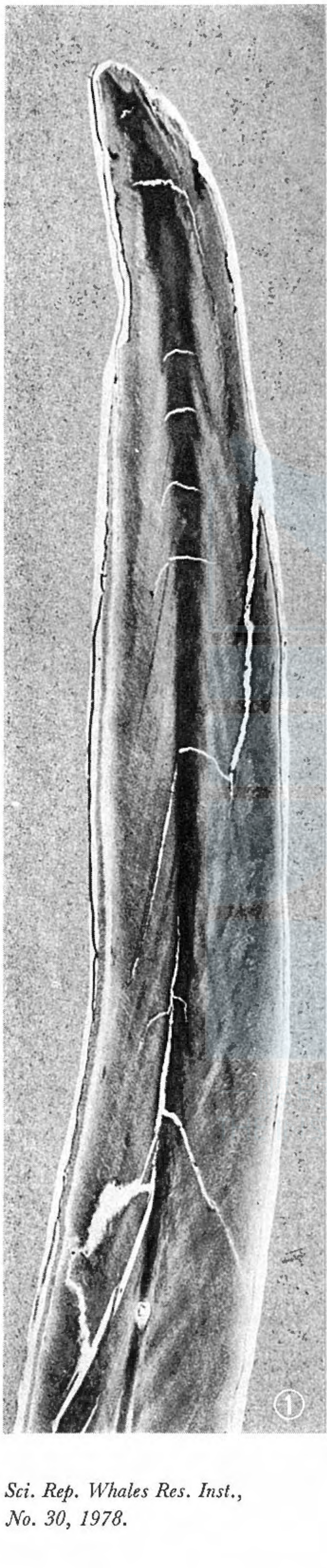
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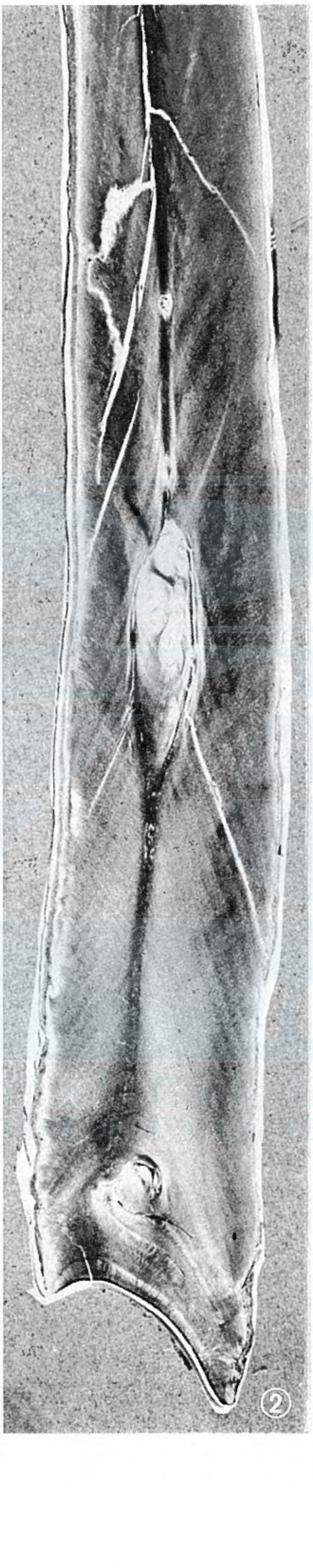
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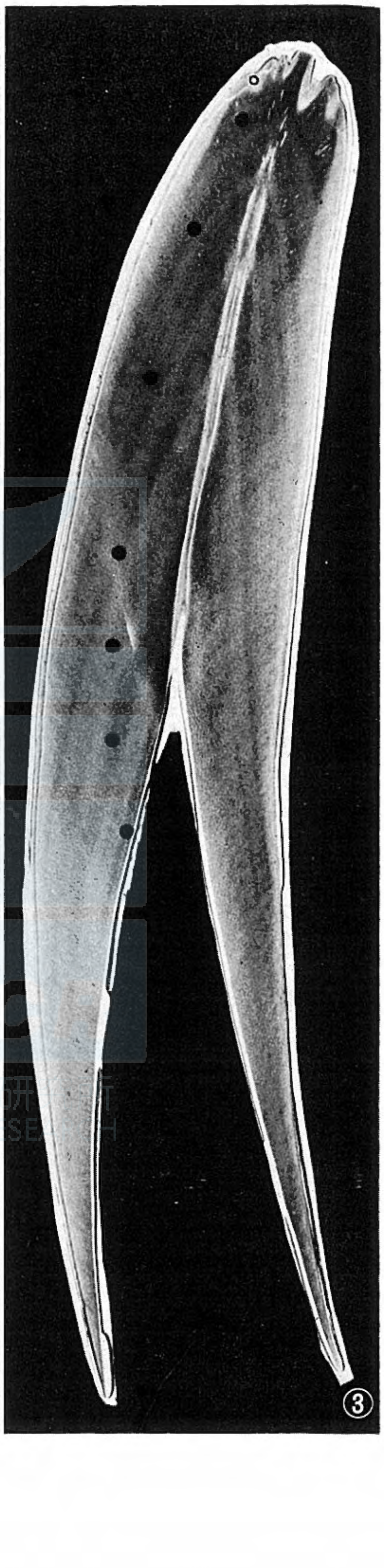
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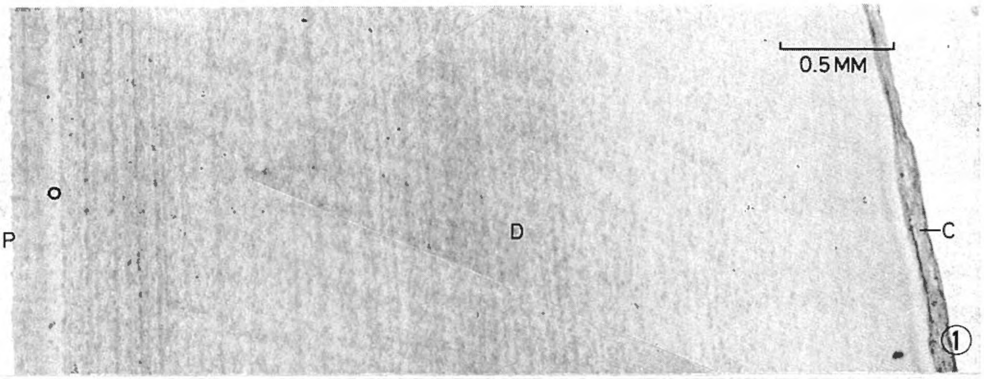
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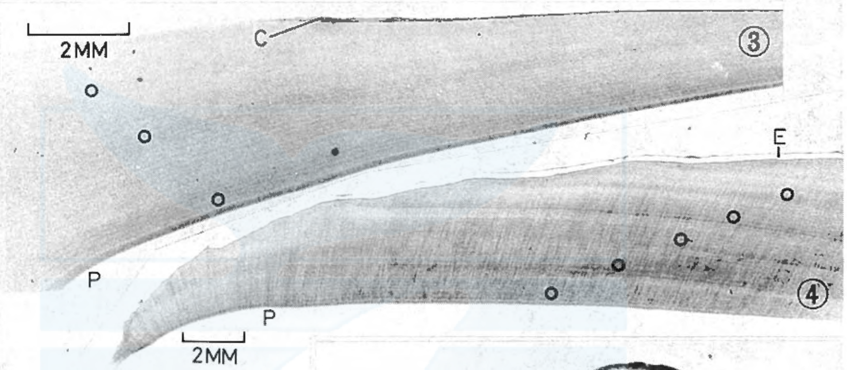
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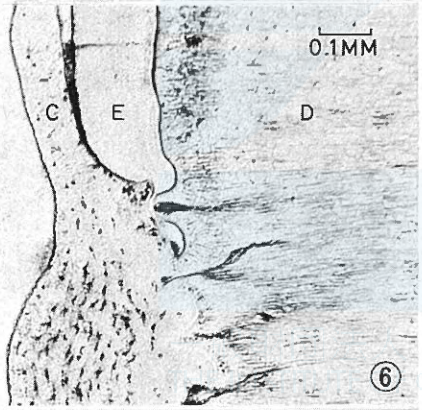
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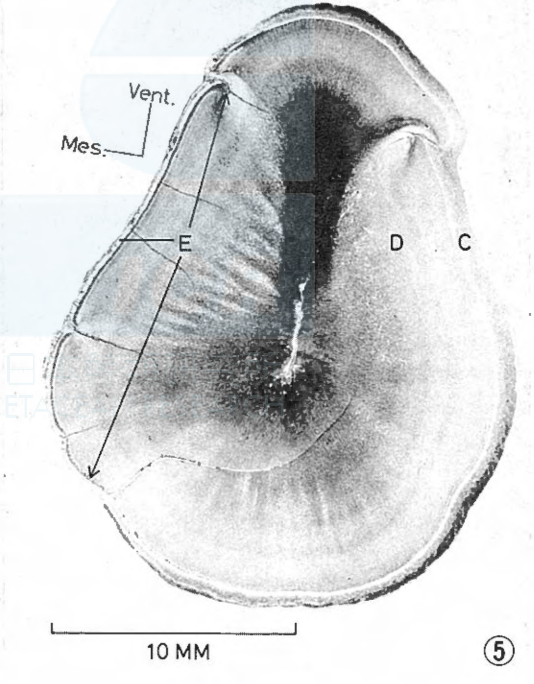
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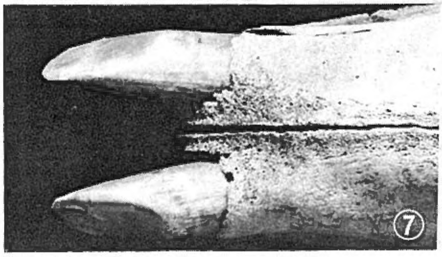
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ON THE EXAMINATION AGAINST THE PARASITES OF ANTARCTIC KRILL, *EUPHAUSIA SUPERBA*

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In order to obtaine more information on the nutritive value as human foods or animal feeding stuffs and to estimate any existence of the potential health hazards, samples prepared from frozen krill were examined against the parasites.

MATERIALS AND METHODS

Antarctic krill, *Euphausia superba* were collected by use of the plankton nets in Antarctic Ocean by a catcher boat of Taiyo-Gygyo K.K. The localities, number and size of Antarctic krill examined are shown in Table 1. The krill were immediately stored at −40°C on the boat. These frozen samples were brought in our laboratory. The krill were pressed between two glass plates, and were inspected by the binocular dissecting microscope (10x) against the parasites.

TABLE 1. SURVEY OF THE PARASITES IN ANTARCTIC KRILL, *EUPHAUSIA SUPERBA*

			at Antarctic krill			
No.	Date	Locality	Body length* (SD)**	Body weight* (SD)**	No. exam.	No. positive of parasites
W I-1	1975-12-1	59°34′S 49°54′E	59.1(47-64)(3.56)	1.21(0.80-1.40)(0.15)	2,823	0
W I-2	1975-12-15	62°47′S 64°39′E	50.7(41-60)(4.89)	0.82(0.40-1.30)(0.21)	9,823	0
W I-3	1976-1-2	62°22′S 83°45′E	45.3(35-57)(5.96)	0.50(0.30-0.95)(0.17)	11.576	0
W I-4	1976-1-15	65°14′S 59°15′E	47.5(35-58)(4.83)	0.68(0.35-1.10)(0.21)	9,754	0
W I-5	1976-2-1	65°35′S 55°38′E	46.5(35-55)(5.27)	0.50(0.15-1.08)(0.19)	11,406	0
W I-6	1976-2-13	65°30′S 56°02′E	46.7(34-60)(5.74)	0.60(0.20-1.20)(0.22)	10,406	0
Total					55,295	0

*: No. of examined specimens = 50; mm. and gram.

**: SD = standard deviation

RESULTS AND DISCUSSION

As shown in Table 1, 55,295 specimens of *Euphausia superba* in total examined were negative for the parasites at all.

Although the larvae of many species of helminthic have been found in various marine invertebrates (Sarsa, 1885 ; Lebour, 1917 ; 1923 ; Jepps, 1937 ; Uspenskaja, 1960 ; Rees, 1961 ; Dollfus, 1964 ; Oshima *et al.*, 1969 ; Overstreet, 1970 ; Komaki, 1970 ; Vivares, 1971 ; Reimer *et al.*, 1971 ; Smith, 1971 ; Shimazu, 1971 ; 1972 ; 1975a, b ; Shimazu and Oshima, 1972 ; Ramadevi and Rao, 1974 ; Kagei, 1974 ;

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Sluiters, 1973 ; 1974 ; Shiraki *et al.*, 1976), the parasites of the health hazards were the larvae of *Anisakis* spp. and *Terranova* sp. (Anisakinae: Nematoda), and the larvae of *Anisakis* spp. and *Terranova* sp. have been found in various invertebrates including the euphausiids (Uspenskaja, 1960: *Thysanoessa raschii;* Oshima *et al.*, 1969, Shimazu and Oshima, 1972: *Thysanoessa raschii*, *Thysanoessa longipes*, *Euphausia pacifica;* Smith, 1971: *Thysanoessa inermis*, *Thysanoessa longicaudata;* Kagei, 1974: *Euphausia pacifica;* Sluiters, 1973, 1974: *Thysanoessa raschii*), the amphipoda (Uspenskaja, 1960: *Caprella septentrionalis*), the branchurans (Decapoda) (Uspenskaja, 1960: *Hyas araneus*), arrow worms (Chaetognatha) (Reimer *et al.*, 1971) and Prawns (Shiraki *et al.*, 1976: *Pandalus borealis* and *P. kessleri*) (Banning, 1970: *Meganyctiphaens norvegica*). However, according to the results of many previous papers and this examination, Type-I larvae of *Anisakis* are recognized to be heavily infected in the northern euphausiids, but the infection rates are decreased gradually in the lower latitude (Kagei, 1974). It is interesting that this geographical distribution is by the quantity of infected final hosts, the heavily infection with *Anisakis* larvae in the northern fishes and inhabited quantity of euphausiids, and the examination of 35,319 *Euphausia superba* from the Antarctic ocean by Kagei (1974) was negative for the larvae of *Anisakis* and other parasites. In the present examination, *Euphausia superba* from various parts of the Antarctic ocean is also negative for the larvae of *Anisakis*. This is interesting to related to that the present of *Anisakis* spp. in marine mammals from the Atlantic Ocean was not occured as found at the report of Kagei and Kureha (1970).

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