THE
SCIENTIFIC REPORTS
OF
THE WHALES RESEARCH INSTITUTE

No. 27

ICR
一般財団法人　日本鯨類研究所
THE INSTITUTE OF CETACEAN RESEARCH

THE WHALES RESEARCH INSTITUTE
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OSTEOLOGICAL STUDY OF THE MINKE WHALE FROM THE ANTARCTIC

HIDEO OMURA

Whales Research Institute, Tokyo

ABSTRACT

Two skulls and postcranial bones of the minke whale from the Antarctic were studied, comparing with two specimens from the North Pacific. Characters noted in the skull are: breadth of skull is narrow, rostrum is also narrow and long and the flank is rounded and flat in profile, anterior margin of nasals is concave, at the vertex of skull triangular region is not formed by frontal and parietal between nasals and supraoccipital or in a more advanced stage of telescoping, lachrymal is large and rectangular, hamular process of pterygoid is short and broad. In the vertebrae the 7th cervical lacking parapophysis. Lateral tubercle of the pelvic bone situated towards mid-length of the bone in male.

Above are the main differences which separate it from the minke whale in the northern hemisphere, though the whale in the North Atlantic has also comparatively long rostrum and is separated by this character, together with difference in form of the white band of flipper, from that in the North Pacific. In the light of the present stage of knowledge it is not concluded that the minke whale from the Antarctic (*Balaenoptera bonaerensis*) is a distinct species from *B. acutorostrata*.

INTRODUCTION

The problem whether the little piked or minke whale from the Antarctic (*Balaenoptera bonaerensis*) is a distinct species from the minke in the northern hemisphere (*B. acutorostrata*) has not been finally solved yet, though Utrecht and Spoel (1962) and Ohsumi *et al.* (1970) report the name *B. bonaerensis* is a synonym of *B. acutorostrata*. The conclusion of these authors are mainly based on the external morphological characters, and in addition the latter authors have counted number of vertebrae of three small foetuses and found no distinction in this respect. Detailed osteological study on adult specimen is needed in the light of the present status of affairs.

In the 1971–72 season Dr S. Ohsumi had been in the Antarctic on board Jinyo Maru, a minke whaling expedition and has collected two complete sets of the skeleton. These bones are the main material of this paper. In addition to these, in 1969 I fortunately could collect two sets of skeleton of the minke whale from the North Pacific, by courtesy of Mr T. Miyodori, owner of minke whaling catcher boat operating on the coast of Japan. These bones are also studied for comparison. Dr S. Ohsumi has also collected a number of hyoid bones of the

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minke whale from the Antarctic in the same season. A taxonomic study based on these hyoid bones has already been published by Satake and Omura (1974).

MATERIAL

The particulars of the specimens treated in this paper are shown in Table 1. The specimen 71J2793 and 71J2883 were brought from the Antarctic, kept in a cold storage chamber of Jinyo Maru, and unloaded at Tokyo port from where they were transported to the laboratory in fresh condition on 30 March 1972. A few amount of meat and other soft parts were still attached to bones. Baleen plates were also remained on the beak of the skull. After removal of these, most bones were burried in earth in order to extract oils contained in them. Flippers were enveloped with nylon mosquito nets before burying, in precaution against missing of small phalanges. They were dug out from the earth in December 1973. From small bones e.g. small caudal vertebrae, hyoid bones, chevron bones, sterna, etc. oils were extracted by boiling in laboratory and then soaking in water.

TABLE 1. PARTICULARS OF THE MINKE WHALE SPECIMENS

Specimen no.	Body length (m)	Sex	Date of catch	Position of catch	Age
71J2793	8.5	M	Feb. 12, 1972	65°-21′S, 76°-37′E	Ad. 25 years*
71J2883	9.8	F	Feb. 16, 1972	65°-00′S, 89°-37′E	Ad. 39 years*
AY69B	6.6	M	Apr. 12, 1969	Coast of Japan	Juv.
AY69A	5.4	M	Apr. 28, 1969	Coast of Japan	Juv.

* Age determined by Dr S. Ohsumi by means of ear plug.

Bones of the specimens AY69A and AY69B were buried in sand of beach of Ayukawa by Mr T. Miyodori. They were dug out from sand after 15 months and transported to W.R.I. The specimen AY69A was mounted for display and now being kept at Suginami Kagaku Kyoiku Center, Tokyo, an educational institution for school children in Suginami ward. Other specimens have been kept at W.R.I.

As shown in Table 1 the age of the specimens is quite different between samples from the different hemispheres. Two specimens from the Antarctic are adult and all vertebral epiphyses are completely fused to their centra, whereas two specimens from the North Pacific are very young and none of the epiphyses is fused to the body of the vertebra. Age of the specimens from the Antarctic was determined by Dr S. Ohsumi as being 25 and 39 years respectively by means of ear plug, but for the specimens from the North Pacific no age determination was made.

This difference in age between specimens from different hemispheres makes it difficult to arrive at correct conclusions from only the direct comparison of these bones.

SKULL (Plates I-V)

At the first glance it was noted that the skull of the minke whale from the Antarctic differs from that of the North Pacific in having more rounded or convex outline of the rostrum in dorsal view, and the rostrum itself is flat in profile. According to Tomilin (1967) the most important features of the skull of *Balaenoptera acutorostrata* in the northern hemisphere are the following. " Size small, usually not exceeding 2 m. Rostrum triangular, pointed, with straight flanks, shorter, and wider at base than in other rorquals. Fronto-nasal process of the maxillary abbreviate. Viewed from above, nasal bones triangular, relatively large, convex or flattened (but not concave) along the anterior margin. Os nasale ca 1.5 in the fronto-nasal process (never 2). Nasal bones produced so far anteriad that their fore ends reach the line

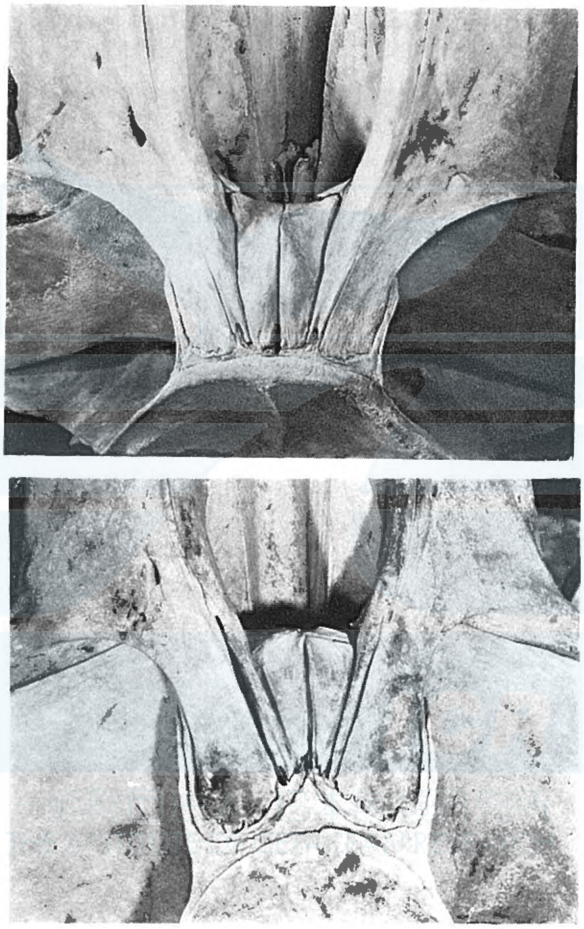

Fig. 1. Dorsal view of nasals of the minke whale. Upper. Specimen 71J2883 from the Antarctic. Lower. Specimen AY69B from the North Pacific.

connecting the curves of both maxillaries near the base of the fronto-nasal processes ". The two specimens from the North Pacific (AY69A and AY69B) agree with this description well, but the two skulls from the Antarctic are different. Their flanks are not straight, but curved, and nasal bones concave along the anterior margin. Size of the skull is large and both exceed 2 m in length, but this is not striking, because these skulls were obtained from whales of over 8 m in length, and the Tomilin's largest skull (2 m) belonged to a whale of 7.3–8 m.

The most striking feature in the dorsal aspect of the skull is the form of the nasals and arrangements of bones at vertex of skull, between posterior end of nasals and supraoccipital bone. Difference in nasals is also observed in the frontal view.

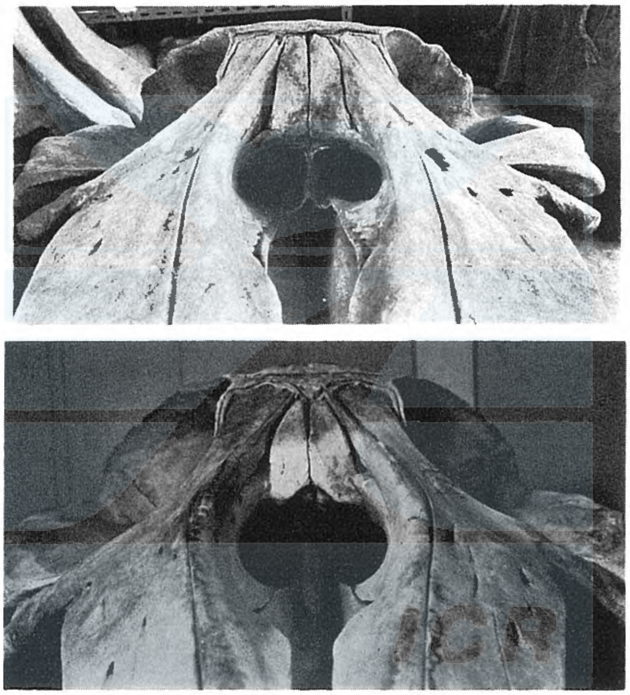

Fig. 2. Frontal view of nasals of the minke whale. Upper. Specimen 71J2883 from the Antarctic. Lower. Specimen AY69B from the North Pacific.

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These differences are clearly demonstrated in Figs. 1 and 2. As shown in these figures the anterior margin of the nasals is concave in the specimen from the Antarctic, whereas in those from the North Pacific convex (Fig. 1). The inferior surface of the nasals from the Antarctic is flat and shows no special feature, but in the specimens from the North Pacific anterior and proximal part of the right and left nasals is concave, and together forming a half elliptic groove, as shown in Fig. 3 by dotted line.

Another difference is in the arrangement of bones at the vertex of the skull. In the specimens from the Antarctic posterior ends of nasals, premaxillaries, and maxillaries are arranged roughly in line, nearly parallel to the margin of the supraoccipital bone. Frontal is present as a narrow band between these bones, but the parietal does not appear in this region of the skull. It covers frontal on the side of the fronto-nasal process of the maxillary. On the other hand in the specimen from the North Pacific the posterior end of nasals is situated more anteriorly, and premaxillaries end posteriorly than nasals, and maxillaries more posteriorly than those bones. Thus triangular region is formed by frontal, but frontal itself is also represented by narrow band and between frontal and supraoccipital there present parietal, also triangular in shape. In Figs. 1 and 2 only the photograph of the specimen AY69B is shown, but in the specimen AY69A too the shape of nasals and arrangement of bones at the vertex of the skull is quite similar. In conclusion above the minke whale from the Antarctic has attained a more advanced stage of telescoping than that from the North Pacific.

Omura (1957) reports three skulls of the minke whale from the coast of Japan, and this time these skulls were reexamined, especially on characters stated above.

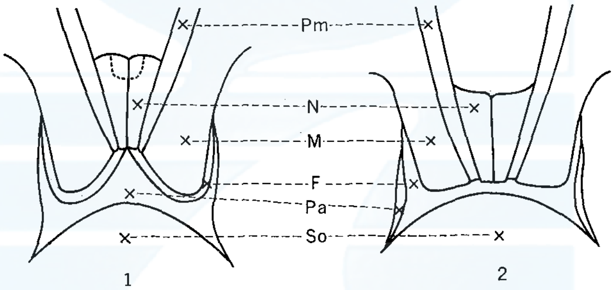

Fig. 3. Schematic drawing of vertex of skull of the minke whale.
1. From North Pacific. 2. From Antarctic.
Pm ...... Premaxillary, N ...... Nasal,
M, ... Maxillary, F ...... Frontal,
Pa ...... Parietal, So ...... Supraoccipital.

In addition I examined three more skulls preserved at various places in Japan. Places where these six skulls preserved are: one at the National Science Museum in Tokyo, one at the Tokyo University of Fisheries, two at the Whale Museum in Ayukawa, one in Shiogama, and one in Matsushima. Length of these skulls are ranged from 1,060 mm to 1,520 mm. The largest specimen is the specimen kept at the National Science Museum, but in this specimen too vertebral epiphyses are only fused to their centra completely in the first three cervicals and last ten caudals. Thus all of the specimens are thought juvenile or semi-adult. In all of the specimens the form and position of nasals are quite similar to those shown in Figs. 1 and 2. The parietal is triangular form at the vertex of the skull in general, but the forward projection on the mid-dorsal line is bifurcated in the specimen AY69A, and in a specimen kept in Matsushima most part of this triangular region of the parietal is covered by supraoccipital (Fig. 4). In the above two specimens, however, the

Fig. 4. Vertex of skull of the Matsushima specimen, showing triangular region between nasals and supraoccipital. (photograph by Dr A. Kawamura).

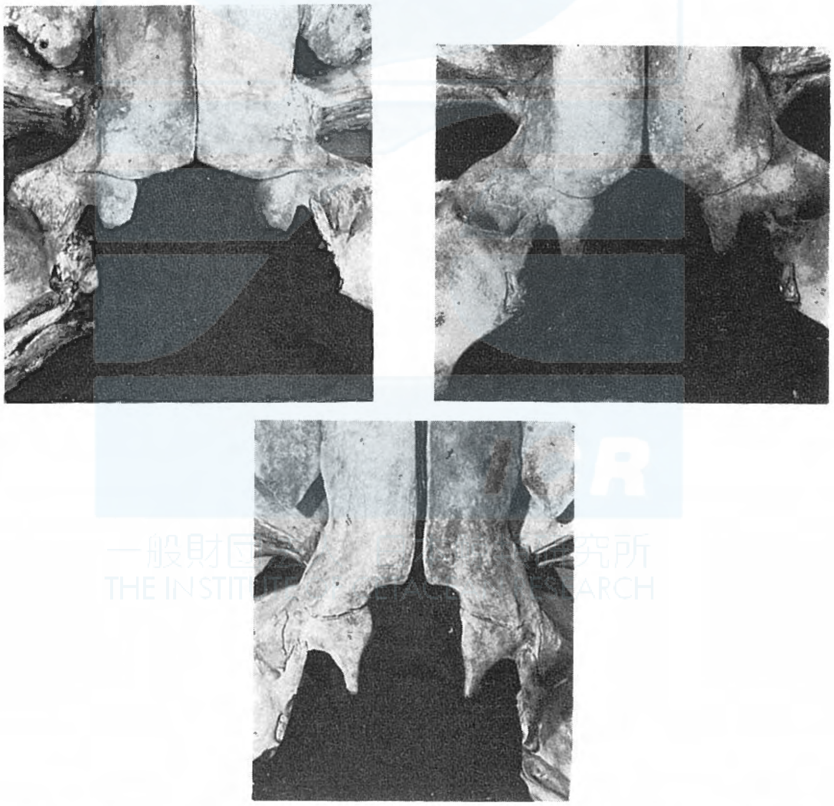

Fig. 5. Ventral view of skull of the minke whale, showing posterior part of palatines and pterygoids. Right. Specimen 71J2793 from the Antarctic. Left. Specimen 71J2883 from the Antarctic. Lower. Specimen AY69B from the North Pacific.

frontal posterior to nasals, premaxillaries, and maxillaries is triangular in dorsal view.

The skull length of the Matsushima specimen is 1,220 mm and it is thought that this specimen came also from a juvenile animal.

On the inferior side of the skull differences are noted by visual comparison between specimens from different oceans, at the posterior margin of palatines and in the form of the hamular process of pterygoid. In the skulls from the Antarctic the posterior margin of palatines, from mid-ventral point to articulating point with pterygoid, is roughly straight, whereas in the specimen from the North Pacific this line is much concave. The hamular process of pterygoid is short and broad in the specimens from the Antarctic, but it is slender and pointing in the specimen from the North Pacific (Fig. 5). The posterior margin of palatines, however, subject to individual variation, and in the specimen AY69A this line is convex rather than concave. Among other specimens noted before the lines are concave in five specimens and convex in one specimen. But the hamular process of pterygoid is slender and pointing in all specimens, in which this part of the skull remaining unbroken.

Skull measurements and calculated percentages against skull length are shown in Table 2. There are rather wide ranges of individual variation, and in some measurements values of the two Antarctic skulls and the two North Pacific skulls are overlap each other. But there are a number of measurements in which values are not overlap between the specimens from different oceans. In the specimens from the Antarctic the length of the rostrum and breadth at its middle are larger than others (Measurement nos. 7, 10, and 11), though practically no difference is noted in its width at base (M. no. 12). These differences are large, especially in the specimen 71J2883, the larger whale, but see also Fig. 6. Mandibles are also larger than in the specimens from the North Pacific (M. nos. 33–36), and they have a bit higher coronoid process (M. nos. 37 and 38). There seems no proportional difference in the breadth of the skull (M. nos. 16, 17 and 18), but the breadth of occipital bone is larger in the specimens from the North Pacific (M. no. 21). Size of occipital condyles as well as foramen magnum are also larger proportionally (M. nos. 22–26). But the proportion of these bones in posterior part of skull subject to age. In the black right whale proportional length in these bones decreases with age (Omura *et al.*, 1971).

The breadth of the vertex of skull or breadth across the fronto-nasal processes of maxillaries is broader in the North Pacific whale (M. nos. 13 and 14), and length of orbit, measured at distal end of frontal, is larger also. But no conclusion could be reached due to scanty number of material. Anterior breadth of nasal seems to be greater in the North Pacific specimens (M. no. 9), but this can not be concluded so, because it is very difficult to measure correctly in the specimens from the Antarctic.

On the inferior side of the skull significant differences are noted. In the skulls from the Antarctic the vomer extends more forward, hence larger (M. no. 28), and palatines and pterygoids are situated more posteriorly than in the speci-

TABLE 2. SKULL MEASUREMENTS OF THE MINKE WHALE

	Measurements	Actual length	
		Antarctic 71J2793 M 8.5 m Ad.	Antarctic 71J2883 F 9.8 m Ad.
1.	Codylo-premaxillary length	2,115	2,350
2.	Length of premaxillary, right	1,490	1,710
3.	„ „ „ , left	1,510	1,707
4.	„ „ maxillary, superior, right	1,450	1,645
5.	„ „ „ „ , left	1,390+	1,645
6.	Tip of premaxillary to vertex	1,520	1,710
7.	„ „ „ „ nasals	1,364	1,550
8.	Length of nasals, median	133	170
9.	Breadth of nasals, anterior	98	137
10.	Length of rostrum	1,354	1,630
11.	Breadth of rostrum at middle	399	534
12.	Breadth of rostrum at base	630	770
13.	Breadth across maxillaries at vertex	187	237
14.	Breadth of frontal across nasals	231	261
15.	Breadth between maxillaries at nares	237	307
16.	Breadth of skull, squamosal	1,075	1,256
17.	„ „ „ , frontal	1,047	1,219
18.	„ „ „ , maxillaries	991	1,144
19.	Length of orbit, frontal, right	188	207
20.	„ „ „ „ , left	190	207
21.	Breadth of occipital bone	760	886
22.	Breadth across occipital condyles	203	228
23.	Height of occipital condyle, right	131	145
24.	„ „ „ „ , left	124	142
25.	Breadth of foramen magnum	70	79
26.	Height of foramen magnum	97	127
27.	Length from foramen magnum to vertex	605	650
28.	Tip of premax. to anterior end of vomer, median	258	290
29.	„ „ „ „ „ „ „ palatine, median	1,505	1,642
30.	„ „ „ „ posterior „ „ „ „	1,782	2,055
31.	„ „ „ „ „ „ „ pterygoid	1,935	2,150
32.	Breadth across hamular processes of pterygoid	210	236
33.	Length of mandible, straight, right	2,063	2,285
34.	„ „ „ „ , left	2,075	2,265
35.	„ „ „ , curved, right	2,247	2,454
36.	„ „ „ „ , left	2,260	2,445
37.	Height of mandible at coronoid, right	303	311
38.	„ „ „ „ „ , left	302	315
39.	„ „ „ „ condyle, right	201	220
40.	„ „ „ „ „ , left	204	233

mens from the North Pacific (M. nos. 29, 30 and 31).

Above are the major differences noted in Table 2. Tomilin (1967) presents a table comparing cranial indices of the Atlantic and Pacific populations in the northern hemisphere, and noted that the Atlantic individuals are characterized

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FROM THE ANTARCTIC AND NORTH PACIFIC

in mm		% of skull length			
N. Pacific AY69B M 6.6 m Juv.	N. Pacific AY69A M 5.4 m Juv.	71J2793	71J2883	AY69B	AY69A
1,382	1,140	100.0	100.0	100.0	100.0
986	797	70.4	72.8	71.3	69.9
984	798	71.4	72.6	71.2	70.0
939	780	68.6	70.0	67.9	68.4
933+	755	—	70.0	—	68.0
1,017	834	71.9	72.8	73.6	73.2
872	692	64.5	66.0	63.1	60.7
94	87	6.3	7.2	6.8	7.6
97	71	4.6	5.8	7.0	6.2
869	687	64.0	69.4	62.9	60.3
252	210	18.9	22.7	18.2	18.4
441	367	29.8	32.8	31.9	32.2
152	138	8.8	10.1	11.0	12.1
174	137	10.9	11.1	12.6	12.0
178	115	11.2	13.1	12.9	10.1
708	613	50.8	53.4	51.2	53.8
703	597	49.5	51.9	50.9	52.4
625	535	46.9	48.7	45.2	46.9
156	146	8.9	8.8	11.3	12.8
157	146	9.0	8.8	11.4	12.8
563	473	35.9	37.7	40.7	41.5
157	154	9.6	9.7	11.4	13.5
98	120	6.2	6.2	7.1	10.5
96	100	5.9	6.0	6.9	8.8
83	80	3.3	3.4	6.0	7.0
90	85	4.6	5.4	6.5	7.5
376	297	28.6	27.7	27.2	26.1
219	206	12.2	12.3	15.8	18.1
856	700	71.2	69.9	61.9	61.4
1,102	910	84.3	87.4	79.7	79.8
1,205	990	91.5	91.5	87.2	86.8
127	—	9.9	10.0	9.2	—
1,330	1,005	97.5	97.2	96.2	88.2
1,330	1,010	98.1	96.4	96.2	88.6
1,400	1,045	106.2	104.4	101.3	91.7
1,390	1,050	106.9	104.0	100.6	92.1
170	148	14.3	13.2	12.3	13.0
179	150	14.3	13.4	13.0	13.2
135	115	9.5	9.4	9.8	10.1
132	116	9.6	9.9	9.6	10.2

by a relatively longer rostrum.

In Fig. 6 I have compared several cranial indices of the minke whales from the North Atlantic, North Pacific, and from the Antarctic. Figures for the North Atlantic and North Pacific are cited from Tomilin (1967). For the North Pacific

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whales, among four specimens he used, two were cited from True (1904) and two from Cowan (1939), and my previous data (Omura, 1957) were not included. In Fig. 6, therefore, all data obtained from the coast of Japan are also shown, but separately from Tomilin's figures. Further he grouped specimens into two categories of juvenile (skull length less than 133 cm) and adult (skull length over 150 cm) and calculated mean value for each group, but since samples are limited in number so in Fig. 6 only ranges of value are shown. From his table only figures for adult whales are cited, because the specimens from the Antarctic are all adult. But specimens from the coast of Japan are all juvenile, except one specimen in which the skull length is 1,520 mm and exceeds his criteria.

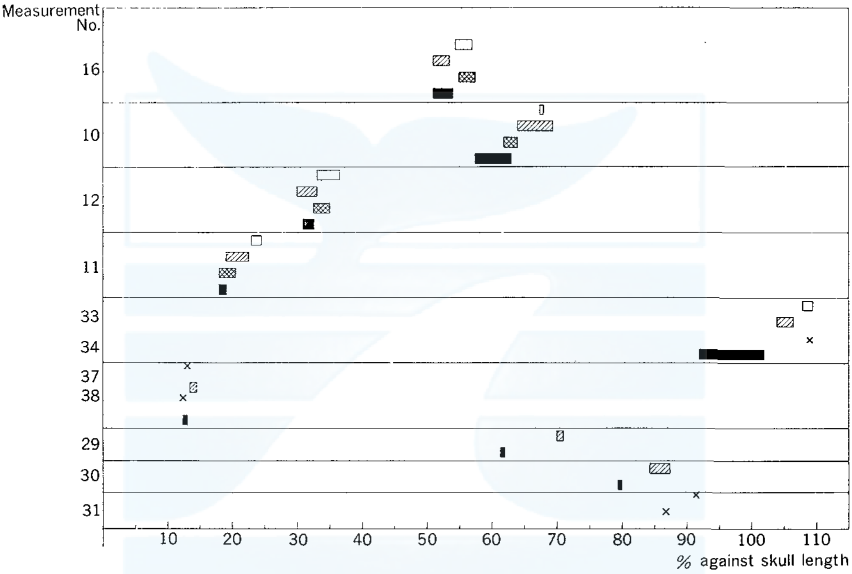

Fig. 6. Comparative cranial indices of the minke whale populations in the North Atlantic, Antarctic, and North Pacific. White . . . North Atlantic, Hatched . . . Antarctic, Double hatched . . . North Pacific (from Tomilin), Black . . . North Pacific (coast of Japan). Each square denotes ranges of value, and cross single value. For measurement number see text.

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The measurements compared in this fugure are the following.

Measurement no.	16.	Breadth of skull, squamosal.
,, ,,	10.	Length of rostrum.
,, ,,	12.	Breadth of rostrum at base.
,, ,,	11.	Breadth of rostrum at middle.
,, ,,	33, 34	Length of mandible, curved.
,, ,,	37, 38	Height of mandible at coronoid.
,, ,,	29.	Tip of premaxillaries to anterior end of palatine.

,, ,, 30. Tip of premaxillaries to posterior end of palatine.

,, ,, 31. Tip of premaxillaries to posterior end of ptergoid.

For the measurements 29, 30, and 31 only the data in the present paper are available.

In the greatest breadth of the skull at squamosal the Antarctic specimens differ from those from the North Atlantic and North Pacific (adult), but similar to those of the juvenile specimens from the North Pacific (M. no. 16). Tomilin (1967) found relatively faster growth of the zygomatic and orbital width and in his juvenile specimen (cited from Cowan, 1939) this value is 52.7 percent of the skull length and come into ranges of specimens from the coast of Japan. If this is true the minke whale from the Antarctic has more narrower skull than those from the northern hemisphere. The length of rostrum is greater in the North Atlantic and Antarctic specimens than in the North Pacific specimens. The breadth of the rostrum at its base as well as at middle is shorter in the Antarctic specimen than in the North Atlantic specimen, but rather dubious when compared with the North Pacific specimen. In the figure some differences are also noted in the length of the mandible, but it seems to me that there are some differences in method of measurement, because this length is the length measured along the outer curve of mandible, which is rather difficult to measure correctly. Height of mandible at coronoid seems higher in the Antactic specimen, but samples are very limited and it is premature to arrive at any conclusion.

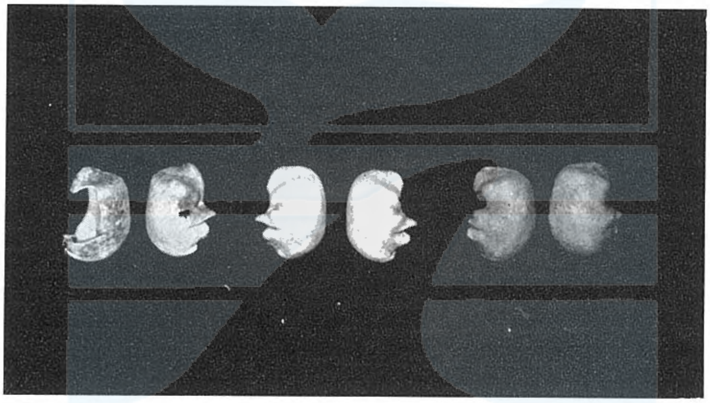

Fig. 7. Tympanic bullae of the minke whale. From left to right. Specimens 71J2793, 71J2883 both from the Antarctic, and AY69B from the North Pacific.

On the inferior side of skull no data is available for the specimen from the North Atlantic. In Fig. 6 are shown, therefore, only measurements of the present specimen. As stated already the vomer extends more anteriorly in the Antarctic specimen, but this is probably due to a difference in age, if an assumption is made that the vomer attains larger size with age independently from premaxillaries and maxillaries. Difference in the relative position of palatine and pterygoid is thought due to the difference in rostrum length. In the Antarctic specimens these bones are situated more posterior part of skull than in the North Pacific specimens. But when the rostrum length is subtracted from these values no dif-

TABLE 3. MEASUREMENTS OF TYMPANIC BULLAE OF THE MINKE WHALE FROM THE ANTARCTIC AND NORTH PACIFIC (in mm)

Specimen	Length		Greatest breadth		Thickness at middle	
	Right	Left	Right	Left	Right	Left
Antarctic						
71J2793	90	92	68	69	47	48
71J2883	94	95	65+*	74	50	48
N. Pacific						
AY69B	90	90	–*	71	46	46

* Broken.

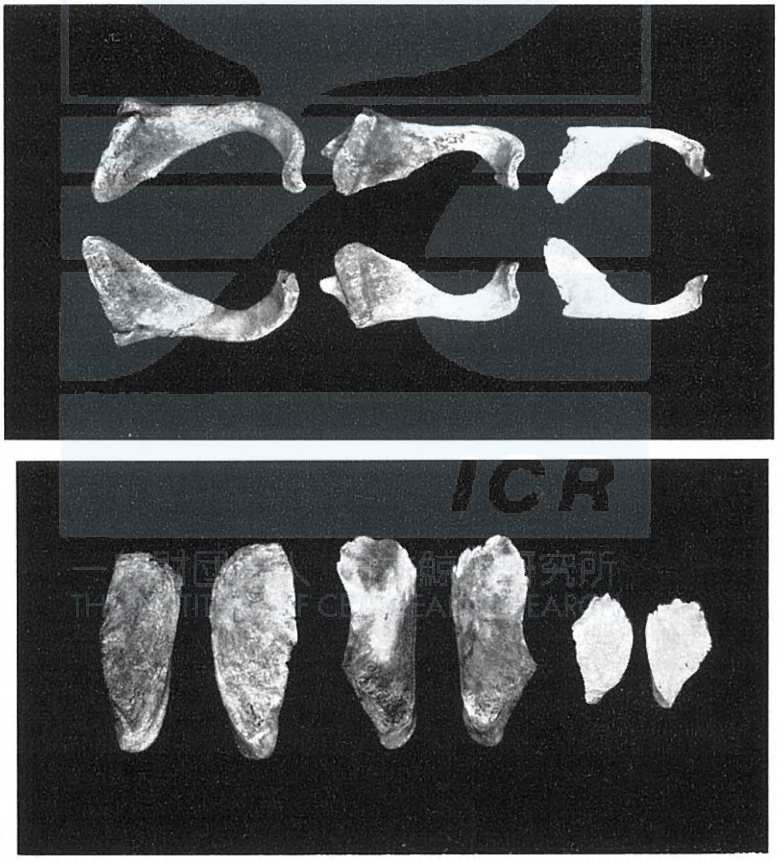

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Fig. 8. Malars (upper) and lachrymals (lower) of the minke whale. From left to right. Specimens 71J2883, 71J2793 both from the Antarctic, and AY69B from the North Pacific.

ference is noted between specimens from different oceans.

In Fig. 7 are shown the tympanic bullae of the minke whale from the Antarctic, compared with those from the North Pacific. As seen from the photograph and measurements in Table 3 no special difference is noted between bullae from different oceans. Bullae of the specimen 71J2883 are larger than other specimens, but in the remaining specimens the size is nearly the same. Compared with other three specimens reported by Omura (1957) also no special feature is noted in the size of bulla, notwithstanding differences in the size of whale body.

The malars and lachrymals are shown in Fig. 8. As seen in the photograph malars are quite similar in shape in general but lachrymals are of some interest. In the Antarctic specimen lachrymals are comparatively large and roughly rectangular in shape, like in other balaenopterid whales, but those from the North Pacific are short and one end is pointing and they resemble closely to another specimen reported by Omura (1957). It is suggested, therefore, this character is of some importance in taxonomic consideration. Measurements of malars and lachrymals are shown in Table 4.

TABLE 4. MEASUREMENTS OF MALARS AND LACHRYMALS OF THE MINKE WHALE FROM THE ANTARCTIC AND NORTH PACIFIC (in mm)

Specimen	Malar				Lachrymal			
	Length 1)		Breadth 2)		Length		Breadth	
	Right	Left	Right	Left	Right	Left	Right	Left
Antarctic								
71J2793	244	240	31	30	264	258	81	82
71J2883	254	253	40	38	247	265	99	104
N. Pacific								
AY69B	169	181	18	17	115	113	63	61

1) Greatest 2) At mid-length

VERTEBRAE (Plates VI-IX)

The vertebral formulae of the present specimens are as follows:

Antarctic specimen
71J2793 C 7, D 12, L 10, Ca 20, Total 49.
71J2883 C 7, D 11, L 12, Ca 20, Total 50.
North Pacific specimen
AY69B C 7, D 11, L 12, Ca 18, Total 48.
AY69A C 7, D 11, L 11, Ca 19, Total 48.

Thus among these specimens from different oceans there is a difference in total number by 1–2. In two specimens from the North Pacific reported by Omura (1957) the total number of vertebrae are 48 and 47. Both have 7 cervicals, 11 dorsals, 12 lumbars, and caudals are 18 and 17 respectively. Tomilin (1967) describes that "Vertebral formula reduced as compared to other rorquals: C 7, D 11, L 12, Ca 18, total 48. However, the vertebral count may reach 50 owing

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to additional vertebrae in the lumbar (up to 13) and caudal (19–20) regions ".

True (1904) lists up the vertebral formulae by various authors then known to him, and among them the largest number is 50, reported by Turner (1892) from Granton, Scotland. To this specimen he describes that " The enumeration of Sir Wm Turner is probably the most accurate, having been made under favorable circumstances, and with the intent of correcting previous errors ". This may be the basis of the above statement of Tomilin. In any case 50 might be rather exceptional number in the northern hemisphere.

The present specimens from the Antarctic have 49 and 50 vertebrae in total respectively, suggesting a difference in this respect. But Ohsumi *et al.* (1970) counted number of vertebrae of three fetuses of the minke whale from the Antarctic. Among these two had 48, and one 49 vertebrae. These fetuses are small and their body length has ranged from 46.5 to 50.5 cm, and the number of caudal vertebrae was uniformly 18. This number of 18 caudals is smaller by two, compared with the present specimens. Further study is needed, therefore, and it may be premature at present to conclude definitely in this character.

The two specimens from the Antarctic have already attained their physical maturity, and vertebral epiphyses are ankylosed to their centra completely. On the other hand the specimens from the North Pacific are both immature, and none of the epiphyses fused to their centra.

Anterior view of cervicals of the specimens 71J2793, 71J2883, and AY69B are shown in Plate VI. As seen in these photographs there are some individual variation in the stage of development of neural spines. In the specimen 71J2793 the neural spine is not developed completely in the 3rd and 4th cervicals. In these vertebrae the right and left spines do not united at their tips, whereas in other two specimens they fused completely. Development of the diapophyses and parapophyses is also subject to individual variation, though it seems certain that the development subject to growth of whale body in general. For example these processes do not fused at their tips on the left side of the 3rd cervical of the specimen 71J2793, whereas complete ring is formed in the specimen 71J2883. But in the 5th cervical complete ring is formed on both sides in the former specimen, whereas ring is not formed on both sides in the latter specimen. In the North Pacific specimen complete ring is formed in the 5th cervical on both sides and on the right side of the 6th. In another two specimens from the North Pacific reported by Omura (1957) none of these rings is formed, even in the axis. A 25 feet (7.5 m) male specimen had cervicals of lesser develpoment than in a 6.6 m male whale.

Accordingly differences in form of cervicals, especially of the development stages of processes, are not thought as important from the taxonomic stand point. However there is one thing to note. In the specimens from the Antarctic the 7th cervicals are lacking parapophysis and there is no sign of tubercle. But in the North Pacific specimen this process is present also on the 7th cervical, as shown in Plate VI. In the another two specimens from the North Pacific also parapophysis is present on both sides, though it is reduced to a tubercle (Omura, 1957). Cowan (1939) states that " in 7 (7th cervical) it (parapophysis) is reduced to a tubercle (in his two specimens from British Columbia, Canada)". For the specimens of *Balaenoptera acutorostrata* (in the North Atlantic) True (1904) describes that "parapophyses of the 7th cervical reduced to a tubercle".

Number of the dorsal vertebrae of the minke whale from the Antarctic is 11 in the specimen 71J2883, but 12 in the specimen 71J2793. The former specimen has 11 pairs of ribs and the latter specimen has 11 pairs and one additional rib. The articulating facet with rib on the distal end of transverse processes appears from the 3rd dorsal vertebra in both specimens. In the former specimen the last dorsal vertebra with the facet is the 9th, and the largest is the 4th. In the latter specimen the corresponding vertebra is 11th and 5th. Both specimens from the North Pacific have 11 dorsals and they coincide with other two specimens reported by Omura (1957).

The number of the lumbar vertebrae is 10 and 12 in the specimens from the Antarctic, and 11 and 12 in the specimens from the North Pacific. If the additional rib in the specimen 71J2793 deemed as accessory and the number of dorsal vertebrae is counted as 11 instead of 12, then the number of dorsal and lumbar vertebrae is not different between the specimens from the different oceans, only the difference is in the number of caudal vertebrae.

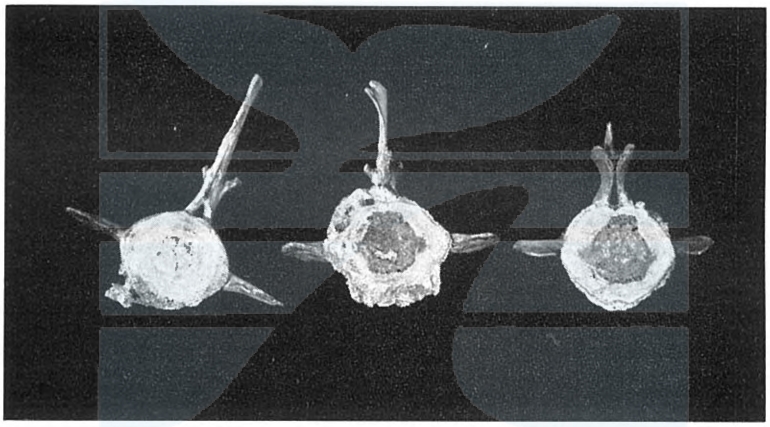

Fig. 9. 2nd, 3rd, and 4th caudal vertebrae of the specimen 71J2883 from the Antarctic. From left to right. 2nd (posterior view), 3rd (posterior view), and 4th (anterior view).

The first caudal vertebra perforated with vertical foramen on transverse processes is the 5th caudal in both specimens from the Antarctic. But in the specimen 71J2793 only the right transverse process is perforated and from 6th both processes have the foramen. The last vertebra with transverse processes is the 7th caudal in both specimens, and the last vertebra with spinous process is the 10th (71J2883) and 11th (71J2793) respectively. In the specimens AY69B and AY69A from the North Pacific the transverse processes perforated from 3rd and 4th caudal vertebrae, and the last vertebra with transverse processes is 7th and 8th, and the last vertebra with spinous process is 10th and 9th caudal respectively. However these character may subject to individual variation and less important from the taxonomic standpoint.

The specimen 71J2883 from the Antarctic is of some interest from the pathological view. In this specimen 2nd, 3rd, and 4th caudal vertebrae are developed abnormally, possibly from some pathological cause (Fig. 9). The posterior and inferior part of the centrum or the articulating facet with chevron bone developed extraordinarilly, forming tubercles. The articlating part of the chevron bone also developed into tubercular large face. The posterior margin of the 3rd caudal also developed and it covers anterior margin of the 4th partly. Similar abnormality was also observed in 2nd and 3rd caudals of a *Ziphius cavirostris* (Omura, 1972)

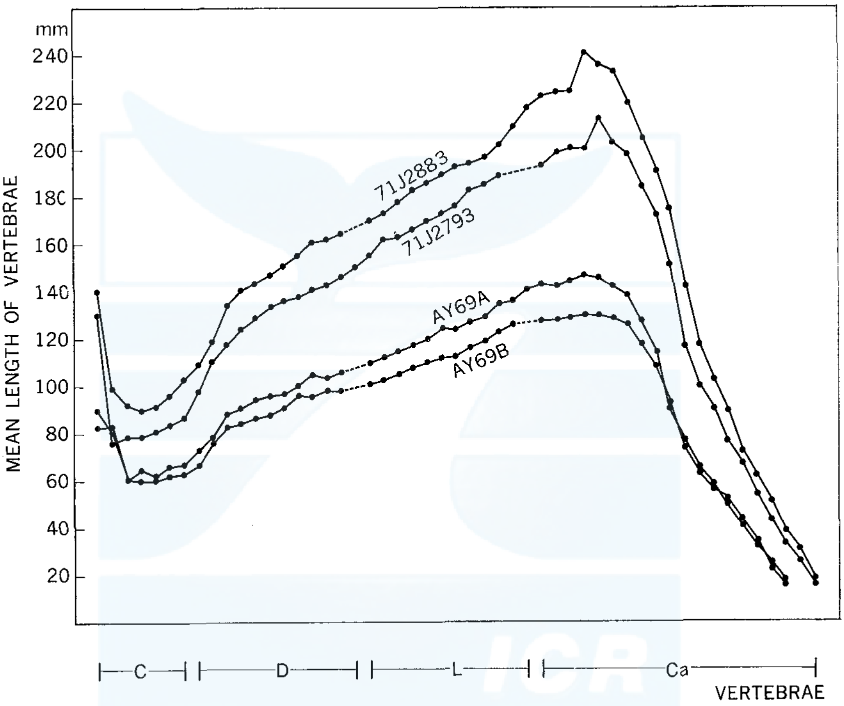

Fig. 10. Comparison of size of vertebrae of minke whales from the Antarctic and North Pacific. Upper two lines denote specimens from the Antarctic, and lower two lines specimens from the North Pacific.

Measurements of vertebrae are shown in Appendix. From these measurements I have calculated the mean length of each centrum using the following formula reported before (Omura, 1971), in order to compare volume of each vertebra.

$$\text{Mean length} = (a \times b \times c)^{1/3}$$

where a, b, and c are the breadth, height, and length of the centrum respectively.

Results of calculation are shown in Fig. 10. I also calculated percentages against their first lumbar, but in this case four lines are overlapping in most parts, except in cervical and 4th-6th caudal regions. The 4th caudal of the specimen 71J2883 shows somewhat higher value compared with neighboring vertebrae, but this is partly due to extraordinary growth as stated already. Also in the specimen 71J2797 the 5th caudal shows high value. In this vertebra the breadth of centrum is the largest among the series of vertebrae. On the other hand two specimens from the North Pacific draw more smoothed curve in these regions. Such differences may be attributable to the difference of age partly, but in general the trend of four curves does not differ materially and such differences shown by Omura (1971) among different species of baleen whales are not noted.

TABLE 5. SKULL AND VERTEBRAL LENGTH OF THE MINKE WHALE FROM THE ANTARCTIC AND NORTH PACIFIC

Specimen	Skull	Cervical	Dorsal	Lumbar	Caudal	Total
			(Actual figures in mm)			
71J2883	2,350	315	1,335	2,309	2,782	9,091
		(7)	(11)	(12)	(20)	
71J2793	2,115	280	1,389	1,764	2,439	7,987
		(7)	(12)	(10)	(20)	
AY69B	1,382	223	935	1,646	1,720	5,906
		(7)	(11)	(12)	(18)	
AY69A	1,140	209	862	1,302	1,590	5,103
		(7)	(11)	(11)	(19)	
			(Percentage)			
71J2883	25.85	3.47	14.68	25.40	30.60	100.0
71J2793	26.48	3.50	17.39	22.09	30.54	100.0
AY69B	23.40	3.78	15.83	27.87	29.12	100.0
AY69A	22.34	4.10	16.89	25.51	31.16	100.0

Figures in parentheses show number of vertebrae.

In Table 5 are shown the total length of skull and vertebrae of the minke whale from the Antarctic and North Pacific. The vertebral length is the total of the length of each centrum. Accordingly this length does not show actual length *in situ*. Further the vertebral length is shown dividing into four regions of cervical, dorsal, lumbar, and caudals. The length of skull and each region of vertebrae are also shown their percentage figures against total length of skul and vertebrae. In comparing these figures it will be noted that in the length of cervicals and caudals there is no significant difference between specimens from the Antarctic and North Pacific. The skull length is somewhat larger in the specimens from the Antarctic than those from the North Pacific. The dorsal and lumbar regions show individual variation, reflected by different number of vertebrae, but when the two regions are considered together, then the specimens from the North Pacific have somewhat larger dorsal and lumbar regions than those from the Antarctic. The combined

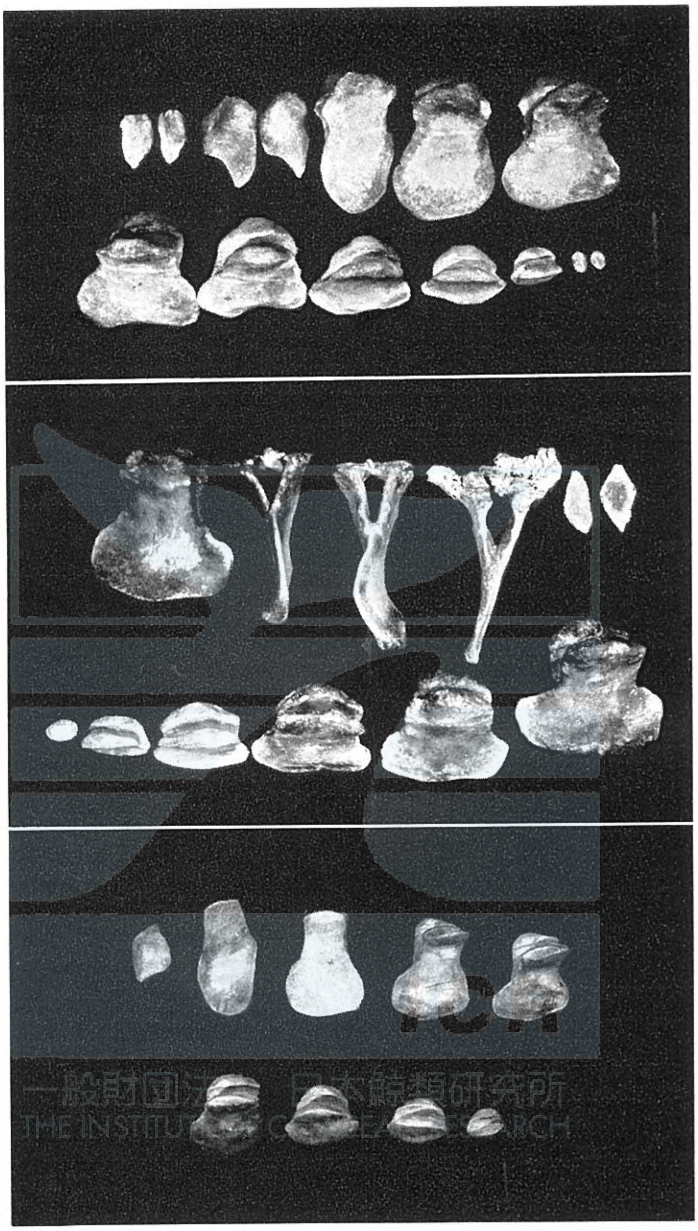

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Fig. 11. Chevron bones of the minke whale. Upper. Specimen 71J2793 from the Antarctic. Center. Specimen 71J2883 from the Antarctic. Lower. Specimen AY69B from the North Pacific. From left to right. 1st, 2nd, 3rd and so on, but in the center photograph from right to left. The 2nd, 3rd, and 4th chevrons of 71J2883 are anterior view, showing bone bridge at proximal end of laminae.

percentages of these regions are around 40 percent in the specimen from the Antarctic and the corresponding figure from the North Pacific exceed 42 percent. In the specimen reported by Omura (1971) this figure is 44.66 percent of the total length, and the skull length occupies 22.25 percent of the total.

The proportional length of skull and vertebrae may differ between adult and juvenile specimens even in the same species or population, and definite conclusion is very difficult to reach. But the last mentioned specimen is the largest among I have ever examined of the minke whale skeleton from the North Pacific and semi-adult as stated already. Its body length is 7.5 m and the skull length is 1,520 mm. It is suggested, therefore, the Antarctic minke whale has more larger skull compared with that from the North Pacific, and this is a reflection of more longer rostrum as shown in Fig. 6. In the external body proportions this is also suggested in the proportional length from tip of snout to center of eye (Ohsumi *et al.*, 1970).

TABLE 6. MEASUREMENTS OF CHEVRON BONES OF THE MINKE WHALE FROM THE ANTARCTIC AND NORTH PACIFIC (in mm)

	71J2793		71J2883		AY69B		AY69A	
	Length	Height	Length	Height	Length	Height	Length	Height
1	*43 47	*80 77	*38 52	*93 97	*57 ?	*86 ?	*55 ?	*98 ?
2	*73 79	*124 132	91	266	78	164	45	101
3	103	202	162	270	108	156	82	134
4	147	213	190	246	112	144	88	128
5	176	186	211	229	110	124	84	112
6	172	149	207	197	99	107	74	96
7	153	119	171	154	104	80	65	82
8	146	101	169	120	86	60	62	67
9	121	80	138	89	52	30	—	—
10	74	46	87	55	—	—	—	—
11	*32 29	*22 22	*47 ?	*33 ?	—	—	—	—

* Not united. Question mark means missing.

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The chevron bones of the two specimens from the Antarctic and a specimen from the North Pacific are shown in Fig. 11. From the minke whale from the Antarctic 11 chevron bones were secured from the both specimens. In the specimen 71J2793 the first two and the last one, and in 71J2883 the first and the last are not united of the right and left laminae. In the specimen from the North Pacific 9 chevrons were obtained and only in the first two laminae separated. Chevron bones are of little taxonomic value, but chevrons of the specimen 71J2883 are of some interest. As seen in Fig. 9 in the 2nd, 3rd, and 4th chevrons there are bony bridges connecting right and left laminae at their proximal ends. In the 2nd it developed abnormally as stated already, but in the 3rd and 4th no such abnormality is observed. One explanation may be, therefore, that the bony bridge is formed when the whale has attained very high age. Of course this is not conclusive and further study is needed. In Table 6 measurements of chevron bones are given.

RIBS AND STERNUM (Plates X and XI)

Ribs of the minke whale from the Antarctic are massive in general compared with those of the North Pacific specimen, but this may of course be attributable to the difference in age. There is no difference in number, having 11 pairs of ribs in specimens from the Antarctic and also from the North Pacific, but as stated already a specimen from the Antarctic (71J2793) had one small accessory rib in addition to 11 pairs. In one specimen from the Antarctic (71J2793) from 2nd to 9th rib are doble-headed, but in other specimen (71J2883) clear double-head is observed only in the 2nd and 3rd. Specimens from the North Pacific are similar to the latter specimen in this respect. Measurements of ribs are shown in Table 7.

TABLE 7. STRAIGHT LENGTH OF RIBS OF THE MINKE WHALE FROM THE ANTARCTIC AND NORTH PACIFIC (in mm)

No.	71J2793		71J2883		AY69B		AY69A	
	Right	Left	Right	Left	Right	Left	Right	Left
1	721	730	794	*570+	505	510	435	417
2	1,060	1,103	1,133	1,153	733	740	627	630
3	1,216	1,229	1,335	1,333	880	875	730	742
4	1,279	1,263	1,384	1,380	907	915	755	762
5	1,163	1,262	1,410	1,381	895	910	753	748
6	1,210	1,206	1,355	1,389	865	875	735	718
7	1,163	1,156	1,326	1,295	838	863	730	714
8	1,096	1,085	1,209	1,219	*715+	830	682	690
9	1,030	1,025	*1,160+	1,155	805	805	643	642
10	*910+	987	1,200	1,160	780	755	630	622
11	*770+	*826+	990	1,202	*752+	*800+	427	352
12	—	*448+	—	—	—	—	—	—

* Broken and not estimated.

TABLE 8. MEASUREMENTS OF STERNUM OF THE MINKE WHALE FROM THE ANTARCTIC AND NORTH PACIFIC (in mm)

	71J2793	71J2883	AY69B	AY69A
Length	394	388	275	205
Breadth	348	365	205	167

The form of the sternum is cruciate in general in the specimens both from the different oceans, but it varies individually and has less taxonomic value. Photographs of sterna of the specimens 71J2793, 71J2883, and AY69B are shown in Plate XI, but quite similar forms are already reported from the minke whale from the North Atlantic (True, 1904; Tomilin, 1967). Measurements of sterna are shown in Table 8.

SCAPULA AND FLIPPER BONES (Plates XII-XVI)

Scapullae of the two specimens from the Antarctic and one specimen from the North Pacific are shown in Plate XII. They are typical of the balaenopterid whales in form. Acromion and coracoid are well developed. In the specimen 71J2793 the superior margin is somewhat depressed compared with other two specimens. The upper curvature may subject to individual variation, though Tomilin (1967) describes that in the juveniles, the contour of this part of the body is more convex, and in the adults, more or less straightened. In Table 9 measurements of scapullae are shown, together with ratio of breadth against height of the scapula. As seen in this table the specimen AY69A shows somewhat smaller value in this ratio, whereas in other specimens no remarkable difference is noted. But the relative size of the bone increases with age, growing much more intensively in width than in height (Tomilin, 1967). No special difference is noted between scapullae from the different oceans.

TABLE 9. MEASUREMENTS OF SCAPULA OF THE MINKE WHALE FROM THE ANTARCTIC AND NORTH PACIFIC (in mm)

	71J2793		71J2883		AY69B		AY69A	
	Right	Left	Right	Left	Right	Left	Right	Left
Greatest breadth	812	805	874	864	535	544	394	391
Greatest height	449	452	491	491	312	307	260	258
Length of acromion, inferior	219	217	253	251	127	132	102	92
Breadth of acromion, distal end	65	69	72	79	39	42	25	26
Length of coracoid, inferior	87	84	95	98	65	69	—	—
Breadth of coracoid, distal end	50	52	59	60	26	28	—	—
Length of glenoid fossa	163	163	182	192	126	129	142*	138*
Breadth of glenoid fossa	121	118	133	133	79	80	69	68
Ratio of breadth against height	1.81	1.78	1.78	1.76	1.72	1.77	1.52	1.52

* Including coracoid.

Humerus, radius, and ulna (Plates XIII and XIV) also present no noticeable feature between samples from the Antarctic and North Pacific. In the former specimens epiphyses are united to the body in humerus completely, and in radius and ulna only the proximal epiphyses are united, and distal epiphyses are not ankylosed in both specimens. In the specimens from the North Pacific none of the epiphyses is united to the body. Of course this difference is due to the difference in age, and complete ankylosis in these regions of body may occur when the whale reached very high age, long after the completion of vertebrae. Measurements of humerus, radius, and ulna are shown in Table 10.

Carpals are of no special feature. They are shown in Plates XV and XVI, together with phalanges. Measurements of phalanges are shown in Table 11. As seen in Plates and Table no distinction is noted between specimens from

TABLE 10. MEASUREMENTS OF HUMERUS, RADIUS, AND ULNA OF THE MINKE WHALE FROM THE ANTARCTIC AND NORTH PACIFIC (in mm)

	71J2793		71J2883		AY69B		AY69A	
	Length	Breadth	Length	Breadth	Length	Breadth	Length	Breadth
Humerus								
Right	284	152	303	164	232	110	191	118*
Left	288	151	306	161	229	109	190	118*
Radius								
Right	549	89	573	119	379	67	299	50
Left	550	88	577	117	383	67	301	48
Ulna								
Right	501	68	540	85	342	45	301	36
Left	499	67	544	84	345	44	306	35

Note: Length and breadth measured at middle.
* Greatest.

TABLE 11. LENGTH OF PHALANGES OF THE MINKE WHALE FROM THE ANTARCTIC AND NORTH PACIFIC (in mm)

Specimen	Phalanx	Right				Left			
		I	II	III	IV	I	II	III	IV
71J2793	1	75	99	80	56	75	101	79	56
	2	75	85	77	53	76	88	77	55
	3	62	62	62	46	62	62	62	46
	4	46	43	44	34	46	46	46	31
	5	25	29	32	—	29	31	35	—
	6	—	21	23	—	—	23	24	—
	7	—	15	17	—	—	18	16	—
	8	—	10	—	—	—	11	7	—
71J2883	1	86	109	89	61	89	109	91	61
	2	96	112	98	60	96	114	100	61
	3	77	80	84	63	78	84	84	63
	4	56	59	63	50	53	60	63	50
	5	—	40	47	—	—	41	47	—
	6	—	29	34	—	—	28	34	—
	7	—	—*	21	—	—	20	21	—
	8	—	—*	—	—	—	14	—	—
AY69B	1	51	64	53	45	52	64	55	44
	2	49	57	50	39	49	56	51	38
	3	39	42	40	31	39	41	41	31
	4	26	28	28	17	25	29	28	16
	5	—	19	18	—	—	19	18	—
	6	—	13	11	—	—	12	11	—
	7	—	7	—	—	—	8	—	—
	8	—	—*	—	—	—	6	—	—

Note: Metacarpals are included,
* Possibly missing.

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different oceans, except their size. The phalangeal formula of these specimens is I_{4-5}, II_8, III_{6-8}, IV_4, which is in the range of the formula I_{3-5}, II_{6-9}, IV_{5-8}, V_{3-4} given by Tomilin (1967). Of course his IV and V correspond with III and IV in this paper

HYOID AND PELVIC BONES

Hyoid bones of the two specimens from the Antarctic have already been treated by Satake and Omura (1974), together with other specimens, and no further description is needed.

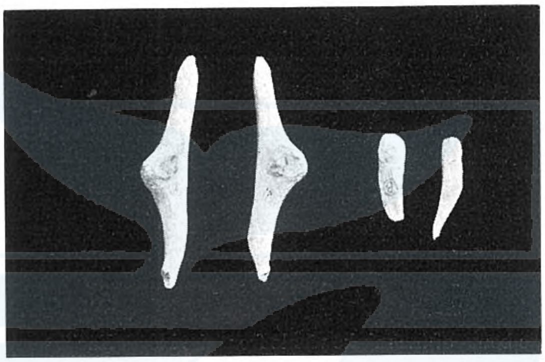

Fig. 12. Pelvic bones of the minke whale from the Antarctic. Left. Specimen 71J2793, a male of 8.5 m long. Right. Specimen 71J2883, a female of 9.8 m long.

Pelvic bone is of some interest morphologically. As seen in Fig. 12 the pelvic bones of the male are much larger than those of female. The spcimen 71J2793 is a male of 8.5 m in length and the specimen 71J2883 is a female of 9.8 m. Their ages are 25 years and 39 years respectively (see Table 1). Accordingly this difference in size and form is attributable to the difference by sex. Hosokawa (1951) found marked sexual and specifical dimorphism in the form of pelvis in the fin and blue whale fetuses. Omura *et al.* (1971) also describe sexual difference of pelvic bones in the black right whale. In this case male has much larger bones than in female.

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In the specimen 71J2793 the length of right and left pelvic bones are 200 and 204 mm and their width are 46 and 42 mm respectively. The corresponding figures of the specimen 71J2883 are 78, 93, and 23, 19 mm respectively. The form of the right and left bone is similar in the former specimen, but in the latter somewhat different and one is more slender than the other.

In the specimens from the North Pacific pelvic bones were missing in the specimen AY69B, but in AY69A, a male of 5.4 m long, the length and width of both pelvic bones are 84, 30, and 87, 27 mm respectively. Thus the size is a bit larger than that of the specimen 71J2883. The form resembles to the specimen reported by Omura (1957) from a 18 feet (5.4 m) male. He also presents photograph showing the pelvic bones of a 25 feet (7.5 m) male (Fig. 13). In this specimen the pelvic bones are much elongated. This whale was a semi-adult as already stated, but possibly the whale was mature sexually, because average body length at sexual maturity is 22–23 feet (6.6–6.9 m) in males (Omura and Sakiura, 1956). When the pelvic bones of this specimen are compared with those of the specimen 71J2793 a difference is noted in their form. In the former specimen from the North Pacific the length of pelvic bones are 174 and 181 mm respectively and a bit smaller than the latter specimen from the Antarctic, but still quite comparable.

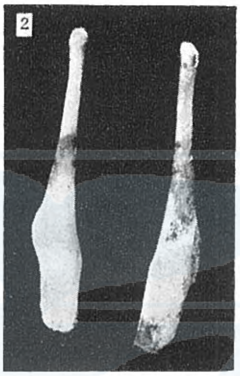

Fig. 13. Pelvic bones of the minke whale from the North Pacific. A male of 7.5 m long (cited from Omura, 1957).

In this specimen the tubercles, tuberculum laterale, are less eminent and situated more posteriorly than the specimen from the Antarctic. Further in the specimen from the North Pacific the cranial processes are long and much slender than in those from the Antarctic. The percentage figures of width against length of right and left pelvic bones are 16 and 14 percent respectively in the specimen from the North Pacific, whereas the corresponding figures of the specimen from the Antarctic are 23 and 21 percent respectively. This difference in ratio is a reflection of less developed lateral tubercles in the specimen from the North Pacific. For the female no comparable material is available for the North Pacific minke whale.

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DISCUSSION

In the foregoing chapters the characteristics of the minke whale from the Antarctic are discussed mainly comparing with the whale from the North Pacific. The minke whale from the North Pacific was named *Balaenoptera davidsoni* by Scammon (1872). True (1904) compared two skulls from the North Pacific, including the type of *davidsoni*, with those of *acutorostrata* from the North Atlantic. His conclusion was " there cannot be said to be a constant difference in any of the proportions between the specimens from the two oceans ". Cowan (1939) and Omura (1957) supported this conclusion, but Tomilin (1967) found that " Cranial indices of both populations show that the Atlantic individuals (adult and, particularly, juvenile) are characterized by a relatively longer rostrum ". And he concluded " We consider this character, which is manifested also by the general proportions of the body (Table 61), as a significant difference between the North Atlantic subspecies *Balaenoptera acutorostrata acutorostrata* Lecépède, 1803–1804 and the North Pacific *Balaenoptera acutorostrata davidsoni* Scammon, 1872 ". In this connection I like to point out the difference in the form of the transverse white band on the flipper. This problem was first raised by Scammon (1872), but his description is not explicit as pointed out by True (1904) and his figure (Scammon, 1874) of white band is not correct.

In the minke whale from the North Pacific the anterior margin of this white band runs nearly perpendicular to the flipper and there is a promontory or projection of white area into the black, towards the mid-line. This is well shown in Plate II of Omura and Sakiura (1956). Almost all minke whales from the North Pacific investigated by myself and my colleague exhibit this pattern. The minke whale taken at Los Angeles Harbor also has similar pattern (Fig. 2 of Fry, 1935). On the other hand in the minke whale from the North Atlantic the margin of the white band draws roughly semi-circle and no forward projection of white area is noted. This form is well demonstrated in the upper photograph of Plate I of Moore and Palmer (1955) and also in Fig. 3 of Sergeant (1963).

In the skull no other difference than that pointed out by Tomilin seems to present between the specimens from the North Pacific and North Atlantic. Judged from the photographs shown by True (1904) the anterior margin of the nasals is flattened as described by Tomilin (1967). The triangular region formed by frontal and parietal on the vertex of the skull, between nasals and supraoccipital which shows lesser degree of telescoping, seems also present, although I could not find out any description on this particular point of the skull in other literatures. The form of the hamular process of the Massachusetts specimen is quite similar to my specimen from the North Pacific. In the post-cranial bones differences are noted in two characters between specimens from the Antarctic and North Pacific. One is the presence of parapophyses on the 7th cervical in the specimens from the North Pacific, but lacking in those from the Antarctic. The North Atlantic specimens have also this processes on the 7th cervical, as already stated. Another difference is in the form of the pelvic bones, but I could not examin this on the North Atlantic specimen.

The number of vertebrae does not differ between specimens from the North Atlantic and North Pacific, but further counting is needed in whales from the Antarctic. A distinction is noted in the hyoid bone between specimens from the Antarctic and North Pacific, the former specimen having more longer stylohyals proportionally (Satake and Omura, 1974), but nothing is known of the specimen from the North Atlantic.

In the external morphological characters which separate minke whales from the Antarctic from those from the northern hemisphere are: 1) no white band present on flipper, and 2) baleen plates are white at the front of the series and

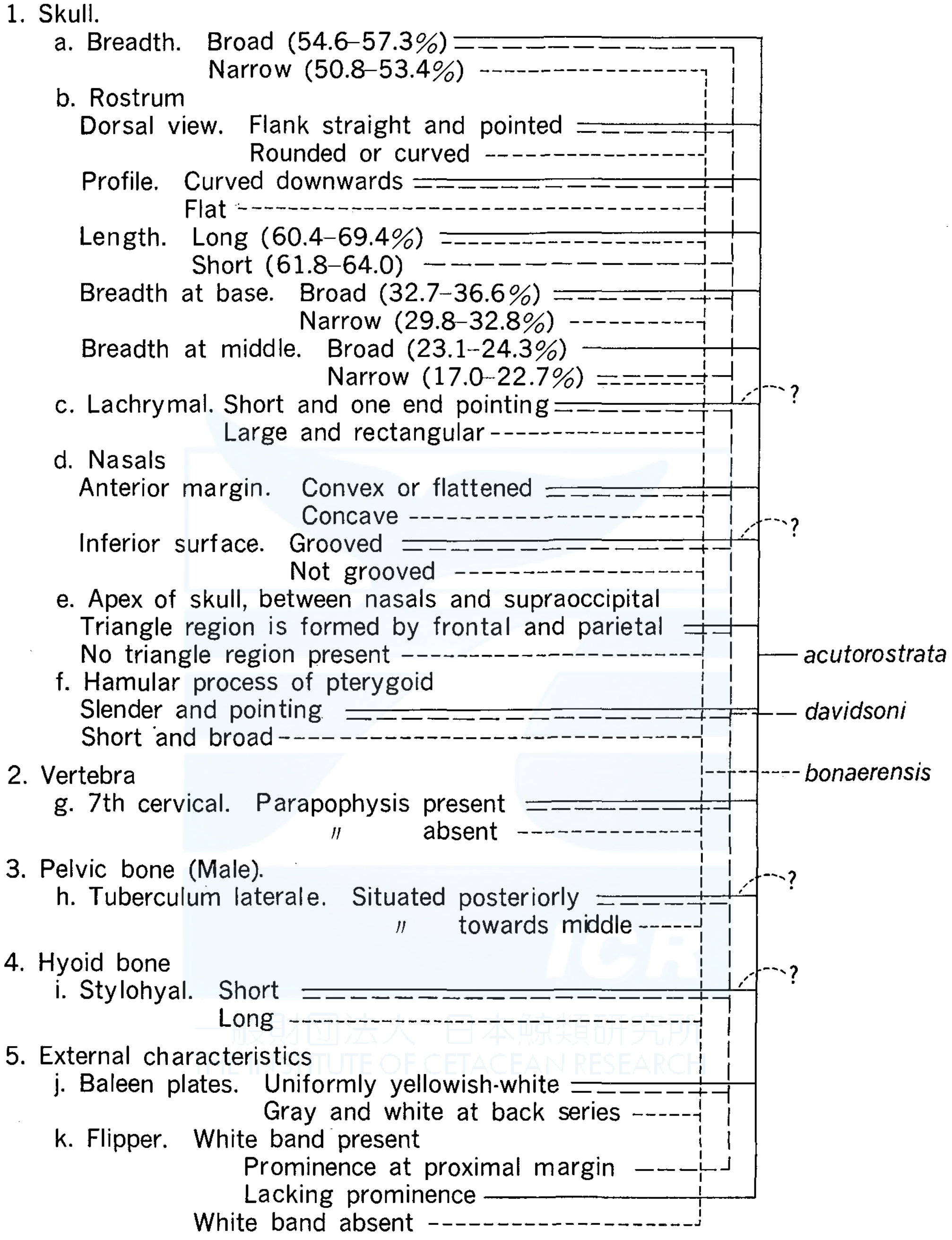

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Fig. 14. Relationship among the minke whale populations from the North Atlantic (*acutorostrata*), North Pacific (*davidsoni*), and Antarctic (*bonaerensis*).

gray and white at the back, whereas uniform yellowish-white in whales in the northern hemisphere (Williamson, 1961; Utrecht and Spoel, 1962; Kasuya and Ichihara, 1965; Ohsumi *et al.*, 1970).

In Fig. 14 the relationship among the minke whale populations from the North Atlantic (*acutorostrata*), North Pacific (*davidsoni*), and Antarctic (*bonaerensis*) is shown. In the figure the skull indices are the percentages figures against skull length, and all from the mature specimens, cited from Tomilin (1967. Table 61) for the North Atlantic and North Pacific specimens. These figures are the ranges of one or two groups, for example the breadth of skull shows ranges of two populations of *acutorostrata* and *davidsoni* altogether on one hand (broad) and ranges of another population *bonaerensis* on the other (narrow).

Fig. 14 is a summary of this study and the next problem is the validity of these characters. The most weak point in osteological study of large whales is only limited number of samples are available, and it is difficult to ascertain whether the difference is specific or subspecific or only individual or by growth. There are rather wide individual variations in measurements of skulls and other bones. Form of rostrum and other particular bones would also subject to variation. Relation between form of nasals and flat or bending down rostrum is of some interest. In the sei whale (*Balaenoptera borealis*) nasals are convex and rostrum is bending, whereas in the Bryde's whale (*B. edeni*) nasals are concave and rostrum is flat. It is thought, therefore, these are connected with food and feeding or other ecological matters of whales concerned. But no conclusion cannot be reached at present. Accordingly further study is needed in order to clarify these characters listed in Fig. 14. But even at this stage it can be said that the Antarctic population *bonaerensis* is more distinctly separated from other two populations in the northern hemisphere, i.e. *acutorostrata* and *davidsoni*, though this distinction may not specific level. Further it has attained a more advanced stage of telescoping than the populations in the northern hemisphere.

The North Pacific population *davidsoni* is separated from the North Atlantic population *acutorostrata* in having relatively shorter rostrum and different pattern of white band on the flipper. The Antarctic population *bonaerensis* is separated from the above two populations in having relatively narrow skull and rostrum, and in other 9 characters, as shown in Fig. 14. The habitat of this population is not confined within the Antarctic waters and it follows south and north migration, but possibly it is limited in the southern hemisphere.

Williamson (1961) found great similarity of this population (his « Balaena » whales) *Balaenoptera bonaerensis* Burmeister, 1867, and the likelihood that *B. huttoni* Gray, 1874 is also of the same species, and proposed that all three types be regarded as specimens of *B. bonaerensis* provisionally. But he added that " It has yet to be discovered whether this latter is a true and separate species or a subspecies of *B. acutorostrata* ". As already stated the number of vertebrae is not differ, at least at this stage of study, between *B. acutorostrata* and *B. bonaerensis*, though much differences are found in other particular points, it cannot be concluded that *B. bonaerensis* is a distinct species from *B. acutorostrata*.

Another question is the occurrence of the minke whale with white band on flipper in the southern hemisphere (Williamson, 1961). Taylor (1957) reports observation of rorquals in pools in sea-ice in the Crown Prince Gustav Channel, Antarctic peninsula, and describes that " some of the rorquals had light patches on the upper surface of their flipper ". But no information is available at present to know the relationship between this population of the minke whale in the southern hemisphere and *B. acutorostrata*, nor between this population and *bonaerensis*.

ACKNOWLEDGMENTS

I am much indebted to many persons during the course of this study. First of all my sincere thanks are due to Dr S. Ohsumi, Far Seas Fisheries Research Laboratory, who kindly secured two sets of skeleton of the minke whale from the Antarctic, and to Mr T. Miyodori, owner of minke whale catcher boat operating on the coast of Japan, who supplied also two sets of skeleton from the North Pacific. These four skeletons form the basis of this study.

During the preparation of bones as complete sample many persons helped me greatly, including Dr S. Ohsumi and Dr T. Kasuya and his co-workers at Ocean Research Institute of the University of Tokyo. Dr A. Kawamura, Mr S. Machida and Miss Yuko Satake of Whales Research Institute have assisted not only in preparation of bones but also in taking measurements and photographs. I am very grateful for them all.

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APPENDIX. MEASUREMENTS OF VERTEBRAE OF THE MINKE WHALE FROM THE ANTARCTIC AND NORTH PACIFIC (in mm.)

1. SPECIMEN 71J2793 FROM THE ANTARCTIC

Serial no.	Vertebral no.	Greatest breadth	Greatest height	Centrum			(axbxc)$^{1/3}$
				Breadth (a)	Height (b)	Length (c)	
1	C 1	383	222	207	R. 131 L. 133	81	130
2	2	527	220	182	R. 125 L. 126	29	76
3	3	454	176	157	106	30	79
4	4	461	173	149	112	30	79
5	5	454	185	143	115	32	81
6	6	441	211	141	118	35	84
7	7	455	228	142	118	43	87
8	D 1	479	240	149	118	53	98
9	2	470	273	166	117	68	110
10	3	469	332	158	117	88	118
11	4	527	358	159	119	100	124
12	5	608	381	162	119	111	129
13	6	699	408	161	124	121	134
14	7	758	424	165	122	128	137
15	8	791	438	161	121	135	138
16	9	801	435	165	122	140	141
17	10	804	445	166	123	142	143
18	11	790	455	168	125	149	146
19	12	781	474	168	130	154	150
20	L 1	736	492	172	141	153	155
21	2	730	493	176	143	161	162
22	3	723	519	179	145	167	163
23	4	698	511	182	148	170	166
24	5	678	501	186	152	173	170
25	6	646	525	187	157	175	173
26	7	639	525	190	159	181	176
27	8	618	555	194	163	190	183
28	9	601	550	196	165	195	185
29	10	585	550	202	167	199	189
30	Ca 1	521	549	209	170	203	193
31	2	482	518+	208	180	212	199
32	3	445	515	207	182	215	201
33	4	384	403+	212	181	213	201
34	5	326	388	234	193	210	213
35	6	279	330	219	186	204	203
36	7	231	265	216	182	198	198
37	8	T.P. disappear	252	190	177	184	184
38	9		216	165	181	170	172
39	10		189	155	172	130	151
40	11		143	137	133	88	117
41	12		S.P. disappear	124	109	74	100
42	13			109	96	69	90

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APPENDIX. Continued.

Serial no.	Vertebral no.	Greatest breadth	Greatest height	Centrum Breadth (a)	Centrum Height (b)	Centrum Length (c)	$(a\times b\times c)^{1/3}$
43	14			94	83	62	77
44	15			81	70	54	67
45	16			65	54	45	54
46	17			51	42	36	43
47	18			40	31	30	33
48	19			35	21	25	26
49	20			18	15	17	17

2. SPECIMEN 71J2883 FROM THE ANTARCTIC.

Serial no.	Vertebral no.	Greatest breadth	Greatest height	Centrum Breadth (a)	Centrum Height (b)	Centrum Length (c)	$(a\times b\times c)^{1/3}$
1	C 1	386	247	227	R. 146 L. 137	85	141
2	2	677	260	211	115	39	99
3	3	476	217	187	121	34	92
4	4	559	206	173	123	34	90
5	5	511	221+	172	124	36	92
6	6	541	263	170	132	39	96
7	7	546	266	171	132	48	103
8	D 1	575	258	174	132	56	109
9	2	579	324	181	132	70	119
10	3	538	373	182	137	96	134
11	4	621	408+	183	140	109	141
12	5	705	429	178	140	120	144
13	6	798	445	174	142	129	147
14	7	855	462	173	142	140	151
15	8	896	468	178	142	148	155
16	9	918	480	187	147	151	161
17	10	924	486	183	149	156	162
18	11	918	502	185	151	160	165
19	L 1	786	516	183	165	164	170
20	2	798	533	186	167	167	173
21	3	755+	565	193	167	176	178
22	4	767	575	197	172	180	183
23	5	760	511+	201	173	186	186
24	6	634+	589	202	179	187	189
25	7	723	624	203	186	191	193
26	8	705	622	207	179	198	194
27	9	665+	623	212	178	202	197
28	10	575+	483+	217	183	209	202
29	11	564+	451+	224	188	220	210
30	12	612	616	234	194	229	218
31	Ca 1	561+	553+	239	199	234	223
32	2	534	598	234	205	239	225
33	3	512	561	234	204	239	225
34	4	468	424+	253	236	235	241
35	5	400+	435+	268	208	237	236
36	6	332	350+	266	206	231	233
37	7	266	325+	244	200	219	220

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APPENDIX. Continued.

Serial no.	Vertebral no.	Greatest breadth	Greatest height	Centrum			$(axbxc)^{1/3}$
				Breadth (a)	Height (b)	Length (c)	
38	8	T.P. disappear	290	219	195	203	205
39	9		254	187	201	186	191
40	10		220	171	199	157	175
41	11		S.P. disappear	153	174	107	142
42	12			145	127	88	117
43	13			117	112	80	102
44	14			100	98	75	90
45	15			70	81	66	72
46	16			68	66	54	62
47	17			57	52	46	51
48	18			45	35	38	39
49	19			47	22	30	31
50	20			24	14	18	18

3. SPECIMEN AY69B FROM THE NORTH PACIFIC.

Serial no.	Vertebral no.	Greatest breadth	Greatest height	Breadth (a)	Height (b)	Length (c)	$(axbxc)^{1/3}$
1	C 1	272	176	167	R. 108 L. 98	41	90
2	2	364	188	152	76	46	81
3	3	319	147	122	79	23	61
4	4	307	138	119	81	29	65
5	5	320	156	117	83	25	62
6	6	314	174	116	85	29	66
7	7	336	185	117	85	30	67
8	D 1	366	193	122	85	38	73
9	2	343	232	117	82	49	78
10	3	345	272	121	82	69	88
11	4	382	288	116	83	78	91
12	5	420	308	116	84	84	94
13	6	466	320	116	83	91	96
14	7	505	330	116	81	96	97
15	8	538	340	118	82	102	100
16	9	559	344	129	85	106	105
17	10	573	360	121	85	109	104
18	11	572	377	120	87	113	106
19	L 1	558	388	124	91	117	110
20	2	564	400	124	94	120	112
21	3	562	414	128	95	124	115
22	4	582	421	129	98	128	119
23	5	546	?	130	101+	131	120
24	6	548	447	133	106	134	124
25	7	533	445	132	105	137	124
26	8	525	440	133	109	141	127
27	9	est. 490	422	135	110	145	129
28	10	est. 462	419	141	113	153	135
29	11	429	425	141	115	156	136
30	12	392	415	147	118	160	141
31	Ca 1	est. 352	392	148	123	161	143

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APPENDIX. Continued.

Serial no.	Vertebral no.	Greatest breadth	Greatest height	Centrum			$(a \times b \times c)^{1/3}$
				Breadth (a)	Height (b)	Length (c)	
32	2	325	366	145	123	162	142
33	3	302	327	151	126	161	145
34	4	255	286	157	129	157	147
35	5	221	252	157	128	154	146
36	6	178	225	153	126	149	142
37	7	146	200	144	128	142	138
38	8	T.P. disappear	175	126	127	129	127
39	9		147	117	121	105	114
40	10		108	101	100	72	90
41	11		S.P. disappear	87	83	62	77
42	12			74	68	55	65
43	13			67	58	51	58
44	14			54	52	45	50
45	15			43	41	39	41
46	16			35	30	31	32
47	17			25	22	27	25
48	18			20	16	18	18

4. SPECIMEN AY69A FROM THE NORTH PACIFIC.

Serial no.	Vertebral no.	Greatest breadth	Greatest height	Centrum			$(a \times b \times c)^{1/3}$
				Breadth (a)	Height (b)	Length (c)	
1	C 1	260	170	159	R. 107 L. 107	34	83
2	2	305	169	152	81	47	83
3	3	286	148	115	80	24	60
4	4	288	149	111	81	24	60
5	5	285	163	108	82	26	61
6	6	293	174	109	83	26	62
7	7	306	175	110	82	28	63
8	D 1	312	180+	114	79	34	67
9	2	308	204	119	78	48	76
10	3	321	235	119	77	63	83
11	4	368	248	115	75	72	85
12	5	404	254	112	75	78	87
13	6	444	264	110	74	85	88
14	7	466	273	110	76	89	91
15	8	494	283	116	80	94	96
16	9	502	290	113	78	96	95
17	10	496	297	113	84	100	98
18	11	480	303	112	82	103	98
19	L 1	est. 460	314	114	86	105	101
20	2	460	320	115	89	108	103
21	3	460	326	116	92	110	105
22	4	452	335	117	95	113	108
23	5	449	292+	117	98	115	110
24	6	441	353	122	99	117	112
25	7	429	350	121	99	119	113
26	8	414	350	124	102	122	116
27	9	390	349	130	103	127	119

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APPENDIX. Continued.

Serial no.	Vertebral no.	Greatest breadth	Greatest height	Centrum			$(axbxc)^{1/3}$
				Breadth (a)	Height (b)	Length (c)	
28	10	377	343	131	108	131	123
29	11	361	333	133	112	135	126
30	Ca 1	318	329	132	115	138	128
31	2	285	304	129	115	140	128
32	3	265	275	131	115	144	129
33	4	230	250	135	115	140	130
34	5	197	229	138	117	136	130
35	6	173	206	140	116	133	129
36	7	144	179	135	114	129	126
37	8	120	154	119	114	120	118
38	9	T.P. disappear	132	103	115	108	109
39	10		S.P. disappear	94	103	80	92
40	11			82	82	61	74
41	12			68	69	53	63
42	13			65	58	49	57
43	14			59	50	45	51
44	15			51	41	38	43
45	16			39	31	31	33
46	17			23	23	21	22
47	18			17	14	16	16
48	19			10	9	8	9

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EXPLANATION OF PLATES

PLATE I

Dorsal view of skull of the minke whale from the Antarctic and North Pacific.
Fig. 1. Specimen 71J2793 from the Antarctic.
Fig. 2. ,, 71J2883 ,, ,, ,,
Fig. 3. ,, AY69B ,, ,, North Pacific.

PLATE II

Ventral view of skull of the minke whale from the Antarctic and North Pacific.
Fig. 1. Specimen 71J2793 from the Antarctic.
Fig. 2. ,, 71J2883 ,, ,, ,,
Fig. 3. ,, AY69B ,, ,, North Pacific.

PLATE III

Lateral view of skull of the minke whale from the Antarctic and North Pacific.
Fig. 1. Specimen 71J2793 from the Antarctic.
Fig. 2. ,, 71J2883 ,, ,, ,,
Fig. 3. ,, AY69B ,, ,, North Pacific.

PLATE IV

Posterior view of skull of the minke whale from the Antarctic and North Pacific.
Fig. 1. Specimen 71J2793 from the Antarctic.
Fig. 2. ,, 71J2883 ,, ,, ,,
Fig. 3. ,, AY69B ,, ,, North Pacific.

PLATE V

Dorsal view of mandibles of the minke whale from the Antarctic and North Pacific.
Fig. 1. Specimen 71J2793 from the Antarctic.
Fig. 2. ,, 71J2883 ,, ,, ,,
Fig. 3. ,, AY69B ,, ,, North Pacific.

PLATE VI

Anterior view of cervical vertebrae of the minke whale from the Antarctic and North Pacific.
Fig. 1. Specimen 71J2793 from the Antarctic.
Fig. 2. ,, 71J2883 ,, ,, ,,
Fig. 3. ,, AY69B ,, ,, North Pacific.

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PLATE VII

Lateral view of vertebrae of the minke whale from the Antarctic. Specimen 71J2793.
Fig. 1. Cervical and dorsal vertebrae.
Fig. 2. Lumbar vertebrae.
Fig. 3. Caudal vertebrae.

PLATE VIII

Lateral view of vertebrae of the minke whale from the Antarctic. Specimen 71J2883.
Fig. 1. Cervical and dorsal vertebrae.
Fig. 2. Lumbar vertebrae.
Fig. 3. Caudal vertebrae.

PLATE IX

Lateral view of vertebrae of the minke whale from the North Pacific. Specimen AY69B.

Fig. 1. Cervical and dorsal vertebrae.
Fig. 2. Lumbar vertebrae.
Fig. 3. Caudal vertebrae.

PLATE X

Ribs of the minke whale from the Antarctic.

Fig. 1. Specimen 71J2793.
Fig. 2. ,, 71J2883.

PLATE XI

Ribs and sternum of the minke whale.

Fig. 1. Ribs of specimen AY69B from the North Pacific.
Fig. 2. Sternum of specimen 71J2793 from the Antarctic.
Fig. 3. Sternum of specimen 71J2883 from the Antarctic.
Fig. 4. Sternum of specimen AY69B from the North Pacific.

PLATE XII

Scapullae of the minke whale from the Antarctic and North Pacific.

Fig. 1. Specimen 71J2793 from the Antarctic.
Fig. 2. ,, 71J2883 ,, ,, ,,
Fig. 3. ,, AY69B ,, ,, North Pacific.

PLATE XIII

Humerus, radius, and ulna of the minke whale from the Antarctic and North Pacific. Right side.

Fig. 1. Specimen 71J2793 from the Antarctic.
Fig. 2. ,, 71J2883 ,, ,, ,,
Fig. 3. ,, AY69B ,, ,, North Pacific.

PLATE XIV

Humerus, radius, and ulna of the minke whale from the Antarctic and North Pacific. Left side.

Fig. 1. Specimen 71J2793 from the Antarctic.
Fig. 2. ,, 71J2883 ,, ,, ,,
Fig. 3. ,, AY69B ,, ,, North Pacific.

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PLATE XV

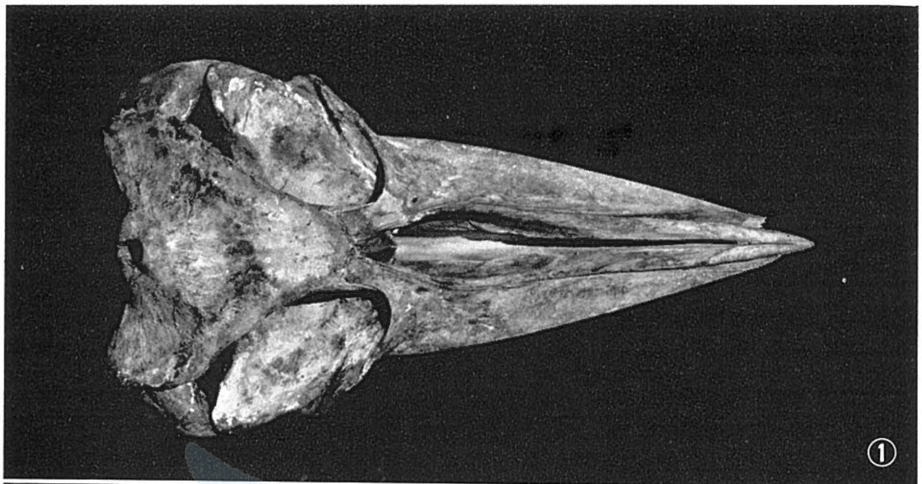
Carpals and phalanges of the minke whale from the Antarctic and North Pacific. Right side.

Fig. 1. Specimen 71J2793 from the Antarctic.
Fig. 2. ,, 71J2883 ,, ,, ,,
Fig. 3. ,, AY69B ,, ,, North Pacific.

PLATE XVI

Carpals and phalanges of the minke whale from the Antarctic and North Pacific. Left side.

Fig. 1. Specimen 71J2793 from the Antarctic.
Fig. 2. ,, 71J2883 ,, ,, ,,
Fig. 3. ,, AY69B ,, ,, North Pacific.



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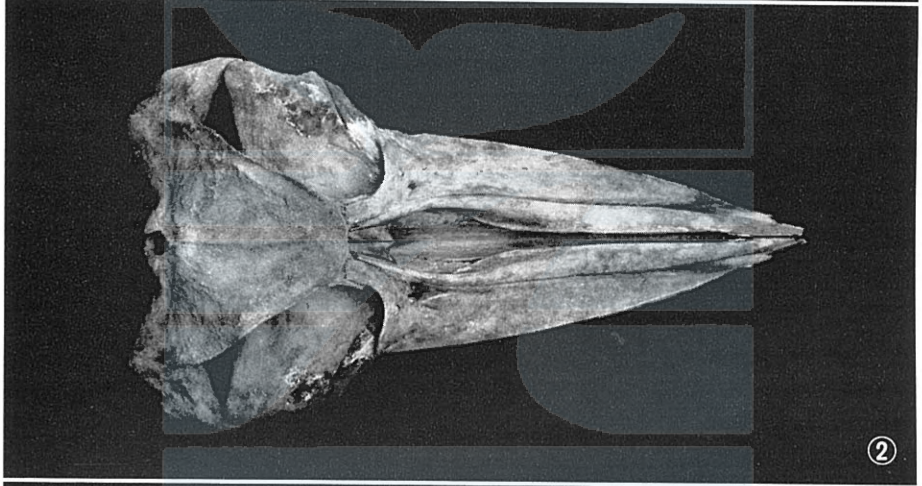

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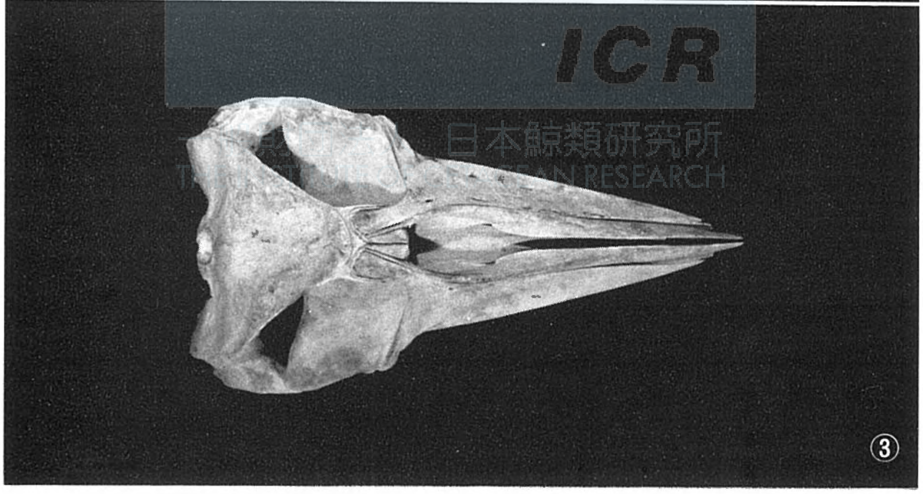

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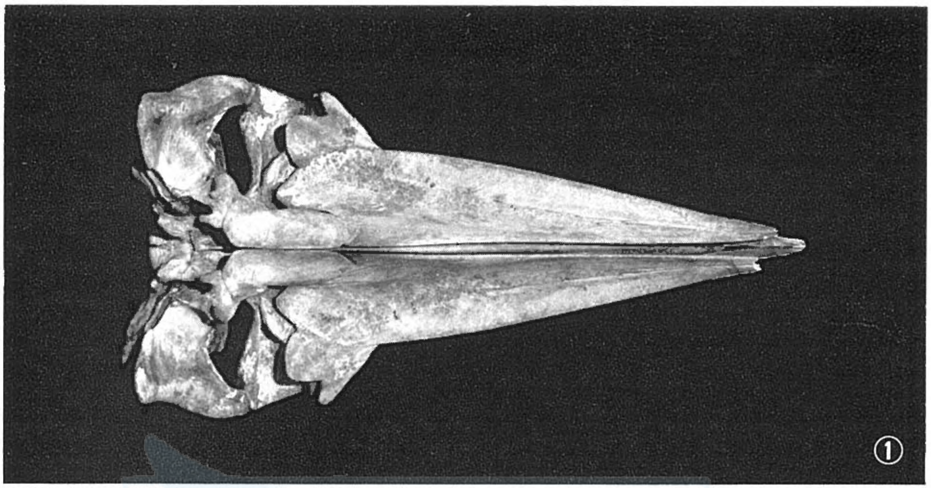

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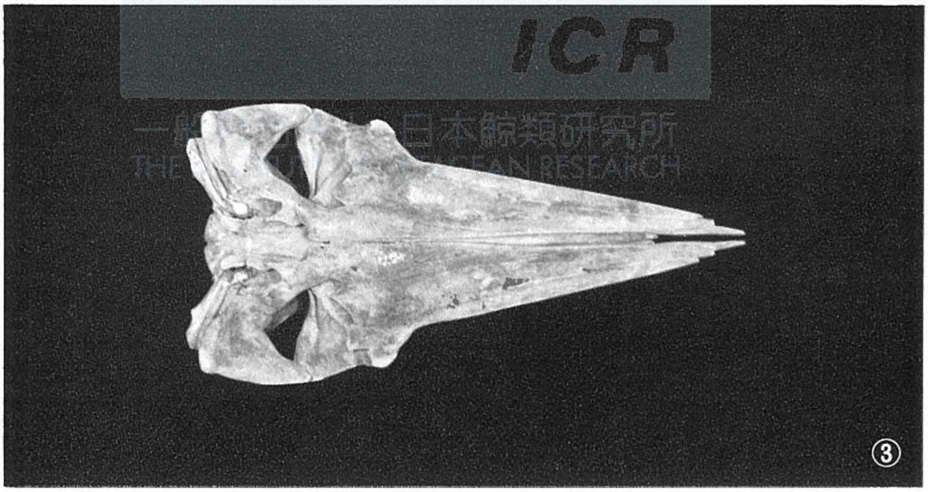

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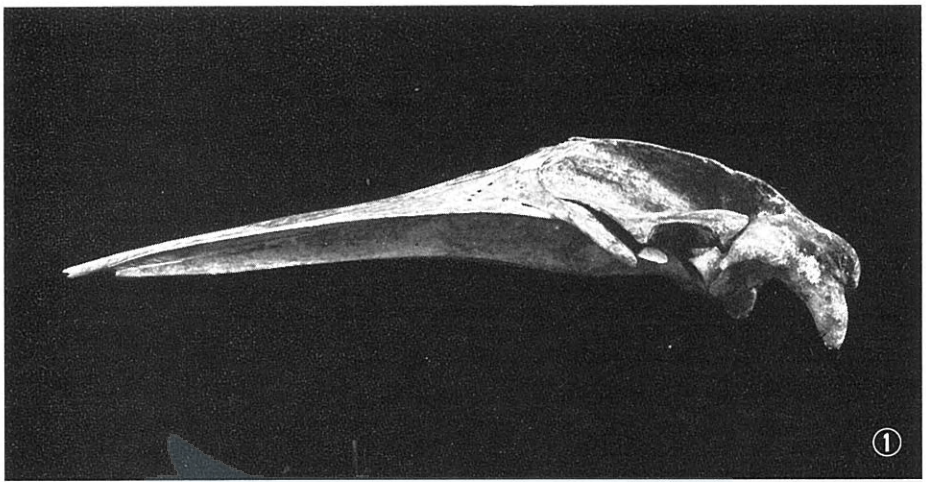

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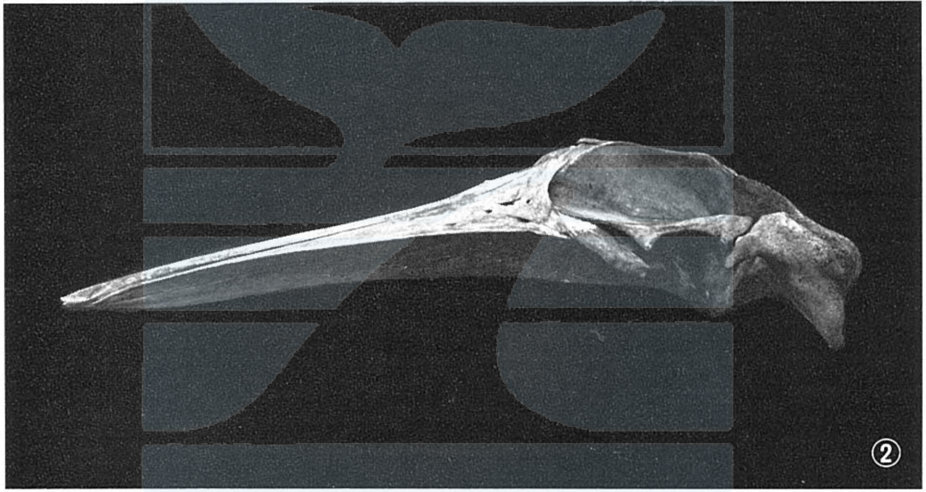

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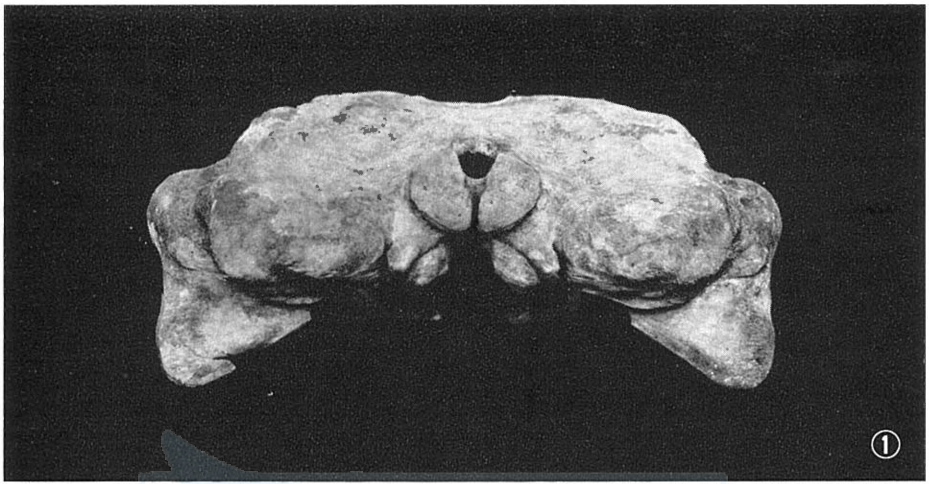
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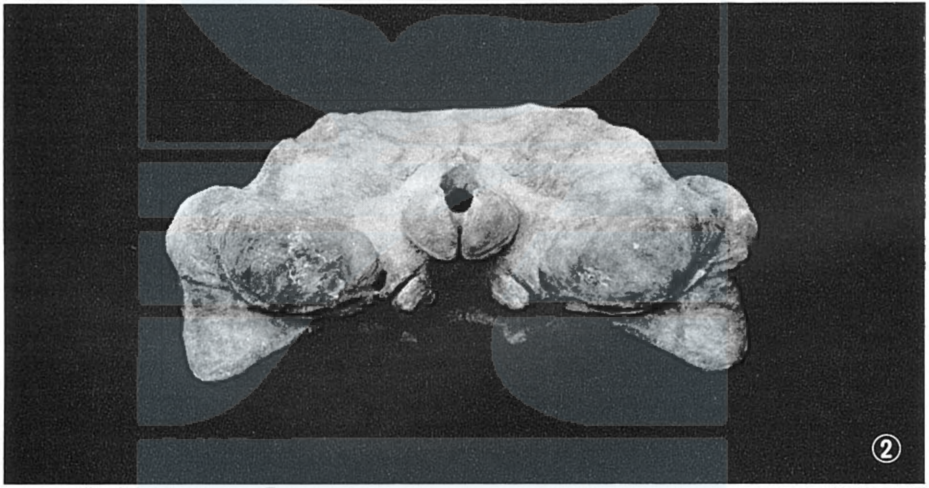
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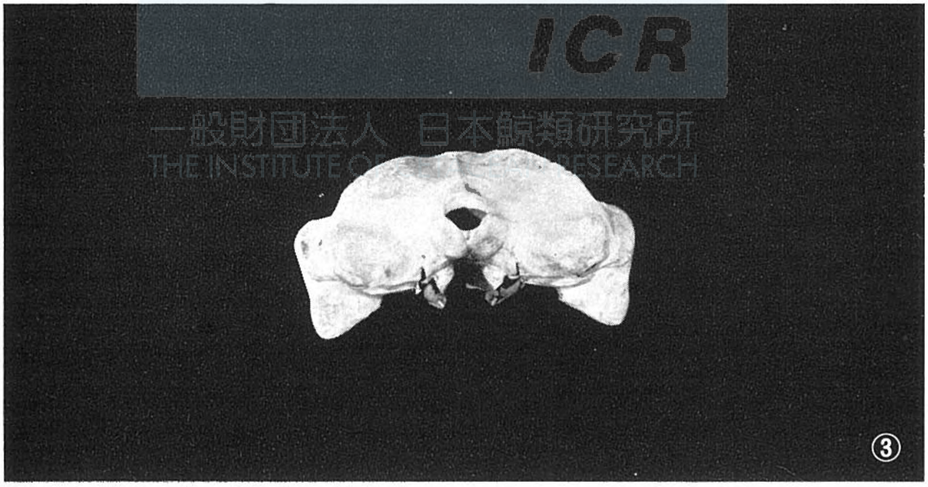
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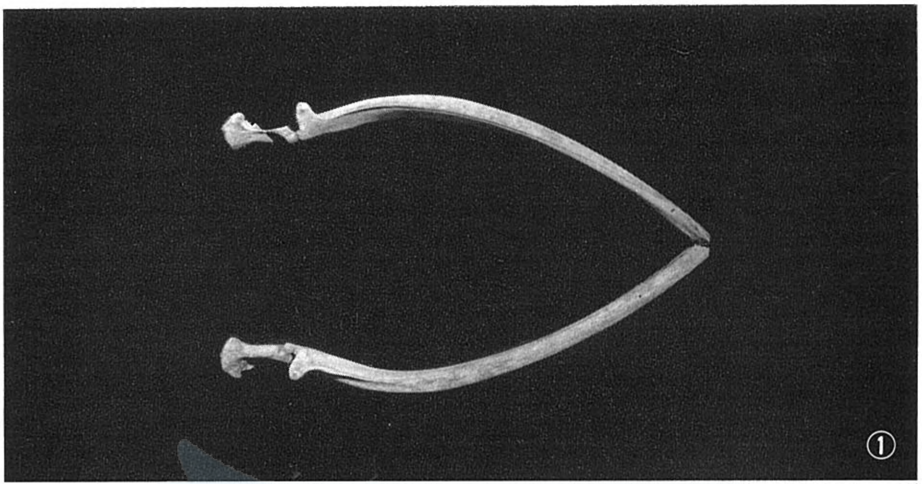
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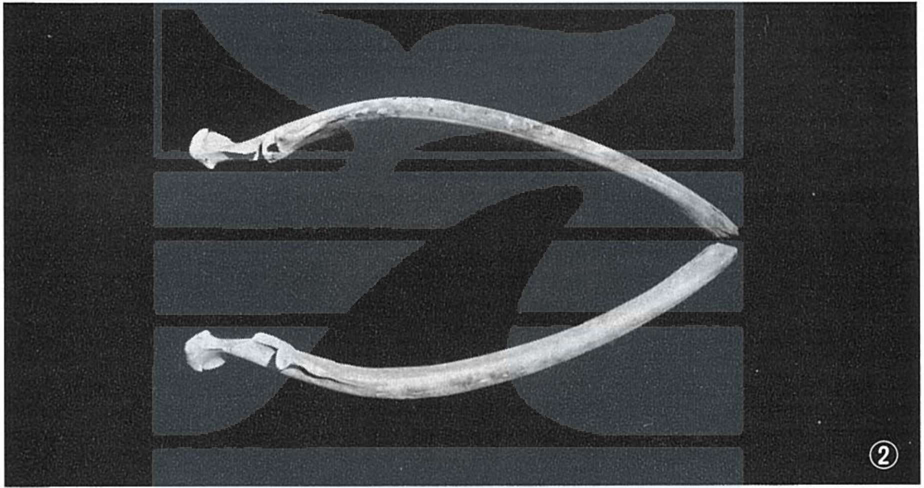
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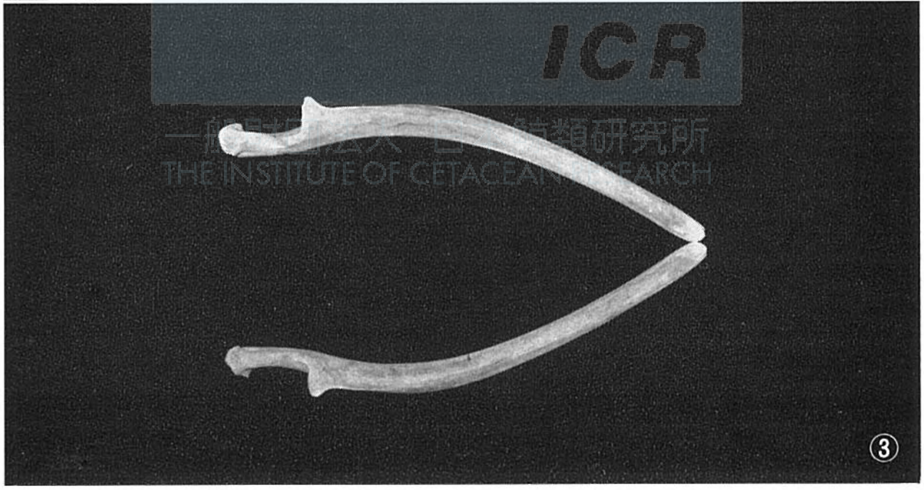
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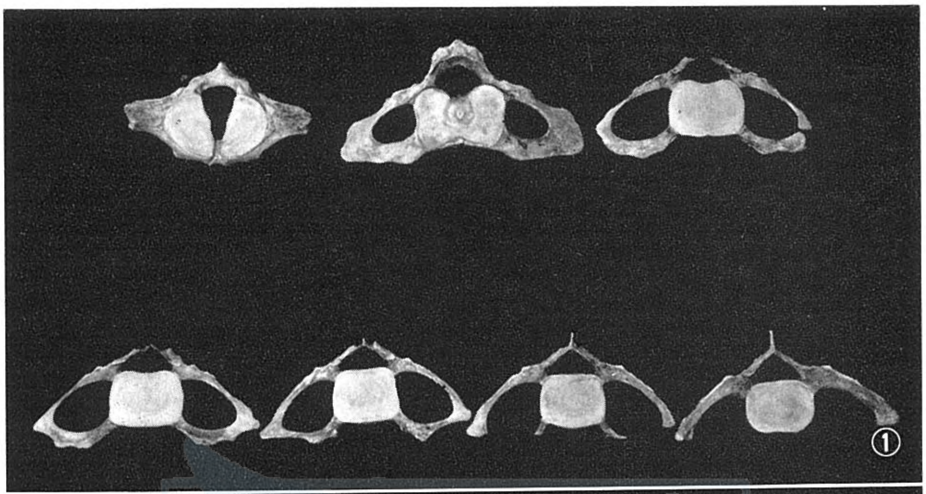
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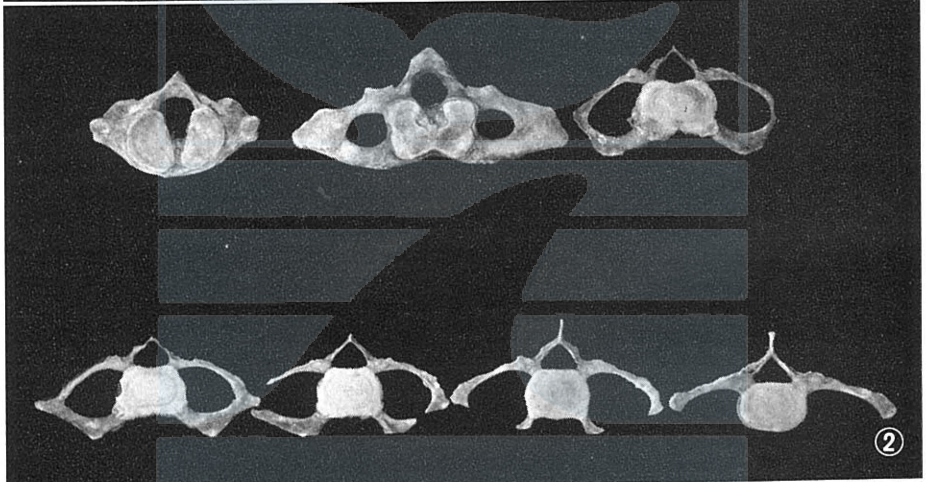
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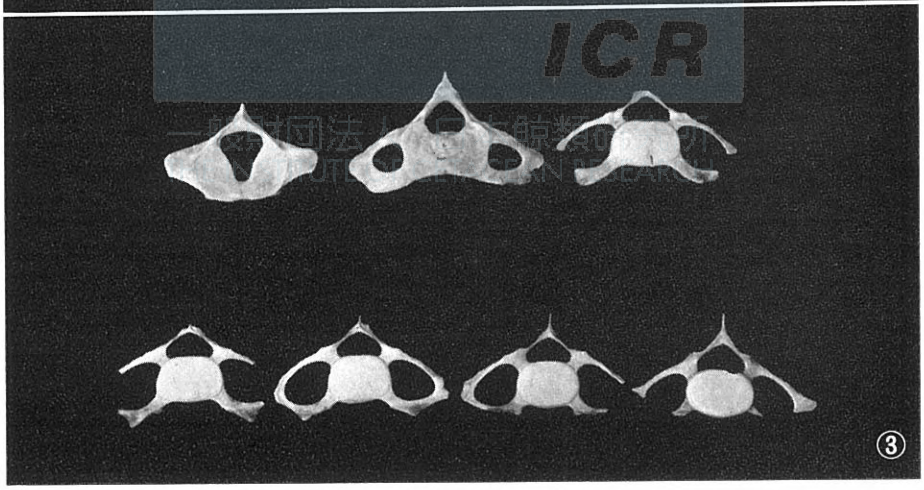
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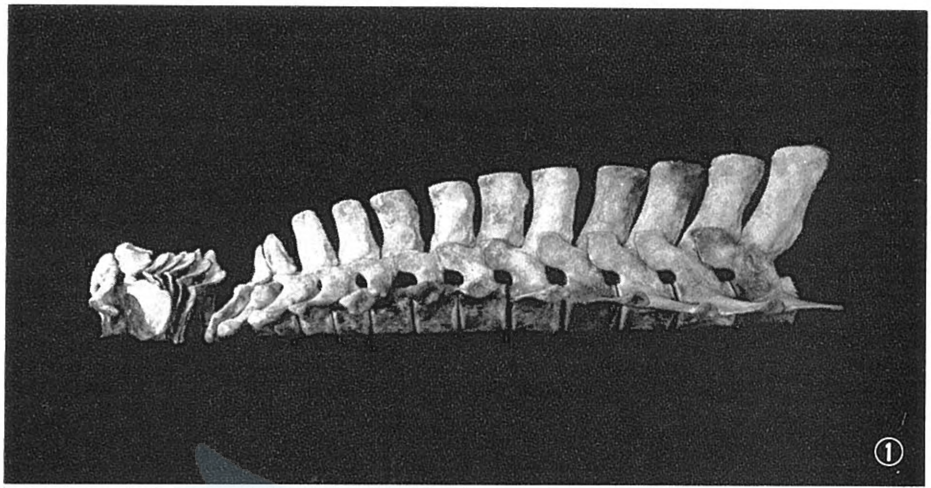
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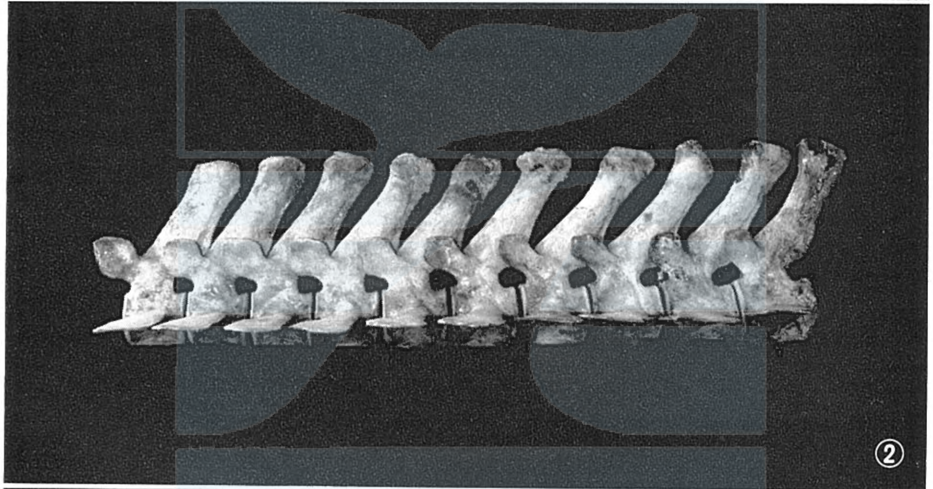
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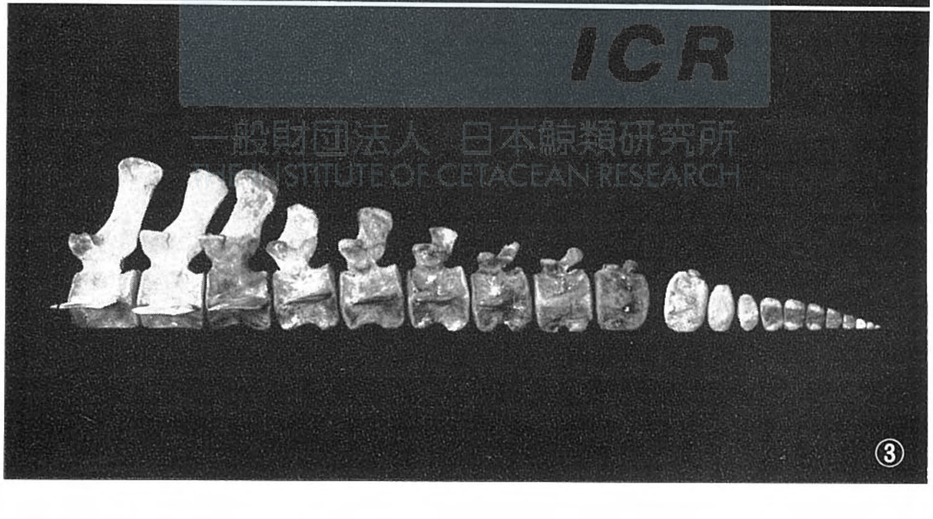
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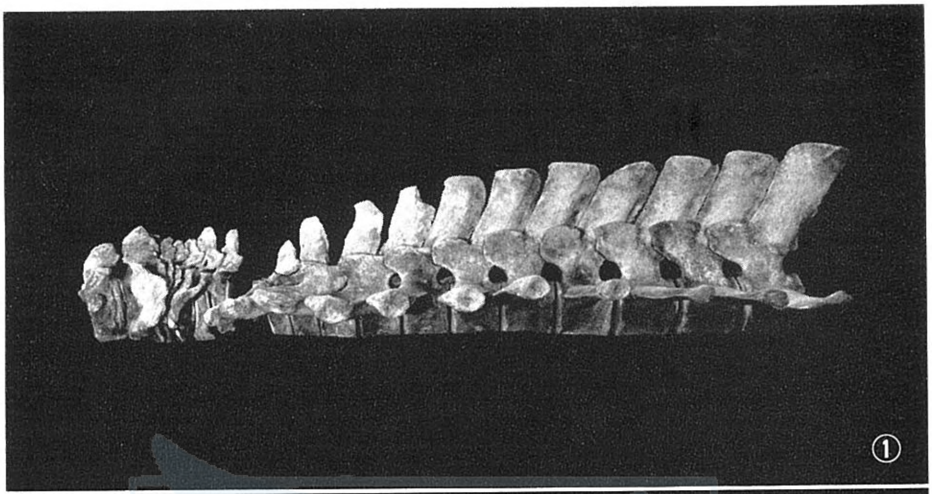

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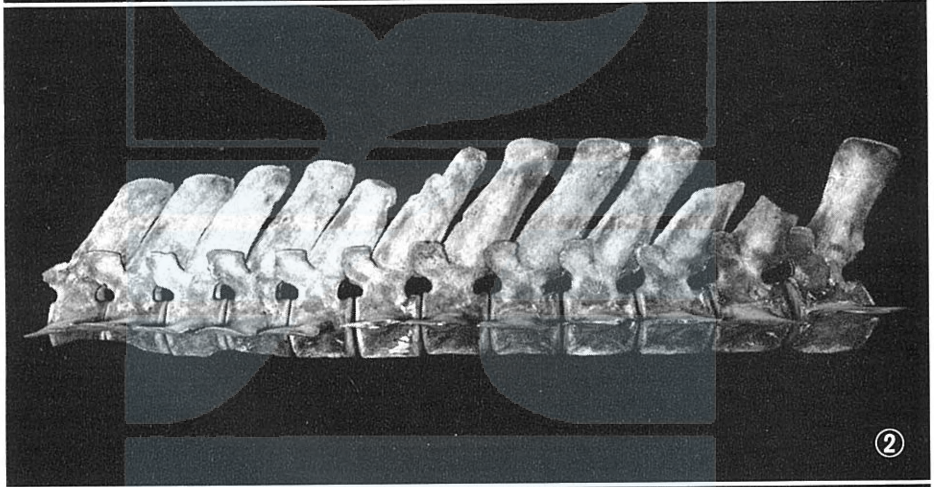

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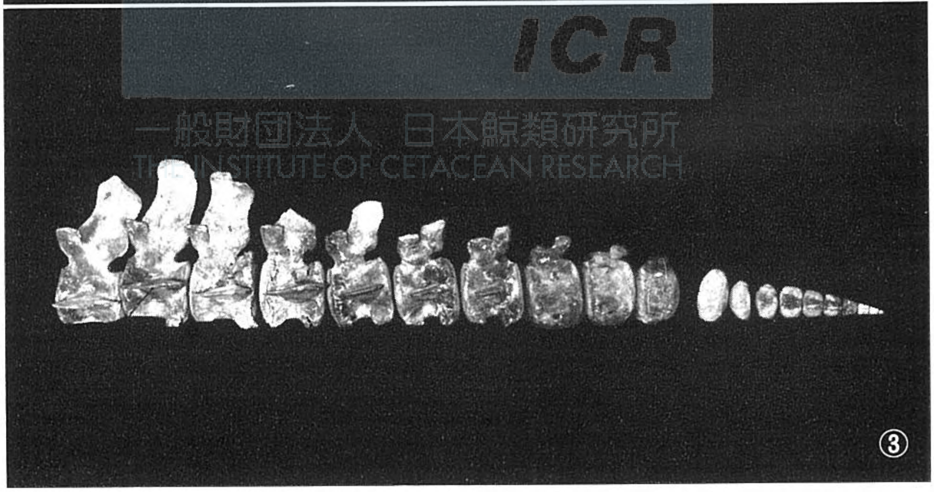

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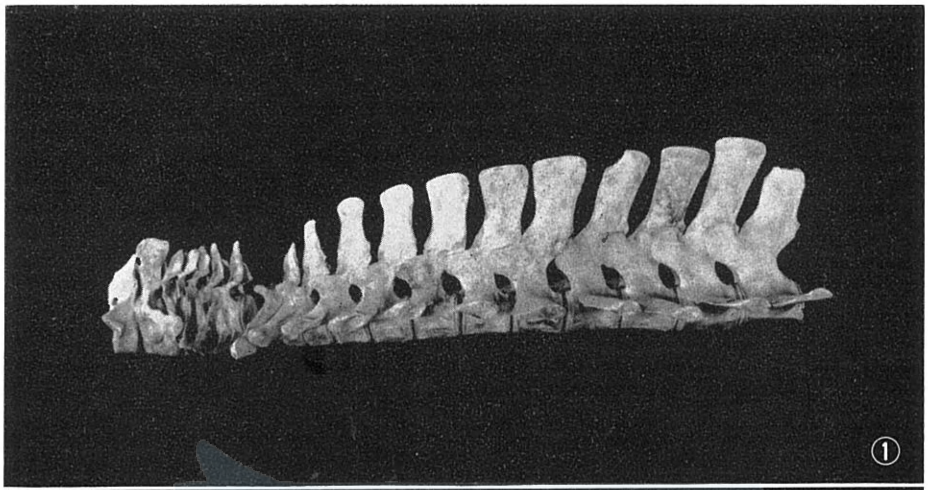
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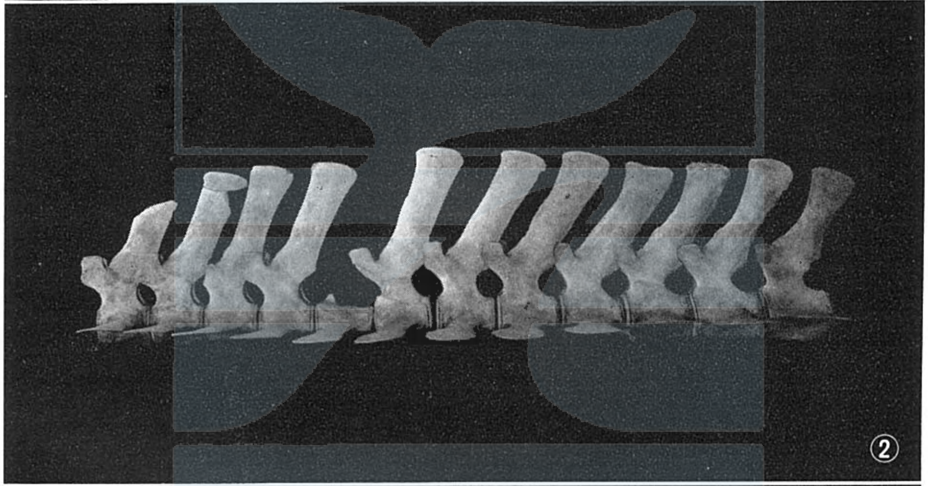
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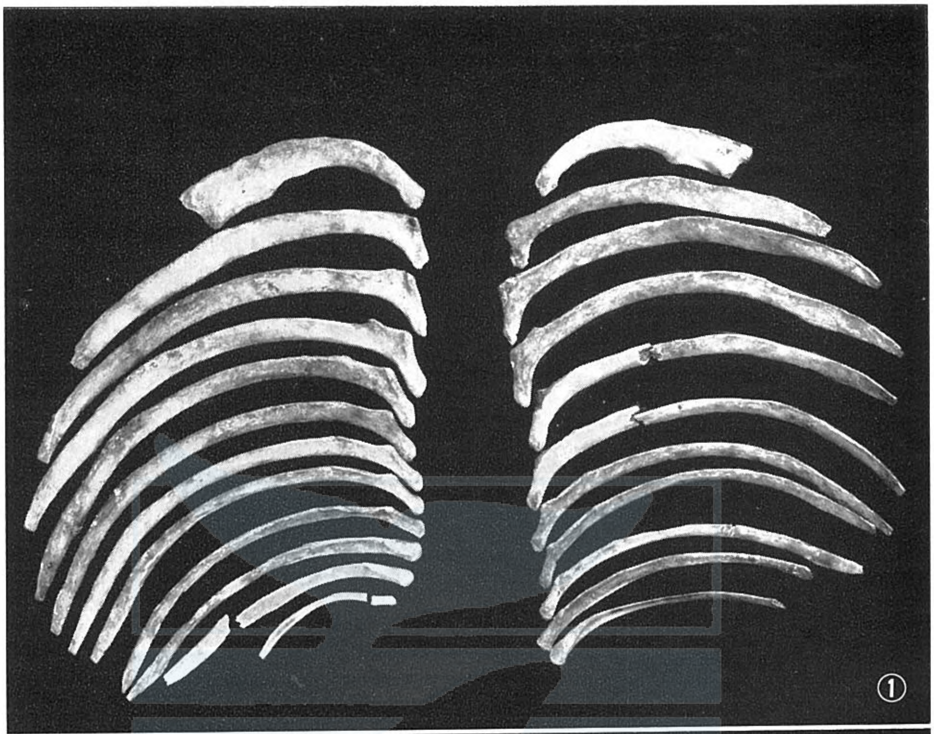
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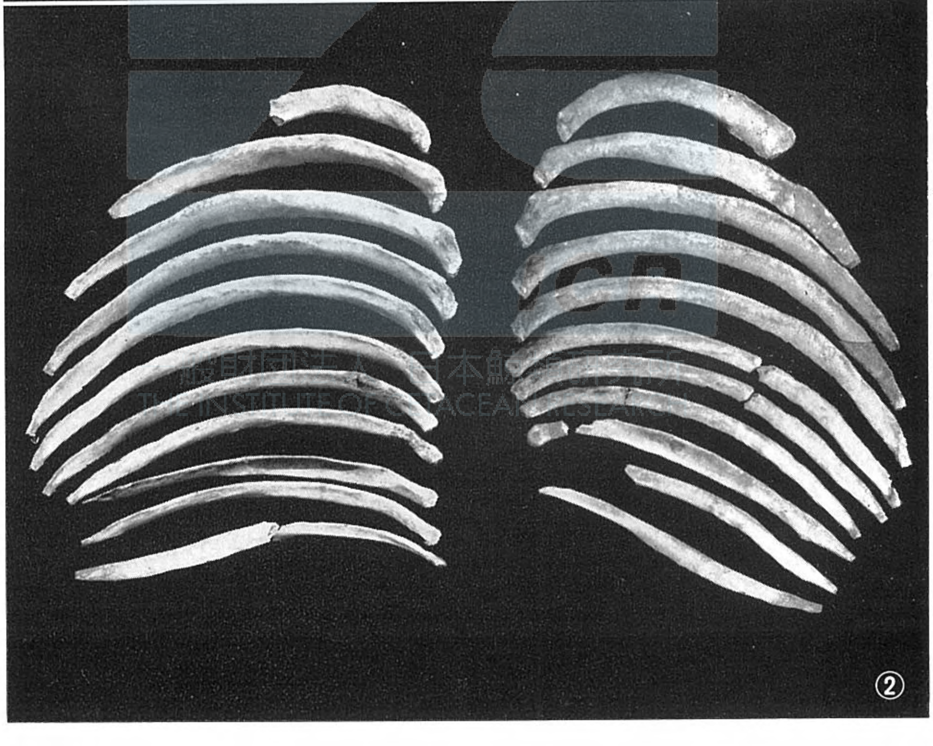
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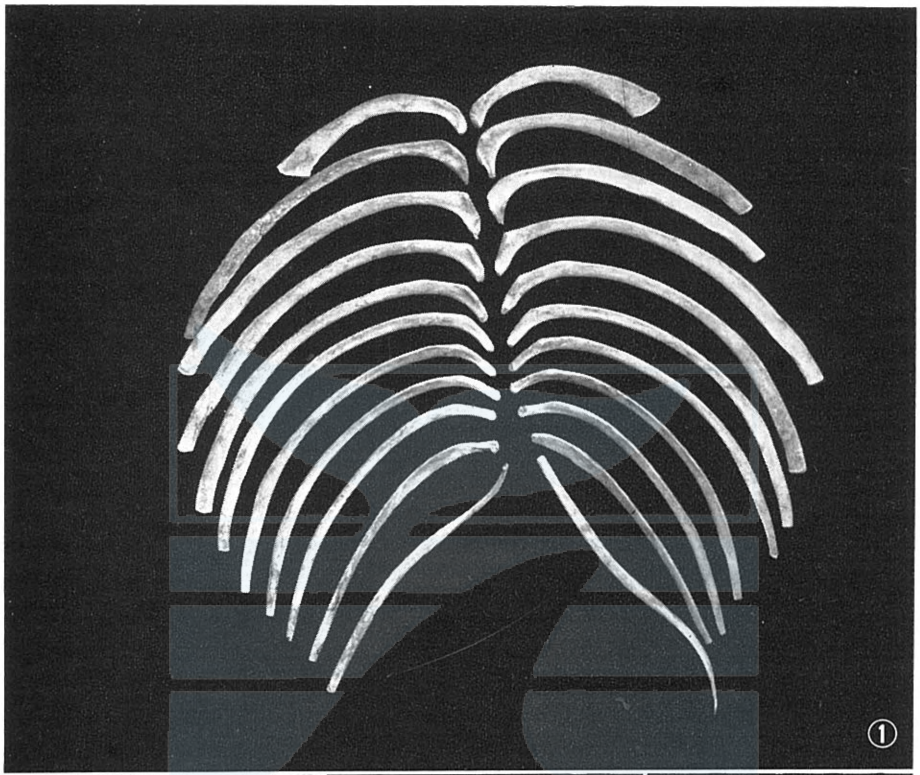

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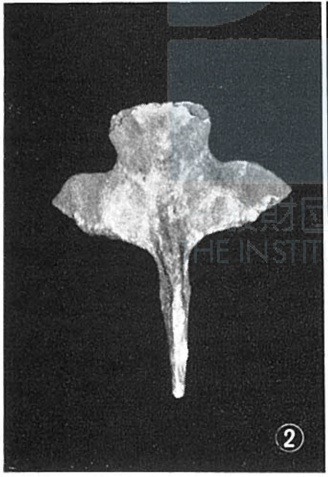

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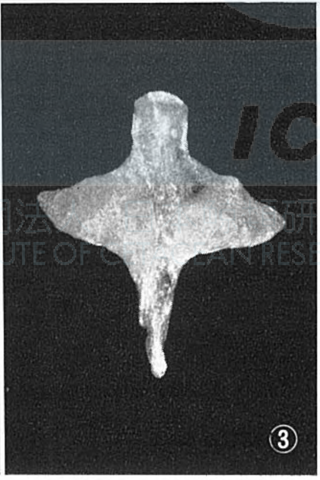

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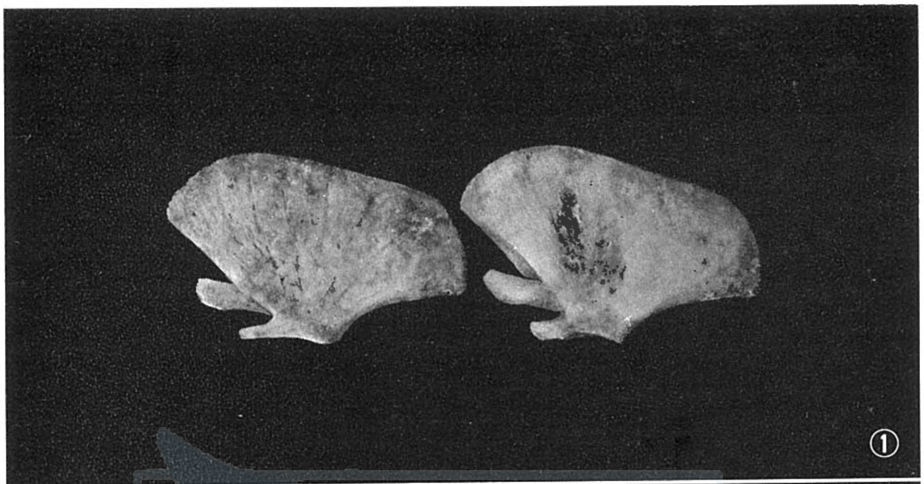

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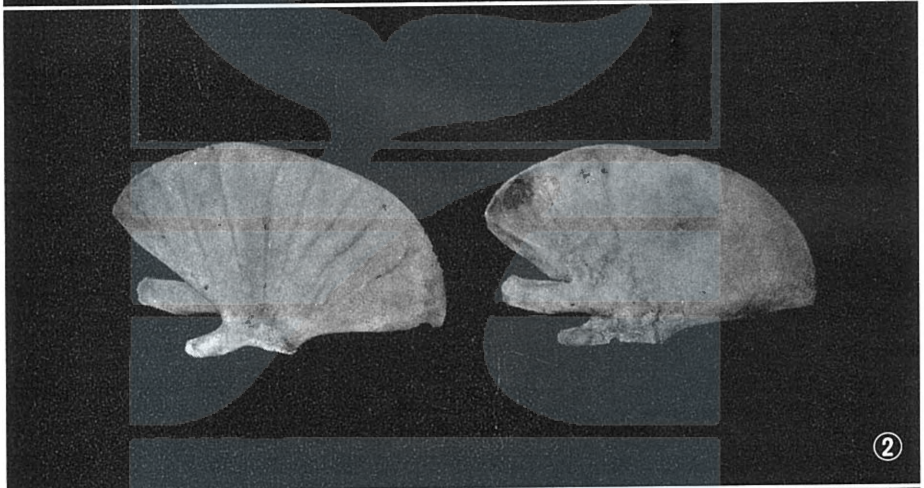

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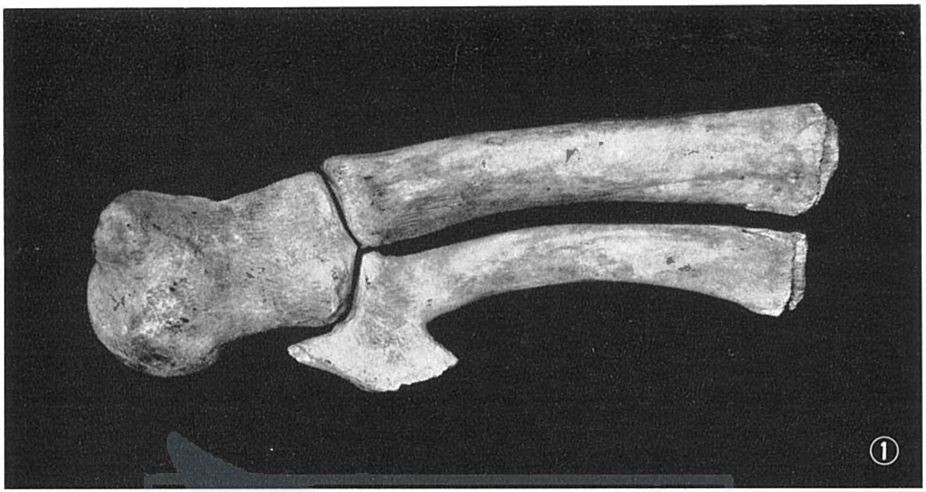

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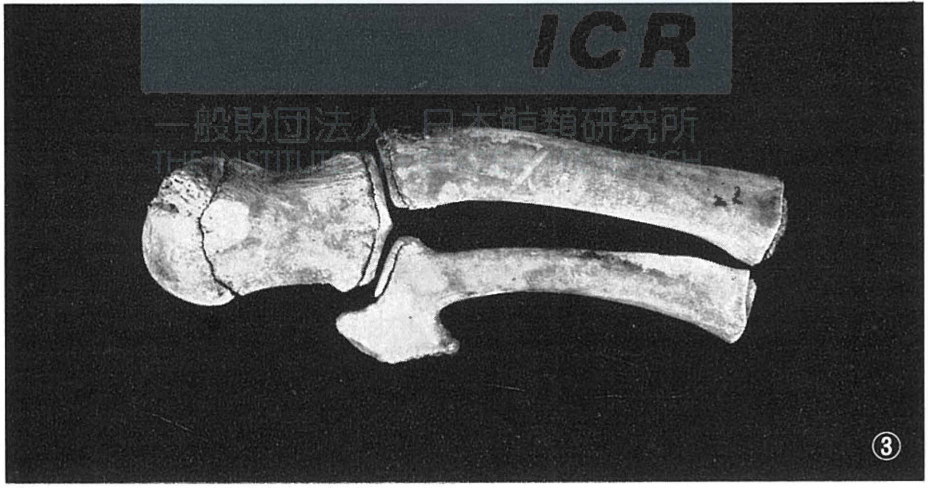

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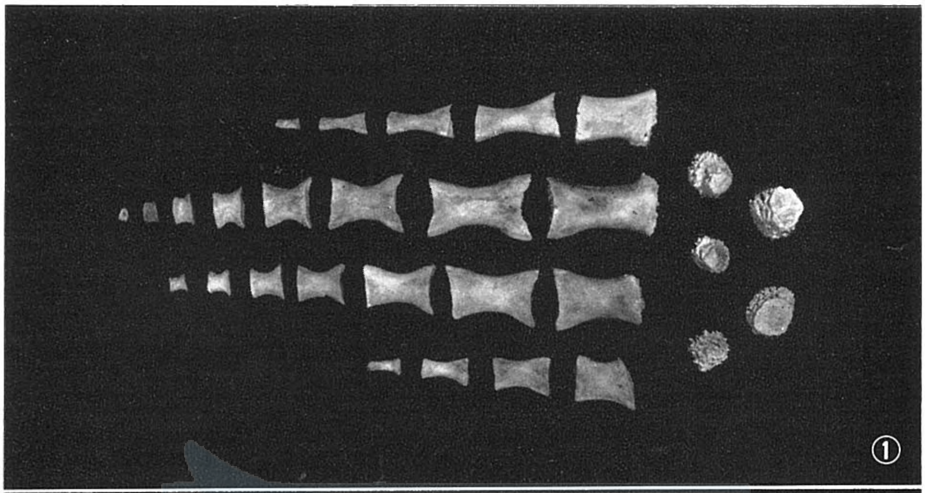
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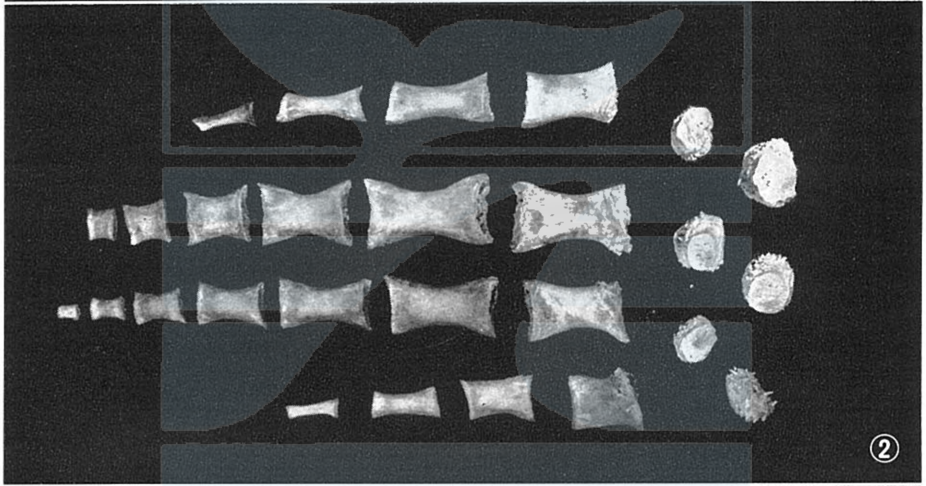
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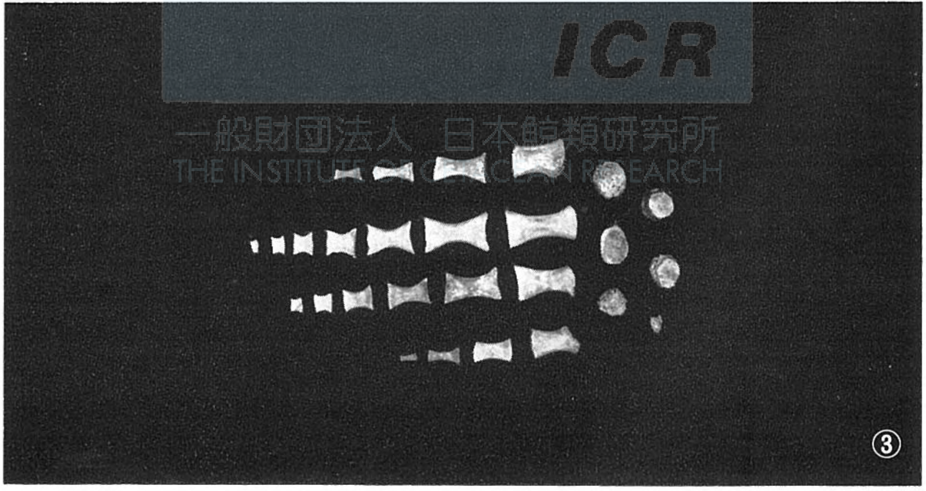
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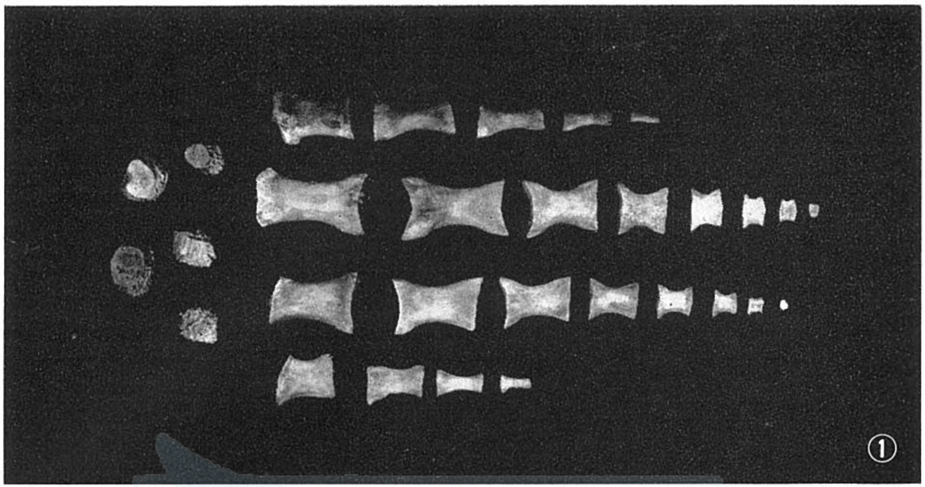

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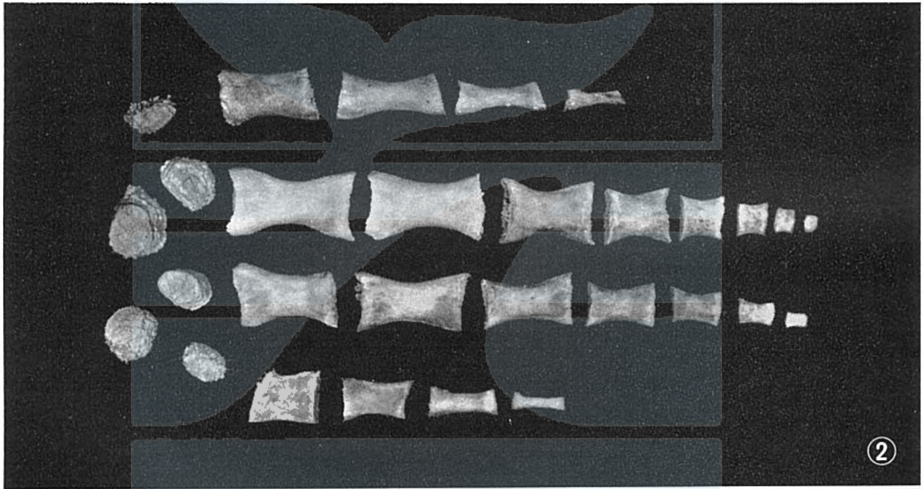

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MINKE WHALES OFF BRAZIL

GORDON R. WILLIAMSON
Heather Cottage, Kessock, Inverness, Scotland, Britain

ABSTRACT

Minke whales are the main catch off Costinha 7°S at the NE tip of Brazil. The whales congregate each September-October-November over the continental slope in water 27°C. About 700 whales are caught per year. All are of the southern hemisphere subspecies *Balaenoptera acutorostrata bonaerensis*.

Caught whales are lengths 7.5–10.7 metres (average 8.5 m) which correspond to ages 7–50 (average 15 years old). All the males and about 90% of the females are mature. In the catch females outnumber males 2 ♀♀: 1 ♂. No foetuses of visible size occur. Lactating females with calf are seldom seen.

Available data do not permit a firm conclusion regarding the length of the reproductive cycle. Some data suggest a one-year cycle, some data suggest a two-year cycle. Calves appear to be born in waters of intermediate temperature and intermediate latitude.

Minke whales are common off Brazil and Durban yet rare off west south Africa. Perhaps they migrate north mainly up the western side of the South Atlantic, unlike sei whales which migrate up both sides.

Suggestions for future research are made.

INTRODUCTION

Tropical whaling station winter catches are of special interest to biologists because they reveal what whales are doing during the reason in which mating and birth occur.

7°S from the equator is the whaling station of Costinha, at the NE tip of Brazil, near Joao Pessoa and 140 km north of Recife (Fig. 1). Brazil has been a member of the International Whaling Commission during 1951–66 and since 1973 and biological data on each whale killed have been supplied to the Bureau of International Whaling Statistics at Sandefjord since 1953 Some basic statistics on Costinha whale catches are given by Paiva (1961) and Paiva and Grangeiro (1965, 1970).

This report gives a general account of the Costinha whaling station and describes the catch of minke whales, which is now the main species caught. The data from Costinha are of exceptional interest because

- the season is the tropical winter
- catching occurs during six months unbroken period
- the effort is constant; one catcher all the time
- the catching area is the same all season long
- the minke whale stock is in virgin condition.

Sci. Rep. Whales Res. Inst.,
No. 27, 1975, 37–59.

Minke whales are caught in great numbers in the Antarctic and about 32,000 have been caught in the southern hemisphere since minke whale hunting began in earnest about ten years ago (Table 1).

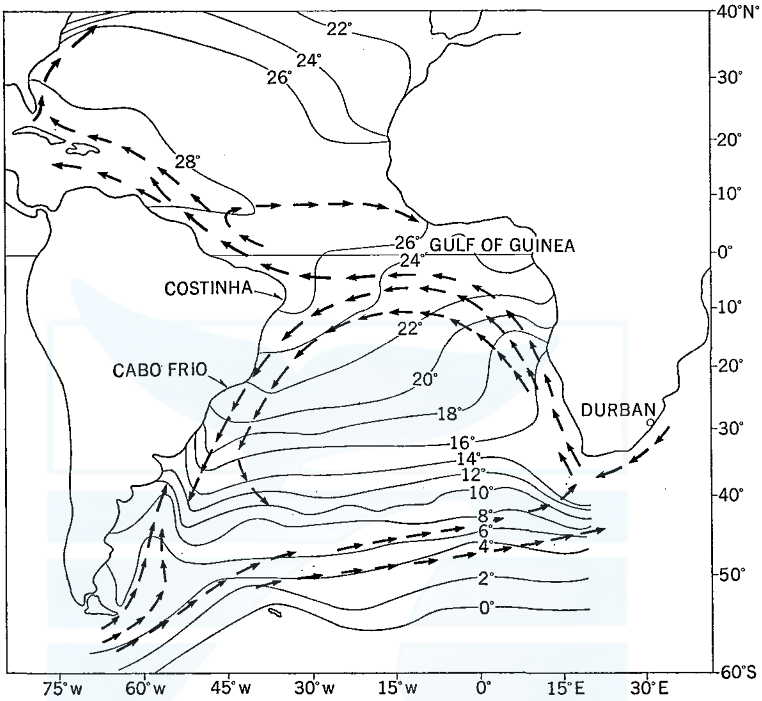

Fig. 1. Atlantic Ocean showing currents (arrows) and October water temperatures.

MATERIAL USED

This paper is based on data on whaling operations and whale catches off Costinha supplied through the kindness of the owners of the station, Compania de Pesca Norte do Brasil, Mr. Kiyohisa Kanda president and Mr. Issao Ishigami manager. The catcher gunner Captain Sato and station foreman Mr. Masahiro Saito supplied much information. Mr. Kanda visited Britain to discuss details with me and two British scientist friends of mine visited the whaling station briefly.

Each whale landed at Costinha has the following particulars recorded

- date killed
- position killed
- length in feet in straight line from snout tip to tail notch
- sex
- whether foetus of noticeable size is present
- stomach contents (in some seasons).

Blubber. The thickness of the blubber on the back of the body just below

TABLE 1. CATCHES OF MINKE WHALES IN THE SOUTHERN HEMISPHERE 1950–APRIL 1975 (DATA FROM BUREAU INTERNATIONAL WHALING STATISTICS)

Year	Antarctic*	Brazil	Durban	Total
1950	—	—	—	—
51	—	—	—	—
52	9	—	—	9
53	—	—	—	—
54	3	—	—	3
55	—	—	—	—
56	42	—	—	42
57	46	—	—	46
58	493	—	—	493
59	103	2	—	105
1960	205	—	—	205
61	162	—	—	162
62	2	—	—	2
63	21	2	1	24
64	101	44	1	146
65	7	67	2	76
66	10	352	5	367
67	18	488	6	512
68	605	456	97	1158
69	59	617	112	788
1970	30	701	171	902
71	44	900	204	1148
72	3054	702	135	3891
73	5745	650	173	6568
74	8000	765	117	8882
75	7000	—	—	7000
Total	25759	5747	1024	32530

* Antarctic catches are listed as follows: 1961/62 catch is listed under 1962 etc.

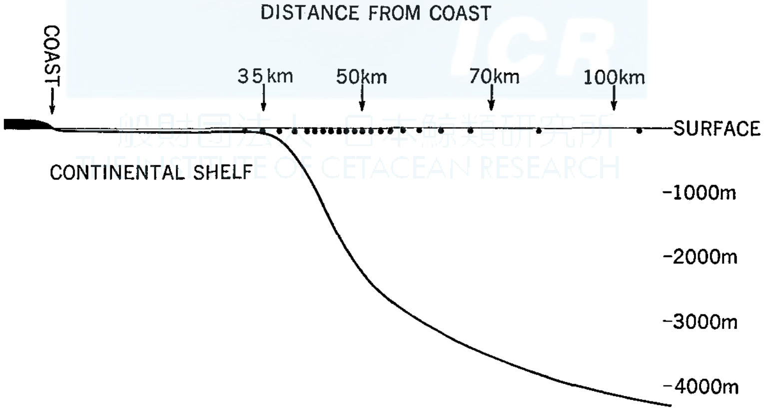

Fig. 2. Distribution of minke whales off Costinha. Dots represent whales. This diagram shows relative abundance of whales, not actual numbers. (Data from whaling company.)

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the dorsal fin was measured to the nearest 0.5 cm on all whales caught between August 16th–December 20th, 1974 (see Fig 7).

Testis samples. To determine the degree of spermatogenesis in the testes, samples of testis tissue were preserved from three male whales during each month June–December of the 1974 season. The samples were airmailed for histological examination to Dr. R. F. Macadam of Raigmore Hospital Pathology Department, Inverness, Scotland.

Vagina smear samples. To determine the nature of the "white mucus" in the vagina of female whales, smear slides were made of the contents of the vaginas of three female whales of mature size during each month June–December of the 1974 season. The smears were airmailed to Dr. R. F. Macadam for histological examination.

The Bureau of International Whaling Statistics, Sandefjord, Einar Vangstein director, has supplied data where needed.

Data on minke whales off west south Africa and off Durban have been supplied respectively by the Sierra Fishing Agency manager Mr. R H Shepperd and Dr. Peter Best.

HYDROGRAPHY

Costinha whaling station is located 750 km (470 miles) south of the equator at latitude 7°S on the NE corner of Brazil. The continental shelf is narrow about 30 km wide, and drops steeply into the abyss (Figs. 1 and 2).

A warm equatorial current approaches the coast from the east and becomes divided by the land into north-flowing and south-flowing branches.

During the main whaling season September–October–November, sea surface temperatures over a wide area off Costinha are about 27°C.

Frech bite wounds of the type made by the 40-cm-long whale-biter shark *Isistius* are common on whale off Costinha, suggesting this tiny pelagic shark must be common in the area. (The discovery of the causal agency of these wounds was made by Jones (1971).) Large sharks 1.5–2.5 m long are plentiful over the continental shelf within 30 km of the coast and cause much trouble biting chunks out of the dead buoyed whales, but in oceanic water further out from the coast dead whales are not attacked by large sharks.

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HISTORY AND DAILY OPERATIONS AT COSTINHA

Whaling at Costinha started in 1910. Since 1951 inclusive the station has been operated by Compania de Pesca Norte do Brasil (COPESBRA) with head office in Recife. This is a subsidiary of Nippon Reizo K.K. (Japan Ice Storage Co.) of Tokyo and the key personnel are Japanese.

One antarctic-type catcher Seiho Maru No. 2 (306 tons) is used. It leaves port about 0400 hours each day, hunts all day at distance of 30–140 km from the coast, and returns with its catch to port after dark about 2000 hours—midnight. The whales are cut up during the night. The meat is salted and dried and is sold locally in Paraiba state and the oil is sold for leather tanning in south Brazil. The whaling season is from June to December.

The virgin relative abundance of whale species off Costinha appears from the catches (Table 2) to have been:

minke, sei, humpback and sperm—common
bryde—occasional
fin and blue—very rare

At Costinha, whalers killed the easy-to-kill and large species first and catches have been dominated in turn by humpback, sei and now finally minke and sperm whales (Table 3). Sei and bryde's whales were not recorded separately in the catch records prior to 1967, but have been separated since then. During 1967–74 the catch of sei and bryde's totalled 251 and 25 whales respectively, that is, sei were 90% of the catch of the combined species. The percentage of sei was presumably higher prior to 1960 before antarctic hunting reduced the sei stocks.

Paiva (1961) and Paiva and Grangeiro (1965, 1970) give data on the 1960/67 whale catches of all the species, mainly recording numbers caught each month, mean lengths each month, sex ratios, sexual condition and stomach contents.

Off Cabo Frio whaling station further south in 23°S more fin whales occur than off Costinha but otherwise the relative abundance of whale species is similar at the two places (Table 4).

The once-large stock of humpback whales features little in the catch of either station in recent years due to the fact that it was greatly reduced by hunting in the 1904–1920 period.

TABLE 2. NUMBER OF WHALES KILLED OFF COSTINHA, BRAZIL 7°S DURING 1910–74. (DATA FROM TABLE 3)

English Name	Brazilian Name	No Killed 1910–74	Present Status
Blue	baleia azul	1	rare
Fin	baleia fin	3	rare
Sei	baleia espardate	about 3,600	rare
Bryde	baleia cabeca de suenga	about 350	rare
Minke	baleia minke	5,747	very common
Humpback	baleia preta	1,542	rare
Sperm	cachalote	517	common

MINKE WHALES

Existing knowledge on minke whales

Minke whales are the commonest remaining species of baleen whale in the southern hemisphere and are also common in the northern hemisphere. In the southern hemisphere the latest estimate of the population is 300,000 minke whales (Ohsumi and Masaki, 1974a).

The taxonomy of minke whales became complicated by the discovery that

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TABLE 3. WHALE CATCHES OFF COSTINHA 1910–74 (1924–49 DATA FROM PAIVA 1961, OTHER YEARS DATA FROM BUREAU INTERNATIONAL WHALING STATISTICS)

<table>
<tr><th>Year</th><th>Humpback</th><th>Sei*</th><th>Bryde*</th><th>Minke</th><th>Blue</th><th>Fin</th><th>Sperm</th><th>Total</th></tr>
<tr><td>1910</td><td colspan="8">Catch taken but no record kept</td></tr>
<tr><td>11</td><td>102</td><td>—</td><td>—</td><td>—</td><td>—</td><td>—</td><td>—</td><td>102</td></tr>
<tr><td>12</td><td>342</td><td>—</td><td>—</td><td>—</td><td>—</td><td>—</td><td>—</td><td>342</td></tr>
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<tr><td>14</td><td>317</td><td>—</td><td>—</td><td>—</td><td>—</td><td>—</td><td>—</td><td>317</td></tr>
<tr><td>1915–23</td><td colspan="8">No catch taken, station closed</td></tr>
<tr><td>1924</td><td>62</td><td>—</td><td>—</td><td>—</td><td>—</td><td>—</td><td>—</td><td>62</td></tr>
<tr><td>25</td><td>42</td><td>—</td><td>—</td><td>—</td><td>—</td><td>—</td><td>—</td><td>42</td></tr>
<tr><td>26</td><td>32</td><td>—</td><td>—</td><td>—</td><td>—</td><td>—</td><td>—</td><td>32</td></tr>
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<tr><td>28</td><td>40</td><td>—</td><td>—</td><td>—</td><td>—</td><td>—</td><td>—</td><td>40</td></tr>
<tr><td>1929–46</td><td colspan="8">Catches taken but no records kept</td></tr>
<tr><td>1947</td><td>11</td><td colspan="2">14</td><td>—</td><td>—</td><td>—</td><td>—</td><td>25</td></tr>
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<tr><td>51</td><td>28</td><td colspan="2">151</td><td>—</td><td>—</td><td>—</td><td>—</td><td>179</td></tr>
<tr><td>52</td><td>9</td><td colspan="2">153</td><td>—</td><td>—</td><td>—</td><td>1</td><td>163</td></tr>
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<tr><td>59</td><td>8</td><td colspan="2">294</td><td>2</td><td>—</td><td>—</td><td>11</td><td>315</td></tr>
<tr><td>1960</td><td>10</td><td colspan="2">500</td><td>—</td><td>—</td><td>—</td><td>1</td><td>511</td></tr>
<tr><td>61</td><td>11</td><td colspan="2">504</td><td>—</td><td>—</td><td>—</td><td>5</td><td>521</td></tr>
<tr><td>62</td><td>8</td><td colspan="2">272</td><td>—</td><td>—</td><td>—</td><td>4</td><td>284</td></tr>
<tr><td>63</td><td>10</td><td colspan="2">253</td><td>2</td><td>—</td><td>—</td><td>7</td><td>272</td></tr>
<tr><td>64</td><td>—</td><td colspan="2">256</td><td>44</td><td>—</td><td>—</td><td>4</td><td>304</td></tr>
<tr><td>65</td><td>—</td><td colspan="2">149</td><td>67</td><td>—</td><td>—</td><td>13</td><td>229</td></tr>
<tr><td>66</td><td>—</td><td colspan="2">72</td><td>352</td><td>—</td><td>—</td><td>24</td><td>448</td></tr>
<tr><td>67</td><td>—</td><td>49</td><td>6</td><td>488</td><td>—</td><td>—</td><td>20</td><td>563</td></tr>
<tr><td>68</td><td>—</td><td>58</td><td>6</td><td>456</td><td>—</td><td>—</td><td>39</td><td>559</td></tr>
<tr><td>69</td><td>—</td><td>56</td><td>6</td><td>617</td><td>—</td><td>—</td><td>75</td><td>754</td></tr>
<tr><td>1970</td><td>—</td><td>23</td><td>3</td><td>701</td><td>—</td><td>—</td><td>76</td><td>803</td></tr>
<tr><td>71</td><td>—</td><td>18</td><td>2</td><td>900</td><td>—</td><td>—</td><td>55</td><td>975</td></tr>
<tr><td>72</td><td>—</td><td>5</td><td>—</td><td>702</td><td>—</td><td>1</td><td>66</td><td>774</td></tr>
<tr><td>73</td><td>—</td><td>6</td><td>1</td><td>650</td><td>—</td><td>—</td><td>75</td><td>732</td></tr>
<tr><td>74</td><td>—</td><td>2</td><td>1</td><td>765+</td><td>—</td><td>—</td><td>29</td><td>797</td></tr>
<tr><td>Total</td><td>1,542</td><td>about 3,600</td><td>about 350</td><td>5,747</td><td>1</td><td>3</td><td>517</td><td>11,768</td></tr>
</table>

* Sei and Bryde's whales were not distinguished prior to 1957, but Sei probably composed 90% of the catches: see text.

+ Includes 3 minke killed but lost at sea. Anomalous differences in whale totals in many seasons are caused by circumstances like this: the total killed exceeds the total measured.

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southern hemisphere whales have a different colour pattern from northern hemisphere whales (Williamson, 1959; Ohsumi *et al.*, 1970). In nearly all other respects the minke whales of the two hemisphere are identical and it is probably reasonable to consider the whales of the two hemispheres as being no more than separate subspecies with the following names:

Southern Minke Whale *Balaenoptera acutorostrata bonaerensis* Burmeister, 1867.

Northern Minke Whale *Balaenoptera acutorostrata acutorostrata* Lacépede, 1804.

Knowledge of the biology of southern minke whales advanced greatly with the publication of the reports of Ohsumi *et al.* (1970) and Ohsumi and Masaki (1974a and 1974b). The following summary is based on these reports augmented by information from the studies of northern minke whales by Omura and Sakiura (1956) and Jonsgard (1951).

Southern minke whales are born about 2.8 m long after a gestation period of about ten months. Calves are suckled on milk for about four months and are weaned when about 4.5 m long. They become sexually mature at about six years of age when males are about 7.2 m long and females 8.0 m long. Males in which the larger of the two testes weighs more than 0.4 g are usually sexually mature. Minke whales grow to about fifty years maximum age and to maximum lengths of 9.8 m in males and 10.7 m in females (Table 5).

In the Antarctic, most of the whales are large. Of whales caught 54% are females. About 55% of the females and 86% of the males are mature. Of ma-

TABLE 4. WHALES CAUGHT AT CABO FRIO WHALING STATION 23°S NEAR RIO DE JANEIRO 1960-63 BY SOCIEDADE DE PESCA TAIYO LIMITADA. (DATA FROM BUREAU INTERNATIONAL WHALING STATISTICS)

Year	Humback	Sei and Bryde	Minke	Blue	Fin	Sperm	Total
1960	3	250	No catching attempted	—	21	28	302
61	2	453		—	10	97	562
62	3	338		1	49	81	472
63	2	93		—	4	35	134
Total	10†	1134††		1	84	241	1470

† Humpbacks had already been greatly reduced in numbers.

†† Proportion of Sei and Bryde in the combined species catch are not known.

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TABLE 5. AVERAGE LENGTH AT SEXUAL MATURITY AND MAXIMUM LENGTH OF MINKE WHALES. SEXUAL MATURITY OCCURS AT ABOUT 6 YEARS OF AGE.

Hemisphere	Area	Mean Length at sexual maturity (m)		Maximum length (m)		Author
		♂	♀	♂	♀	
Southern Hemisphere	Antarctic	7.2	8.0	9.8	10.0	Ohsumi *et al.* (1970) and Ohsumi and Masaki (1974a)
„ „	Brazil	—	—	9.8	10.7	Whaling company
Northern Hemisphere	Newfoundland	—	—	9.1	9.1	Sergeant (1963)
„ „	Norway	6.9	7.3	8.5	9.1	Jonsgard (1951)
„ „	Japan	6.9	7.3	8.8	9.1	Omura and Sakiura (1956)

ture females about 90% are pregnant, and resting mature females are seldom found in the Antarctic. Immature whales are most numerous in the Antarctic in the early summer (November-December).

Ovulation rate is estimated to be 0.89 per year (Ohsumi and Masaki 1974b).

88% of mature females ovulate in spring August–Deptember when they are still lactating (P. Best, pers. comm. based on examination of 16 lactating females killed off Durban by special permit).

Minke whales are believed to bear one calf per year. A wide range of foetus sizes amongst pregnant females in the Antarctic indicates a long mating season.

The migrations of minke whales are probably an annual oscillation about a central latitude of perhaps 40°S, in which the magnitude of oscillation increases steadily as a whale gets older and larger. Calves, most immature whales, and mature females in resting condition keep to the 20°S–50°S latitudes of mild water temperatures. It is the pregnant females, the larger of the immature females and the mature males which go far south. Whales caught south of 60°S are of average age 15 years and average length 8.5 m (age range 7–50 years, length range 6–10 m).

Mature whales probably make an annual migration from close on the equator to the high Antarctic and back, a distance of about 14,500 km (8,000 nautical miles) round trip. At the southern end of their migration they feed on krill and concentrate right at the edge of the pack ice in 60°S–70°S latitude. They are so aboundant and concentrated that Japanese catchers could kill more than 20 minke whales per day if they wished (Ohsumi, pers. comm.).

Minke whales characteristically divide themvelves into groups dominated by a certain sex or age of whale, more so than in other baleen whale species. This habit makes it very difficult for scientists to obtain the random samples which are required in order to make accurate calculations of the population size etc.

Costinha catches of minke whales

All minke whales caught are of the southern hemisphere type of minke whale *Balaenoptera acutorostrata bonaerensis* as described by Burmeister (1867), Williamson (1959) and Ohsumi *et al.* (1970). See Plate I.

Each year the first minke whales arrive from the south in late June and July. They appear singly about 100 km off the coast over deep ocean water and move slowly north. Later groups appear. Groups of whales usually contain 4 or 5 individuals, which are sometimes of one sex, sometimes mixed sexes. Less frequent pairs of whales are usually one male with one female. The whales mostly swim over 2,500-meter-deep water about 10–30 km beyond the steep edge of the continental shelf, about 40–60 km from the coast (Fig. 2).

Maximum numbers of minke whales are present during September–October–November (Table 6, Fig. 4) and highest catches and highest catches per day are obtained in October. Whales of progressively larger sizes enter the area each successive month and they depart in the same sequence (Fig. 4 and Table 7). In November numbers of whales decrease, groups are no longer seen, only pairs and single whales, and the last individuals leave in December.

The sex ratio among caught whales is 2 ♀♀ 1: ♂ (67%♀). The largest individuals caught were several 9.8 m males and several 10.7 m females.

(Sei whales off Costinha, by contrast, during the years 1950–65 when big catches were taken, were caught in greatest numbers during August and September and 40–50% were females in typical years).

Water temperatures are about 27°C during the September–October–November season of abundance (Fig. 1).

Some minke whales can be seen as far north as the extreme NE tip of Brazil (5°S latitude, 250 km north of Costinha) but the whaling company state that none turn left along the north coast of South America.

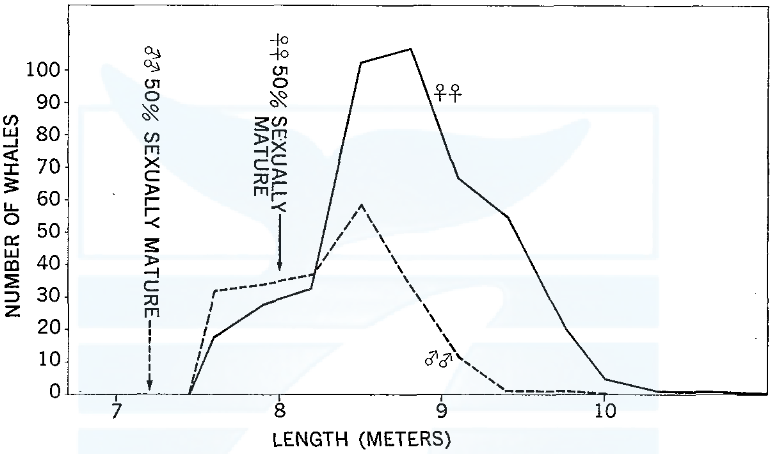

Fig. 3. Lengths of minke whales in a typical season's catch at Costinha (650 whales caught in 1973). The arrows show the mean lengths at which sexual maturity is attained. The males are probably all mature and the females 90% mature. (Data from Bureau International Whaling Statistics.)

Minke whale catches by year, month and sex are given in Table 6 and length frequencies of catches in typical seasons are given in Figs. 3 and 4 and Table 7. Correlation of the length frequencies with the results of Ohsumi *et al.* (1970) and Ohsumi and Masaki (1974b) allows the ages and maturity of the catches to be deduced and the following conclusions reached:

- at the beginning of the season, small numbers of immature females and a very few immature males are present. Most of these are not shot because they are too small to the worth shooting. They leave the area by mid-spring; mid-September.
- mature whales start to arrive in the area in July, and from mid-September onwards nearly all minke whales in the area are mature.
- of the total catch of females about 90% are mature, of the total catch of males about 100% are mature.
- the ages of whales in the catch range 7–50 years old with average age 15

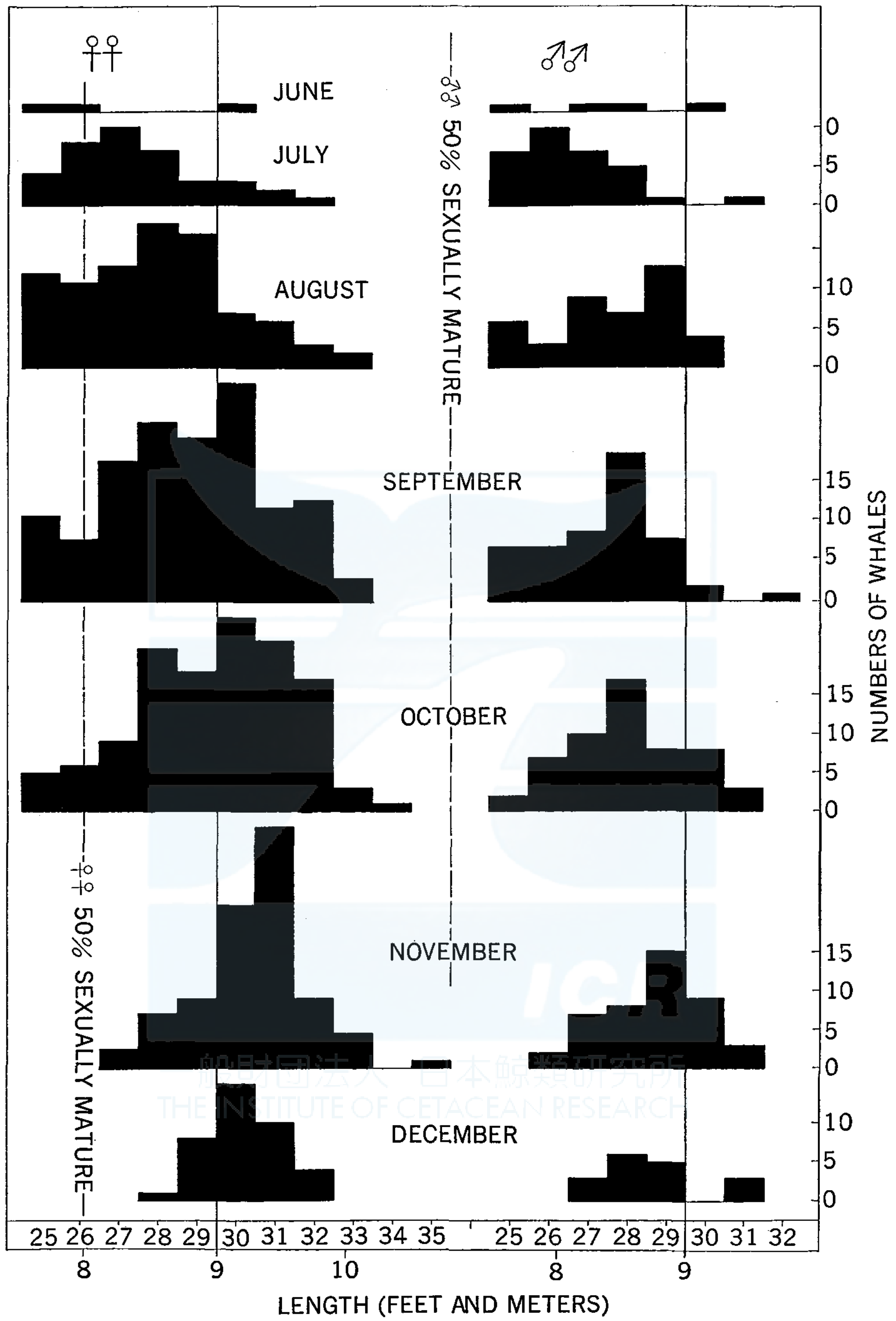

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Fig. 4. Length frequencies of each month's catch of minke whales in a typical season at Costinha (762 whales caught in 1974). Whales of progressively larger sizes enter the area each successive month and depart in the same sequence. (Data from Bureau International Whaling Statistics.)

TABLE 6. MINKE WHALES KILLED IN EACH MONTH OFF COSTINHA, BRAZIL 1969–74. (DATA FROM WHALING COMPANY)

		No. minke whales killed								
		June	July	Aug	Sept	Oct	Nov	Dec	year	%♀
1969	♂	1	21	34	49	48	48	6	207	
	♀	5	28	54	88	102	105	28	410	67%♀
	Total	6	49	88	137	150	153	34	617	
1970	♂	2	47	49	44	44	32	6	224	
	♀	6	52	86	110	104	104	15	477	68%♀
	Total	8	99	135	154	148	136	21	701	
1971	♂	6	32	38	92	114	43*	*	325	
	♀	0	45	62	159	199	110*	*	575	64%♀
	Total	6	77	100	251	313	153*	*	900	
1972	♂	3	10	33	57	49	61	18	231	
	♀	2	12	51	108	138	117	43	471	67%♀
	Total	5	22	84	165	187	178	61	702	
1973	♂	—	4	26	45	64	60	11	210	
	♀	—	2	62	99	146	108	23	440	68%♀
	Total	—	6	88	144	210	168	34	650	
1974	♂	4	31	42	53	55	44	17	246	
	♀	3	38	89	137	127	84	38	516	68%♀
	Total	7	69	131	190	182	128	55	762	
6-year total	♂	16	145	222	340	374	288	58	1443	
	♀	16	177	404	701	816	628	147	2889	67%♀
	Total	32	322	626	1041	1190	916	205	4332	

* Catch stopped due to Brazilian local quota having been reached.

TABLE 7. MEAN LENGTHS OF MINKE WHALES IN EACH MONTH CAUGHT AT COSTINHA DURING 1966–67. (FROM PAIVA AND GRANGEIRO 1970)

Month	Males mean length *m* (no. measured)		Females mean length *m* (no. measured)	
	1966	1967	1966	1967
July	7.8 (13)	7.9 (14)	8.1 (12)	7.9 (22)
August	7.9 (11)	8.0 (21)	8.3 (17)	8.5 (39)
September	8.2 (25)	8.4 (27)	8.3 (64)	8.8 (83)
October	8.6 (33)	8.3 (46)	9.0 (98)	8.8 (133)
November	8.7 (25)	8.4 (40)	9.1 (52)	8.9 (67)

years old, the same as typical Antarctic catches.

During September–October–November a whitish mucus is found in the vagina of all female whales, also occasionally in late August and early December. The lips of the vagina of these females are a reddish colour. None of the female whales contain a visible embryo in the uterus.

About twelve mothers with calf are seen each year.

The stomachs of nearly all the whales are empty. A little krill is found in the stomachs of about 3% of the whales.

5,747 minke whales have been killed off Costinha so far plus a further 200 whales have been taken by factory ships in the Antarctic region 15°W–70°W which presumably are from the same stock. So far there are no signs of depletion of the minke whales off Costinha: average lengths of whales and catch per day's hunting are not decreasing (Table 8).

In August 1972 the catcher made a single voyage 400 km eastward out into the open ocean. Although the main concentration of minke whales was located close beyond the continental shelf edge, a few minke whales were seen all the way out as far as the catcher went.

TABLE 8. CATCH OF MINKE WHALES PER DAY'S HUNTING IN PEAK MONTH OF SEASON (i.e. October) AND AVERAGE LENGTH OF SEASONS CATCH OFF COSTINHA 1966-74. (DATA FROM WHALING COMPANY).

Year	No. caught per day's hunting in October	average length *m*	
		males	females
1966	4.2	8.3	8.8
67	5.1	8.3	8.7
68	4.3	8.3	8.7
69	4.8	8.3	8.6
1970	4.8	8.3	8.8
71	5.0	8.2	8.8
72	6.0	8.7	9.2
73	6.8	8.3	8.9
74	5.9	8.2	8.6

Blubber thickness results. The method of measuring the blubber thickness was the same as used by Ohsumi *et al.* (1970), in order to obtain comparable results. Due to the fact that off Costinha whales of progressively larger size occur in successive months, simple averaging of blubber thickness measurements does not produce a useful result. Therefore I selected for analysis only whales of a certain length range, and selected the range 8.4–9.3 m (27.5–30.5 feet), as plenty whales of this size occurred in all months. About one half of all the whales caught were in this length range. The blubber thickness of males and females in this length range are shown in Figs. 5 and 6.

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The results allow the following conclusions to be made:

- females have slightly thicker blubber than males. This is the opposite to Ohsumi *et al*'s (1970) findings in the Antarctic, where males had thicker blubber than females.
- the blubber of females is thicker than the blubber of males by about 0.5 cm. among whales killed in August and increases steadily to 1.1 cm thicker among whales killed in December.
- although male whales after September become thinner in successive months, among females the blubber is thicker in whales killed in successive months. The whales are not feeding, therefore cannot be getting fatter due to feeding. The increase in blubber thickness among females is presumably due to

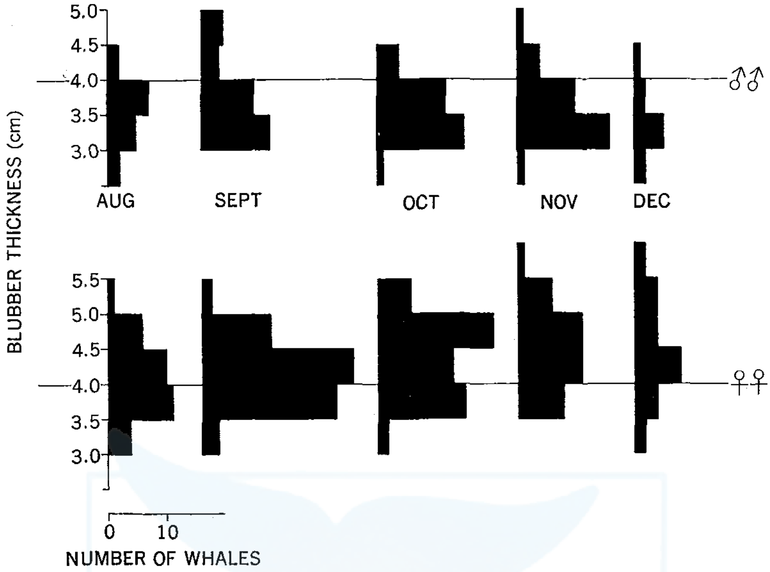

Fig. 5. Blubber thickness of whales in length range 8.4–9.3 m (27.5–30.5 feet) caught off Costinha during August 16-December 20th 1974. 118 males and 215 females were in this length range, which is about half of all whales killed during this period.

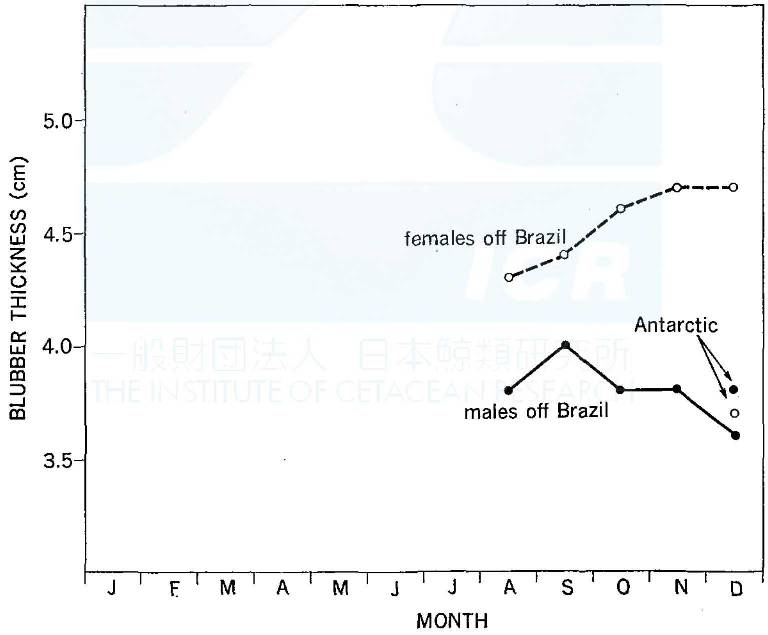

Fig. 6. Mean blubber thickness of southern minke whales in length range 8.4–9.3 m in different months of the year. August-December data from off Brazil calculated from Fig. 5, December data from Antarctic (Ohsumi et al 1970, Fig. 4).

greater fatness among the new whales which enter the area each month.

- female minke whales caught during August–December off Brazil appear to be fatter than those caught in the Antarctic during December (Fig. 6.) and males are of similar fatness. This contrasts with other rorqual species. However this may be due to accidented differences between my and Ohsumi's technique for measuring the blubber.

Testis results. Dr. R. F. Macadam reports "Testis specimens" from only seven mature whales caught off Brazil were well preserved and these included specimens from August, September, October and Novembers. These specimens, plus testis specimens from five mature whales caught in the Antarctic during November-December 1971 (kindly supplied by Dr. S. Ohsumi) were examined.

The specimens were fixed in 10% formol saline at the whaling station, and later embedded in paraffin wax, sectioned 5 microns thick and stained with Haematoxylin and Eosin and also by the Masson trichrome technique. Plate 4 shows photographs of testis specimens representative of whales caught in Brazil and in the Antarctic.

Testes from the seven whales caught off Brazil during August-November all showed many sperm in the tubules and active spermatogenesis in progress. These whales must have been capable of fertilizing femals. Plate 5 shows a single tubule and the numerous sperm in it magnified X1000.

Testes from the five whales caught in the Antarctic during November-December were not so well preserved as the Brazil specimens. All five whales showed a low degree of spermatogenetic activity and only a few sperm."

Vagina smear results. Dr. R. F. Macadam reports "the smears were well preserved and consisted of mucus containing many vaginal epithelial cells, many micro-organisms and no sperm. In humans, sperm in the female vagina disintegrate 2–3 days after copulation. Therefore the absence of sperm in the vaginas of these 18 females only indicates that none of them had mated within three days prior to being caught. They may nonetheless have mated during other days of the month."

Fig. 7. Position on body at which blubber thickness was measured. The position fulfils the requirements of being accessible on a hauled-up carcase, on the line of one of the main flensing cuts and identifiable with accuracy.

West South Africa and Durban catches of minke whales

Off west south Africa, minke whales are uncommon. Gunners operating out of Saldanha reported that they never saw minke whales there (Williamson, 1959).

TABLE 9. LIST OF ALL MINKE WHALES SEEN IN AREA 0°–30°S 0°–17°E OFF SW AFRICA DURING 2½ YEARS ALMOST CONTINUOUS WHALING BY FACTORY SHIP "SIERRA" NOV 1972–MAY 1975. (ALL MINKE WHALES SEEN WERE KILLED. DATA FROME SIERRA FISHING AGENCY)

Date	Lat	Long	Temp Sea Surface	Length *m*	Sex	Sexual Condition	Stomach Contents
March 17, 74	13°33′S	11°21′E	23°C	9.4	M	mature	empty
June 11, 73	5°46′S	10°36′E	24°C	7.3	F	?	empty
Nov 8, 73	7°02′S	11°23′E	26°C	8.2	M	mature	empty
Nov 20, 74	14°27′S	11°27′E	21°C	8.8	F	mature, no visible foetus	empty
Nov 21, 72	16°10′S	10°55′E	22°C	9.7	F	mature, no visible foetus	some krill

TABLE 10. COMPARISON OF CONDITION OF MINKE WHALES OFF COSTINHA 7°S, DURBAN 30°S AND ANTARCTIC OCEAN 55°–65°S. (COSTINHA DATA FROM WHALING COMPANY, DURBAN DATA FROM P. BEST PERS. COMM., AND ANTARCTIC DATA FROM OHSUMI *ET AL* 1970, AND OHSUMI AND MASAKI 1974b).

	Costinha, Brazil 7°S	Durban S Africa 30°S	Antarctic Ocean 55°S–65°S
Months in which minke are most abundant	Sept-Oct-Nov	all months some present	Dec–Jan–Feb
Temperature of sea surface during season of abundance	27°S	20–25°C	0°C
% of all whales caught that are sexually mature	95	mature and immature present (see text)	70
% of mature females that are accompanied by calves	3	small numbers during August-September	0
% of mature females that have no calf and no visible foetus	97	?	7
% of mature females that are pregnant with visible foetus and have no calf	0	0	90
Mean length of foetuses	—	—	0.27 m (December)
% female among whales at sea	about 60%	unknown	Great variations in different areas
% female among killed whales	67% ♀	30% ♀	54% ♀ but great variations in different areas
% stomachs containing food	3	?	55
Grouping of whales at sea	Many small groups and a few single whales. Most groups are of 4–5 whales.	Small groups and a few single whales. Some lactating mothers with young calf during August-September.	Many groups of 2–6 whales, a few single whales and a few groups of up to 100 whales. Groups usually dominated by one sex.

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Mr. R. H. Shepperd reports that the factory ship " Sierra " during 2½ years almost continuous whaling Nov 1972–May 1975 in the area 0°S–30°S, 0°–17°E off west south Africa has only sighted five minke whales (Table 9). They were all shot and proved to be mature animals.

During the same period the " Sierra " sighted several thousand sei whales.

Off Durban 30°S (Table 10) Dr. Peter Best reports that minke whales are present in moderate numbers all year round in waters which range 20°–25°C annually. They appear to be most numerous during winter and spring (June–November). The annual catch of about 150 minke is a mixture of sexually mature and immature animals. During August-September in sea of temperature about 20°C some lactating mothers with young calves are seen each year.

DISCUSSION

Separation of north and south atlantic stocks. South Atlantic minke whales migrate as far north as NE Brazil 5°S and on the African side odd individuals migrate to off Angola with 5°S the extreme northernmost record to date (Table 9). The nearest localities from which north atlantic minke whales have been recorded are Florida and the Mediterranean (Moore and Palmer, 1955; Scattergood, 1949). About 5,000 km separates the nearest records, thus it seems unlikely that members of the north and south hemisphere stocks ever meet.

Route of northward migration. By what routes do whales travel from the Antarctic to NE Brazil? After the feeding season, most whales all round the Antarctic head north. In wide areas of the Indian and Pacific Oceans there is no land and the whales must meet and mate successfully in mid ocean. In the western South Atlantic most whales, after a northward swim of varying length seem likely to strike the sloping coast of South America at some point. The slope of the coast "funnels" the whales together and causes them to become concentrated as they proceed northwards. For those whales which continue furthest into warm waters, the NE corner of Brazil is the focal point where maximum concentration occurs.

It seems probable that most minke and sei whales which arrive off Costinha have followed the continental shelf edge from varying distances further south, while a smaller number have arrived direct from the open ocean. The minke whales off Costinha concentrate about 20 km beyond the edge of the continental shelf (Fig. 2). Further out to sea and on the shallow continental shelf there are only a few minke whales.

The low-frequency noises made by rorquals can be heard at distances of at least 180 km (Cummings and Thompson, 1971, p. 1197) and thus minke whales on the open ocean, when they get within this range of the continental slope, probably hear and are attracted to the concentration of whales.

The virtual absence of minke whales off west south Africa, and yet their presence off the eastern southern Africa (Durban) and eastern south America, suggests an assymmetry in the autumn northward migration from the Antarctic. It appears that minke whales migrate chiefly up the western side of the southern atlantic, heading into the south-flowing Brazil current, but keep clear of the north-flowing Benguela current.

If this is the case, the coast of Brazil may be the mating ground of minke whales from a wide sector of the Antarctic.

Sei whales in contrast migrate up both sides of the South Atlantic.

Length of the reproductive cycle. Studies to date conclude that minke whales bear one calf each year and have a one-year reproductive cycle; thus reproduce twice as fast as all the larger rorqual species.

In truth, available data are not conclusive on this matter. Some facts suggest a one-year cycle, some facts suggest a two-year cycle.

Evidence which suggests a one-year cycle:

- about 88 % of mature female minke whales ovulate during the latter part of the lactation period, in August–September (see section ' Existing knowledge on minke whales '). This makes it possible for minke whales to become pregnant during late lactation, thus producing one calf per year. Overlapping of lactation with pregnancy does not occur in the larger rorquals, all of which have a resting period of several months between the end of lactation and mating (Fig. 5).

Evidence which suggests a two-year cycle:

- The 27 cm average length of foetuses in December Antarctic catches (Table 10) indicates that mating must occur in about September (compare Omura and Sakiura, 1956, Fig. 23). A ten-month pregnancy would result in calves being born in July and the four month lactation would last till November. However, during September-October-November, hundreds of calf-less mature females arrive off Costinha. These females cannot have born a calf recently, therefore it seems impossible that they are producing one calf per year.
- The 0.89 per year ovulation rate of minke whales is basically similar to, although somewhat higher than, the ovulation rates of the other rorqual species (Table 12). (It must be remembered that all these rates are estimates only). If minke whales really reproduced twice as fast as other rorquals, their ovulation rate should be double that of other species—about 1.4 ovulations per year. But it is not near this value.

  The 0.89 per year ovulation rate of minke whales could not allow *all* the females of the population to bear a calf every year but it is nonetheless compatible with the existence of a basic one-year cycle. An individual female during a ten year period could have 8 calves at one year intervals and one calf after a two year interval (assuming all ovulations produce calves).

  As pregnancy and lactation total 14 months duration, a one-year cycle can only exist if new pregnancy occurs two months before the end of lactation, that is; the cycles overlap by two months.

  The fact that in the Antarctic 90% of mature female minke whales are pregnant, compared with 66% among blues, 80% among fine and 69% among sei (Table 11) does not clarify the reproduction rate. It is compatible *either* with minke whales having a higher reproductive rate than the other species (though hardly double the rate of the other species) *or* with minke whales having a two-year cycle in which resting mature females have the habit of seldom entering the Antarctic.

By examination of the ovaries of mature females caught off Costinha it should be possible to obtain the vital missing evidence.

If these calf-less whales are only just ovulating or have not yet ovulated, they must have passed a true resting stage since parting from their calf and thus must have a two-year reproductive cycle.

If the whales have already ovulated (and in this case they will presumably be in early pregnancy) then it is likely that they ovulated and mated puring lactation, and this overlap would allow a one-year reproductive cycle.

Further data are needed to clarify the reproductive cycle of minke whales.

TABLE 11. COMPARATIVE DATA ON SOUTHERN HEMISPHERE RORQUAL SPECIES DURING THE COOL-WATER SUMMER FEEDING SEASON

Species	greatest numbers of adults furthest south	% females in catch	% mature in catch		% of mature females that are pregnant	timing of migration of immatures
			♂♂	♀♀		
Blue	December[1]	47[1]	?	?	66[1]	later than matures[2]
Fin	January[1]	50[1]	?	?	80[1]	later than matures[2]
Sei	February[3]	?	94[4]	92[4]	69[3]	
Minke	?	54[5]	86[6]	55[6]	90[5]	earlier than matures[5]

Sources of data. 1=Mackintosh 1942, p 270, Table 25 and Fig. 27.
2=Laws 1961, p 341. 3=Gambell 1968 p 39–40 and Table 5.
4=Doi *et al* 1967, table 14. 5=Ohsumi and Masaki 1974b.
6=Ohsumi *et al* 1970 p 107.

TABLE 12. OVULATION RATES PER YEAR OF RORQUAL WHALES

Species	average number of ovulations per year	evidence used to calculate th value	author
Blue	0.69	Average of the average number of recent ovulations in several hundred antarctic whales of three sexual classes (pregnant, resting and recently-ovulated non-pregnant).	Laurie in Purves and Mountford 1959 p 139 based on Laurie 1937, p 250
Fin	0.72†	Average of ovulation rates from three types of 2-year breeding cycles, found by counting corpora albicantia in several hundred antarctic whales.	Laws 1961, p 463
	0.77	Average rate in 6 marked antarctic whales captured 19 or more years later, found by counting corpora albicantia.	Ohsumi 1964, p 66
Sei	0.69	No of oestrous cycles in 2-year breeding cycle x average number of ovulations per oestrous, found by counting corpora albicantia in 644 whales caught off Durban.	Gambell 1968, p 123
Minke	0.87	No of corpora albicantia in 1359 antarctic whales of known age	Ohsumi and Masaki 1974, p 9

† value halved from original 1.43 consequent to Roe's (1967) discovery that ear plugs of southern hemisphere fin whales accumulate only one (not two) growth layers per year—see Gambell (1968) p 124.

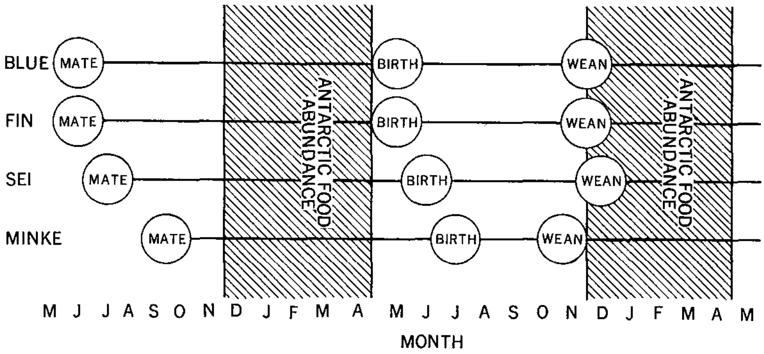

Fig. 8. Reproductive cycles of rorqual whales: comparison of timing of events. (Blue and Fin data from Mackintosh and Wheeler 1929 and Laws 1959, Sei data from Gambell 1968, Minke data from Omura and Sakiura 1956 and present report).

Location, season and temperature of giving birth. The presence of calves with their mothers in 20°C water off Durban 30°S, but seldom in 27°C water off Costinha 7°S suggests that minke whales give birth in relatively cool and southerly waters and do not usually, bring their calves into the warmest waters. This is interesting because scientists traditionally believe that all whales bear their calves in the warmest part of their range. In minke whales it is chiefly the mature adults which enter the truly hot tropical waters. What is the purpose of this?

Newly weaned minke calves off Japan are not found in water colder than about 15°C (author's data) thus presumably suckling occurs in waters of about 20°–15°C and females do not enter waters cooler than 15°C until after parting from their calf.

What catch of minke whales can be sustained indefinitely off Costinha? If the southern hemisphere population estimate of 300,000 minke whales is correct, and if they are equally distributed around the longitudes, then about 45,000 are living in the 15°W–70°W western part of the South Atlantic and about 75,000 in the whole South Atlantic.

The annual yield that this population could sustain cannot be determined at present but it will have to be shared between Costinha and the factory ships which hunt the same stock in the Antarctic.

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Future research

1 At Costinha a biologist should spend a season and:
  - examine the uteri of all females to check whether tiny embryos are present or absent
  - examine ovaries of all females to determine presence or absence of corpora lutea
  - take samples of testes in each month to determine state of spermatogenic activity
  - take samples from *every* female of the vagina contents, examine them for

sperm and thus discover whether any of the whales are actually mating.

2 Whale-searching cruises and tagging should be used to investigate:
  - is there a belt of minke whales stretching between Brazil and Africa during the winter season?
  - what numbers of minke whales are present in winter in mid-ocean areas, off the west coast of S. America and off the east and west coasts of Australia? Do northward migrating minke keep to the west warm-current sides of the southern oceans?
  - in what temperature and latitudes does mating occur?
  - in what temperatures and latiudes are calves born?

3 A factory-ship should be asked to catch samples of minke whales at all latitudes on its way to and from the Antarctic.

SUMMARY OF NEW KNOWLEDGE ABOUT MINKE WHALES

The data from Costinha reveal the following new facts

- immature whales precede mature whales in the migration to the north (Fig. 4).
- as whales get older and larger they migrate north later in the season (Fig. 4, Table 7). The main concentration occurs during September-October-November.
- the 2 ♀♀: 1 ♂ sex ratio among caught whales at Costinha, even making allowance for gunners selecting large and therefore female whales preferentially, suggests that there is a real imbalance of the sex ratio off Costinha and that many of the smaller mature males do not migrate so far north
- mature whales go much further north to 7°S and into warmer water 27°C than do immature whales
- calves are born and suckled somewhere to the south of and in less warm temperatures than the waters in which the adults congregate off Costinha
- immature whales precede mature whales in the migration to the feeding grounds (whereas in blue and fin whales the mature animals move south before the immatures; see Table 11).
- the simultaneous presence during November–December of considerable numbers of minke whales both off Brazil and in the Antarctic 7,000 km to the south indicates either or both of the following: that there is great variation in timing of migration between different individual adult whales and/or separate high latitude and low latitude stocks of minke whales exist. The results of analysis of blubber thickness in different months also support this conclusion.

ACKNOWLEDGMENTS

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Dr. R. F. Macadam of Raigmore Hospital Pathology Department, Inverness, Scotland carried out the histological examinations of the vagina smear and testis samples.

Larry Foster of General Whale, California made the beautiful drawing of the whale (Plate I).

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EXPLANATION OF PLATES

PLATE I

Southern Minke Whale *Balaenoptera acutorostrata bonerensis* Burmeister 1867. Drawn by Larry Foster of General Whale, California from photographs of alive and dead specimens.

PLATE II

Baleen plates of a typical Southern Minke Whale caught off Brazil. Note the assymetry of the pigmentation; the pale plates extend further back on the right side than on the left side, as also occurs in the fin whale.

PLATE III

Unusual case of minke whales trapped over-winter in pack ice in a coastal fjord of Graham Land, Antarctica. In normal winters these individuals might be off Brazil. (From Taylor 1957, photos copyright of British Antarctic Survey.)

Plate IV

Comparison of testis of two mature whales caught off Brazil with testis of two mature whales caught in the Antarctic. In the Brazil whales, active spermatogenesis is occurring; in the Antarctic whales very little spermatogenes is is occurring. Sperm are visible only in the Brazil specimens and are the tiny black dots in the tubles. Magnification X150. Photographs by Dr. R. F. Macadam.

Plate V

Testis tubule showing many sperm (the tiny black dots are the nuclei of the sperm heads). From 9.1 m whale caught off Brazil, November 7 1974. Magnification X1000. Photograph by Dr. R. F. Macadam.

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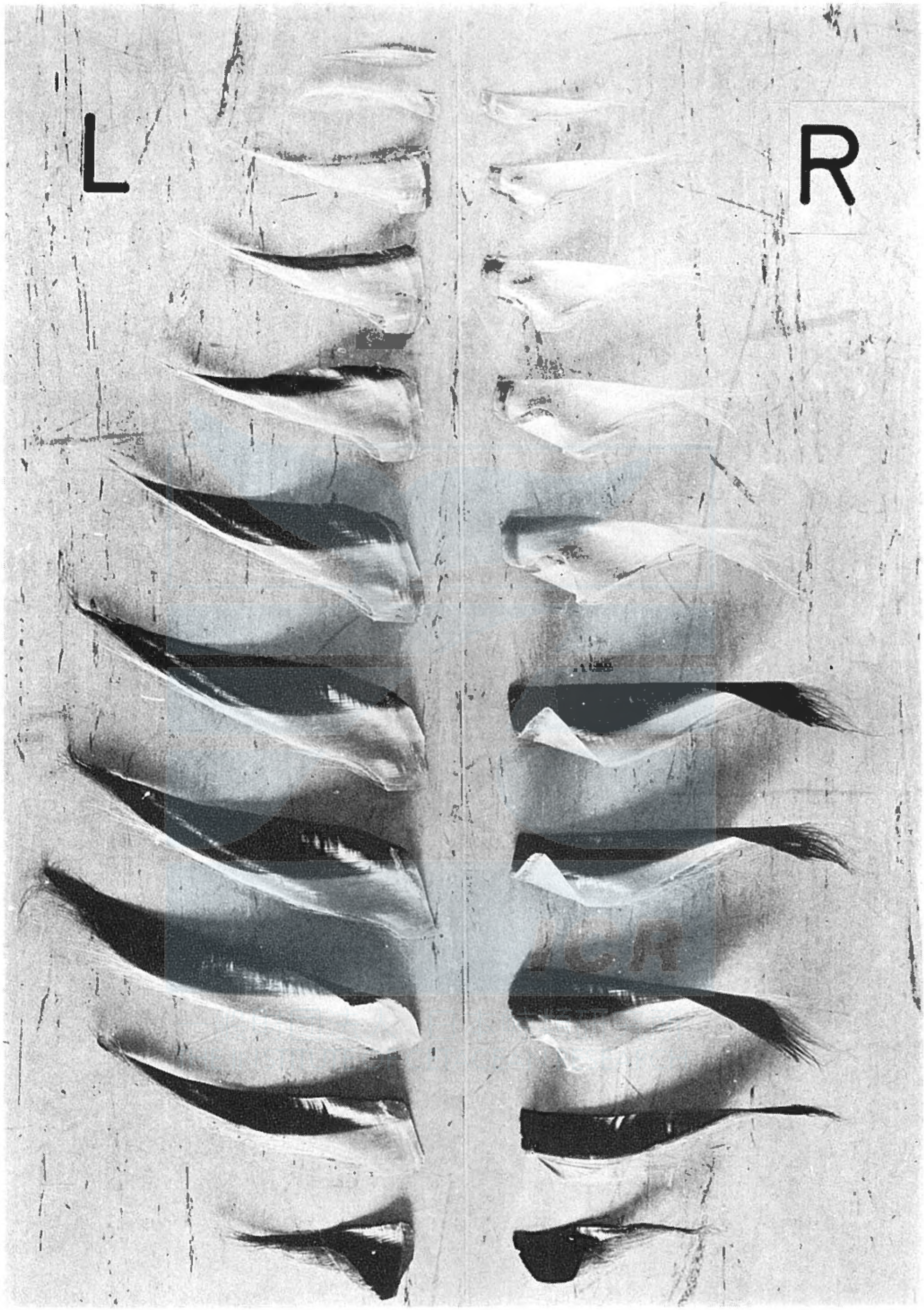
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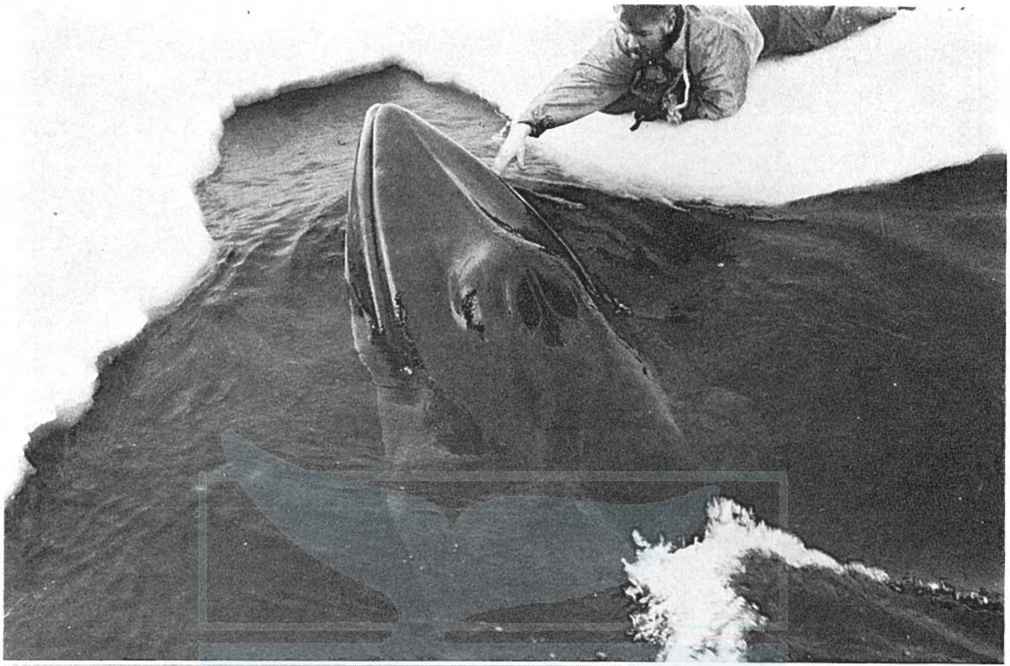

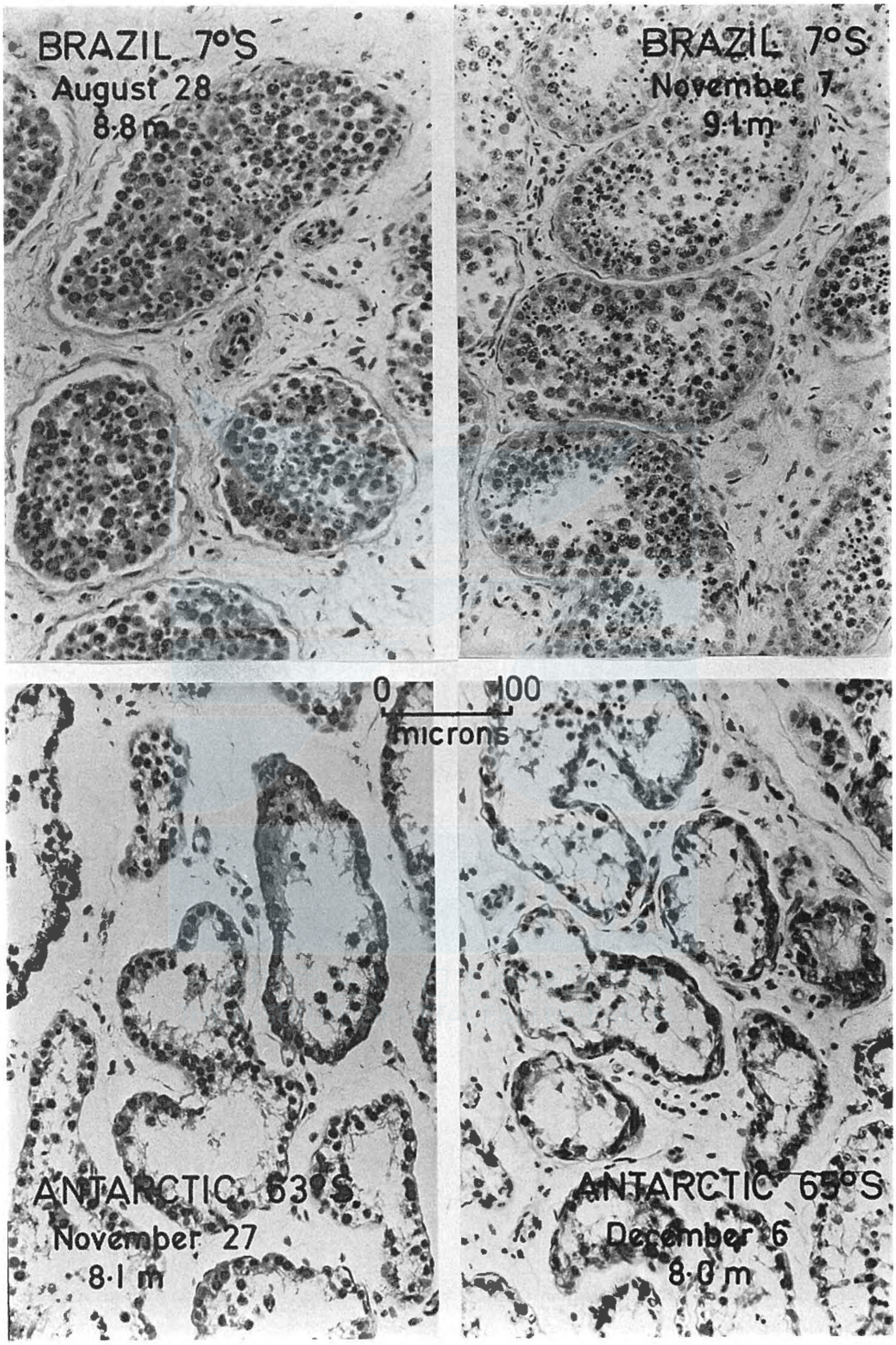
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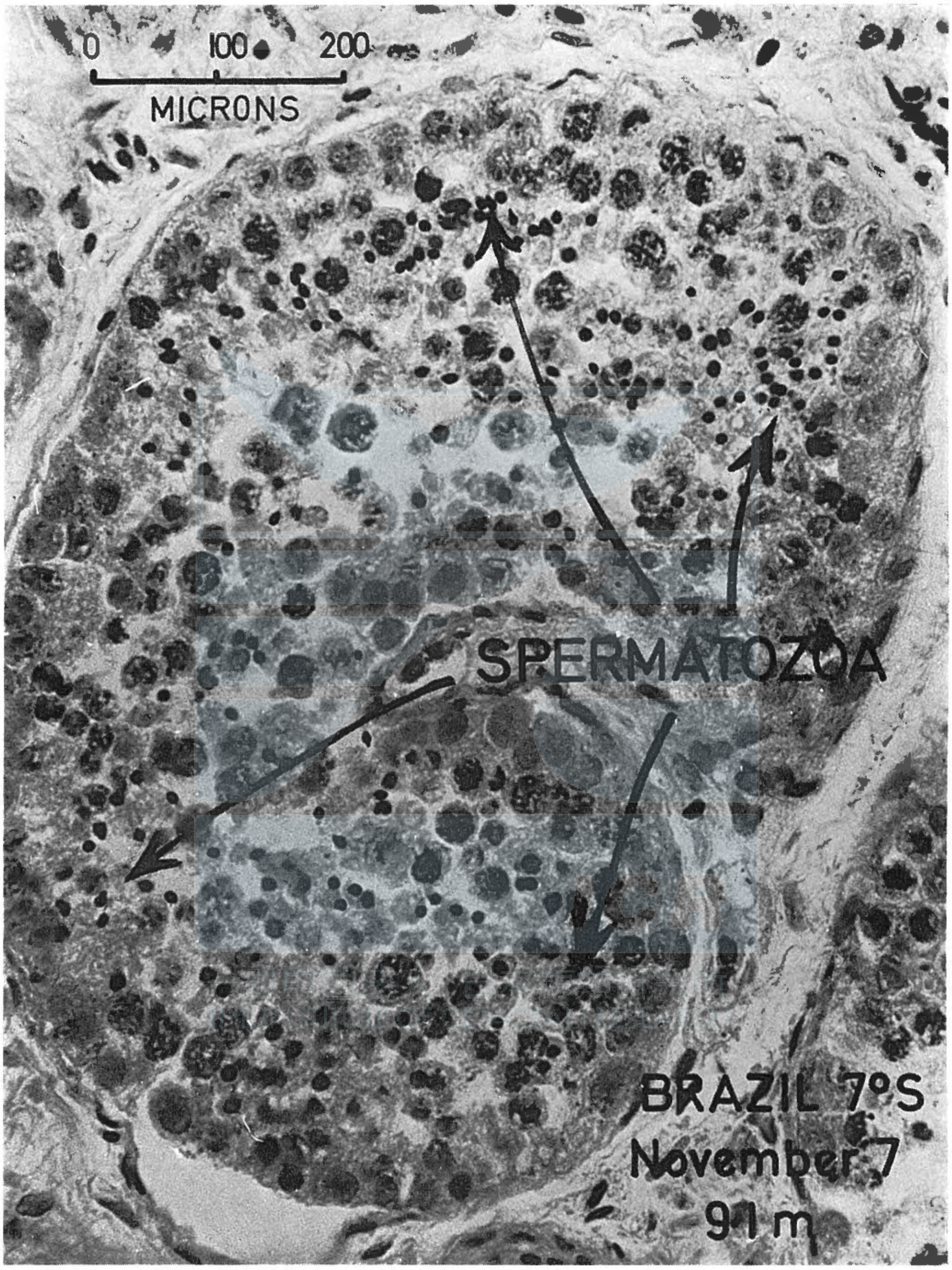
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A CONSIDERATION ON AN AVAILABLE SOURCE OF ENERGY AND ITS COST FOR LOCOMOTION IN FIN WHALES WITH SPECIAL REFERENCE TO THE SEASONAL MIGRATIONS

AKITO KAWAMURA

Whales Research Institute, Tokyo

ABSTRACT

The energy cost for locomotion and possible distance of the migrations to and from the feeding grounds for southern fin whale were estimated being based on the amount of whale oil by girth measurements. A 18.1 meter fin whale keeps about 90 m^2 of the blubber area as substantially important for expending the preserved whale oil, and about 1.8 m^3 of oil is preserved in 2.0 cm thick of the blubber. The energy cost for locomotion by swimming in material fin whale was estimated as 0.022 $Kcal^{-1} \cdot Kg^{-1} \cdot Km^{-1}$ by extrapolating parameters onto the known regressions of body weight-energy cost relationships in aquatic animals, and an integrated distance of migrations which is covered by following above mentioned parameters would be somewhere between 20,000 and 30,000 Km. These figures lead to a consideration that it is not unlike but generally quite possible to do have some food intake through the breeding migrations of whales since energy budget for locomotion in large rorquals seems to be scarcely well balanced in general pattern of their movements. These overall situations regarding the energy for locomotion were discussed along with the seasonal distributions of whales and also with the so-called problem of the breeding grounds.

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INTRODUCTION

In the consideration on the seasonal changes of nutritive condition in California gray whale, *Eschrichtius robustus,* Rice and Wolman made a calculation on the expected amount of energy expenditure throughs wimming locomotion being based on the body weight difference due to the combustion of tissue before and after their migratory journey, and the weight loss was assumed as a function of oxidation of fat (Rice and Wolman, 1971). Being found that the overall energy budget for locomotion seems well balanced, Rice and Wolman (1971) concluded that gray whale must be able to perform migrations of such large distance as invade far deep into the Bering Sea and/or the Chukchi Sea without causing any malnutrition, and described, " there is no reason to assume that gray whale must feed while on the winter grounds ". Since gray whale is one of a well known regular migrators among large whales, the above mentioned result itself would be appropriate in the subject of controversy concerning to energy budget of migrating whales. Very

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recent aerial observations, however, revealed that gray whale clearly feed on small fishes on the way of their southbound migrations (Sund, 1975).

On the other hand, however, the baleen whales other than gray whale actually distribute with more larger numbers in the world oceans. They are balaenid and balaenopterid species of which the latter would be historically most important relating to human activities as an industorial resource. The general ecology around balaenopterid whales especially in so-called rorquals much differs from that in gray whale, that is to say, we are still in need of a verification in rorquals on this matter whether or not we will find similar conclusion to the results by Rice and Wolman. Under these circumstances I made a calculation and assessed the energy cost in relation to the swimming locomotion along with the overall energy budget through the seasonal migrations in southern fin whale, *Balaenoptera physalus*, and then extended a consideration to the seasonal distribution of whales.

NOTES ON THE SEASONAL MIGRATIONS OF WHALES

The conception that large whales are very likely to make seasonal migrations which extend over those vast oceans seems to have come in general knowledge as a result of accumulating a great deal of fragmental evidences brought on by navigators, fishermen and whalemen through many past years, but its substantial features remains still obscure even today. One of well dealt descriptions on the seasonal distributions in a north and south direction in the North Atlantic balaenopterids species was worked out by Scoresby (1820), by which our knowledge on the migrations of whales made much progress. Discussing on the evidences of whale sightings in nineteenth centuries, Scammon (1874) could describe only a possible north- and southbound migratory habits for humpback whale, *Megaptera novaeangliae*, and right whale, *Eubalaena gracialis* in northern hemisphere is unlikely to migrate crossing over the equator. There are another evidence that some blue whale, *Balaenoptera musculus* remains in the waters off California throughout the year. The seasonal migrations and the movements of whales are such variable and complicated by each whale species and place from time to time that the matter cannot be said as the comprehensively well explained subject.

Although it was not the aim in his discussion, True (1904) described that some North Atlantic humpback whale migrates down to at least 18°N latitude. Kellogg (1929) well reviewed on the migrations of six species of baleen whales based on the available evidences by that time. Although his descriptions were mainly confined to the northern species of whales, he (Kellogg, 1929) also mentioned but briefly on the migrations in southern species. By his above mentioned review the general idea concerning to the migrations of whales became much clear but still mysterious especially in recognizing the movements of whales as a large scaled and successive event performed through a life span of each whale individual, that is, the migrations of animals in broad sence. The comparative field study by Mackintosh and Wheeler (1929) on the biological and morphological characters in southern blue and fin whales of both South Georgia and Saldanha Bay made our knowledge on the migrations of whales much concrete. Shortly, it can be said that pattern of the whale migrations to the extent as have currently been recognized conception may be basically established by their work. However, movements of whales and where they may stay during winter or so-called non-feeding seasons are almost unknown even today except those traditional expressions of somewhere of " warm temperate or tropical waters."

According to Mackintosh and Wheeler (1929) connective tissue lies beneath the very surface skin of whales is the main body for depositing fatty substances, and the thickness of the blubber itself varies by season in southern species, that is, more thin layered blubber is found just after the winter and get more fat by an approach of autumn as a result of voracious feeding through the past several months in the feeding ground, whereas little feeding takes place in South African waters. With these facts along with a possible identity of whale populations which occur in both South Georgian and South African waters, it was obvious that both blue and fin whales are likely to make meridional migrations by season through which they do not feed but can continue swimming around by expending the blubber oil as the energy source for their locomotion. The general idea of the seasonal migrations of large baleen whales became clear to such somewhat fixed forms as having been recognized. At the same time the reason why they have to migrate into those " warm temperate or tropical waters " was well explained by supposing that cold feeding grounds of almost freezing point would be disadvantageous for parturition and for new born calf to keep well its body temperature. The conception seems fairly well established and there have found no additional evidences or explanations regarding this matter even in recently published articles which in part dealt seasonal distributions, feeding and breeding migrations for large whale species of the world oceans (e.g. Slijper, 1958; Jonsgård, 1966; Mackintosh, 1965, 1966; Nishiwaki, 1966; Matthews, 1968). However, Kellogg (1929) considers that there must be some fin whales throughout winter season in the South Georgian waters, and Mackintosh (1965) thinks the status of whale migrations as a possibly very loose and/or somewhat random movements in general, that is, some individuals may stay in the feeding grounds throughout a whole year while the other may not undertake those annual back and forth movements so regularly. Reviewing on the geographic ranges and seasonal distributions for large whales in the North Atlantic, Jonsgård (1966) considered that some whales may stay in the boreoarctic part of the North Atlantic, but he did not deal much about the breeding migrations by reason of less documented subjects. On the other hand, Mackintosh (1966) described two kinds of interesting and suggestive ideas on the status of migrating whales whether they are apt to concentrate or disperse in the breeding grounds. Matthews (1968) explained the seasonal migrations of whales schematically but he remained within showing a " warm temperate or tropical seas " as the destination of migrating whales. Recent description by Gaskin (Gaskin, 1972) concerning to whales migrations made a subject clear in a concrete form that the sea region where the reproduction of fin whale takes place would be found in the offshore waters within 150 miles or thereabouts.

Where are the large whales during winter or reproductive season is still mysterious subject which could be approached only by accumulating a scattered evidences on whale sighting. In the North Pacific region, for instance, a possible place for over wintering in fin and sperm whales seems to be still beyond of our scientific knowledge. Although an approximate movements of migrating whales may be recognized after the general principle as mentioned above, it seems still in need of further investigations and considerations to prove the matter more clearly. For

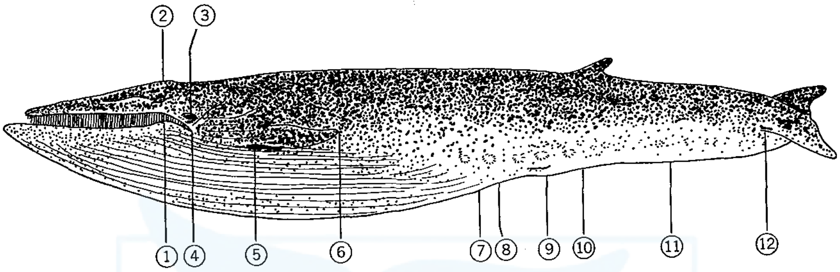

Fig. 1. Points for girth measurements. Encircled numerals correspond to those in Table 1 and Fig. 3.

TABLE 1. GIRTH MEASUREMENTS IN THE SOUTHERN FIN AND

	Ser. No.	1656†	1671††	1673	1676
	Sex	F	F	M	M
	Body length (m)	21.1	17.5	17.6	17.5
	Thickness of blubber (cm)	7.0	6.5	6.5	5.0
	Date of catch (month/day)	3/11	3/12	3/12	3/13
	Position of catch (S)	49–09	49–16	49–16	49–28
	(E)	77–42	79–32	79–32	80–31
1	Highest point of lip	—	—	—	200
2	Center of blow hole	—	—	—	—
3	Eye	—	—	—	—
4	Angle of gape	—	—	—	860
5	Anterior base of flipper	—	810	900	850
6	Tip of flipper	—	—	—	—
7	Posterior end of ventral grooves	—	—	—	—
8	Unbilicus	780	644	674	630
9	Center of genital aperture	—	—	560	530
10	Anus	560	496	448	464
11	Center between dorsal fin and base of tail flukes	—	—	330	300
12	Base of tail flukes	286	238	208	208

* Measurement at 140 cm anterior from the base of tail flukes
** ” 110 ” ”
*** ” 150 ” ”
1) Measurement at 238 cm posterior from the base
2) Posterior margin
†) Pregnant: foetus of 281 cm, female
††) Not pregnant

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instance, whether or not non-feeding activity during seasonal migrations explains or actually fills overall locomotion energy required for migrating into those " warm temperate or tropical seas " only by expending the blubber oil without causing malnutrition.

MATERIAL AND METHOD

During the course of 1971/72 Antarctic whaling season when I was on boad of the mother ship " Tonan Maru No. 2 " of the Nippon Suisan Co. Ltd., girth of fin and minke whales was measured at three to nine points of the carcasses (Fig. 1). True (1904) noted several girth measurements on the basis of one side or whole of carcasses, and Captain Roys gave 39 ft. of girth for 95 ft. blue whale in 1800's (Scammon, 1874). However, since very little girth measurements have been done in the ordinal program of the biological examinations on whale carcasses, I would like present here the whole row data of the girth measurements in nine fin whales (6 male and 3 female) and four male minke whales for the convenience of later use (Table 1). As shown in Table 1 both fin and minke whales were caught in the mid March of 1972. Two-meter measure was used for actual measurement by

MINKE WHALES CAUGHT IN 1971/72 ANTARCTIC SEASON

Fin					Minke			
1678††	1679	1692	1702	1705	16-1	16-2	23-1	26-2
F	M	M	M	M	M	M	M	M
19.3	17.4	20.9	17.7	18.1	8.4	8.2	?	8.4
6.5	5.5	6.0	5.5	7.0	4.6 (Avg.)	4.6 (Avg.)	4.6 (Avg.)	4.6 (Avg.)
3/13	3/13	3/14	3/14	3/14	3/16	3/16	3/16	3/16
49-28	49-28	49-46	49-46	49-46	53-58	53-58	53-58	53-58
80-31	80-31	80-03	80-03	80-03	85-16	85-16	85-16	85-16
—	—	240	180	220	—	—	—	—
—	—	—	—	770[2]	316	316	314	354
—	—	310	—	—	—	—	—	—
—	—	—	794	—	420	426	408	412
—	—	860	854	—	480	492	448	470
—	—	—	804[1]	790	—	—	—	—
—	—	—	—	—	490	500	440	452
—	—	720	640	920	450	480	426	432
596	560	626	540	600	372	376	346	356
558	480	560	470	532	296	290	262	280
380*	296**	354	300*	320***	234	216	200	216
268	186	232	192	220	100	108	108	100

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sliding the scale like a looper. The air which had been filled in the ventral cavity to make the carcasses afloat was discharged when the carcasses were pulled up onto the flensing deck except no. 1673 fin whale which kept some amount of air but not fully. Each girth measurements given in Table 1 are obtained by doubling the actual figure from one side measurement. Measurements at nos. 1 and 3 points show only the upper half, that is, only a part of the skull.

Since no measurement for so-called body proportion analysis on the carcasses concerned in Table 1 was conducted, the proportion data obtained in the South Georgian fin whales by Mackintosh and Wheeler (1929) were adopted as the possibly most well representing figures to know relative position of the girth measurements (Fig. 2). Of six fin whales 18.1 meters of male individual (no. 1705 specimen in Table 1) which was most well measured was selected for the calculation of body surface area, and consequently, the volume of the blubber. By this treatment the whole body surface area was calculated section by section as given in Fig. 3. Anterior part from blow hole and tail flukes were excluded from the calculation since these two are considered unlikely to relate to the question to be discussed here. Dis-

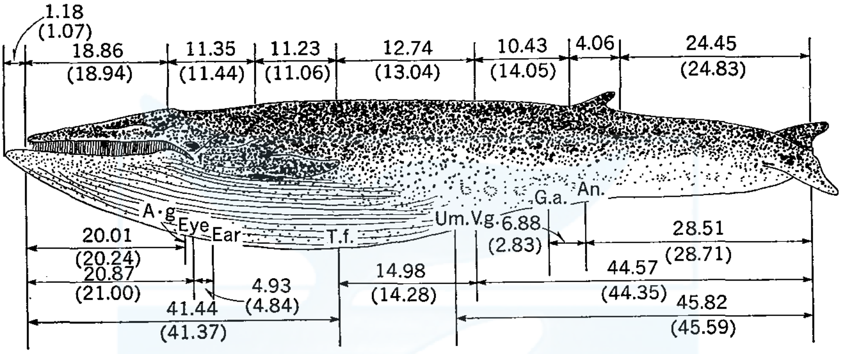

Fig. 2. Average body proportions (in percentage figures) for the southern fin whales. Figures for female are given in brackets (Calculated from the data by Mackintosh and Wheeler, 1929).

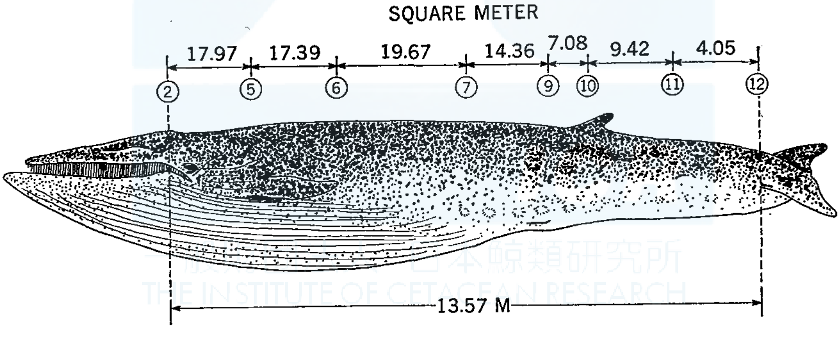

Fig. 3. Surface area of body trunk for a southern fin whale (18.1 m, male).

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tance between notch of flukes and the anterior base of tail flukes was hardly determined clearly, and 4.0 percent was adopted tentatively for its proportion: then the actual body length which concerns to a consideration is 13.57 meters, and the whole body surface area corresponds to 13.57 meter body length is calculated as 89.924 square meters (ca. 90 m^2).

The thickness of the blubber with connecting tissue beneath the epidermis and dermis considerably varies with the seasons. In southern fin whales caught in the South Georgian waters averaged difference in the thickness of the blubber against body length in percentage figures was 0.37 for summer and 0.27 for winter respectively (Mackintosh and Wheeler, 1929). The material of 18.1 meter fin whale showed 7.0 cm thick blubber, that is, 0.39 percent against its body length while it was only 5.0 thickness (ca. 0.29 percent) in another material of 17.5 meter male fin whale. Comparing these figures with those obtained in South Georgian waters, the 7.0 cm thick blubber in 18.1 meter fin whale would possibly be at its upper most extremes as the function of depositing whale oil, and similarly, 5.0 cm thick blubber would be at its lower extremes. These facts suggest that the blubber oil which corresponds to 2.0 cm difference in the thickness of the blubber is likely to be consumed through the migratory journey. According to Slijper (1958) about 40.0 percent of the blubber is in general consisted of connecting tissues. So if we take this figure into considerations the total volume of whale oil preserved in the 2.0 cm thick blubber for 18.1 meter fin whale would be calculated as about 1.80 cubic meters. Assuming five months between May and September as for the duration of whale migrations, the blubber oil as the energy source for locomotion would

TABLE 2. DATA AND ASSUMED CONSTANTS CONCERNING TO THE CALCULATIONS FOR FIN WHALE LOCOMOTION*

Species	Fin whale: *Balaenoptera physalus*
Position of catch	49°46′S, 80°03′E
Date of catch	March 14, 1972
Body length	18.1 m
Sex	Male
Thickness of blubber	7.0 cm
Area of blubber concerned**	89.9 m^2
Body weight***	34.0 tons
Thickness of blubber expended	2.0 cm
Caloric value for blubber oil	9.34–9.45 Kcal/gr.
Specific gravity of blubber oil	0.92
Energy cost for locomotion	0.022 Kcal/gr./Km
Efficiency of muscle in performing external work	25%
Condition of swimming	10 knots, laminar flow
Estimated migration distance	2.1×10^4–2.3×10^4 Km

* for further detail see Schmidt-Nielsen (1970, 1972) and Kawamura (1973a, b)

** body trunk proper: anterior part from blow hole and appendages are excluded

*** after the formula by Ash (1952)

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be about 0.36 $m^3 \cdot month^{-1}$, or 1.2×10^4 $ml \cdot day^{-1}$. Since generally known caloric value and specific gravity of fin whale oil is 9.34–9.45 $Kilocalories \cdot gram^{-1}$ and 0.92 respectively, the unit volume of consumable whale oil could be converted to 1.1×10^4 $gram \cdot day^{-1}$, or $10.27 \times 10^4 - 10.39 \times 10^4$ $Kilocalories \cdot day^{-1}$. The grand total of consumable energy during five month migrations in 18.1 meter fin whale would be about $1.55 \times 10^7 - 1.57 \times 10^7$ Kilocalories. Data and some constants concerning to above mentioned calculations are given in Table 2.

ENERGY COST FOR LOCOMOTION IN FIN WHALES

The energy cost for swimming locomotion in large whales is still unknown. However, it seems possible to speculate the energy cost for locomotion by the aid of known data in small toothed whales and in some another kind of aquatic animals (e.g. Schmidt-Nielsen, 1970, 1972). As I showed previously (Kawamura, 1972), the energy cost in large whales seems to be very less expensive when it is compared with the case found in another species of aquatic animals. Only four percent or thereabouts in daily feeding rate in sei whale (Kawamura, 1974) and possibly similar figures in another species of baleen whales would support very less energy expenditure for locomotion in those large whales. According to Schmidt-Nielsen (1972) the energy cost in a dolphin of 100 Kilogram body weight is about 0.1 $Kilocalories \cdot Kilogram^{-1} \cdot Kilometer^{-1}$ when it swims through laminar flow of water over the body at 10 knots in speed if we assume its conversion efficiency of muscle in performing external work would be 25.0 percent whereas 22.0 percent was assumed by Gawn (1948). In general the energy cost for locomotionin animals is closely related to the body weight of animals, and changes by following after the exponential like curve (Schmidt-Nielsen, 1970, 1972). Then the energy cost or metabolic rate such as 0_2 $ml \cdot gr^{-1} \cdot h^{-1}$ in relation to the body weight of animals can be expressed under logarithmic scale by three different regressions each of which shows difference by the kind of living media; whether the animal flys, runs, and/or swims. Since these corelations can be followed in aquatic animals and seems to be not unreasonable for extrapolating treatment, the energy cost for locomotion (= swimming) in large whales would be known reasonably by extrapolating their body weight onto known energy cost—body weight relationships.

Then the energy cost for swimming in 18.1 meter fin whale which weighs about 34 tons is estimated as 0.022 $Kilocalories \cdot Kilogram^{-1} \cdot Kilometer^{-1}$ if the same parameters are assumed as in the case of dolphins, that is, the animal swims at the speed of 10 knots under laminar flow of water over the body and 25 percent in the efficiency of muscle in performing external work. (See Schmidt-Nielsen, 1972, fig. 7) Similarly a blue whale of 100 tons of body weight would expend about 0.014 $Kilocalories \cdot Kilogram^{-1} \cdot Kilometer^{-1}$ as its energy cost for swimming. The data indicate that the large rorquals seem to expend some 1/5 to 1/7 times of energy cost than the dolphins.

The actual energy cost in 18.1 meter and 34 tons of fin whale may be 7.48×10^2 $Kilocalories \cdot Individual^{-1} \cdot Kilometer^{-1}$, and some $2.10 \times 10^4 - 2.36 \times 10^4$ times of these cost would be required for five months migration since its totaled energy corresponds to 1.55×10^7—1.57×10^7 Kilocalories. These facts indicate that the 18.1 meter fin whale can migrate for the distance of some 2.1×10^4—2.3×10^4 Kilometers by expending its blubber oil preserved in 2.0 cm thickness of the blubber. Actually, however, slightly more energy expenditure must be took into considerations since the metabolic rate as examined in human body increases for 10–20 times according to the physical conditions whether he moves vigourously or rests (Yoshikawa, 1959). Jumping, leaping or breaching (Racovitza, 1903) behaviours in large whales are often observed on high seas, and several times of these kind of violent movements which may be induced by playing, chasing, and/or escaping from the enemy would possibly be a quite daily event in the wild life. All of these are responsible for increasing the energy expenditure, since whales were assumed as migrate constantly under 10 knots of swimming speed throughout their migratory journey. In gray whale, however, Rice and Wolman (1971) have found well balanced energy budget being based on the " actively swimming animal ", and 10 knots in swimming speed would also be allowed for general considerations as a totally averaged figure in energy expenditure.

CONSIDERATION ON THE AMOUNT OF WHALE OIL AND THE ENERGY COST

The calculation as has been described in previous section was introduced by following after the several assumptions: 1) Whale oil preserved in the blubber around head and ventral grooves, and that in bones and internal tissues are not utilized as the energy source for locomotion, 2) Whale oil which corresponds to 2.0 cm thickness of the blubber which covers over main body trunk is consumed as the energy source for locomotion, 3) Energy cost for swimming locomotion in large rorquals was estimated by extrapolating the parameters into the known regression line in aquatic animals and, 4) As it was assumed in the case of dolphins, the efficiency of muscle in performing external work would be 25 percent, and the animal swims at 10 knots under laminar flow of water over the body.

Concerning to an absolute amount of whale oil itself, the whales body under alive would contain much more than that considered in this report. For instance, Omura *et al.* (1942) showed that the 18 m meter fin whale caught in the coastal waters of Japan yielded 0.73., 0.5 and 0.5 tons of whale oil from the blubber, bones and internal organs respectively. Arai *et al.* (1950), on the other hand, showed that 53 percent of the blubber around whales head contained whale oil and 65 percent was in the blubber around the back. Following to these oil rich parts the muscle around lumber to tail flukes, ventral grooves and/or abdomen contains rather rich (Feltmann *et al.* 1948) but less than 20 percent or so of whale oil. That is, the potential in preserving the whale oil as the energy source would be reduced to about 1/3 when it is compared with oil rich parts, and the amount of whale oil from an individual must be more greater than usually expected, whereas their importance as the energy source for locomotion would be less than the blubber oil, since most of whale oil preserved in bones or some other parts other than the blubber is considered to be unlike from physiological reasons to be consumed for the purpose of locomotion.

It is well known fact that whales caught in the beginnings of Antarctic whaling season show slender body trunk due to not only their thin layered blubber but also possible consumption of oil and fatty substances preserved in the whole body. Considering on this fact along with a comparison in metabolic physiology found in another animals, the whale oil preserved in the tissues other than the blubber would be consumed to some extent as the energy source for locomotion. And if we assume some physiological analogy between whales and human body (Yoshikawa, 1959), whales under some peculiar occasions or situations may consume not only their oil but also do even proteins of body tissues.

Whale bones also contain a considerable amount of whale oil, but it is presumably not consumable as the energy source for locomotion by reason of the function of bones themselves. The strength of animal bones is the function of their sectioned area and it increases only by following after a square number relations with body length whereas body weight of animals which must be suspended by the bones increases by cube number relations. Although the whales, a typically well adapted animals for aquatic environment, do not need such strength as terrestrial animals, and the bones of whales are not structured well like those animals. Then the function or physiological process which makes the strength of bones reduce much by consuming the contained whale oil may have to be kept as little as possible. Still more, the deposit of whale oil among many organs seems to occur firstly in the internal organs, fatty layer and then in the bones by this order (Omura *et al.* 1942). This fact also supports the assumption that whale oil preserved in the bones seems to be hardly consumed as the energy source for locomotion.

From these discussions it would be reasonable to consider that there are some still more amount of consumable whale oil in living animals while some are not available as the energy source for locomotion. As it was described previously the whale oil only from the blubber can make the whales swim for 20,000 km or thereabouts. Then if some additional energy source for locomotion is expected, the distance could be moved potentially without reducing any physiological functions such as a malnutrition in large rorquals would be somewhere between 20,000 Km and 30,000 Km. On the other hand, Mackintosh (1966) supposed the migrating distances covered by large rorquals must be somewhere between 1,000 and 3,000 miles. These figures, however, correspond to only about 17 to 50 degrees of latitudes, and are considered rather under estimations.

There are no ways to prove how much extent the energy cost obtained by an extrapolation for large rorquals is appropriate or not. The estimated energy cost of about 1/5 of dolphins, however, can be discussed little more in the point of metabolism of animals. The basal metabolism of animals closely relates to the body surface area. Bottlenosed dolphin, *Tursiops truncatus* which weighs 100 Kg. has 1.85 m^2 of body surface area (Ridgway, 1972). If it is assumed that the surface around its head occupies about 20 percent of the whole, the surface around body trunk would be 1.5 m^2. On the other hand, 18.1 meter fin whale has about 90 m^2 of body surface area which actually corresponds to 13.5 meter long of body trunk only, and weighs 34 tons. Comparing with these figures of both bottlenosed dolphin and fin whale, the ratio in body weight shows 340 times larger in fin whale whereas only 60 times in the ratio of body surface area. The well averaged number of respiration in dolphins and phocids is 2 to 3 respirations$\cdot$minute^{-1} while it is 1 to 2 respiration(s)$\cdot$minute^{-1} in fin whales (Scholander, 1940). The large whales consume comparatively little amount of oxygen than the dolphins, and are able to swim under very well controlled energy coefficient. In this respect a slight change in body length or body surface area affects well on the whole metabolism of animals by following after the Rubner's surface law. Actually, since the body surface area of fin whale would reduce to some extent while they are enroute through migrations, the energy cost for locomotion may also reduce. This may be one of the reasons why large rorquals perform seasonal migrations by less energy expenditure than the dolphins and also possibly than the figures estimated by extrapolation. It is possible, therefore, that the energy cost and body weight relationships in large whales may not expressed by a simply extended regression lines but by a slightly curved or the folded lines with different coefficient.

However, these relations which have been known in another animals are well expressed by setting up a simple regression even for between mouce and horse. Concerning to this extrapolating problem, Schmidt-Nielsen (1972) described as "Although we have no inherent right to extrapolate from the salmon to the dolphin, we can safely assume that both animals are hightly adapted and effective swimmers, and extrapolating from a 1-kilogram salmon to a 90-kilogram dolphin is not unreasonable ". Similarly it was considered that large whales also could be extrapolated onto the regression line. In concluding this section the followings may give a standards: the energy cost for swimming locomotion in average sized fin whales is 0.02 Kcal.$\cdot$Kg$^{-1}\cdot$Km^{-1}, and overall distance which could be moved without feeding both on breeding grounds and on the way would be somewhere between 20,000 km and 30,000 km.

MIGRATIONS OF WHALES AND ESTIMATED DISTANCE TO BE PERFORMED

Generally recognized destination for migrating rorquals is " warm temperate or tropical seas " if not exclusively. Therefore, it would be worth to discuss whether or not the distance which was estimated by the available amount of energy for locomotion and its cost for swimming in fin whales is an accessible distance along with the known evidences regarding the migrations of whales to the warmer waters.

If we assume that the whales leave the Antractic feeding grounds at 60°S and start their northbound migrations heading for the equator and again return to the start line along the same meridional pathways, the distance covered by this round trip is 13,320 km. That is, the whales are able to move or play around more for only 7,000 km or corresponding energy expenditure. Since little is known on the pattern of daily life in large whales except several but fragmental observations (e.g. Schevill and Watkins, 1966; Cousteau and Diolé, 1972), it seems still in some difficulty to estimate even an integrated distance performed by a whale in a day. It is, however, reasonable to consider that whales are unlike to swim straight but trace a quite complicated pathways which gives far more doubled distance than is considered by an actual situation, since the daily behavior of animals may possibly have not necessarily any objects from one end to the other.

Following fact is very suggestive concerning to the daily movements of whales. In the whaling ground which is one of the terminal places in whales migrations, where the whales stay for some duration within a certain range to feed by moving back and forth, it is often experienced that the whales having been spotted in the previous evening are hardly found again in the next day. In this case it is well supposed that the whales had moved for a considerable distance during the previous night. To make the matter clear it would be convenient to assume the case that those whales were sighted again after 3 hour scouting through surrounding waters at the speed of 15 knots. Then about 2 hours out of 3 hour scouting would be the component giving away from the starting point, that is, the whales moved at least for 2 hours as to give the distance between catcher boat and themselves. J.-Y. Cousteau attached a specially designed marks on the back of a fin whale to make him easy for chasing it through the night, and he observed that the whale usually continued to move at the speed of 6 to 7 knots though the whale stopped several times during the observations (Cousteau and Diolé, 1972, p. 72). Their observations give us a knowledge that the whale may considerably move around even through a night. From these facts it would be quite natural to consider that the whales are apt to move at least for several tenth miles within a night. If the whale migrates from 60°S to the equator at 10 knots in swimming speed, 15 days would give them enough time to get to their destination; the terminal sea regions of so-called " warm temperate or tropical seas " where the whales stay for the rest 4 to 5 months. There is no reason to doubt that the daily behaviour of whales differs much both in feeding and breeding grounds. The estimated distance for nocturnal movements in large whales, 30 miles per 10 hours agrees well with the swimming speed found under the natural or undisturbed conditions, and that distance would be a minimum or close to the lower extremes, since it was estimated being based upon a possible zigzag movements. The whales seem to move at least about 72 miles (=130 km) in a day, and 15,000 to 16,000 km would be the integrated distance covered during 4 month stay in the terminal sea regions.

Accordingly the grand totaled distance which is performed through 5 month round trip migrations would be at least some 28,000 to 30,000 km. As it was shown previously the 18.1 meter fin whale is able to move only for 20,000 km or thereabouts by expending its blubber oil of 2.0 cm thickness, and may have to face a shortage of locomotion energy unless the whale oil or fat of another source was consumed supplementally. These estimations suggest that even well adapted whales for aquatic environment are hardly possible to perform migratory journey to those " warm temperate or tropical seas ".

However, if the supply of whale oil from the muscle and connecting tissues in addition to that from the blubber could be considered, and/or if slightly more than 2.0 cm thick of the blubber oil was consumed, the budget of energy expenditure required for those migrations would be well balanced. Actually the large rorquals distribute all over the world oceans and most of them sternly keep 4 to 5 cm thick of the blubber even after a very long journey for 5 to 6 months. On the other hand, there are actually the whales which keep very thin blubber even in late March, the time they have to leave the feeding grounds for breeding. These very slender bodied whales seem unlike to consume their blubber oil any more as the energy source for locomotion, since it may cause some physiological difficulties to reduce their blubber oil deposit, and the statistics on the thickness of the blubber also suggest its unlikelihood. Then slender bodied whales have to change or modify their migratory pattern and fashion of life, which may somewhat different substantially from that of the majority of normally fatted whales. For instance, poorly fatted whales cannot but remain within some migratory range and/or have to migrate into some productive and organism rich coastal waters where they can feed to a certain extent. The whales may have to swim so economical basis as to reduce the energy expenditure as little as possible since the energy for locomotion in any kind of whales does not seem to have been provided sufficiently. It is well known fact in the Antarctic feeding grounds that the whales move longitudinally for rather widely ranged zone extending for two or three of six sectors, whereas they are apt to follow the cource along the continent or islands in breeding migrations, and little of them migrate into the real mid oceans. These general tendencies are well observed by whale sighting at high seas and by the recovery of whale marks (e.g. Dawbin, 1959; Ivashin, 1971; Mözer, 1971). Whales which have distributed rather randomly within the feeding grounds are apt to concentrate along their migratory pathways but it is far sparce and loosely packed gatherings like a stream and is hardly comparable to so-called school or herd of animals. Humpback whale apparently shows some gatherings as a unit of local populations enroute their breeding migration (Dawbin, 1964; 1966), but these kind of whale movements if not clear like the humpback whale may also be found in rorquals. These general tendency in whale movements or migratory habits may closely related to the productive seas or the occurrence of rich standing stocks of organisms, and most of which is found in the marginal waters along the continent or islands. A fertile zone such as an equatorial divergence regions too attracts whales even if it is found on high seas. Considering on the food and feeding of baleen whales, Nemoto (1959, p. 281) concluded that the movement of whales in the North Pacific and Bering Sea regions is closely related to the geographical characters such as the shape of the sea, and fin whale occurring in those waters can be considered as " ocean and marginal denizen ".

The energy for locomotion in rorquals migrations seems to be balanced on the whole. It is, however still desirable to minimize the energy expenditure as little as possible since an amount of whale oil preserved in a body is far less for a luxuariant consumption. Therefore, it would be better and/or appropriate for most of migrating whales to take linear like pathways both in north- and south-bound migrations.

For instance, little number of whales in the southern waters of Australia would migrate to the tropical African coast by crossing the Indian Ocean diagonally. Sperm whales evidently swim at least 600 miles within 8 days between the Antarctic and South African coast (Clarke, 1972). This fact strongly suggests that the whales on the whole, once they begin the migrations, can travel very rapidly even though they feed on squids on the way.

The migrating whales are considered to be apt to invade into the almost same or very close region of terminal seas every season. In the coastal waters off Abashiri, Hokkaido, there once was a fin whale which was easily identified by its characteristically well damaged dorsal fin, and this animal used to be spotted if not entirely in the same place at least in the beginning of season (Omura and Kawamura, 1968). Similar evidence or possibility is also documented in the Antarctic fin whale of Area II based on the recovery of whale marks (Brown, 1962, p. 14), and, these situation was expressed as " something like a migration route " (Mackintosh, 1966) which is somewhat similar to " corridors " called in the migration of birds (Orr, 1970). Since it would be hardly possible to modulate the season and place of migrations with considerable accuracy, the migration of whales as a everlasting phenomenon could be recognized only when the migrations of whales were assumed as follows; in order to perform the migration with those above mentioned kinds of accuracy, the whales may have to migrate at full or near at full speed without wasting time on the way by following well known migratory pathways along with the aid of well experienced navigation.

GENERAL CONSIDERATIONS IN CONNECTION WITH THE DISTRIBUTION OF WHALES

As it has been discussed in the previous section, the budget of energy expenditure for locomotion in large rorquals seems rather complicated, and cannot but consider the subject analogically by the aid of some assumptions, since there are so little suggestive evidences which were obtained in the field observations. For instance, it is still beyond of our knowledge where and when the perturition and mating of rorquals will actually take place in those vast " warm temperate or tropical seas ". No other evidences except those have been refered to seem to be left for the further discussion, and following discussions are a kind of conclusive view points in which the movements of whales is considered along with the general features of the distribution of whales.

In rorquals the pattern, habits and the behaviours in the way of life are quite naturally and generally recognized as a regular migrators which move between cold polar seas and warm temperate or tropical seas, and these are considered appropriate from the overall budget of their energy expenditure for locomotion, since majority of whales are likely to be well balanced in this instance. However, an amount of whale oil or fatty substances preserved in the whales body considerably varies with the physiological status or biological characters endowed with each whale species. Still more, the wild animals would presumably have to keep afford in the energetic budget to make their behaviour more fruitsfull under the wild environment whereas the budget in energy expenditure actually seems to be very tight. In this instance, it would be reasonable and natural to suppose that the whales usually must feed to a certain extent even if they are on the way of migrations. California gray whale which are supposedly well balanced in the energy expenditure can perform seasonal migration without taking any foodstuff through their round trip migrations (Rice and Wolman, 1971). Even in gray whale, however, feeding activity seems to be not unusual at least in their southbound migration close to the regions of their breeding grounds (Sund, 1975). The idea that more rorquals do not seem to feed or be under almost starved condition during their migrations (e.g. Jonsgård, 1966; Mackintosh, 1966) would be hard to believe if not exclusive. In general the metabolic rates increase high in the warmer environment than in the colder one, and this may become serious in small younger animals since they swim under relatively high energy cost for locomotion than the well aged animals. That is why large rorquals do not concentrate much in mid oceans where a monotonous but well stabilized environment prevails, but more commonly found in some coastal or offshore waters of structural complexity, that is, the region of high production or rich in standing stocks of organisms which is undoubtedly advantageous for occasional feeding. Two ways of the possible status for migrating rorquals whether they concentrate or disperse in the breeding grounds (Mackintosh, 1966) are quite suggestive on the whole. In the latter instance the evidence that many whales are spotted in offshore waters within a certain ranges in lower latitudes strongly suggests a possible feeding activity of whales as the case explained by Clarke (1962). Even planktivorous species of baleen whales apt to feed on shoaling small fishes and their larvae according to the time and place. A typically similar situation is found in the comparison for food habits between the North Pacific and the Antarctic (Nemoto, 1959; Kawamura, 1973, 1974). That is, there reason to believe that the baleen whales in breeding grounds may feed on some organisms such as the larvae of skipjacks, tunas and of many other warm water fishes. By taking these general situations along with presumed physiological conditions and feeding habits in large rorquals into consideration, it seems reasonable to believe the food intake during breeding migrations as the comments by Dr. Sergeant. (Mackintosh, 1966, pp. 143–44).

One of explanations why rorquals migrate to those " warm temperate or tropical seas " is an advantage for breeding especially for the safety of newborn calf of very thin blubber and make them easy to keep body temperature from chilly environment. Antarctic minke whale, *Balaenoptera bonaerensis*, likely to show rather irregular breeding cycle (Ohsumi, personal communication) than the other rorquals which show an approximately one-year cycle. In this instance some individuals of the Antarctic minke whale may have perturition during their stay within the colder region, and how is the case for the calving in bowhead whales, *Balaena mysticetus*, explained. In this respect the Kellogg's pointing out that " it is not the sea temperature but the food conditions that induce whale migrations " would be quite suggestive itself (Kellogg, 1929, p. 45). Kellogg's idea also make us consider that the migrations of whales is desirable to be treated by each whale species.

Results of whale sighting in the Atlantic and Indian Oceans show the year round distribution of large whales in the temperate and tropical regions (e.g. Townsend, 1933; Brown, 1957, 1958; Zenkovich, 1962). In those waters population of whales may be consisted of the several different origins: some may come from newly migrated population and the other may somewhat from endemic or locally separated population such as the fin whales in the East China Sea (Fujino, 1954; Ichihara, 1957) and sei/bryde's whales in the northern waters off North Island of New Zealand (Dawbin, 1959, p. 15). Those locally separated whales seem to stay there throughout the year, and consequently, may have to feed on regardless the seasons. Then it is quite unlikely that the only newly migrated whales do not feed on among those taking food in those local waters. In the waters off California blue whales are usually seen throughout the year (Kellogg, 1929), and they can feed on sardine and prawn in San Quentin region, lower California (Scammon, 1874).

Apart from the seasons, great number of large whales are apt to concentrate in the zones between 30° and 40° of both south and north latitudes of the Atlantic and Indian Oceans (Brown, 1957; 1958), and humpback whale, *Megaptera novaeangliae* stay in the offshore waters of lower latitudes throughout the year along the west coast of South America. In the Arctic regions of the North Atlantic some humpback whales stay throughout the winter (Kellogg, 1929). One of another instances is Pacific black right whale, *Eubalaena gracialis* which are found close to the ice-pack in the Okhotsk Sea and Bering Sea regions, and then fin whale in Queen Charlot Sound, north of Vancouver Island of approximately 50°N during February (Scammon, 1874). These facts indicate that the actual pattern of distributions in large baleen whales, if not entirely, do not always coincide with those ideas generally known as migration cycles. The " tropical seas " is considered unlikely for most whales as to be a destination being invaded after the painstaking long journey, and this make us even doubt whether or not those habits are inevitable for carrying out an appropriate life of whales. In the general fashion of the distribution of whales, however, age, sex, and physiological status of each whales would relate to their migrating movements though the details on this subject have been known little except the case in sperm whales, *Physeter catodon*, which once had caught in all over the world oceans and are known as very highly socialized animals in the mode of line among large whales (e.g. Mackintosh, 1965; Gaskin, 1970; Berzin, 1972). Then the structure of population in baleen whales which occur in " warm temperate or tropical seas " may be a subject to be known in future. The baleen whales may have to feed to a certain extent in food rich waters regardless seasons, kind and origin of whales stocks. Some blue whales are believed to feed actively in the waters south and south east of Madagascar, which are located far north from the Antarctic feeding ground proper (Gambell *et al*, 1974). The ideas of both non-feeding activity and seasonal migrations in large whales are not primarily the phenemon of two sides of a thing but independent each other, if not, the actual features in the distribution of whales would hardly be explained.

CONCLUSION

Some whales keep rather sufficient energy source to perform the migration between cold feeding ground and warm breeding ground while others are hard to accomplish their migrations unless they take food to some extent on the way. Migrating population of whales is composed of individuals which greatly vary in energy potentials. On the whole the budget of energy for locomotion does not always balance well or clearly unbalanced. Under these circumstances some whales may migrate to the tropical seas and others may have to take different pathways of less far or, have to modulate the ways of life although some of them will be fatty in another year and can migrate much distance as the standards. It would be convenient to suppose that whales feed primarily on the way of their breeding migration to get an additional energy for locomotion although the extent of feeding may actually vary with each individuals. Some whales which had not preserved much whale oil cannot but follow the ways along more productive and food rich waters, and/or have to remain within the waters of rather higher latitudes throughout their breeding migration. The migrations of whales, therefore, seem to be a stream like movements of animals as called by Mackintosh (1965), and may be performed with much flexibility from variable fashions of migratory movements. The " warm temperate or tropical seas " which have been believed as the destination of breeding migration still remains as an ambiguous conception. As it has been discussed, however, whales keep potential for making a round trip which corresponds to 120 degrees or more of latitudes, and consequently, the whales in the archipelago of Micronesia, for instance, cannot always be considered as the stray from local population but also possible to consider as the migrants from the polar regions. In this instance, mingling of the populations between northern and southern hemispheres at one of their terminal sea regions would be quite possible but considered the case to be very little. Kellogg (1929), however, suggested much the possibility of mingling in the case of blue whale populations.

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一般財団法人 日本鯨類研究所
THE INSTITUTE OF CETACEAN RESEARCH

一般財団法人　日本鯨類研究所
THE INSTITUTE OF CETACEAN RESEARCH

RECENT STATUS OF THE POPULATION OF INDUS DOLPHIN

TOSHIO KASUYA AND MASAHARU NISHIWAKI
Ocean Research Institute, University of Tokyo, Tokyo

ABSTRACT

A survey of the population of Indus dolphin *Platanista gangetica indi* (Blyth, 1859) was conducted in December 1974. The range of the significant abundance of this subspecies is restricted to the section between Sukkur and Guddu Barrages, and to the section between Guddu Barrage and Taunsa and Panjnad Barrages. The size of the population in the former section was estimated to be between 350 and 400 animals. Even if the populations in other sections are included, the total population seems to be only 450 to 600 animals. The calculated mortality rate, reproductive rate and environmental factors suggest that the population is still decreasing. For the survival of this population, the stop of the killing of this dolphin and the control of water at higher level in winter are suggested.

INTRODUCTION

The dolphin of the genus *Platanista* is found in the Indus River and in the Ganges-Brahmaputra Rivers. There is found a difference of the shape of nasal crest between the dolphins in the two separate rivers (Pilleri and Gihr, 1971). Though Kasuya (1972) reported the difference of the proportion of tail length, as he did not measure the Indus dolphin but referred the data prepared by Pilleri (1970) his conclusion is still doubtful.

It seems to be generally accepted that these two separate populations, started from a single origin, have been isolated long enough to attain some morphological differenciation. However, there are two contrary opinions on their classification. One is to consider them distinct species (Pilleri and Gihr, 1971), and the other is to classify them into two subspecies of a single species (Kasuya, 1972). At the present status of knowledge on these animals, we consider it reasonable to take the latter idea until more distinct morphological or ecological difference is found between the two, or until it is suggested that they do not freely interbreed even when the geographical barrier is not present.

The Indus dolphin was known to have been distributed in the wider range of the tributaries (Anderson, 1878). However, since the start of the construction of permanent barrages for irrigation, the dolphin population have been split up into separate smaller populations (Pilleri, 1970). And in some sections of the river, the population has been decreased or extinct (Pilleri, 1972; Roberts, 1972; Taber *et al*, 1967). The alarming situation of this dolphin was already noticed by Pilleri (1972) based on the observation made in 1969 and 1972 at the lower part of the

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section blocked by Sukkur and Guddu Barrages. The total population of this dolphin has been considered not exceeding 700–1,000 (Anon., 1973).

The present study was conducted in December 1974 to know the present range of distribution of the dolphin and to estimate the population.

RANGE OF DISTRIBUTION

The presence of the dolphin was checked at various bridges or barrages. However, as the dolphin is usually scarce near the barrage even if it is situated in the section where the presence of many dolphins is confirmed by other method (*e.g.* Sukkur or Kashmore Barrage), it was tried to collect more informations from the fishermen or people living by the river. Furthermore, if possible the length of about 1 to 3 km along the stream was observed at each spot.

Section 1, up of Jinnah Barrage

The Jinnah Barrage is situated near Kalabagh Town (71°34′N, 35°59′E). This section was observed on Dec. 15. The wide stream was present only within about 5 km above the barrage, and above the range the river enters into a gorge. Though it was reported by Anderson (1878) that the dolphin was present in the water above Kalabagh, the dolphin was not observed by us. The people in the town denied the presence of the dolphin. The dolphin seems to be absent in this part of the river in recent years.

Section 2, between Chasma and Jinnah Barrages

This part was not observed by us. But considering the small distance between two barrages and the scarcity of water below Jinnah Barrage, the dolphin will not be distributed in this section.

Section 3, between Taunsa and Chasma Barrages

This section was observed at Dera Ismail Khan and Taunsa Barrage on Dec. 14.

The water of the Indus by Dera Ismail Khan was about 500 m in width and seemed to be fairly deep suggesting the possibility of the presence of the dolphin. However we could not find it. A man living on the river bed told that he does not see the dolphin in winter season but he had once seen an animal in summer season.

At the north side of Taunsa Barrage the water was abaut 1,200 m wide. But there was found no dolphin in the area of about 2 km along the river.

From the above informations we consider that the dolphin might be absent in this section or if present the number must be almost negligible.

Section 4, from Guddu Barrage to Taunsa Barrage (R. Indus) and to Panjnad Barrage (R. Panjnad)

This section was studied at 5 spots on 7 occasions as mentioned below.

Though no animal was observed at the down stream of Taunsa Barrage (Dec.

14) and Panjnad Barrage (Dec. 13 and 17), it does not necessarily indicate the absence of the dolphin in this section because the water was scarce below the barrages and the dolphin will not migrate there.

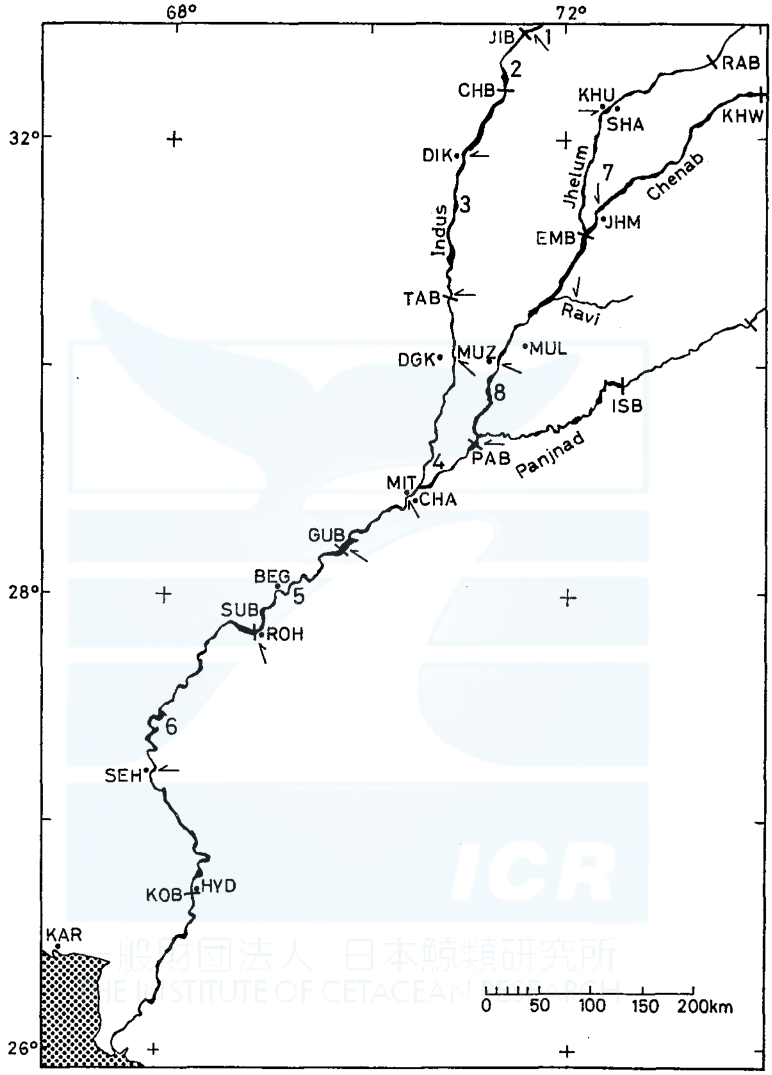

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Fig. 1. Map of the Indus. Black bar indicates the barrage, numeral the number of the section in text, and the arrow the check point of *Platanista*. BEG, Begari. CHA, Chachran. CHB, Chasma Barrage. DGK, Dera Ghazi Khan. DIK, Dera Ismail Khan. EMB, Emerson Barrage. GUB, Guddu Barrage. HYD, Hyderabad. ISB, Islam Barrage. JHM, Jhang Maghiana. JIB, Jinnah Barrage. KAR, Karachi. KHU, Khushab. KHW, Khanki Weir. KOB, Kotri Barrage. MIT, Mithankot. MUL, Multan. MUZ, Muzaffargarh. PAB, Panjnad Barrage. RAB, Rasul Barrage. ROH, Rohri. SEH, Sehwan. SHA, Shahpur. SUB, Sukkur Barrage. TAB, Taunsa Barrage.

By Dera Ghazi Khan, the observation was made on Dec. 14 at the boat bridge connecting Dera Ghazi Khan and Muzaffargarh. The water there was only about 100 m wide and probably less than few meters in depth. No dolphin was found in the ranges of about 1 km at the both sides of the bridge.

Other observations were made along the stream of the length of about 3 km at the boat bridge between Mithankot and Chachran on Dec. 13 and 17. On this spot the water was more plenty than that at Dera Ghazi Khan situating about 150 km north. The width was about 500 m and the current was fast (2 to 3 km/hr). At the first visit one small dolphin (about 120 cm in body length) was observed swimming leisurely at about 100 m north of the bridge, and another slightly larger animal was seen at about 500 m south of the bridge. In case of the second visit, two small individuals were sighted near the latter spot.

At the water just above the Guddu Barrage, there was found no dolphin (Dec. 12).

From the above informations it is safe to conclude that some individuals of the Indus dolphin are distributed in this section of the Indus River. The range of the distribution in winter season will be from Guddu Barrage to the confluence of the Indus and the Panjnad. The length of this part is about 100 km. As this part of the section receives the water from the two rivers, the water level will not be too low to support *Platanista* in winter season.

Section 5, between Sukkur and Guddu Barrages

The presence of the dolphin in this section was confirmed from boats, and the estimation of the population is made in the next section of this report.

Section 6, between Kotri and Sukkur Barrages

The river of this section is devided into two by Ghulam Mohammed Barrage situated about 12 km north of Kotri Barrage. During our trip we only confirmed that the water is very scarce at just below Sukkur Barrage and at Sehwan Town, which is situated slightly south of the midpoint between Sukkur and Kotri Barrages. This indicates the probable absence of the dolphin in the upper part of the section. However, as reported by Pilleri (1972), Mr. Roberts sighted one animal near the north of Ghulam Mohammed Barrage and suggested that the population of the dolphin in the section will be quite small. He also states that *Platanista* is not expected down stream of Kotri Barrage. These informations are considered to be correct.

Section 7, from Emerson Barrage to Rasul Barrage (R. Jhelum) and to Khanki Weir (R. Chenab)

The section was studied on Dec. 16 at the bridge on the Jhelum River connecting Khushab and Shahpur. This bridge is situated nearly at the midpoint between the two barrages. At this point the stream was only from 100 to 150 m in width and shallow. No dolphin was observed.

The other observation was made by the bridge crossing the Chenab River at the north of Jhang Maghiana This bridge is situated about 32 km upper stream of Emerson Barrage. In spite of the close distance from the lower barrage, the water was only bout 70 m wide and was very shallow.

It is reasonable to expect no dolphin in this section, as already suggested by Taber *et al* (1967) through the observation of the Ravi and Chenab Rivers.

Section 8, between Panjnad and Emerson Barrages

The Ravi River, a tributary of the Chenab River, was almost dry in this season (Dec. 16) leaving small ponds on the bed.

At the bridge connecting Multan and Muzaffargarh the stream was about 150 m in width and shallow, and no dolphin was observed on two occasions (Dec. 13 and 16). At Panjnad Barrage an information was collected on Dec. 17 from a fishermen telling that the dolphin is absent in this section.

No dolphin seems to be distributed in this section.

POPULATION IN THE SECTION BETWEEN SUKKUR AND GUDDU BARRAGES

The field observation of the Indus River of this section was conducted in the period from Dec. 7 to Dec. 12, using one (from Guddu Barrage to Begari) or two (from Begari to Rohri) local boats. The size of the boats was about 2.8 m wide and 6.5 m long. The boats cruised only in daytime with a stop for lunch, and usually 2 or 3 biologists watched the front direction of the boat while it was slowly rowed down the stream.

On Dec. 7 1974 our boats left the camp on the east bank of the Indus situating about 1 km south of Begari and arrived at Begari after 10 minutes. Then we took a jeep at Begari for Guddu Barrage. At Guddu Barrage a boat was arranged and we left that place at 1526 of the same day. After spending 2 nights on the boat, we arrived at the camp near Begari at 1900 of Dec. 9. On Dec. 9, as the observation was stopped at sunset (1735), we could not observe the river of about 3 km. On the next day (Dec. 10), we changed the boat and left the camp for Rohri, and arrived there at 0920 of Dec. 12 after spending 2 nights on the boats.

Though it was dry season, the width of the water was more than 200 m (estimated by eye) at any part of the section. However the width was small enough and the weather was calm to keep all the width in the range of observation, except when the water was split into two streams by sand bank or by island. On such cases the observation was always made on the larger stream. The speeds of the current was 2.7 km/hr (Dec. 8), 1.5 km/hr (Dec. 9), or 5.0 km/hr (Dec. 11) at the shore on the faster side of the stream.

The stream probably corresponds to the arm of the Indus running the east side of Tappu Island reported by Pilleri (1970, 1972) was narrow and formed a sort of canal, but was distinguished by fairly wide dry river bed. When Pilleri visited Tappu Island in 1969 the east arm was much larger than the west, but it reduced the size by 1972 to be as wide as the west arm (Pilleri, 1972). Possibly the east arm attained the present condition by continuing the reduction of the size after Pilleri visited there in 1972.

When the dolphin was found, the number of surfacings was counted for each individuals untill the animal passes the level of the boat. The distinction of the individual was made considering the position and interval of surfacings, the size of the animal, and sometimes the swimming direction. Though most of the animals

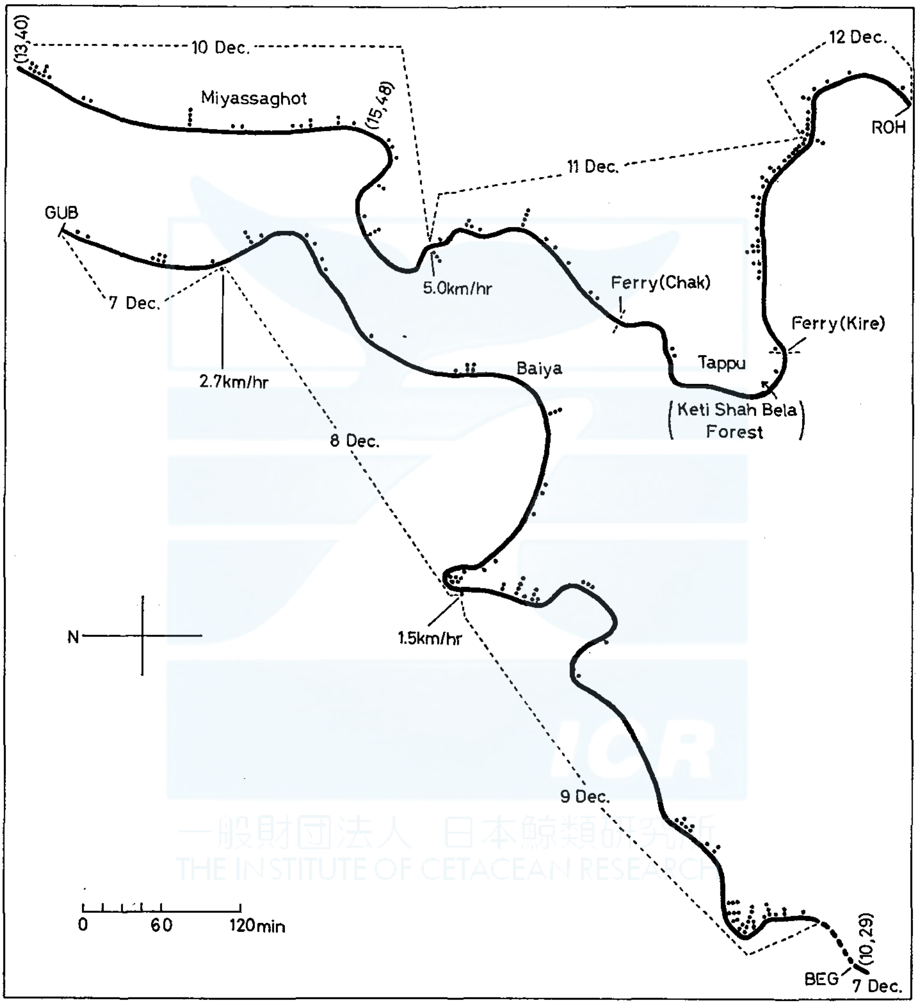

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Fig. 2. Schematic figure of the Indus between Guddu Barrage and Begari (bottom) and between Begari and Rohri (top). Direction of the stream and cruising hours are indicated instead of direction and goegraphical distance. Circle at the left side of the river indicate the dolphin observed in cruising hours, and that at the right the animals observed while anchored. Numbers in parenthesis indicate the roughly estimated number of dolphins and number of surfacings in high density area. BEG, Entrance of Begari Canal. GUB, Guddu Barrage. ROH, Rohri.

seemed to be solitally, the area with high density was usually restricted to some deep places, and the dolphin was scarce in the shallow and rapid stream. In some cases many dolphins were found in a small area (e.g. 100 to 500 m in diameter), and the distinction of the individuals was difficult. Even in these cases it was not sure if the animals were forming a school or only assembling randomly at one spot. These cases are shown with parenthesis in Table 1. In this table the lines are arranged in the order of from the upper stream to the lower stream.

Interval of respiration

One juvenile dolphin (about 120 cm in body length), which was released after the observation, was driven into a small inlet. And the interval of surfacing for respiration was measured for 5 to 20 minutes at various hours of a day in order to get some clue on distinguishing the individual dolphins in the river. This result is shown in Figs. 3 and 4.

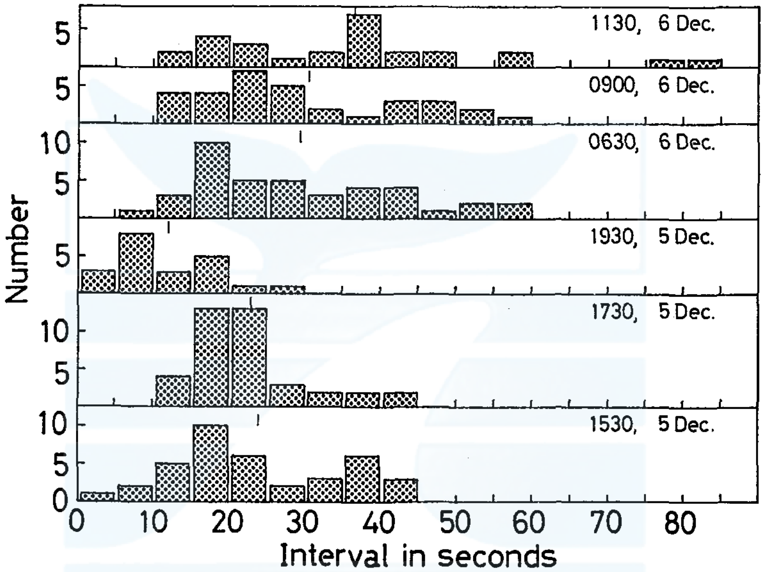

Fig. 3. Frequency of respiration interval of a juvenile *P. g. indi*.

The respiration interval showed wide variation from 4″ to 81″. Judging from the inconspicuous peaks of the frequency, there seems to be three modes of respiration interval. The one is at 20″ or less, the second at about 40″, and the third at 80″. The frequency of the shorter interval had decreased in the second day. This may be related to the decrease of excitement caused by the driving.

The observations of freely swimming animals give slightly different feature. The mean interval of 9 respirations of a median size animal was 64″. The 4 intervals of another median size animal ranged from 10″ to 80″ with a mean of 54″. On the other hand the mean interval of 12 respirations of one small animal, which was swimming slowly at one spot, was 87″. These informations suggest that the ratio of the longer interval may increase in the freely swimming animals, but that there is no significant difference of the mean length of the interval between small and larger animals. These features are also confirmed by the data reported by Pilleri (1970), in which the highest frequency was at 60″, the next peak at 10″, and the average was 42″.

The respiration in night time was checked by the respiration sound. This shows that the respiration in the night is strongly biased to the shorter side.

Estimation of the population

The numbers of dolphins and of surfacings observed in the Indus between Guddu Barrage and Rohri are shown in Table 1. The rough estimation of number of dolphins we sighted is made, as shown bellow, from the total number of surfacings and number of surfacings with the distinction of each individuals.

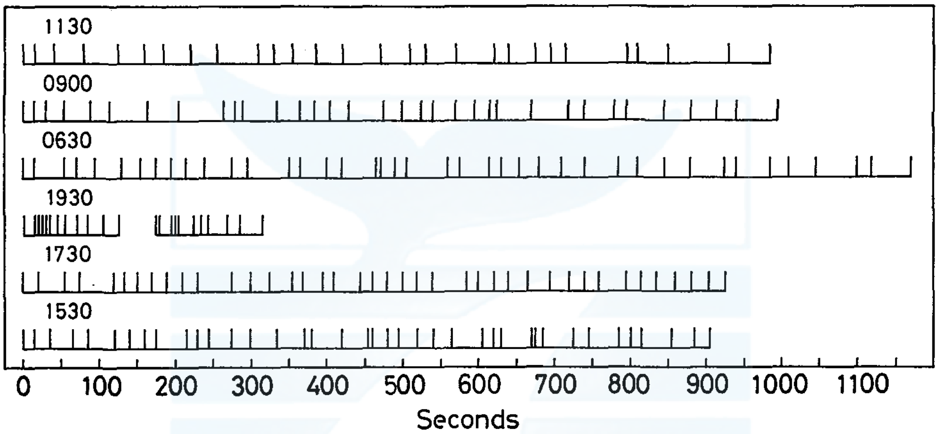

Fig. 4. Respiration pattern of *P. g. indi* based on same data in Fig. 3.

$$(420+117)\frac{182}{420}=256$$

However this does not give the total number of dolphins in the observed water, because the overlooked animals are neglected. Accordingly the following method was used in this study.

Excluding the count of the dolphins made at the places where the dolphins were too concentrated to get reliable distinction of each individual, if the number of dolphins are plotted against the number of surfacings of each individual, there is found a tendency decreasing toward the left (Fig. 5). The frequency of animals sighted twice is higher than that expected from the linear decrease. This may be because, if the first surfacing is sighted, a larger attention is apt to be paid for the second surfacing. If the least square is used for the points between 1 to 5 surfacings, the relationship $y=-15.90x+82.1$, where y is the number of dolphins and x is the number of surfacings, is obtained. However the frequency of the animals with 6 or 7 surfacings does not come on the extended straight line. Possibly these points will include the cases where two or more animals were erroneously considered as a single animal. If each case with 6 (7 cases) or 7 (3 cases) surfacings is considered to be represented by 2 animals with 5 or less surfacings, the real number of animals discussed here should be 192, and above formula should be parallelly slided up for $(7+3)\times 2\div 5=4.0$ and can be shown as follows.

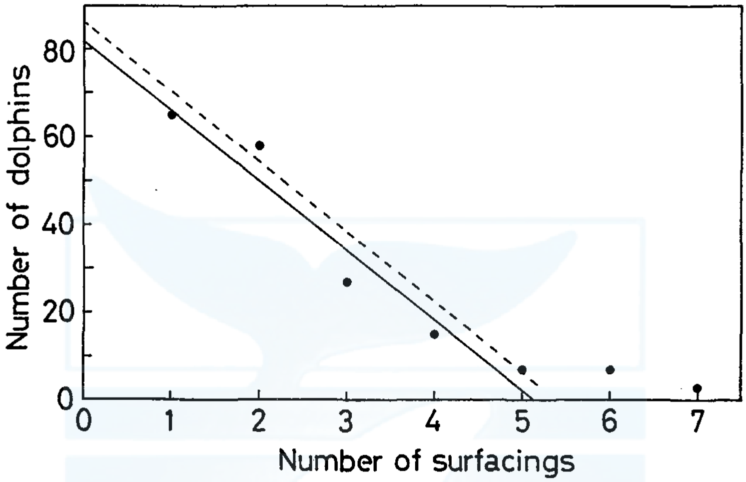

Fig. 5. Frequency of the number of observed surfacings of each individual of *Platanista* in the section between Guddu and Sukkur Barrages. Solid line indicates $y=-15.90x+82.1$, and dotted line $y=-15.90x+86.1$.

TABLE 1. NUMBER OF DOLPHINS AND OF SURFACINGS OBSERVED BETWEEN GUDDU BARRAGE AND ROHRI IN DEC. 1974

Date	Hours of observation	While cruising		While at stop	
		surfacings	dolphins	surfacings	dolphins
7	2°01′	20	10	—	—
7	8′30″	—	—	8	1
8	8°24′	61	28	—	—
9	20′	—	—	1	1
9	9°04′	124	53	—	—
7	10′	(29)	(10)	—	—
10	15′	(40)	(13)	—	—
10	4°24′	66	24	—	—
10	19′	(48)	(15)	—	—
10	2°34′	29	9	—	—
11	13′	—	—	6	3
11	9°00′	90	48	—	—
12	6′	—	—	3	2
12	1°42′	30	12	—	—
Total		420 (117)	182 (38)		

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$$y = -15.90x + 86.1 \quad \text{.......................................} (1)$$

The estimation of the number of overlooked dolphins is obtained from formula (1) as the value of $y=86.1$ corresponding to $x=o$. The real number of dolphins represented by one surfacing is obtained as follows.

$$\frac{182+7+3+86.1}{420} = 0.661 \quad \text{.......................................} (2)$$

From this figure and total number of surfacings counted, the total number of dolphins should have been present in the observed area is obtained as follows.

$$(420+117) \times 0.661 = 355.0 \quad \text{.......................................} (3)$$

This is the minimum estimate of dolphins in the Indus River between Guddu Barrage and Rohri. In order to estimate the total number of dolphins in the section, the number of dolphins in the unobserved area must be added.

There are three occasions where the smaller branch of the stream was not observed in spite of the possible presence of the dolphin. The length of time of those cases were 20′ (Dec. 8), 19′ (Dec. 9), and 8′ (Dec. 9). And the number of spoutings counted in the corresponding main streams were 0, 16, and 0 respectively. Assuming that the same number of dolphins are distributed both in the smaller branch and larger main stream, the following number is calculated as the number of dolphins might have been present in the smaller stream.

$$(0+16+0) \times 0.661 = 10.6 \quad \text{.......................................} (4)$$

However this can be a overestimate, because it is more reasonable to expect the smaller number of dolphins in the smaller branch.

While the cruise of about 1 hour at the upper part of Begari, the observation was not made because of the night time. The number of dolphins in this area can be estimated from the number of surfacings counted in each one hour period at both sides of this area. In the upper area there were observed 47 surfacings in one hour, and in the lower area 64 surfacings. The mean is 50.9 surfacings. This shall represent

$$50.9 \times 0.661 = 33.6 \quad \text{.......................................} (5)$$

However this estimation is also considered to be higher, because the water of the unobserved area was so shallow to have difficulty in cruising at night and the water at both sides of this area was deeper.

Another estimation must be made for the area between Rohri and Sukkur Barrage (about 2 km), where we could not cruise. As the number of surfacings counted during the cruise of the same distance just above Rohri was 14, the number of the dolphins in the areas between Rohri and Sukkur Barrage is obtained as follows.

$$14 \times 0.661 = 9.3 \quad \text{.......................................} (6)$$

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By totalling the figures (3), (4), (5), and (6), 409 is obtained as the number of dolphins between Guddu and Sukkur Barrages. As this figure is a maximum estimation, more reasonable estimation can be between this figure and that of (3), or about 380 animals.[1)]

Size composition

Table 2 shows the number of dolphins and of the surfacings classified by the size of the dolphin in the section between Guddu and Sukkur Barrages. The juvenile animals smaller than about 140 cm in body length are classified into " Small ", the large individuals presumably exceeding 180 cm and having the elongated rostrum were classified into " Large ", and the remaining dolphins into " Intermediate ". Though the frequency of the three sizes are calculated by two methods, one by the number of observed surfacings and the other by the number of identified individuals, there is observed no significant difference between the ratios obtained by two methods. And the approximate ratio of small, intermediate, and large animals is 70 %, 20 %, and 10 % respectively. According to Kasuya (1972) the female *Platanista* in the Brahmaputra River attains the sexual maturity at the length between 170 and 200 cm and grows about 50 cm larger than the male, and the rostrum is especially long in mature females. So it is considered that the individuals classified into large animal in Table 2 represent the mature females, and the intermediate premature animals of both sexes and mature males. This means that the number of mature females is only 10 % of the total population. Even under the unreasonable assumption that all the intermediate animals are sexually mature, the percentage of the mature femals could be 15 % of the total population (an even sex ratio is assumed). In other words, the number of mature females is considered to be surely less than 30 % and probably about 20 % of all the females in the section between Guddu and Sukkur Barrages.

TABLE 2. RELATIVE ABUNDANCE OF THE THREE SIZES OF *PLATANISTA* IN THE SECTION BETWEEN GUDDU AND SUKKUR BARRAGES

	No. of surfacings		No. of dolphins	
	no.	%	no.	%
Small	299	69.9	97	66.4
Intermediate	89	20.8	32	21.9
Large	40	9.3	17	11.7
Total	428	100.0	146	100.0

DISCUSSION

It is indicated that the dolphin is distributed also in the lower part of the section at the north of Guddu Barrage. Though its length is almost same with that of the

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[1)] The fitness of Poisson distribution to the points in Fig. 5 is worse. It gives overlooked animal 28 instead of 86 and the population between 269 and 309.

entire section between Guddu and Sukkur Barrages, the water in the former area is more scarce than in the latter. So the total number of the dolphin in that part must be smaller than that in the section between Guddu and Sukkur Barrages. Possibly it will not exceed the half of the population in the latter section or about 200 animals. If the density of 2 animals in 3 km is applied for the area, the population can be about 100 animals. As the number of dolphins in the section between Kotri and Sukkur Barrages and that between Taunsa and Chasma Barrages is almost negligible, the total number of *Platanista* in the Indus River is estimated to be between 450 and 600. This is the lowest estimation has ever been made on this population.

The ratio of sexually mature females to the total females was obtained in the former section. The corresponding figures of delphinids are 69.1% (calculated from the data in Sergeant, 1962) in *Globicephala melaena*, 68.3% (Kasuya *et al*, 1974) in *Stenella attenuata*, and 58.5% (Kasuya, 1972) in *S. coeruleoalba*. However these may sometimes have a bias derived from the segregation of the animals by different growth stage (Kasuya *et al*, 1974). The real maturity ratio of female *S. attenuata* calculated from the life table in Kasuya *et al* (1974, Table 24) is 59.0%. These values are extremely high compared with that of *Platanista* in the Indus. A possible explanation of this phenomenon is the high mortality rate. If the mean age at sexual maturity is known, the mortality is roughly estimated. Kasuya (1972) suggested on *Platanista* in the Brahmaputra River that the age at the attainment of sexusal maturity in famales might be 10 years of slightly less as in the case of other toothed whales. If 9 years is applied for the age of the female *Platanista* in the Indus River at the attainment of sexual maturity, there can be the following equations.

$$\frac{\int_9^\infty e^{-\mu x}\,dx}{\int_0^9 e^{-\mu x}\,dx}=\frac{\text{No. of mature females}}{\text{No. of immature females}}$$

$$M=1-e^{-\mu}$$

Where μ is the annual mortality coefficient, M the annual mortality rate, x the age of the animal in years. As the number of mature females is 20% of the total females, the annual mortality rate of 0.164 is obtained from the above equations. Even for the assumption of improbably high ratio of mature females 30%, the annual mortality rate is 0.125 Though the mortality can change by the age of the animal, the above calculation will give some idea on the mean mortality rate of *Platanista* in the past. There is another problem in this estimation. The mean mortality thus calculated is largely influenced by the change of the annual recruit, and in the strict sence this value can indicate the real mean mortality only when the population is stable. In a decreasing population the mortality will be underestimated, and in a increasing population overestimated. However, as the environment of the dolphin has been changing worse as mensioned below, it is unreasonable to suspect the increasing population. Accordingly the mortality estimated here seems to be correct or an underestimation.

The next problem in analysing the population of the dolphin is the recruitment rate of *Platanista*. Kasuya (1972) showed that the parturition and mating seasons of *Platanista* in the Brahmaputra River are in winter season and that the calves born in the early winter are weaned by the beginning of the next dry (winter) season. If this reproductive cycle is correct for *Platanista* in the Indus River, the mean calving interval will be at least 2 years. Then the gross annual reproductive rate is calculated as follows, assuming the even sex ratio and the ratio of mature females 20% obtained above.

$$0.20\times\frac{1}{2}\times\frac{1}{2}=0.050$$

Even in case of the unreasonably high ratio of mature females 30%, the gross annual reproductive rate is only 0.075.

The net reproductive rate is obtained as the difference of gross reproductive rate and the mortality rate. It is $0.05-0.164=-0.114$ and surely less than $0.075-0.125=-0.050$. Though this calculation is rough, it will be correct to conclude that the population of *Platanista* in the Indus River has been decreasing at the rate of about 10% per annum. As the environment does not seem changing better, the decrease of the population will be continuing.

One possible reason of the high mortality of this dolphin population can be the unknown amount of the catch by local fishermen. Another and more important factor seems to be the change of the environment caused by the development of the irrigation system as indicated by various authors (Anon., 1973; Pilleri, 1972; Roberts, 1972; Taber *et al*, 1967). The cause of the disappearance of the dolphin in most of the part of the Indus seems to be related directly to the construction of the barrages for irrigation system. The dolphin population, before the construction of the barrages, will have expanded the range of distribution in summer season and retreated to main stream in winter season as in the case of *Platanista* in the Ganges-Brahmaputra Rivers (Kasuya and Haque, 1972). However the construction of barrages blocked the seasonal movement and devided the population into smaller units. Then, as most of the water is used for irrigation in each section, only the subpopulations in few sections where the water level is not too low in winter season have survived at the lower population level. It is told that the water decreases even at Begari so low in February not to allow the use of the local fishing boat. Begari situates at the middle of the section between Guddu and Sukkur Barrages where most of the *Platanista* population is left. This condition will be bad for the survival of the dolphin. Furthermore, if the utilization of water for irrigation increases in future, the survival of this dolphin population will be impossible.

As the conclusion following two acts are suggested for the survival of *Platanista gangetica indi* (Blyth, 1859). One is to stop the poaching of this dolphin. For this purpose the educational propaganda will be needed to deny the erroneous conception on the medical efficiency of the dolphin oil. The other is to keep the water of some section above the certain level even in the winter season. This seems to be possible only through the accomplishment of the economical utilization of the water resources.

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PAST OCCURRENCE OF *GLOBICEPHALA MELAENA* IN THE WESTERN NORTH PACIFIC

TOSHIO KASUYA

Ocean Research Institute, University of Tokyo, Tokyo

ABSTRACT

Six skulls of *G. melaena* excavated at the northern Sea of Japan and at the central part of the Pacific coast of Japan indicate that the species was present in the western North Pacific at least untill about 10th century. However, the absence of any indication of the presence of this species in the collection from recent fauna and in the modern Japanese whaling statistics suggests that the species might have been extinct from the North Pacific or that a small population is surviving in some area of western North Pacific which have not been studied by biologist.

INTRODUCTION

The genus *Globicephala* Lesson, 1828, is constituted by two species *G. melaena* (Traill, 1809) and *G. macrorhynchus* Gray, 1846, (Fraser, 1950; Van Bree, 1971). They have been known, except in the North Pacific, to show antitropical distribution, namely the former species in colder waters and the latter in the warmer waters (Davies, 1960, and 1963).

In the North Pacific, *G. scammonii* Cope, 1869, and *G. sieboldii* Gray, 1846, were reported from Mexican waters and from Nagasaki in the southern Japan respectively, which were later concluded by Van Bree (1971) to be the synonyms of *G. macrorhynchus*. Though it was denied recently (Nishiwaki *et al*, 1967), there were published several reports telling the distribution of *G. melaena* in the Japanese coastal waters, and produced a long history of confusion on the zoogeography of globicephalid species. So, it will be worth to have, in the below, a review on this problem for the better understanding of the biological meaning of the present study.

Andrews (1914) is the first scientist who used *G. scammoni* for the pilot whale in the Pacific coast of Japan. This was based on an animal taken at Ayukawa (38° 18′N, 141°30′E), but he gave no biological reason distinguishing it from *G. sieboldii* reported by Gray (1846). Then Nagasawa (1916) used in his list the name *G. scammoni* for the pilot whale in the Japanese waters, considering that *G. sieboldii* should not be trusted because it was based on a drawings of a young pilot whale reported by Temminck and Schlegel (1844). This was followed by Takashima (1931). However, Ogawa (1937) listed *G. melas* in his list of odontoceti in the coastal waters of Japan, and showed a photograph of so-called *G. melas* (236 cm ♂) taken at Shiogama (38°19′N, 141°02′E) on 28, May, 1935. In this list he tentatively considered *G. melas* as the synonym of *G. sieboldii*. Furthermore in the same list, he listed *G. scammoni*, based on two specimens collected at Ayukawa. And he considered the two Japanese names " Naisagoto " and " Magondo " correspond to *G. melas*, and " Shiogoto " and " Tappanaga " to *G. scammoni*. Though he did not give in his report, the reason of the identification, it is written in his another book (Ogawa, 1950). As this is the start of the erroneous story telling the presence of *G. melaena* in the Japanese coastal waters, some important part is translated here.

> [p. 65] I decided to spend the August of this year [i.e. 1935] for the 2nd trip to collect the specimens . . . at Shirahama in Chiba, Taiji in Kii, and Nagasaki in Kyushu. . . . [p. 76] At Taiji I got 2 *Globicephala* (380 cm♀, 470 cm♂), measured their bodies, counted the number of bones, observed the pigmentation, and sent only the skull(s) back. . . . They were commonest at Taiji and colled " Magondo ". . . . They seemed to have no difference from *G. melas* (Traill) . . . and strengthened my belief that " Magondo (or Naisagoto) " indicates this species. One of the reasons for it is . . . [p. 77] the presence of anchor shaped pale area in the chest region. I had been interested in this fact, since I observed this at Shiogama on 2 or 3 *Globicephala*. . . . In the foreign countries the white or pale area of the shape is reported only on *G. melas* (Traill). Though Cuvier and True say that it extends to anus along the midline of the body, that of my specimen ends at the middle of the ventral region and shows slight difference. There are recorded three different names or " Naisa ", " Shio ", and " Onan " for " Goto (or Gondo) " [Pilot Whale] in the Japanese oldest book on cetaceans (Yamase, 1760). . . . Among which the names " Naisa " and " Magondo " now used at Taiji are considered to be synonyms, and " Onan ", which is equal to " Okigondo ", . . . is supposed to indicate *Pseudorca crassidens* (Owen). . . . [p. 78] The still unknown is " Shio ". I was told at Taiji that this species is large in body size, has long flipper, has white area at the posterior of the dorsal fin, and also called by the name of " Tappanaga " [=long flipper]. And it was also told that the number of catch of this species is few, and caught only in the season(s) of equinox. . . . Before this information I had guessed that " Tappanaga " may correspond to *G. scammoni* Cope (Pacific black fish in U.S.). . . . When I arrived at Ayukawa after receiving the news of the catch of " Tappanaga ", the animal had been already processed. So I identified the species only with a part of skeleton. However, Mr. Hasegawa had observed, by my request, the condition of the anchor shaped pale area on the chest and reported that it was absent. He gave me a photo of the dorsal view of other individual (Fig. 22). . . . There was clearly observed a white fleck behind the dorsal fin of which I heard at Taiji. . . . [p. 79] The photo, shown in the journal of the museum, of a *G. scammoni* Cope . . . in the collection made by Andrews in Japan . . . has no pale area on the chest. From these fact I considered that " Shiogoto (Tappanaga) " corresponds to *G. scammoni* Cope.

Above citation shows that Ogawa's misidentification started in the erroneous idea that some of different common names in different localities must indicate different species. Then he overlooked the fact that all of his samples were collected in the area and seasons influenced by the warm Kuroshio current, and the importance of the osteological characteristics and of the external proportions by which the possibility of *G. melaena* might have been eliminated from his samples, but he put the weight on less reliable pigmentation. And he reached the odd conclusion that *G. melaena* is distributed in the south and *G. scammonii* in the north. This conclusion (Ogawa, 1937) was followed without further confirmation by Kuroda (1938, 1953), Noguchi (1946), and Nishiwaki (1957). Then, Nishiwaki *et al* (1967) concluded, based on the specimens collected by themselves in the Pacific coast of Japan in the summer season and on the two of Ogawa's specimens, that there will be distributed only *G. macrorhynchus* in the area in which the distribution of *G. melaena* was expected by former reports. Though Nishiwaki *et al* (1967; and see Nishiwaki, 1967; and Rice and Scheffer, 1968) found no significant difference between *G. macrorhynchus* in the Japanese coastal waters and *G. scammonii*, they retained the conclusion on the taxonomy of these two species. And now it has become a generally accepted idea that *G. melaena* is not distributed in the North Pacific (Rice and Scheffer, 1968; Van Bree, 1971).

In 1974, however, I had a chance to examine the specimens excavated by Dr. Oba of Hokkaido University and his colleagues from two archaeological sites of Okhotsk culture on Rebun Island in the northern Sea of Japan. Though they are composed of many fragmental bones of odontoceti and mysticeti, the most striking is the presence of skulls of *G. melaena* and the absence of specimens identifiable to *G. macrorhynchus*. This led me to have a discussion on the possibility of existence of *G. melaena* in the western North Pacific.

MATERIALS AND METHOD

Four of 6 skulls of *G. melaena* referred in this study were excavated from the Kabukai A-site on the east coast of Rebun Island (45°20′N, 141°E). Though, ^{14}C dating of charcoal gives 1530±70 B.P. (TK 157) for the lower strata, the date of this site is suspected from known archaeological data to be between 8th century (lowest stratum) and 12th century (upper most stratum) (Oba and Ohyi eds., in press). As shown in Table 1, this site contained the remainings of large whales and of various delphinid species. However, most of them were found in the condition almost completely broken into small pieces. Other than the remains shown in Table 1, there were found 174 vertebrae of *Phocoe noides*, 92 of *Lagenorhychus*, 7 of *Phocoena*, 29 of *Globicephala*, and several vertebrae of large cetaceans. As the excavation was made in a restricted area compared with the expected range of the site, the accurate ratio of the cetacean species consumed by the people is not known at present. But it is safe to say that the delphinid species in the site are, with the exception of *Pseudorca*, composed of the boreal species. Table 1 shows that the number of globicephalid animals found in the upper strata is higher than that in the lower strata. This may suggest the improvement of the fishing technology.

Though the fragments of *Globicephala* skeletons were found in various strata of Kabukai A-site, most of them were unable to be identified the species. Only 4 skulls, RKA 3658, 3983, 3987, and 6054, were identifiable, among which RKA 3983 was young and badly destroyed to measure. The stratum containing the present specimens situates approximately at the middle of upper strata, and had been deposited in a pit representing a ruin of a house of that date. They were found in a stone mound together with 6 skulls of *Globicephala* sp. of various stages of growth and conditions of preservation, 1 *Lagenorhynchus* skull, 1 left tympanic bulla of humpback whale, and a radius of black right whale (?). Further description and interpretation of this site are reported in Oba and Ohyi (eds., in press).

Another skull of *G. melaena* (no. 675) was excavated by Dr. Oba and his colleagues at an archaeological site at Motochi on the west coast of the same island. Though the archaeological study of the site is not finished yet, it is considered to belong to the age between 11th and 13th century (Ohyi, 1972).

The 6th skull of *G. melaena* was found by Mr. M. Yoshimura and offered me for taxomic study. This specimen was excavated from an alluvial silt deposit by the Hekuri River near Tateyama (34°59′N, 139°51′E) at the entrance of Tokyo Bay. This strata belongs to the Numa deposit, and the date of the skull is considered to be equal with the date of fossil coral and of fossil oyster collected at the same stratum of same location (Mr. Yoshimura, pers. comm.). The ^{14}C dating of the coral and of the oyster gives 6,340±140 B.P. and 6,430±130 B.P. respectively (Araki, 1973).

TABLE 1. MINIMUM NUMBER OF CETACEANS REPRESENTED BY BONE FRAGMENTS IN KABUKAI A-SITE4)

Strata	Upper strata1)	Middle strata2)	Lower strata3)	Total
Globicephala	13	4	2	19
Lagenorhynchus obliquidens	3	2	4	9
Phocoena phocoena	1	1	1	3
Phocoenoides dalli	+	3	2	5
Pseudorca crassidens	3			3
Physeter catodon			1	1
Ziphiidae sp.	1			1
Megaptera novaeangliae	3	2	1	6
Balaenoptera borealis		1		1
B. acutorostrata	1			1
Eubalaena glacialis	+	1	1	2

1) Erom surface to fish bone stratum II/III, 2) From fish bone stratum III/IV, 3) From fish bone stratum IV to VI, 4) Calculated in each smaller strata. Vertebrae other than cervical, and bones in flipper are not included, but shown by "+".

For the osteological comparison, the measurements of 25 skulls of *G. macrorhynchus* collected on the Pacific coast of Japan were used. They are 7 skulls in the collection of National Science Museum (Tokyo), 5 skulls of Ogawa's specimen in the collection of the same museum, 1 skull collected at Ayukawa (no date), 3 skulls collected at Choshi (35°42′N, 135°56′E, Dec. 1966), and 9 skulls collected at Arari on the Pacific Coast of Japan (39°49′N, 137°46′E, June 1965 and 1967). The last

13 skulls are kept in the Ocean Research Institute, University of Tokyo. The skull measurements of 4 *G. scammonii* (=*G. macrorhynchus*) specimens in the collection of Los Angeles County Museum (EDM F 298, WAW 46, WAW 47, WAW 48) and one skull kept in the Smithsonian Inst. (USNM 3076), and the measuremnts of 13 skulls from the North Atlantic in the collection of Smithsonian Inst. (USNM nos. 21572, 257412, 257413, 279366, 257414, 37264, 241182, 37261, 22592, 37263, 395712, 22571, 22570) are used here. The measurements of the type specimen of *G. scammonii* (USNM 9074) were provided by Dr. R. L. Brownell. Measurements of 9 skulls of *G. macrorhynchus* cited from Fraser (1950) and Van Bree (1971, =*G. sieboldii*) were used in Figs. 1 and 2.

The measurements of *G. melaena* were obtained on 21 skulls in the collection of Smithsonian Inst. (USNM nos. 395373, 395365, 395372, 395364, 395363, 395361, 395362, 395360, 395357, 16298, 20981, 21118, 14418, 14360, 20958, 303018, 12098, 12097, 12099, 12100, 20957, and EDM 1000) and on 4 skulls in the collection of Los Angeles County Mus. (four EDM specimens).

The catch statistics of *Globicephala* in the Japanese coastal waters were compiled from Geiryo Geppo [the monthly report of whaling operation] of the period from 1949 to 1952, when most intensive fishing for *Globicephala* was operated because of the social demand for the food. This report was originally presented to the government by the owners of the small whaling boats, but now is kept in the Whales Research Institute in Tokyo. The position of the catch is represented in this study by the position of the whaling station, and the number of the catch is shown in each areas obtained by combining several nearby stations.

OSTEOLOGY

The difference between *G. melaena* and *G. macrorhynchus* is found, on the skull, in the shape of premaxillae on the dorsal surface of the rostrum (Fraser, 1950). In the latter species the lateral margins of the premaxillae expand widely at the anterior region of the rostrum to cover, entirely on adult individuals, the maxillae of that part. However, on *G. melaena* this expansion is very weak and the maxillae are widely exposed, even on the adult animal, on the dorsal surface of the anterior part of rostrum. Though Van Bree (1971) says that rostrum is elongated in *G. melaena* than in *G. macrorhynchus*, there was found no difference in the length of rostrum between the two species (Fig. 2.). The number of teeth is fewer and the size of tooth larger in *G. macrorhynchus*.

The five *Globicephala* skulls from Rebun Island and Tateyama are, except one juvenile, those of adult individuals, and the lateral margins of the maxillae and of premaxillae of the 5 skulls are almost intact to allow the accurate comparison. And their feature coincides with that of *G. melaena* in the above characteristics (PLATES). The number and size of alveoli are also rather close to that of *G. melaena* (Table 2). As shown in Fig. 1, the measurements of rostral region show the difference between the two species, and *G. macrorhynchus* from the Pacific coast of Japan shows the perfect coincidence with those of the same species in other areas. However the measurements of 5 measureable skulls from Rebun Island and Tateyama come in the range of *G. melaena* in the North Atlantic. From these reasons the present *Globicephala* skulls are classified into *G. melaena*, and it is concluded that *G. me-*

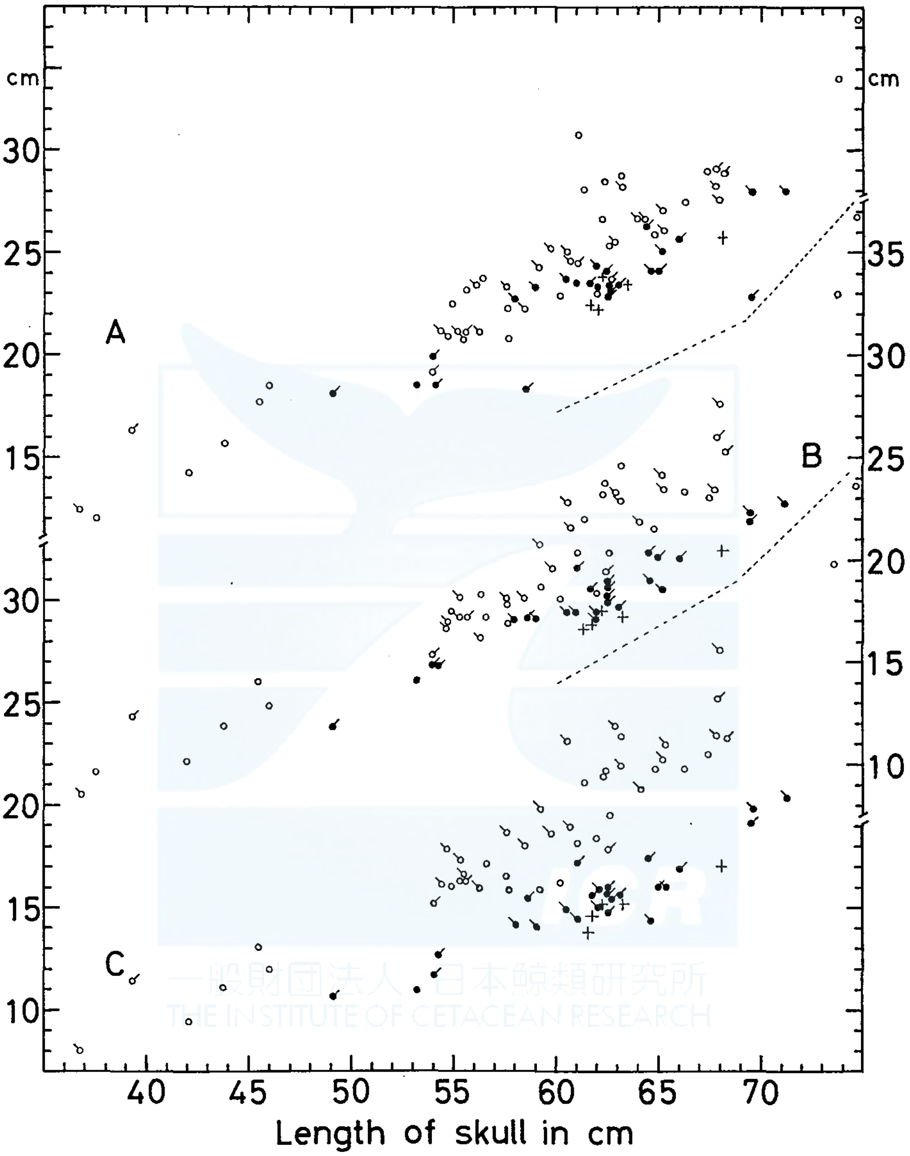

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Fig. 1. Scatter diagram of the measurements of rostral region of *Globicephala*. A: Rostrum basal width. B: Rostrum width at middle. C: Premaxillae width at middle of rostrum. Open circle: *G. macrorhynchus* (Without bar indicates animal from Japanese coast, bar at right that from California coast, and bar at left that from other seas). Closed circle: *G. melaena* (Bar at right indicates animal from Chili, bar at left that from North Atlantic, and no bar no history). Cross mark: *G. melaena* from Japanese coast.

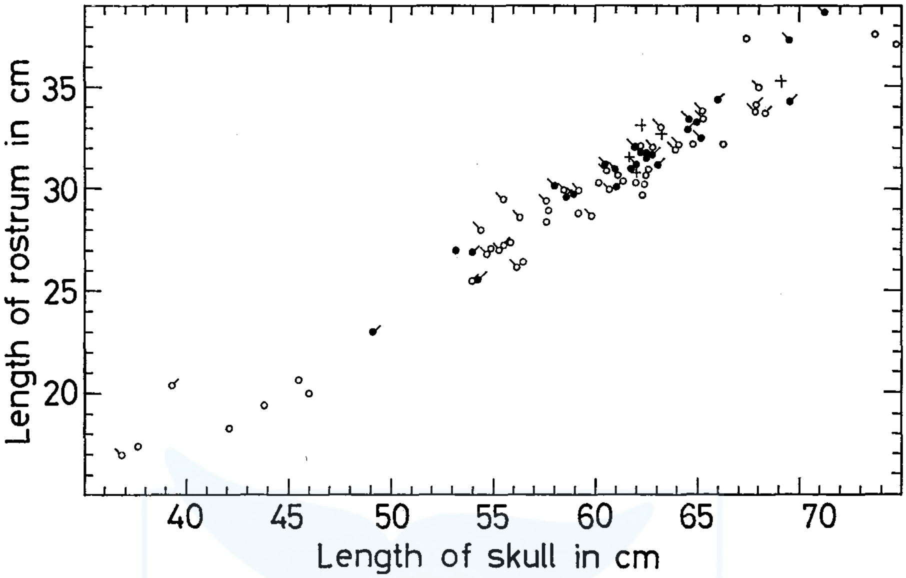

Fig. 2. Scatter diagram showing the relationship between length of skull and length of rostrum. For marks see Fig. 1.

TABLE 2. SKULL MEASUREMENTS OF *G. MELAENA* FROM JAPANESE COAST (MM)

Specimen no. and Locality	KRA3658 Kabukai	675 Motochi	RKA6054 Kabukai	Awa Mus. Tateyama	RKA3987 Kabukai
Measurements					
1. Condylo-basal length	617	619	623	633	681
2. Rostrum length	315	310	331	329	352
3. Rostrum basal width	224	223	119×2	235	257
4. Rostrum width at middle	167	166	87×2	171	200
5. Premaxillae width at same point	138	146	76×2	151	170
6. Maximum width of premaxillae distally	140	148	146	151	172
7. Maximum width of premaxillae proximally	148	156	—	158	174
8. Width of rostrum at the level of no. 6	168	170	90×2	171	205
9. Width across preorbital angles of supraorbitals	175×2	352	178×2	375	399
10. Width across postorbital angles of supraorbitals	—	384	—	415	440
11. Width of skull at orbits	359	349	—	371	405
12. Zygomatic breadth	—	375	—	416	—
13. Width of braincase across parietals	288	285	—	273	299
14. End of rostrum to blowhole	407	394	401	—	466
15. Length of upper tooth row (to end of pmx.)	L168, R166	L163, R154	L201	L175	L190, R205
16. Number of upper teeth	L10, R10	—	L9	L11*	—

* Last alveolus rudimental.

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TABLE 3. COMPARISON OF SOME IMPORTANT SKULL MEASUREMENTS OF TWO SPECIES OF *GLOBICEPHALA*

		G. melaena Japan	*G. melaena* Chili	*G. melaena* N. Atlantic	*G. macrorhynchus* N. Atlantic	*G. macrorhynchus* N. Pacific
1. Condylo-basal length (mm)1)	sample size	5	10	14	13	24
	range	617–681	580–712	590–695	544–680	540–748
	mean	634.6	633.1	619.9	611.8	621.6
	standard error	11.92	13.76	11.80	12.79	11.35
2. Rostrum length (%)	sample size	5	10	14	13	24
	range	50.1–53.1	49.8–54.4	47.2–51.2	48.0–52.2	47.2–51.0
	mean	51.6	51.7	50.2	50.4	49.2
	standard error	0.50	0.46	0.31	0.35	0.21
3. Rostrum basal width (%)	sample size	5	10	14	13	24
	range	36.0–38.2	37.3–40.1	31.2–40.2	37.6–44.6	35.6–48.6
	mean	37.1	38.8	36.9	40.4	41.3
	standard error	0.42	0.28	0.71	0.53	0.76
4. Rostrum width at middle (%)	sample size	5	10	14	13	24
	range	26.8–29.4	27.4–31.9	27.3–33.0	30.5–40.4	28.3–49.0
	mean	27.6	29.2	29.8	34.8	34.1
	standard error	0.45	0.49	0.45	0.86	1.03
5. Premaxillae width at same point (%)	sample size	5	10	14	13	24
	range	22.4–25.0	22.1–28.5	21.5–28.2	29.6–40.4	26.7–47.2
	mean	23.9	24.9	25.2	33.8	32.3
	standard error	0.44	0.65	0.48	0.92	1.02
11. Orbital width (%)	sample size	4	10	10	12	21
	range	56.4–59.5	61.1–65.7	59.2–66.7	62.5–68.6	62.2–78.5
	mean	58.2	62.9	63.1	65.8	68.7
	standard error	0.65	0.76	0.73	0.63	1.02
16. Number of upper teeth	sample size2)	4	14	16	26	48
	range	9–11	9–11	9–12	7–10	6–9
	mean	10.0	9.9	10.3	8.0	7.8
	standard error	0.41	0.20	0.24	0.20	0.14

1) Skulls more than 540 mm are selected. 2) Both sides are dealt separately.

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laena was present at the approximate 10th century in the northern part of the Sea of Japan.

SEASONAL FLUCTUATION OF THE RECENT CATCH

Fig. 2 shows the seasonal fluctuation of the catch of *Globicephala* in the coastal waters of Japan, compiled from the monthly report of the catch in the years from 1949 to 1952. In these years many small whaling boats operated in the Japanese coastal waters for minke whale, ziphioid whales, killer whale, and pilot whale. The fish-

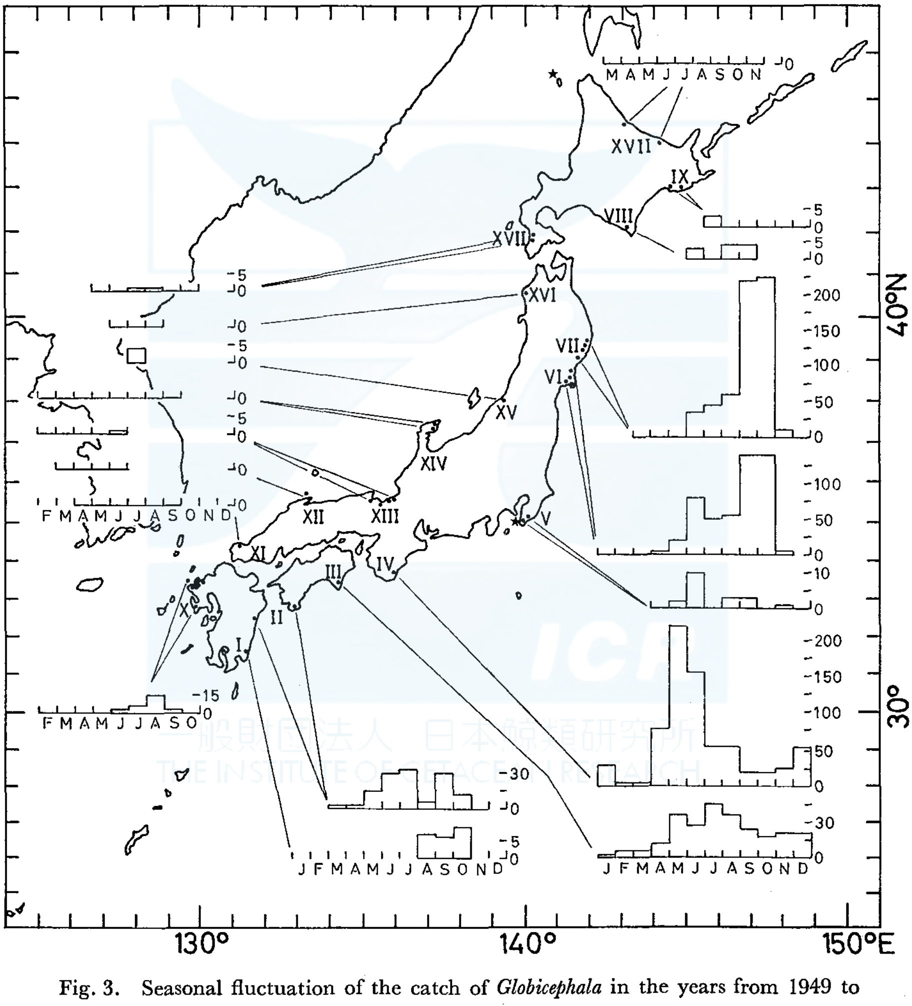

Fig. 3. Seasonal fluctuation of the catch of *Globicephala* in the years from 1949 to 1952. The number of catch is shown by squares, and the months of whaling operation by holizontal line. Closed circle indicates whaling station, and star the position of the occurrence of *G. melaena*. Whaling area is shown by Roman numerals.

ing ground was approximately within the range of 50 nautidcal miles (90 km) from the coast (Omura and Sakiura, 1956). Though they prefered minke whale, they caught other species also, because the demand of whale meat for human consumption was high. Accordingly the seasonal and geographical fluctuation of the catch of *Globicephala* in these years is considered to reflects the abundance of this species. The total number of whaling boats of this type operated was 74 (1949), 66 (1950), 68 (1951) and 69 (1952). And the annual number of *Globicephala* catch was 760 1949), 667 (1950), 591 (1951), and 307 (1952). It is not analyzed yet whether the decrease of the annual catch is the reflection of the depletion of the population or the reflection of economical factors. Probably both of the factors will have influenced on it.

As shown in Fig. 3, the catch in the central and northwest regions (except areas VII to IX) shows, in general, the two peaks one in the autumn and the other in early summer. And the interval between the two peaks is shorter in the northern areas. Though the peak of early summer is inconspicuous in the areas VI and VII, this seems to be the influence of the catch of minke whale. According to Omura and Sakiura (1956), these area is a good whaling ground of minke whale and the season is from January to July with a peak in May. This will have a effect to lower the peak of *Globicephala* in early summer.

However, in the areas VIII and IX, the catch of *Globicephala* shows only one peak. In these areas the season of minke whale is between June and October with a peak in July (Omura and Sakiura, 1956). Accordingly the season of the peak of catch of *Globicephala* in these areas will not be biased, even if the total number of catch is smaller compared with the number of migrating animals.

This fact suggests that the area where *Globicephala* densely distributes moves from the south to the north in the early summer, and after arriving at the latitude of 43°N in July and August, it again moves to the south to arrive at Kii and Shikoku area (32°N to 34°N) in November and December. Possibly this seasonal movement of the whaling ground reflects the migration of one species of *Globicephala* in the Pacific coast of Japan. But as suggested by Fig. 3, some *Globicephala* individuals seem to stay in all seasons in the Pacific coast of the south west region of Japan (areas I to IV).

The catch of *Globicephala* in the sea of Japan and in the northern coast of Kyushu is too scarce to discuss the seasonal fluctuation. But it is safe to say that the catch is restricted to the summer season in spite of the longer operation of whaling in this region. As the number of the catch of *Globicephala* is so few, there may arise a question if the *Globicephala* reported by the fishermen from the Sea of Japan represent real *Globicephala*. However, there is no doubt in the existence of the genus in the Sea of Japan, because a school of *Globicephala* was sighted by myself on 28, August, 1971 at the center of the Sea of Japan (39°04′N, 134°36′E). The surface water temperature at the spot was 24.5°C.

In the Okhotsk Sea, the Japanese whaling boats for small whales operated in the seasons from March to November. But there are no catch of *Globicephala* recorded in the statistics I analyzed. Omura and Sakiura (1956) showed that the season of minke whale in this region lasts from March to July with a peak in May, and the same result was obtained even from my data. After the season of minke whale, they caught *Berardius* and *Orcinus* in the Okhotsk Sea. As the capture of *Globicephala* is not considered to be more difficult than that of *Berardius* or *Orcinus* even if the size is slightly smaller than the latter, they must have captured *Globicephala* if it had been distributed in the sea in that season. According to the personal communication of Mr. S. Miyoshi who has been operating the whaling for more than 20 years mainly in the Okhotsk Sea, he have sighted no *Glogicephala* in the Okhotsk Sea.

These informations strongly suggest that *Globicephala* does not migrate, in the seasons from March to November, to the southern part of Okhotsk Sea where the Japanese whaling boats for small whales operate.

DISCUSSION

On the species of *Globicephala* constituting the catch in the Pacific coast of Japan, the specimens of known locality give the information. All the known records of *Globicephala* in this area, i.e. 6 specimens collected at Arari in June 1967 (Nishiwaki *et al*, 1967), external measurements of 16 animals and 13 skulls collected at Taiji 33°38′N, 135°56′E) in July and August 1969, 1 Ogawa's specimen caught at Shirahama (34°54′N, 137°53′E), 3 animals in a school stranded at Choshi (35°42′N, 140°52′E) in December 1966, 2 Ogawa's specimens presumably collected at Shiogama in May 1932 and 1935 (Ogawa, 1937; Ogawa, 1932 cited in Kuroda 1938), 2 Ogawa's specimens presumably collected at Ayukawa (Ogawa, 1937), and 1 skull and skeleton in National Science Museum in Tokyo killed at 39°28′N, 142°19′E in October 1953, are represented by *G. macrorhynchus*. These animals were collected from the animals representing both the early summer and the autumn-winter peaks.

The comparison of fishing season and oceanographical condition gives another support on the identity of the species. The boundary of the front of warm Kuroshio Current is indicated by the 17°C surface isotherm (Uda, 1954), and in August the boundary go up to the latitude of 43°N (Uda and Nasu, 1956; Miyazaki *et al*, 1974) or to the northern limit of the whaling ground of *Globicephala* analysed here, and retreats in March to 35°N (Miyazaki *et al*, 1974) or to the approximate northern limit of *Globicephala* ground in winter season. From these informations it is concluded that all the catch of *Globicephala* in the Pacific coast of Japan is constituted by *G. macrorhynchus*, and that the species lives in the Kuroshio watermass and moves north and south in accordance with the seasonal movement of the boundary of Kuroshio front. Accordingly the range of normal distribution of *G. macrorhynchus* is expected not to extend into the cold watermass.

There is obtained no data directly indicating the species of *Globicephala* caught by recent whaling in the Sea of Japan. However, the existence of the skull of *G. sieboldii* [=*G. macrorhynchus*] caught at Nagasaki in western Kyushu, the fact that *Globicephala* was caught in the same season with that of *Pseudorca* (areas XI, XII and XVI), one sighting record mentioned in the former section, and the presence of warm Tsushima Current in the Sea of Japan (Uda, 1954) strongly suggest that there is distributed *G. macrorhynchus* in the summer season. So I consider that all the *Globicephala* appeared in the statistics is represented by *G. macrorhynchus*.

As the northern extension of Tsushima current is faint in the north western and northern coast of Hokkaido, there will be expected no migration of *G. macrorhynchus*. Though the water in the eastern part of northern coast of Hokkaido is high in the summer season (Uda and Nasu, 1956), it is restricted to a small locality and will not result in the migration of *G. macrorhynchus*.

From the above discussions it is supposed that G. *melaena* found on the Rebun Island must have been caught in the seasons from late autumn to winter.

Though at present there is no data to have a discussion on the present status of population or on the migration of *G. melaena* in the North Pacific. There can be two possible hypotheses on that problem. The first is to consider that *G. melaena* is extinct in the Okhotsk and in the Sea of Japan. Judging from the carvings excavated at Sakhalin and at Nemuro in eastern Hokkaido (Tsuboi, 1908 and 1909; Yahata, 1943), it is sure that the natives of the Okhotsk coast including the people on the Rebun Island of that date had the techniques to catch even some mysticeti. However, as they seems to have used only hand harpoon and small canoe for the whaling, it is difficult to consider that the *G. melaena* population was exterminated only by the whaling of that date. If the population have been exterminated, we should expect the interspecific competition between *G. melaena* and other organisms. One of the possible competitative mammal species other than man seems to be *Phocoenoides dalli* (True, 1885). On this hypothesis, a possibly small population of *G. melaena* which might have immigrated to the North Pacific is considered to have failed in establishing its niche obstacled by the dominant population of *Phocoenoides*. On the date and the route of the immigration of *G. melaena*, there can be two possibilities. The first is, as suggested by Davies (1962), through the eastern equatorial Pacific in the Würm glacier stage. The second is from the North Atlantic through the Arctic Ocean in more recent age. The vegetation detected by the pollen analysis and the Alpine timberline show that the climate of all the northern hemisphere was warmer in the age between 8,000 B.P. and 2,000 B.P. (Atlantic and Sub-boreal periods) than the present (Deevey and Flint, 1957), and the air temperature at Oslo was suggested to have been higher by 3°–4°C (Tsukada, 1974). The similar result was obtained by Emilliani (1964) by the oxigen isotopic analysis of the Caribbean Sea deposit. Though the exact change of water temperature in the Arctic Ocean of that date is not known, above climatic change seems to have provided the passages for *G. melaena* to North Pacific.

The other hypothesis is to consider that *G. melaena* is surviving at least in the western North Pacific and its adjacent seas, and that it lives in the areas and seasons when the Japanese whaling operation or scientific study was not conducted. For this hypothesis the presence of the peak of density of globicephalid species in November in the southern coast of Hokkaido (Kasuya, 1971) will give some suggestion. As *Orcinus* is recorded separately in his aerial sighting records and the water is too cold to expect *Pseudorca*, the possible species recorded there can be *Globicephala* especially *G. melaena.* According to the personal communication of Mr. K. Sasaki, who is one of the fishermen operating the *Phocoenoides* hunting in January to March in the coast of Iwate and Miyagi prefectures (Pacific coast, 38°N to 40°N in latitude), they sometimes find *Globicephala* while they are operating *Phocoenoides* hunting. The surface water temperature at those positions is told to be 7°C to 8°C. As *Phocoenoides* is mostly found in the water colder than 16°C and above this temperature all of my sightings of *Globicephala* and other temperate or tropical species (e.g. *Pseudorca*, *Tursiops*, and *Stenella*) have occurred (Kasuya, umpublished, Miyazaki *et al*, 1974), the sighting of *Globicephala* mensioned in the above can represent *G. melaena.* But this problem is left to be confirmed. Though the information on the globicephalid founa on the Russian coast is desirable, there seems to be no reliable study (Dr. Yablokov, pers. comm.).

Though it is not the purpose of this study to have a discussion on the Japanese common names indicating *Globicephala*, some comments are added here. At first we must remind that Japanese fishermen can use different names for the animals of various growth stages as usually found in some species of fish, and that the name can be modified even by the fishing season. Ui (1942) reported a case that the pilot whale caught at Taiji in the calm season of November and December is called " Nagi [=calm]-gondo ". It is, of course, expected that the fishermen at different places use different common names. However, it will be easily concluded that " Magondo [=common pilot whale] " used by the whalers at Taiji for *Globicephala* caught at Taiji indicate *G. macrorhynchus* which were formerly misidentified as *G. melaena.* The whalers at Taiji have another name " Tappanaga " indicating so-called another *Globicephala* species. According to a former whaler Mr. Mizutani (pers. comm.), " Tappanaga " is rare at Taiji but commonly caught in the summer season in the northern part of the Pacific coast of Japan. He tells that " Tappanaga " has, as the name indicates, longer flipper than that of " Magondo ", and the size of the body of " Tappanaga " is usually larger and the content of oil is fewer. The distinction of the two is told to be difficult. However, as the relative length of flipper of *G. macrorhynchus* can be expected to increase accompanied with the growth of the animal (Sergeant, 1962), the above distinction is not reliable. Furthermore, the fishing season of " Tappanaga " in northern Japan corresponds to the season of *G. macrorhynchus* mentioned above. Accordingly it is concluded that the name " Tappanaga " does not indicate *G. melaena* but may indicate old individual of *G. macrorhynchus.* I have no new information on " Naisa " or " Naisagoto " and on " Shio " or " Shiogoto " which had been considered to be the synonyms of " Magondo " and " Tappanaga " respectively (Ogawa, 1937). But I suppose that they also indicate *G. macrorhynchus* because they were reported to be found near Taiji and the body length and the swelling of the head is larger in " Shio " than " Naisa " (Yamase, 1760), which is considered to be male secondary sexual character..

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EXPLANATION OF PLATES

PLATE I

Fig. 1. *G. melaena*, ventral view of skull found in the alluvial deposit by the Hekuri River at Tateyama (34°59′N, 139°51′E).

Fig. 2. *G. melaena*, lateral view of the same specimen.

Fig. 3. *G. melaena*, dorsal view of the same specimen.

Fig. 4. *G. melaena*, dorsal view of skull (no. 675) found at Motochi archaeological on the west coast of Rebun Island (45°20′N, 141°00′E).

PLATE II

Fig. 1. *G. melaena*, dorsal view of skull (RKA 6054) found at Kabukai archaeological A-site on the east coast of Rebun Island.

Fig. 2. *G. melaena*, dorsal view of skull (RKA 3658) found at Kabukai A-site.

Fig. 3. *G. melaena*, dorsal view of skull (RKA 3987) found at Kabukai A-site.

Fig. 4. *G. macrorhynchus*, dorsal view of skull, caught at Taiji (33°35′N, 135°43′E) in May 1967.

PLATE III

Fig. 1. *G. macrorhynchus*, dorsal view of skull, California coast, USNM 9076 (?).

Fig. 2. *G. macrorhynchus*, ventral view of the same specimen.

Fig. 3. *G. melaena*, dorsal view of skull, Virginia coast, USNM 303018.

Fig. 4. *G. melaena*, ventral view of the same specimen.

Fig. 5. *G. melaena*, dorsal view of skull, Chili, USNM 395365.

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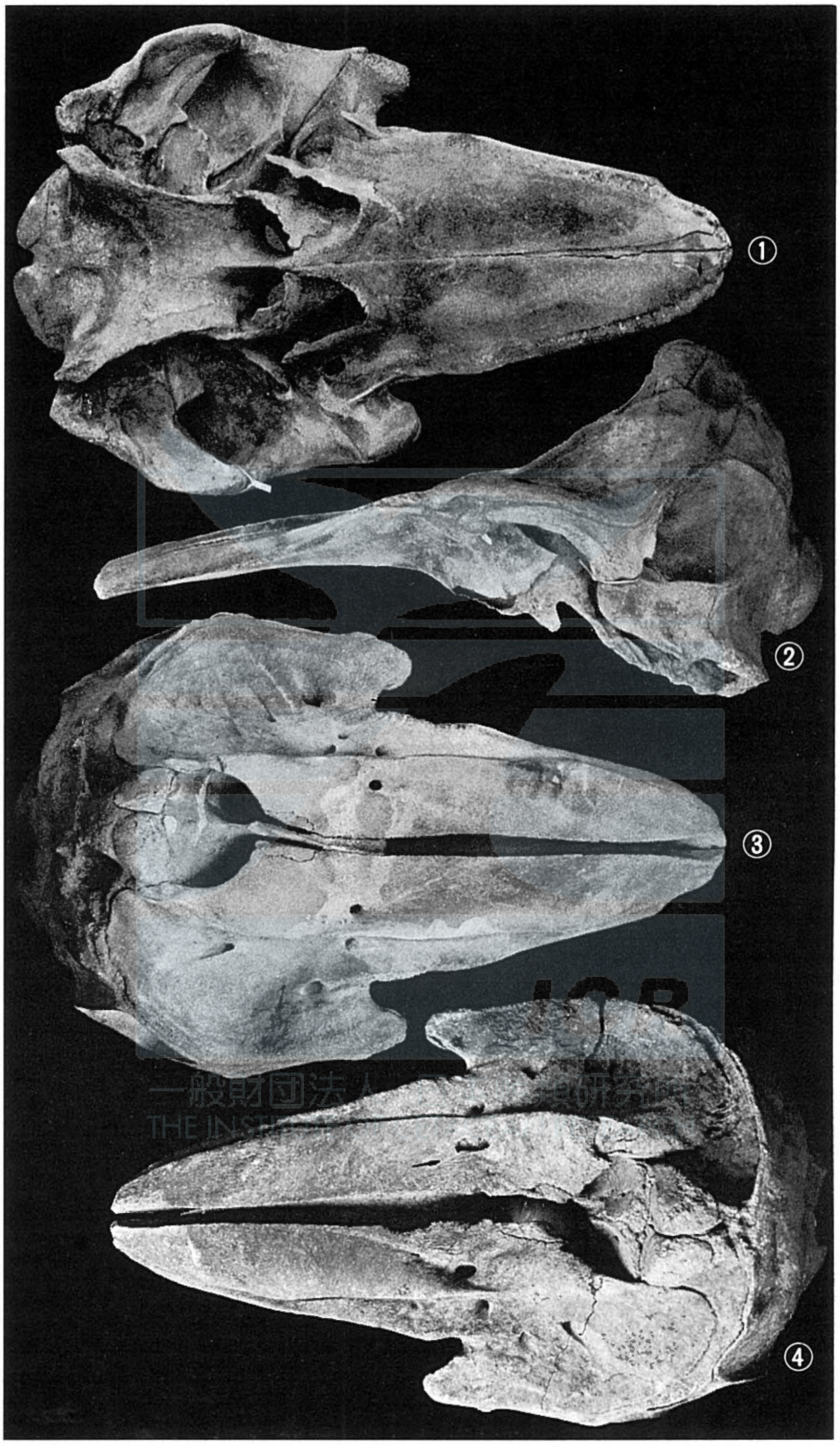
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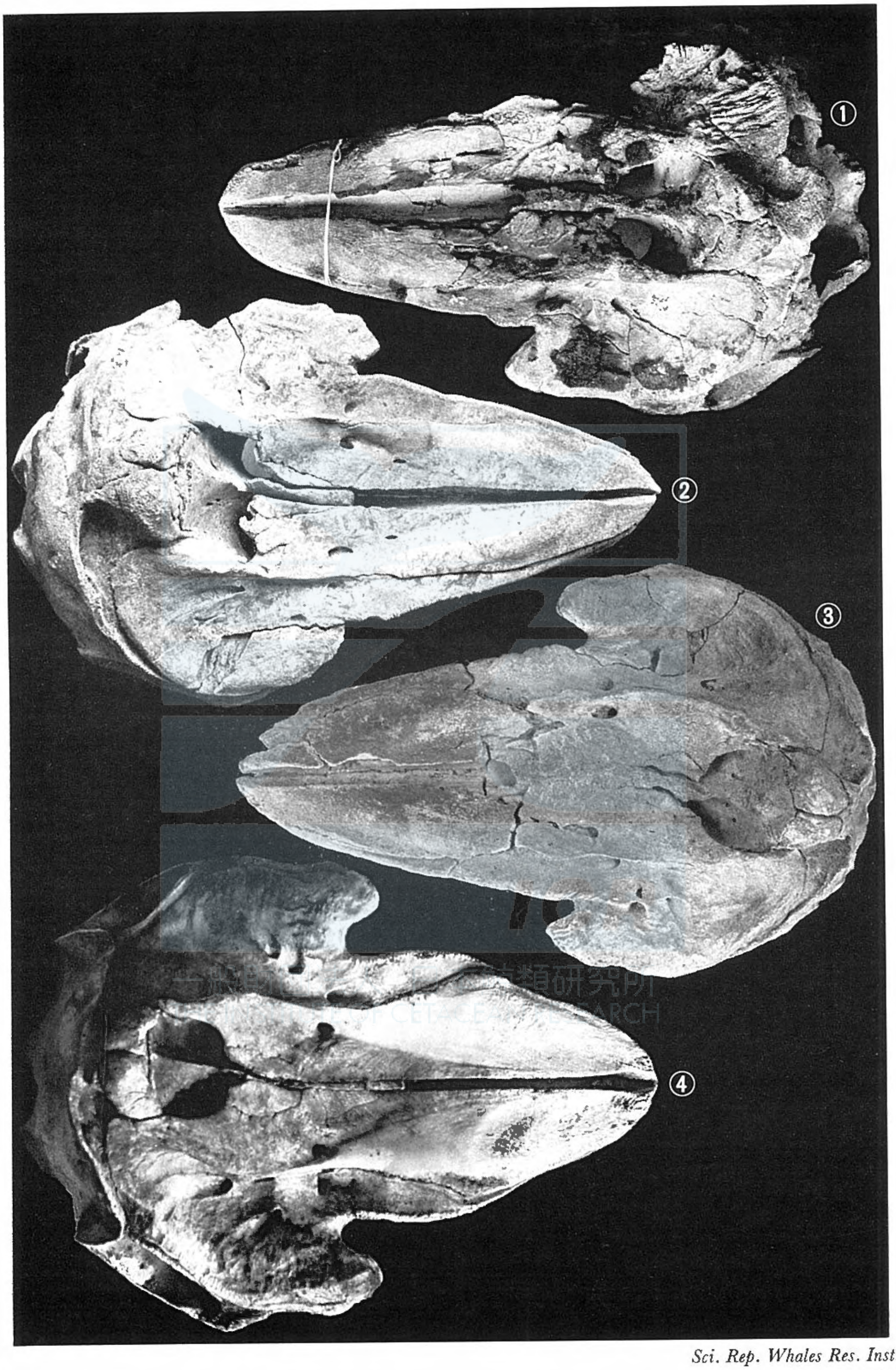

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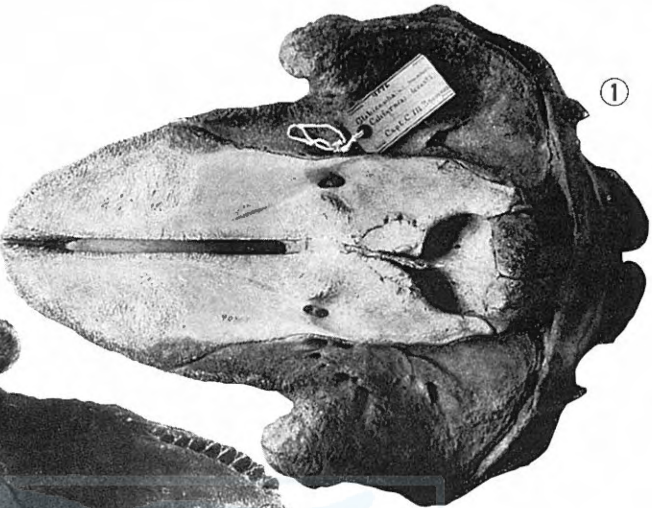
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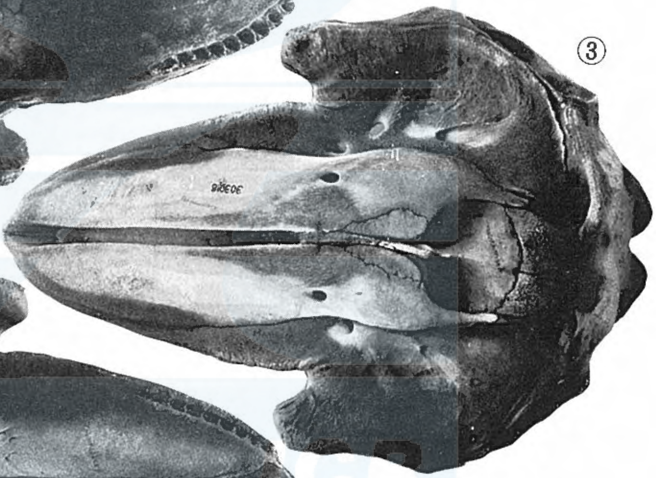
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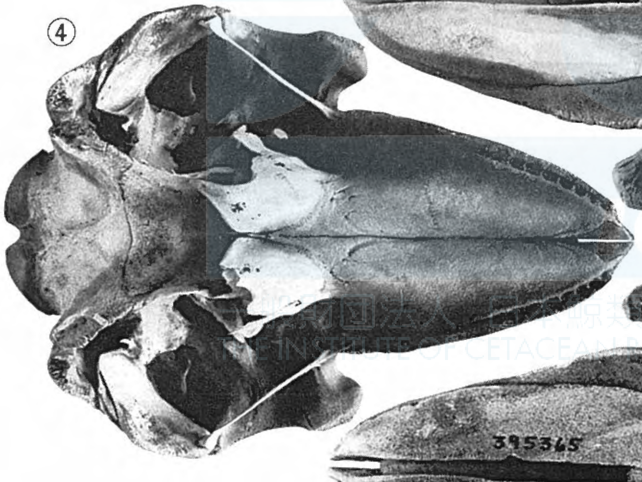
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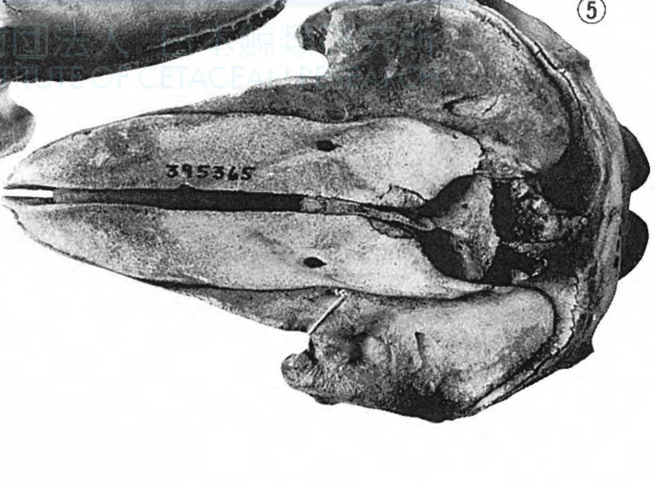

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A STUDY OF THE GENUS *BERARDIUS* DUVERNOY*

CHARLES McCANN

8 Kiwi Street, Heretaunga, Upper Hutt, New Zealand

ABSTRACT

The taxonomy and distribution of the two known species of *Berardius*, *B. arnouxi* Duvernoy and *B. bairdi* Stejneger are reviewed, and some anatomical and biological aspects of the two species are considered.

INTRODUCTION

The members of the genus *Berardius* or Porpoise Whales, in spite of their large size, are little known. Although one of its two closely allied species, *B. bairdi* Stejneger, was known to and fished for by Japanese whalers very early in historic times, it was not scientifically recognised until 1883.

The genus *Berardius* was founded by Duvernoy in 1851 on a skull from Akaroa, Banks Peninsula, New Zealand. The specimen was taken to France by M. Arnoux, who was at the time surgeon to the French corvette *Rhin* commanded by Captain Berard. These two gentlemen are commemorated in the generic and specific names of the type species, *Berardius arnouxi* Duvernoy.

Although more than a hundred years have elapsed since the original description of *B. arnouxi*, barely forty specimens have been reported in literature. By some mischance, the ' o ' was omitted from Arnoux in the original description. Since then, some cetologists have retained the original spelling, *arnuxi*, while others have amended it to *arnouxi*. As the original spelling was almost certainly a ' lapsus calami ', the amended spelling should be adopted.

Flower (1872) gave the first detailed description of the general anatomy of *Berardius* from a specimen then in the Museum of the Royal College of Surgeons. This specimen which had stranded at New Brighton, Canterbury, New Zealand, on 16th December, 1868 had been sent to London by Sir Julius von Haast. Little has since been added.

The two known species are geographically isolated: *B. arnouxi* Duvernoy occurs only in the Southern Hemisphere, in the Southern Pacific and Southern Atlantic Oceans; whilest, *B. bairdi* Stjneger is confined to the Northern Pacific Ocean, concentrating seasonally near Japan while strays are occasionally found

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* This paper was compiled some years ago while the author was still employed as the Vertebrate Zoologist at the DOMINION MUSEUM, Wellington (now the NATIONAL MUSEUM) under the Directorship of Dr. R. A. Falla (now Sir Robert A. Falla), since retired. Dr. R. K. Dell, is the present Director of the National Museum.

The specimen registration numbers quoted in the paper are referred to by the originals with the prefix D. M. or Dom. Mus.

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along the western shores of North America.

Recent papers by Omura *et al.* (1955) and others have discussed the biology and whaling of *B. bairdi*, but no such information is available for *B. arnouxi*. McCann (1962), in a revision of the genus *Mesoplodon* discovered that the calves of *B. arnouxi* had until then been identified as *Mesoplodon hectori* (Gray). Hector (1870) had originally identified the type of *M. hectori* (Gray) correctly as the young of *Berardius arnouxi* Duvernoy, but Gray (1871) declared it a new species of *Berardius*. Turner (1872) cautiously transferred *B. hectori* Gray to *Mesoplodon* where it had remained ever since. McCann's discovery not only places the genus *Mesoplodon* in a more satisfactory systematic position, but indicates that the breeding grounds of *Berardius arnouxi* are in the vicinity of the New Zealand Archipelago.

GENUS *BERARDIUS* DUVERNOY (PLATES I-II)

1851.	*Berardius*	Duvernoy, Ann. Sci. Nat. (3) 15: 52. Type *Berardius arnouxi* Duvernoy. Type locality: Akaroa, New Zealand. Type in *Paris Museum*.
1872.	*Mesoplodon*	Turner, Trans. Roy. Soc. Edin. 26: 778. (*Berardius hectori* (Gray))
1922.	*Paikea*	Oliver, Proc. Zool. Soc. Lond. p. 575. Type *Mesoplodon hectori* (Gray), Type *Brit. Mus.* 1677b. 76. 2. 16. 3.

DESCRIPTION

Large whales attaining 7.8 to 12.7 metres (26 to 42 ft) in length. Head large, buffer-like, without nuchal depression but a pronounced rostrum or beak; upper jaw subacute anteriorly; lower jaw longer than the upper, extremity rounded; two pairs of strongly compressed, functional teeth near the extremity, the anterior larger than the posterior; teeth erupted in both sexes on reaching maturity; occasionally only a single (anterior) tooth present in each ramus; normally no teeth in maxillae. Eye of moderate size. Blowhole median, crescentic. A pair of diverging gular grooves forming an inverted V-shape, the anterior arms not in contact; occasionally an additional pair of shorter grooves may appear; no thoracic nor abdominal pleats. Body fusiform, laterally compressed posteriorly only. Flippers moderately broad and rounded distally; flukes large, shallowly falcate, without median notch although occasionally a shallow indentation may appear mesially. Dorsal fin nearer the caudal, triangular, slightly falcate or represented by a short obtuse elevation.*

SIZE

B. bairdi is larger than *B. arnouxi;* the former reaches 12.6 metres in length (42 ft), whereas the latter has not been known to exceed 9.9 metres (33 ft). Curiously,

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* Perhaps the result of injury or attack by shark.

although *B. bairdi* is the larger and bulkier of the two species, it has a relatively smaller head than *B. arnouxi* (True, 1910: 67).

SEXUAL DIFFERENCES

Females of *B. bairdi* are larger than males, but in *B. arnouxi* both sexes appear to be of very similar size. As the mandibular teeth erupt in both sexes at maturity, the external sexual differences are not as well marked as other genera of the family in which the teeth erupt in the male alone.

GESTATION

The few breeding records available, suggest that the gestation period is approximately ten months and calving takes place during the late spring or early summer.

ANATOMICAL OBSERVATIONS

The skull (Pls. III–VI)

The skull of *Berardius* differs from those of other ziphioid genera in its greater symmetry and simplicity. Its elements are less firmly interdigitated than in other genera. The *mesorostral groove* remains unossified throughout life, i.e. the *mesethmoid cartilage* does not ossify partially nor wholly as in *Ziphius* and *Mesoplodon*. The cranium is relatively more depressed in adults than in the rest of the family, being broader than deep (Pl. VI).

Flower (1872) drew attention to the imperfect closure of the suture between the basisphenoid and presphenoid bones; the suture being, at times, open 12.5 mm (1 in) or more. This is quite normal, not only in *Berardius* but also in other members of the Ziphiidae. In *Berardius*, the suture between the supraoccipital and the frontal bones is also imperfectly closed, but in the rest of the family there is a more complete fusion of these elements. The basioccipital and the basisphenoid elements fuse completely, so that, in all the genera, the line of fusion is not clearly discernible.

In dorsal view (Pl. III, fig. 2), the posterior cranial region is semilunate, the antorbital tubercles forming the ‘ horns ’ of the moon. The rostrum is somewhat lanceolate, arising from within the antorbital notches and is considerably shorter than the mandibles. In side view (Pl. III, fig. 3), the dorsal profile is almost straight; the lower profile rising gently from the pterygoids towards the end of the rostrum. The maxillae are much shorter than the premaxillae, the latter alone forming the extremity. In ventral view (Pl. III, fig. 1) a small portion of the vomer is visible between the pterygoids and palatines. For a short distance anteriorly, the approximation of the margins of the maxillae obscures the vomer, which reappears once more as a linear-lanceolate bony wedge between the maxillae and premaxillae (Pl. III, Vo), but ends considerably short of the rostrum extremity. The premaxillae approximate (but do not fuse) in front of the vomer. An open canal forms a ridge on the ventral aspect of each premaxilla. From the anterior ' segment ' of the vomer, there is a marked difference in the transverse level between the maxillae and premaxillae, the latter being nearer the midline, resulting in a certain amount of flatness in this region.

No basirostral grooves are present, but there is a blind ' pit ' beneath the maxillae just in front of the malar bones (Pl. VII, MP). The position of this pit corresponds approximately to the commencement of the basirostral groove in *Mesoplodon grayi* Haast, the species in which the basirostral grooves are best developed in the family. There is no maxillary notch or tubercle as in *Mesoplodon*, but a maxillary crest is present (PL. 7, MXC).

In *Berardous* the premaxillae are subequal posteriorly, the right being only very slightly wider than the left in the narial region. Their extremities are nodular and are not turned outward as in *Mesoplodon* nor do they overhang the narial opening in the adult. The large bulbous nasal bones overtop the ends of the premaxillae slightly and over-hang the narial opening, supported below by a wide ' bracket ' formed by the posterior wall of the vomer, (Pl. V, fig. 3, Vo). In the newly-born animal the nasals do not attain the full size and are consequently below the level of the extremities of the premaxillae. Two large ' blind pits ' (BP) on the wall of the vomer, just below the nasals (one on either side of the septum) are characteristic of *Berardius* and readily distinguish it from any other genus of Ziphiidae. These pits are clearly visible in both old and young (Pl. V, fig. 3, BP).

The mesethmoid is completely fused with the presphenoid posteriorly. Within the narial cavity the mesethmoid is sandwiched and fused between the recurved walls of the vomer; together they form the narial septum. Anteriorly the mesethmoid emerges from between the vomerine walls and enters the mesorostral groove as a free projection for a short distance, becoming thicker and roughened along its dorsal surface. It is free from the vomer.

The walls of the narial cavity are composed posteriorly and mesially (septum) largely of the vomer; the lateral faces largely of the pterygoid, the premaxillae and small wedges of the maxillae and palatines. A large foramen, situated on the internal lateral face of the nares leads by a canal, laterally, to a large foramen in the orbital region.

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Foramina (Pl. III): In dorsal view, the skull shows several large formina, some of which are useful accessory diagnostic features. Anteriorly, there are two premaxillary foramina, one in each premaxilla (PMXF); two large maxillary foramina, one (sometimes dual or multiple) in each maxilla (MXF). Both pairs of foramina are in front of the narial cavity; in *Berardius* they are approximately on the same transverse level although slight variations in level may occur. At the posterior edge of the maxillary crest or occasionally slightly further back, there is a large foramen connected by a canal with a foramen in the orbital region. This *post-crest foramen* (PCF) (as I propose to call it) is peculiar to *Berardius* and absent in other ziphioids, even in *Hyperoodon ampullatus* which has a greatly exaggerated maxillary crest. Still further back, on the maxillary plate, there is another large foramen

(PMF) (and occasionally an additional one or two); a canal connects this foramen to another in the orbital region.

Antorbital foramina (Pls. VI, VIII): In ventro-lateral view, the skull of *Berardius* has three large foramina in front of the large infundibulliform optic foramen (OPF). These three large foramina are not readily seen in any of the other ziphioid genera as they are concealed within the apparently *single* ' antorbital foramen ' behind a ridge formed by the palatine bone. The anteriormost foramen (Pl. VII, fig. 1) leads by a wide canal to the maxillary foramen (MXF) on the dorsal surface. Occasionally, immediately above this foramen (1), a small foramen perforates the lachrymal bone (L) and passes under it. A short distance behind is another large foramen (Pl. VII, fig. 2) which perforates the lachrymal bone posteriorly; a large vessel leads from this foramen to the dorsal surface of the skull where it appears as the post-maxillary foramen (PMF) (or foramina). Lastly, somewhat below and a little behind the last mentioned foramen and partially below the optic foramen (OPF) is another large foramen (Pl. VII, fig. 3). From this foramen, a large canal passes to a large foramen on the lateral wall of the narial cavity (NF) and another backwards through the foramen lacerum (Pl. X, fig. 1) into the brain cavity. This is the passage of the 5th cranial nerve.

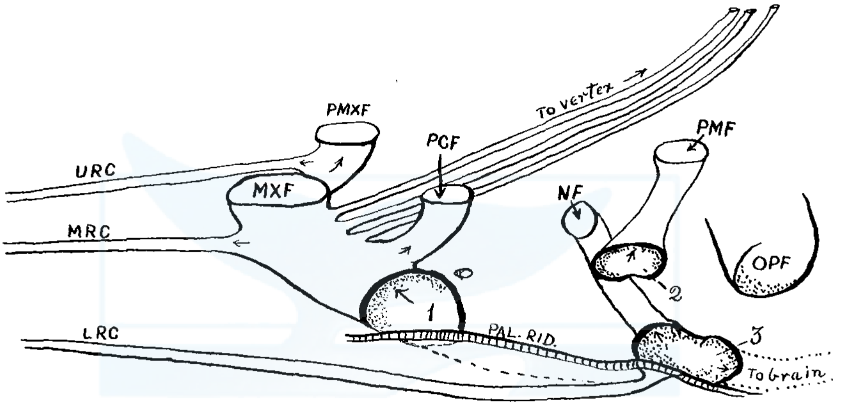

Fig. 1. Arrangement of antorbital foramina (diagramatic). Lettering as in other figures. del. C. McCann.

From within the maxillary foramen (MXF) several secondary canals diverge (text-fig. 1): one large division from the maxillary contributes to the formation of the premaxillary foramen (PMXF); anteriorly a canal passes through the matrix of the maxilla towards the extremity of the rostrum (I term this the *median* rostral canal (MRC)); posteriorly, three similar canals pass backwards under the premaxilla towards the vertex, emerging laterally under the posterior extremity of the premaxilla. Other smaller canals from within the maxillary foramen arise to appear dorsally on or near the base of the maxillary crest. Finally, a large canal from within the maxillary foramen emerges as the maxillary crest foramen (MCF) towards the rear of the crest itself.

From within the premaxillary foramen, a canal is given off anteriorly leading to the extremity of the rostrum. This canal, which I propose to call the *upper rostral canal* (URC), is sandwiched between the premaxilla and the maxilla, particularly proximally.

Attention has already been drawn to the canals leading from within the large posterior foramen to the narial cavity and the brain case. Anteriorly, a small canal passes through the maxtrix of the maxill towards the end of the rostrum; I propose to call this the *lower rostral canal* (LRC). These three rostral canals are readily seen in a cross section through the rostrum.

(In *Ziphius*, the lower rostral canal, instead of passing through the matrix of the maxilla, passes to the exterior at the anterior edge of the palatine bone and continues in a shallow groove to the end of the rostrum underside).

The optic foramen is large and canals lead from it into the cranial cavity, to the internal optic foramen, and through the foramen lacerum.

Behind the optic foramen (OPF), the external foramen ovale (FO) is situated beneath the falciform process (FP) of the squamosal surrounding the tympanic bulla. A little further to the rear, and at a slightly lower level, is the external auditory foramen. The exterior exit of the carotid artery is somewhat irregular in position and size; it is situated at the suture between the pterygoid and the alisphenoid.

Brain case (Pl. X, fig. 1): The brain cavity is amply described by Flower (1872).

Relatively, it appears to be larger than in other members of the family. A well-marked ridge, formed by the orbito-sphenoid and continued upwards by the frontal, is present in *Berardius*. This ridge is developed to a lesser degree in *Hyperoodon*, but absent in both *Ziphius* and *Mesoplodon*.

The base of the brain case appears to be flatter in *Berardius* than in *Ziphius*. The sella tursica and tuberculum sella are both better developed in *Ziphius* (female) than in *Berardius*, and the walls of the cerebellum fossa appear to be more rugose.

In sagittal section the internal cranial foramina are readily visible. From anterior to posterior, they are:

1) A small foramen high up on the wall of the presphenoid close to the midline, entering the nares by a canal. Flower (1872) suggests this may be the rudiments of the olfactory foramen.

2) The large optic foramen perforating the presphenoid.

3) The large sphenoidal fissure (Pl. VII, fig. 1) and the foramen rotundum slightly behind the optic foramen (Pl. VI, OPF), but obscured by the orbito-sphenoidal ridge. These transport the nerves to the orbit and the middle division of the 5th cranial nerve.

4) A small foramen for the carotid artery (Pl. IX, ca). On the floor of the basisphenoid, on a transverse level with the foramen ovale. The canal to the exterior appears as a foramen near the posterior border of the pterygoid.

5) The large foramen ovale further to the rear of the sphenoidal fissure and partially obscured by a ridge of bone. In *Berardius* the sulcus leading from the foramen ovale to the sphenoidal fissure is broad and shallow, but in *Ziphius* and *Mesoplodon* it is more canalised.

6) A foramen for the seventh nerve to the rear of the foramen ovale. This enters the funnel of the auditory meatus and exits through the auditory foramen.

7) The condylar foramen, a small foramen a short distance behind the auditory foramen. This perforates the cerebellar fossa, but has its external opening in the fissure formed by the basioccipital crest and the exoccipital.

8) The auditory foramen, clearly visible to the rear.

Mandibles (Pl. III, fig. 3)

The mandibles in *Berardius* are much longer than the rostrum and permanently expose the large anterior teeth. The distal half of each ramus is comparatively narrow and the upper and lower profiles in this region are almost parallel; the proximal half expands rapidly to form the posterior half. There is no defined ' gonus ' in *Berardius* as in some other ziphioids. The symphysial union is relatively short and the two halves do not anchylose even in old age as in the rest of the family. The mental foramen may be single or multiple and is somewhat erratically situated.

Mandibular teeth (Pl. XII)

Unlike other genera of Ziphiidae, *Berardius* erupts two pairs of functional teeth in both sexes, the anterior pair being usually larger than the posterior. They are strongly compressed laterally. In this, both *Berardius* and *Mesoplodon* agree; and differ from the rest of the family in which the teeth are circular or oval in cross-section.

Viewed laterally, both pairs are roughly triangular, the base being the shortest side, while the anterior edge is frequently slightly longer than the posterior. The lateral faces may be flat or variously undulate with numerous furrows and striae arising along the base and converging towards the apex. Along the antero-posterior edge, the axis is bent outwards slightly. The tip is an acute, enamelled point surrounded by a ' collar ' of dentine. In old animals the teeth are usually so severely abraded, that their tops are flat, almost level with the gum.

Occasionally, only a single tooth (anterior) is present in each ramus.

Vertebrae:

The formula of the vertebrae in the two species is as follows:

Berardius arnouxi: C 7 (3+4); Th 10; L 12 (13); Ca. 19=48 (49).

Berardius bairdi: C. 7. (3+4); Th. 11; L. 12. ca. 16+=46+.

True (1910) observed that the skeletons of both species of *Berardius* are very similar in most details, but there are some specific differences particularly in the number of thoracic vertebrae and of ribs.*

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* Hale (1962) records a specimen of *B. arnouxi* with eleven ribs on one side.

Hector (1878) recorded thirteen lumbar vertebrae in a specimen of *B. arnouxi*, which is still in the collection of the National Museum, Wellington. Wellington (*Slet Mus.* 183) and has unmistakably thirteen lumbar vertebrae. However, *twelve* lumbar vertebrae appears to be the normal number in *B. arnouxi* as shown by other specimens in the National Museum, Wellington. True (1910) remarks that the " discrepancy here shown cannot be accounted for at present, but at all events, none of the formulae of *B. arnouxi* correspond to that of *B. bairdi*."

In the number of thoracic vertebrae, the two species differ specifically. *B. arnouxi* has ten and *B. bairdi*, eleven. The numbers of ribs correspond to the numbers of vertebrae respectively.

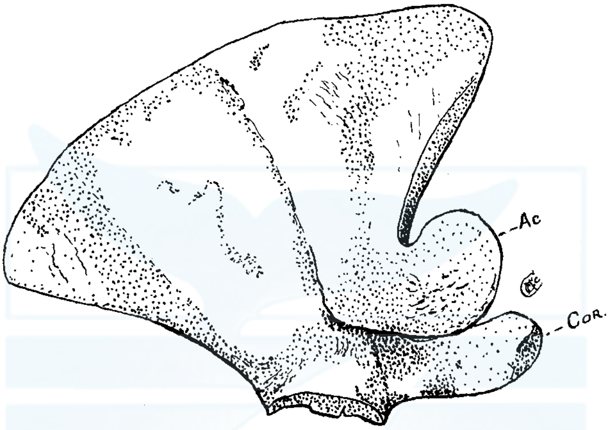

Fig. 2. *Berardius bairdi* Stejneger. Right scapular (714×525 mm.) (after True, 1910, pl. 33, fig. 2).

Cervical vertebrae: The three anterior cervical vertebrae are completely anchylosed in the adult to form a single mass in both species. A newly born specimen of *B. arnouxi* (*Dom. Mus.* 614) has only the first two vertebrae completely fused.

Caudal vertebrae: The number of vertebrae in the caudal region appears to vary slightly (eighteen to nineteen appears to be normal). The small terminal elements may easily be lost or dissolved during maeeration.

Chevron bones: There are normally nine chevron bones, the first usually of two irregular pieces, not united mesially. The fourth and fifth are the largest and best developed.

Sternum:

The sternum is like that of *Ziphius* and *Mesoplodon*, but naturally larger. It is normally composed of five elements, the fifth frequently anchylosed to the fourth and bifid posteriorly.

Scapulae: (Pl. XIII)

Apart from size, the shape of the scapulae is remarkably different in the two species. The acromion and coracoid processes are contrasted; there is a greater space between the two processes in *B. arnouxi* than in *B. bairdi*, and in *bairdi* the acromion almost completely overlaps the dorsal margin of the coracoid (text-fig. 2).

SCHOOLING

Omura and his colleagues (1955) state that *Berardius bairdi* forms schools of ten or more individuals, males appearing in greater numbers than females.

There is some evidence that the breeding school could be dominated by a single master bull. Linear weals and other wounds occur on the bodies of males, particularly old bulls, indicating that there is considerable rivalry among the males —the females seldom exhibit such scarring. Adult females of *Berardius* probably add their quota of scarring on the bulls for unwanted attentions.

MALE RIVALRY

Pike (1953) referring to scars in *Berardius bairdi* offers another explanation of scarring " Numerous white scratch marks appear on the back and flanks of both specimens (Pl. II, III). The scratch marks when found on males of other Ziphiidae and Delphinidae, have been attributed to the teeth of rival males. This explanation seems unlikely to be applicable in this species whose teeth are either buried in the gums [young animals] or are so blunt and protrude so slightly. A more plausible explanation for all species is that the scratches are caused by the sharp ' beaks ' of the squids on which they feed. Similar scratches are found on the heads of sperm whales."

This explanation overlooks the fact that the teeth are extremely sharp when first erupted and only become blunt with age, and that scarring by cephalopods would not be restricted to males, nor would it occur indiscriminately all over the body. The present author believes the scars are the result of male rivalry, a view also held by Omura, Fujino and Kimura (1955). Over several years, I have examined numerous carcases of Ziphiidae and other whales for scarring. I find that in male *Ziphius* linear scars, which are numerous on back and flanks, less common on the body, appear as single weals or exactly parallel weals, ranging from a few centimetres to one metre or more in length. They are produced by one or a pair of teeth ripping along the body, the distance between the parallel scars corresponding to the distance between the mandibular teeth at the extremity of the mandible. Females rarely exhibit linear scarring.

There are also round, oval or elliptical white scars*, particularly by the vent.

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* Recently, my suspicions that the elliptical scars, so commonly met with on the bodies of ziphioids, particularly in the region of the vent, were probably caused by some epizoic crustation were confirmed, when I asked Dr. J. C. Yaldwyn, the Assistant Director of the National Museum to produce the largest ' copepod ' he was aware of in the museum ' collection. This he did and I immediately recognised it as the epizoan responsible for the scars. It proved to be the female of *Livoneca ravnaudi* (M. Edwards): CYMOTHOIDAE. A paper on the subject will appear shortly under our joint names.

In *Mesoplodon*, linear scars are very common on old males, but they are never exactly parallel as in *Ziphius*. As the mandibular teeth are nearer the posterior union of the symphysis in *Mesoplodon* (except in *M. mirus* True) both teeth cannot be brought into play at the same time. (*M. mirus* could produce scars similar to those in *Ziphius*). Circular, oval or elliptical scars also appear on the body as in *Ziphius*.

In *Berardius* there are three types of linear weals: (a) a single rip probably made by a single anterior tooth; (b) parallel line or scars (Pl. II, fig. 5) made by the two anterior teeth, the distance between the weals being approximately that between these teeth; and, (c) parallel linear scars, one larger and deeper than the other, but the width narrower than to the distance between the two anterior teeth. These could be produced by both teeth of one ramus making contact at the same time. All three forms of linear scars have been seen on one old male (Pl. II).

There were also the usual circular, oval and elliptical scars (Pl. II, fig. 5). The circular, oval or elliptical scars referred to probably result from the attack or attachment of suctorial animals. Pike (1951) and Nemoto (1955) discuss and illustrate scars made by cyclostomes, particularly the Sea Lamprey (*Entosphenus tridentatus*), a species confined to the Northern Pacific Ocean. In the whales I have examined the scars showed what appeared to be the impressions left by the transverse lamellae of the discs of sucker-fish. Prolonged attachment could well bring about permanent discolouration of the skin. Concentrations of scars are invariably around the vent, which suggests that the fish congregate in the area to feed on excrement. Squid have been known to scar sperm whales in much the same manner.

Parasitic crustaceans could also be responsible for some of the scarring, some scars suggesting the erstwhile presence of barnacles, e.g. *Coronula*. However, while these dermal barnacles are commonly epizoic on baleen whles, they have not, as far as I am aware, been observed on ziphioids. Circular scars could also result from 'jab' wounds caused by the tip of an opponent's rostrum.

SYNONYMY

BERARDIUS ARNOUXI Duvernoy: The Southern Porpoise Whale

1851.	*Berardius Arnuxii*	Duvernoy, Ann. Sc. Nat. (3) 15: 51. (Type locality: Akaroa, Banks Peninsula, New Zealand. Type in *Paris Mus.*).
1866.	*Berardius Arnuxi*	Gray, Cat. Seals & Whales Brit. Mus. p. 348.
1870.	*Ziphius* (*Berardius*) *Arnouxii*	Owen, Monogr, Palaeontogr. Soc. p. 31, fig. 11.
1870.	*Berardius Arnouxi*	Hector, in Knox, Trans. N. Zeal. Inst. 2: 27.
1870b.	*Berardius Arnouxi*	Hector, Ann. Mag. Nat. Hist. (4) 5: 222. Trans. N. Zeal. Inst.
1870a.	*Berardius Arnouxi*	Haast, Trans. N. Zeal Inst 2: 190.
1870b.	*Berardius Arnouxi*	Haast, Ann. Mag. Nat. Hist. (4) 6: 348. (Repeat of previous article)

1871.	'*Ziphidae*'	Knox & Hector, Trans. N. Zeal. Inst. 3: 125, pls. 13–17.
1871.	*Berardius Hectori*	Gray, Ann. Mag. Nat. Hist, (4) 8: 115–117. (Type locality: Titahi Bay, N. Zeal., Type *Brit. Mus.* 1677b. 76. 2. 16. 3.)
1872.	*Mesoplodon Hectori*	Turner, Trans. Roy. Soc. Edin. 26: 778.
1872.	*Berardius Arnouxi*	Flower, Trans. Zool. Soc. Lond. 8: 203–234, pls. 27–29.
1873.	*Mesoplodon Knoxi*	(part.) Hector in Knox, Trans. N. Zeal. Inst. 5: 167 (Part type, Titahi Bay specimen, *Brit. Mus.* 1677b. 76. 2. 16. 3)
1873.	*Mesoplodon Hectori*	Hector, Trans. N. Zeal. Inst. 5: 170.
1874.	*Mesoplodon Hectori*	Gray, Trans. N. Zeal. Inst. 6: 96–97.
1876.	*Berardius arnouxi*	Buller, Trans. N. Zeal. Inst. 8: 407.
1878.	*Mesoplodon hectori*	Hector, Trans. N. Zeal. Inst. 10: 338, p. 16.
1878.	*Mesoplodon hectori*	Flower, Trans. Zool. Soc. Lond. 10: 416, pls. 71 and 72 fig. 4.
1880.	*Berardius arnouxi*	Van Beneden & Gervais, Osteogr. Cet. pp. 377, 515, Atlas pls. 21–23.
1893.	*Mesoplodon hectori*	Forbes, Proc. Zool. Soc. Lond. p. 277.
1900.	*Mesoplodon hectori*	Beddard, Book of Whales, Lond. p. 220.
1900.	*Berardius arnouxi*	Beddard, Book of Whales, Lond. p. 228–233.
1910.	*Berardius arnouxi*	True, Bull. U.S.N.M. 73: 77.
1920.	*Berardius arnuxi*	Marelli, An. Mus. Nac. Secc. Zool. Buenos Aires. 30: 411–444, pls. 1–5.
1922.	*Berardius arnouxi*	Oliver, N. Zeal. Journ. Sci. Tech. 5: 135.
1922.	*Paikea hectori*	Oliver, Proc. Zool. Soc. Lond. p. 575. (Type, *Brit. Mus.* 1677b. 76. 2. 16. 3).
1924.	*Mesoplodon hectori*	Harmer, Proc. Zool. Soc. Lond. p. 542.
1939.	*Berardius arnuxi*	Hale, Rec. S. Austr. Mus. 19 (4); 5.
1950.	*Mesoplodon hectori*	Fraser, Proc. Linn. Soc. Lond. 162: 50, pls. 3, 4.
1957.	*Berardius arnouxi*	Taylor, Proc. Zool. Soc. Lond. 129 (3): 325–332, pl. 3, figs. 1–4.
1962a.	*Berardius arnouxi*	McCann, Tuatara 10 (1): 13–18, pls. 1, 2.
1962b.	*Berardius arnouxi*	McCann, Rec. Dom. Mus. 4 (9): 83–94 pls. 1–5.
1962.	*Berardius arnuxi*	Hale, Rec. S. Austr. Mus. 14 (2): 231–243, pls. 5, 6, text fig. 1.
1974.	*Berardius arnouxi*	McCann, Sci. Rep. Whales Res. Inst., Japan, No. 26, 145–155, Figs. 1–23, pls. 1–8.

DESCRIPTION

General external characters as in the genus

Teeth (Pl. XII): The anterior mandibular teeth are normally larger than the posterior. Viewed laterally both are roughly triangular in shape, the base being the shortest side, and the anterior frequently longer than the posterior. The lateral faces may be flat or undulate with numerous furrows or striae arising along the base and converging towards the tip. Viewed antero-posteriorly, the vertrical axis is inclined slightly outwards in its upper portion. The apex is formed of an enamelled point of about 10 to 12 mm surrounded by a ' collar ' of dentine. On the inner face of the enamelled cusp there may be one or two vertical furrows. In old animals the tooth is worn down to a flat-top level with the gum.

Size: *Berardius arnouxi* may attain a length of 9.6 m (32 ft). The difference in size between the sexes does not appear as pronounced as in *B. bairdi.*
Measurements in the flesh, ad. male. *Dom. Mus.* 1,433 (Col. C. McCann)

Total length 8.50 m; snout to anterior edge of dorsal 6.150 m; Snout to genital 5.60 m; genital to anal 0.30 m; length of penis 0.90 m; circum. of penis at base 0.23 m; snout to eye 1.50 m; snout to flipper 1.77 m; gape 0.59 m; snout to blowhole 1.10 m; blowhole 0.13 m; Beak 0.551 m; throat groove 0.55 m; anal opening 0.23 m; Fluke across 2.444 m.

Neonatals so far recorded do not exceed 3.0 m (11 ft) but the records could be of animals prematurely born when the true neonatal length be slightly greater.

Colour: " The colour of the whole animal was of a deep velvety black, with the exception of the lower portion of the belly, which had a greyish colour." (Haast, 1870).

" The colour was black with a purple hue, except a narrow band along the belly which was grey. The muzzle, flippers and tail lobes were intensely black." (Hector, 1878: 338).

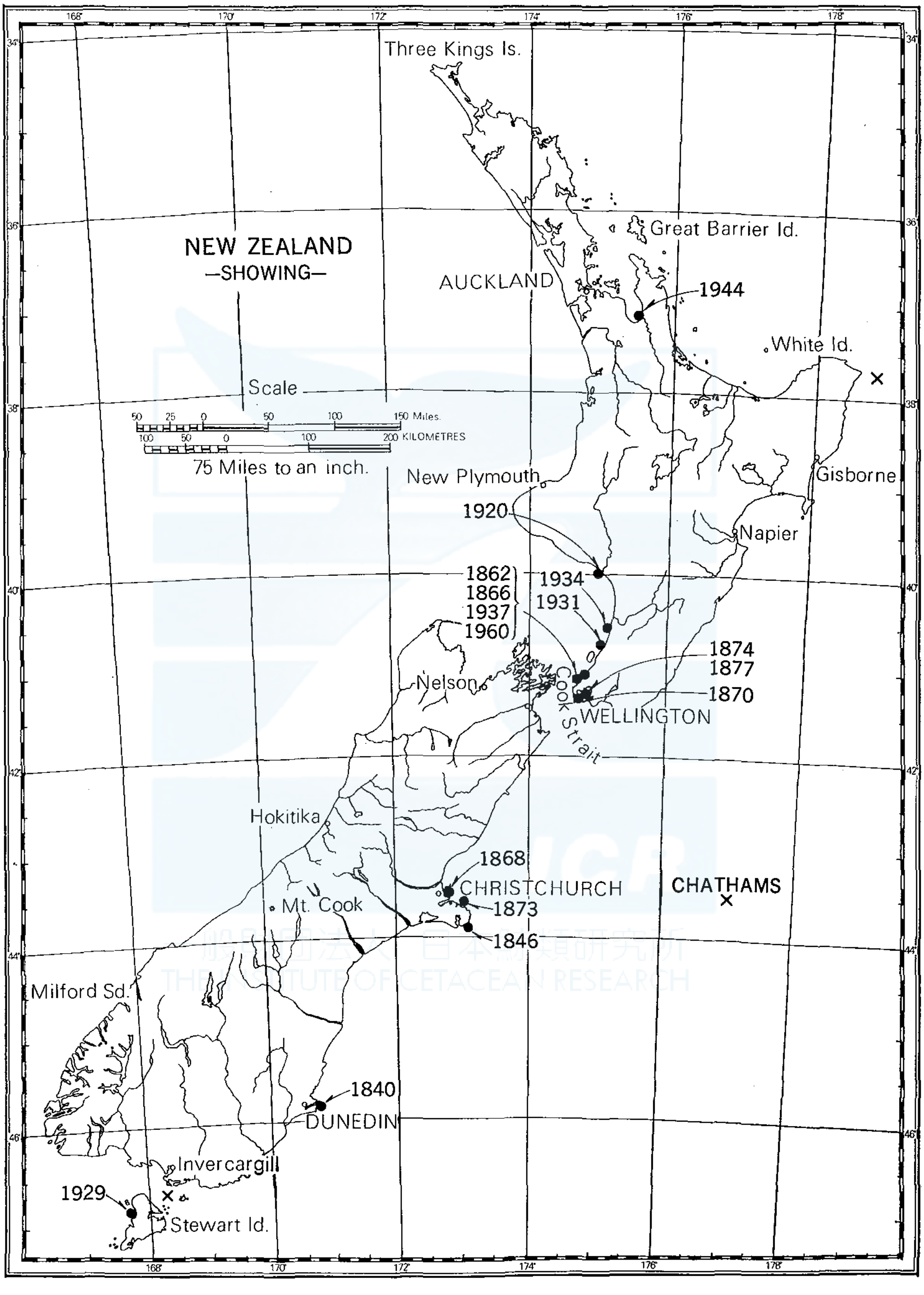
An old male from Pukerua Bay (Pls. I–II), although decomposing, clearly showed a dirty white dorsal surface. This colour extended from the ' crest ' of the head to shortly behind the dorsal fin. Parts of the dorsal fin and some surrounding areas were even whiter. The rest of the body was brownish black (Pl. I and II, fig. 1). As most observers describe the dorsaum is black, it is possible that in this individual the dorsum may have bleached during exposure, after death and before stranding.

DISTRIBUTION

Berardius arnouxi is apparently confined to the South Pacific and South Atlantic Oceans, between 30°S and Antarctica. Odd specimens have stranded along the eastern shores of New Zealand as far north as 37°S, but these strandings have been later than the normal period when this whale visits the New Zealand area.

Specimens: (See text—fig. 3)

New Zealand Waters: Otago Peninsula, 1840 (*Otago Mus.* A14.37 mandibles); Stewart Island (*Otago Mus.* A24.69, skull), 2 teeth (*Dom. Mus.* 523); Mason Bay, Stewart Island, February, 1929 (*Dom. Mus.* 523); Mason Bay, Stewart Island, February, 1929 (*Dom. Mus.* 416, skeleton); Centre Island, Foveaux Strait (*Dom. Mus.* 528, worn tooth); Chatham Islands (*Otago Mus.* A339); Coast near Wanganui, before 1920 (*Wang. Mus.* A339); Coast near Wanganui, before 1920 (*Wang. Mus.* skeleton); Worser Bay, Wellington, January 1870 (*Dom. Mus.* 7, skull), 12th January, 1877 (*Dom. Mus.* 183, skull); 30th January, 1876 (*Dom. Mus.* 239, 2



財団法人 日本鯨類研究所 THE INSTITUTE OF CETACEAN RESEARCH

Fig. 3. Strandings of *Berardius arnouxi* Duv. in New Zealand.

teeth); Saltwater Creek, north of Banks Peninsula, 27th December, 1873 (*Dom. Mus.* 1402, skeleton); New Brighton Beach, Christchurch, 16th December, 1868 (*Roy. Coll. Surg.*, skeleton); Akaroa, Banks Peninsula, 1846 (Type, *Paris Mus.*), (*Brit. Mus.* 96.11.20.1, male); South Tapu, Thames Coast, 13th March, 1944 (*Auck. Mus.*); Te Horo Beach Wellington District, 13th January, 1931, male, 8,400 mm (28 ft); Otaki Beach, Wellington Dist, 4th January, 1934, female, 8, 100 mm (28 ft.), (*Dom. Mus.* 528, 4 teeth);* Pukerua Bay, Wellington District,18 th February 1960, old male, 8,850 mm (29– ft), (*Dom. Mus*. 1433, 2 teeth); **Pencarrow, Wellington Harbour, male 9,000 mm (30 ft, male), female 6,000 (20 ft), ft), (*Dom. Mus.* 526, 2 teeth); Lyall Bay, Wellington, 1874 (Buller); East Cape, (*Dom. Mus.* 527, 1 tooth); Titahi Bay, Wellington District, January, 1866, male 2,725 mm (9– ft), (*Britl Mus.* 1677b 76. 2. 16. 3, Type of *B. hectori* Gray); Plimmerton, Wellington District, 25th January, 1937, 3,200 mm (10 ft, 8 in.), (*Dom. Mus.* 614, skeleton); ' New Zealand ', (*Brit. Mus.*), (U.S.N.M. 21511).

Australian waters: Port Lorne, S. Australia, 27th December 1935, 8,700 mm (29 ft), (*S. Austr. Mus.* M. 5012)

Antarctic waters: Taylor, April 1955 (Photographs).

Argentine waters: Arroyo del Pescado, Los Talas, 29. 5. 1918, female, 7,800 mm (26 ft), (*Mus. Nac.* Buenos Aires).

South Atlantic waters: South Shetland Islands, female (*Brit. Mus.* 1934. 6. 15. 1); Falkland Islands (*Brit. Mus.* 1949. 8. 19. 1); La Plata, 29th May, 1918, female, (*Mus. Nac.*, Buenos Aires).

Of thirty specimens recorded from New Zealand waters, the majority stranded during the late spring or early summer (December to February–March). Two neonatals which may have been premature births are recorded as stranding in January 1866 and 1937 (as *Mesoplodon hectori* (Gray)). The presence of adults and neonatals during the same period of the year suggests that *Berardius arnouxi* visits the New Zealand area to breed. On the other hand, photographs of *Berardius arnouxi* locked in the ice in April 1955 (Taylor, 1957) show that they return to the Antarctic region to feed. These observations point to a seasonal north and south migration.

The single recorded Australian specimen, a gravid female was found in the same period in which *Berardius* visits New Zealand waters.

The number of *Berardius arnouxi* visiting New Zealand waters annually is unknown, particularly as their visits do not coincide with the whaling season (May to August), and they are not at present of commercial value. Any information we have is derived from chance strandings.

In the South Atlantic, there appears to be a similar pattern of movement presents itself, but the records are too few for definite conclusions. A single neonatal has been recorded from one of the smaller islands of the Falklands group (Fraser, 1950), but its exact time of stranding is unknown.

As with *Mesoplodon*, species of *Berardius* appear to calve near the larger archi-

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* Porirua Harbour, Wellington District, January 1862, male, 8100 (27 ft), (*Fide* Knox, 1871: 125)

** The sex of these two specimens is in doubt as they were reported and the teeth of the adult collected by a layman. They may have been a female and calf.

pelagos of the world in both hemispheres. *B. arnouxi* in the New Zealand and South Atlantic archipelagos and *B. bairdi* around the Japanese Archipelago.

FOOD

Haast (1870) notes that the stomach contents of one animal contained about half a bushel of the horny beaks of cephalopods (squids). Haast mentions ' Octopus ', but this is hardly likely, as the octopus is an inshore animal, whereas squids are pelagic and often occur in vast shoals.

ANATOMICAL OBSERVATIONS

Cranium (Pls. III, IV): The cranium of the adult has been well described and figured by Duvernoy (1851) and Flower (1872).

The skull of *Berardius* exhibits almost perfect symmetry (Flower 1872). The same symmetry appears in the newly-born young. The large bulbous nasals are a prominent feature of the vertex in the adult, but the nasals are not so conspicuous in the newly born (Pl. IV, fig. 1). The extremities of the premaxillae rise above the nasals and are slightly curved forwards, not so recumbent as in the adult, nor do they overhang the narial cavity as in some species of *Mesoplodon*. Further, they do not twist outwards as asymmetrically as in *Mesoplodon;* they are almost equal in size, the right premaxilla being *very* slightly larger than the left.

The recurved walls of the vomer, with the mesethmoid bone sandwiched between them contribute to the formation of the narial septum, the mesethmoid bone eventually emerging anteriorly into the mesorostral groove as a free projection between the margins of the premaxillae. The ossified projection of the mesethmoid terminates as an irregular, rough or nodular projection, extending as far forwards as a transverse line drawn through the middle of the maxillary crest. In the flesh, the mesethmoid bone is continuous with the mesethmoid cartilage and fills the mesorostral groove. In *Berardius* the mesorostral groove is permanently open and is never partially nor wholly filled by bone as in some species of *Mesoplodon*. Posteriorly, the vomer forms a broad ' bracket ' beneath the large nasals with a large blind pit (BP) on either side of the septum. The shape of the ' bracket ' and the presence of the blind pits are distinctive of *Berardius*.

Anteriorly, the vomer extends about two-thirds the length of the rostrum forming a trough for the mesorostral cartilage. Ventrally, much of the anterior end of the vomer is visible, wedged between the premaxillae. This condition is also found in the newly-born young (Pl. IV, fig. 2, Vo).

In dorsal view, the rostrum is somewhat spearshaped. No distinct maxillary turbercle is present but there is a maxillary crest. In side view, its dorsal profile is straight; the lower gradually descends from its anterior extremity towards the pterygoids. In ventral view, the broad maxillary prolongations are seen embracing the premaxillary extremities with the vomer wedged between. In transverse section, the rostrum is considerably broader than deep near the middle.

The adult skull is broader than high, but in the newly-born the height is greater than the breadth.

Foramina (Pl. IX, fig. 1): The premaxillary and maxillary foramina are on approximately the same transverse level. The premaxillary is very much smaller than the maxillary which frequently has secondary foramina around it. The post-crest foramen and the secondary foramina are not pronounced in the neonatal skull.

Antorbital region (Pl. IX, fig. 2): The antorbital tubercle is exaggerated by the presence of a deep antorbital notch. In dorsal view, the tubercle is seen to be formed by the maxilla and a small portion of the malar bone, with the anterior extremity of the frontal, a short distance behind forming the orbit. In side view, the broad anterior end of the frontal is shortly behind the end of the maxilla and the anterior projection of the malar bone. At the lower corner of the frontal, a narrow portion of the lachrymal bone is visible but not on a level with the lateral margin of the frontal. Ventrally, the malar bone alone appears to form the tubercle; the lachrymal bone falls short of the lateral margin of the frontal. There is a triangular wedge between the frontal and the malar.

The antorbital notch is margined by the maxilla alone.

In the newly-born, the arrangement is somewhat different. In dorsal view, the malar borders the antorbital notch; the lachrymal is just visible in front of the anterior extremity of the frontal. The orbital portion of the frontal is not laterally expanded as in the adult, but forms a narrow margin to the maxilla behind the tubercle. In side view, the large ' cuboidal ' end of the lachrymal abuts the anterior end of the frontal and a very small portion of the malar is also visible. Ventrally, the lachrymal and malar bones predominate in the formation of the tubercle and malar bones predominate in the formation of the tubercle to the exclusion of the anterior end of the frontal and maxilla.

Mandibles: The extremity of the mandibles protrudes considerably beyond the rostrum, so much so that the anterior teeth are outside the mouth when it is closed. The distal half of the mandibles is comparatively narrow and the upper and lower profiles are almost parallel. The proximal half expands rapidly to form the posterior portion of the jaw. The symphysial union is comparatively short and the two halves appear never to fuse together as in some other genera. The mental foramen may be single or multiple and somewhat irregularly situated on either side, even in the same individual.

Eyes: The relative size of the eye ' sockets,' in relation to the length of the skull, is smaller than in either *Ziphius* or *Mesoplodon.* The jugal process is accordingly comparatively short.

Ear Bones (Pl. XI): The bulla and the periotic of an adult measure 73 by 48 mm and 80 by 45 mm respectively (*Dom. Mus.* 1406). In the newly-born the same bones in the same order measure 54 by —— mm, periotic not stated (*Brit. Mus.* 1677b. 76. 2. 16. 3); 51 by —— mm, periotic not stated (*Brit. Mus.* 1949. 8. 19. 1); 51.5 by 36 mm and 56 by 32 mm (*Dom. Mus.* 614).

Scapula (Pl. XIII): In *B. arnouxi* the vertebral border is more or less straight, not conves as in *B. bairdi;* both the anterior and posterior borders are more vertical than in *B. bairdi.* The anterior border is almost straight, whereas in *B. bairdi* it is convex dorsally, and slightly concave ventrally; the posterior border is less concave than in *B. bairdi.* The anterior spinous fossa is relatively narrower than in *B. bairdi.*

The acromion is almost level with a vertical dropped from the anterior angle; the upper and lower profiles are, at first, almost parallel but gradually diverge towards the extremity; in some specimens the extremity is decidedly wider. In *B. bairdi,* the acromion falls short of a vertical dropped from the anterior angle and the lower profile turns abruptly upwards producing an almost semicircular anterior margin, which gives the entire process a somewhat circular or spiral border.

The coracoid and acromion processes are subequal in length whereas in *B. bairdi* the former exceeds the latter. In dorsal view the two processes are divergent, but in *B. bairdi* there is very little space between the two. The coracoid is narrow with both upper and lower profiles slightly concave; in *B. bairdi* the process is broad and slightly curved upwards with the upper profile concave, the lower convex.

SYNONYMY

BERARDIUS BAIRDI Stejneger: Japanese Porpoise Whale

1883.	*Berardius bairdi*	Stejneger, Proc. U.S.N.M. 6: 75–77. (Type locality: Bering Island; type *U.S.N.M.* 20992).
1883.	*Berardius vegae*	Malm, Bihang K. Svenska Akad. Handl. 8 (4): 109.
1886.	*Berardius bairdi*	Stejneger, Journ. Amer. Geogr. Soc. N.Y. 18: 317–328.
1900.	*Berardius bairdi*	Beddard, Book of Whales, Lond. p. 233.
1910.	*Berardius bairdi*	True, Bull. U.S.N.M. 73: 60, pls. 26–33. 34, fig. 7, 35, fig. 7; 36, fig. 7; 39; 42.
1931.	*Berardius bairdi*	Kellogg, Journ. Mamm. 12: 73–77.
1942.	*Berardius bairdi*	Matsuura, Zool. Mag. Zool. Inst. Fac. Sci. Jap. Univ. 54: 466–473.
1943.	*Berardius bairdi*	Matsuura Marine Mamm. (Kaiju). 298 pp.
1948.	*Berardius bairdi*	Scheffer & Slipp, Amer. Midl. Nat. 39 (2): 266.
1949.	*Berardius bairdi*	Scheffer, Pacific Sci. 3: 353, fig. 1.
1953.	*Berardius bairdi*	Pike, Journ. Mamm. 34: 98–104, pl. 1.
1953.	*Berardius bairdi*	Slipp & Wilke, Journ. Mamm. 34: 105–113, pls. 1, 2.
1953.	*Berardius bairdi*	Omura, Fujino & Kimura, Sci. Rep. Whales Res. Inst. Jap. 10: 89–132 (*per errorum baildi*)
1958.	*Berardius bairdi*	Omura, Sci. Rep. Whales Res. Inst. Jap. 13: 213–214, figs. 1, 2.

DESCRIPTION (PL. XIV FIG. 1)

General external characters as in the genus. There is no marked difference in the size and shape of the mandibular teeth in either sex; (they are erupted in both sexes alike on reaching maturity (Omura, 1955). Pike (1953) examined an 8.7 m (29 ft) females which he regarded as both physically and sexually immature, and found the teeth were " completely buried." His observations support those of Omura (1955).

The largest teeth on record are: (anterior) vertical height 89; antero-posterior width 103 mm; lateral diameter ——; (posterior) vertical height 60 mm; antero-posterior width 37 mm; lateral width ? for a male of 9.9 m (33 ft); (interior) vertical height 93 mm; antero-posterior width 72 mm; lateral diameter ?; (posterior) vertical height 55 mm; antero-posterior width 33; lateral width ?; for a 8.7 m (29 ft) female (Pike, 1953).

Size: *B. bairdi* is up to 3.0 m (10 ft) longer than *B. arnouxi*. The largest known female measured 12. 6 m (42 ft). Males are about 2.0 m (approx. 7 ft) smaller than females.

Colour: Pike (1953) describes a male and female as follows: " In these specimens the body is black on the head, back, flukes and flippers. The undersurface is of a slightly lighter shade, with white patches at the umbilicus and some white and grey markings. The male has a conspicuous diamond-shaped white patch at the umbilicus and some white around the genital opening. The female is lighter in colour and the skin was covered by abrasions caused while the whale was being towed into the station. Numerous white scratch marks appear on the back and flanks of both specimens (Pls. I, II, V)."

Omura *et al.* (1955) state: "According to our observations, however, color of whole body is pure black or somewhat lighter, even on the under surface of the body is pure black or somewhat lighter, even on the under surface of the body. It is not certain, but most whalers say that there are two groups of *Berardius*, one being black and another slatish. As there are many white scratch marks (Pls. I–II) on the skin of *Berardius*, especially in old bull, the colour looks more lighter than it is in such whales. There are white patches in three regions of the ventral side of the body, i.e. on the throat, between the flippers and at the umbilicus (Pls. II–IV, Pl. III, fig. 2). Every *Berardius* seems to have the white patch on the throat or between the flippers, there are considerably individual differences."

DISTRIBUTION

Berardius bairdi is restricted to the Northern Pacific Ocean; concentrating in Japanese waters during the breeding season in spring and summer. Occasional stray individuals or small schools are found off the North American coast.

Specimens: Bering Island (Type, *U.S.N.M.* 20992); St. George Island, ad. female (*U.S.N.M.* 49726); Centerville, California, ad. male (?), (*U.S.N.M.* 49725); St. George Island, young male, (*U.S.N.M.* 49727); Bering Island (?), (Grebnitzki?) (*U.S.N.M.*); about 10 miles off Kains Island, Quatsino Sound, 5th July, 1950, ad. male, 9.9 m (33 ft), (Pike, 1953); 20 miles E.S.E. of Cape St. James, 9th August, 1951, imm. female, 8.7 m (29 ft), (Pike, 1953); one mile south of Ocean City, Washington, July 1950, 16.5 m (35 ft), (Slipp and Wilke, 1953); Japan, *Nat. Sci. Mus.*, 10.8 m (36 ft); Santa Cruz, California, June, 1925 (*Mus. Calif. Acad. Sci.* skull);

COMMERCIAL WHALING

In summer and autumn, *B. bairdi* concentrates in Japanese waters north of the 30°N parallel. The Japanese whaling season is from April to November (Omura *et al*, 1955: 93), reaching its peak in the summer months of July and August. Omura and colleagues found the main concentration in the southern part of the range off the east coast of Japan proper, the whales moving in northwards, according to the whalers, as the season advances. After breeding, they apparently leave for feeding grounds in more northern latitudes.

Whaling commences in the northernmost area in the Okhotsk Sea earlier than elsewhere and has a second peak in autumn but it is supposed that there is a different population or community in the Okhotsk Sea from elsewhere.

The small numbers taken along the western shores of Japan may be due to few schools passing west through the Soya and Tsugaru Straits.

The American season is from April to September or October, but as *Berardius* is a sporadic visitor it is less important than in Japan (Scheffer and Slipp, 1948: 256).

BREEDING

Omura *et al* (1955, fig. 28) extrapolate length records to arrive at the following " the pairing of *Berardius* takes place in February and the parturition in December in most individuals, length of gestation being about 10 months." Omura (1958) however, records an anomalous 12 mm long embryo taken in August, and True (1910) records a newly-born calf discovered in June.

The neonatal length, in most cetaceans, is approximately one-third the length of the parent. Accordingly, in *Berardius bairdi* which can grow to about 12.6 m (42 ft), the newly-born calf should approximate 4.2 m (14 ft). Omura *et al* (1955) estimated the neonatal length as 4.5 m (15 ft). The largest foetus they record was in September and measured 4.2 m (14 ft). Stejneger (True, 1910: 64) records a newly-born calf of 4.8 m (16 ft) washed up on Bering Island on June 5, 1883, with the remains of the umbilicus still adhering.

FOOD

Pike (1953) records the stomach contents of a young female as: " about two gallons of small rockfish and squid remains."

PARASITES

Omura *et al.* (1955) record *Conchoderma* sp. attached to the teeth (Pl. XIV, 2). This barnacle has been recorded on the teeth of *Hyperoodon ampullatus* and *Physeter catodon* (Wolff, 1960), and I have found it on a tooth of *Mesoplodon grayi*. A species of *Conchoderma* is also found commonly on *Megaptera nodosa*, never on the animal itself but attached to the barnacle *Coronula*, so commonly found on the Humpback. Unlike *Coronula*, *Conchoderma* must have a hard substrate to attach itself to.

Pike (1953) recorded nematodes in the stomach of a specimen of *B. bairdi*.

ACKNOWLEDGMENTS

The author wishes to thank Dr. R. A. Falla, Director, Dominion Museum, Wellington, for the opportunity of undertaking the work; Dr. R. R. Forster, Director, Otago Museum, Dunedin, for the loan of material; Dr. R. K. Dell and Mr. B. Hamlin for valuable comments and suggestions on the manuscript; Mr. P. M. Hedgland, Photographer, Dominion Museum, for the excellent anatomical photographs; Dr. H. Omura, Whales Research Institute, Japan, for permission to reproduce the photographs of *Berardius bairdi;* and Miss M. Hall, Librarian, Dominion Museum at the time, for help in obtaining literature.

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APPENDIX I. MEASUREMENTS OF SKULLS

	A	B	C	D	E	F	G	H	I	J
1	1392	—	1420	1240	1193	1262	1220	1200	1270	1174
2	894	—	870+	820+	780	800+	780+	785	865	800
3	1080	—	1040	970+	918	1000+	900+	910	1040	—
4	494 !	—	560	555	455	570	518	475	530	493
5	684	—	720	623	615	710	660	620	625	577
6	748	—	700	675	610	710	640	620	660	584
7	—	—	445	380	405	430	410	395	—	378
8	150	—	169	166	158	184	172	160	155	149
9	—	—	—	108	90	95	92	95	80	—
10	—	—	211	205	201	208	192	180	—	—
11	210	—	219	199	195	221	183	195	—	189
12	102	—	92	87	75	82	90	90	91	80
13	—	—	240	235	210	215	200	202	180	—
14	—	—	390	350	370	415	340	350	380	—
15	—	—	71	78	65	73	65	82	63	72
16	213	—	218	215	194	194	186	192	—	186
17	—	—	168	156	137	166	133	128	—	—
18	1236	1245	1240	—	1065	1158	1055	1050	1011	—
19	294	350	327	—	262	287	250	280	245	—
20	222	230	210	—	202	212	213	193	—	—

APPENDIX II. MEASUREMENTS OF

	A	B	C	D	E	F	G	H	I
1	1378	1524	1423	1062(?)	1474	1440	1343	1438	1421
2	880	960	925	578%	1025	908	870	923	—
3	—	1185	1130	720+	1187	1146	865	1122	1170
4	—	563	544	—	575	569	525	582	571
5	666	766	682	530	716	693	657	757	686
6	—	750	675	520	740	732	660	748	—
7	—	—	—	—	—	447	397	445	—
8	188	207	197	—	223	208	194	206	201
9	—	—	—	—	—	—	—	—	—
10	181	215	195	165	197	204	203	215	194
11	238	235	217	187	239	238	239	246	230
12	96	110	98	83	100	98	94	102	98
13	—	—	—	—	—	—	—	—	—
14	—	—	—	—	—	—	—	—	—
15	84	85	82	83	71	86	72	78	—
16	240	261	228	195	235	246	216	221	238
17	168	193	171	142	178	180	173	170	163
18	1282	1334	1289	883+	1360	1334	1190	—	1300
19	145+	292	295	145+	310	—	—	—	276
20	223	271	230	175	245	241	212	222	234

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OF *BERARDIUS ARNOUXI* (MILLIMETERS)

K	L	M	N	O	P
1350	1372	587 E	505+	601	1260
903	919	343	280+	358	765
1078	1097	443 E	383+	469	648(?)
525	533	235	252	240	—
—	625	228	207	228	—
662	671	258	238	242	700
—	—	—	140	—	435
150	152	37	46	35	168
—	—	—	37	—	—
—	—	—	82	—	200
203	208	—	116	—	218
69	74	49	49	50	98
—	—	—	84	—	—
—	—	—	197	—	—
62	61	—	38	—	—
188	191	90	93	91	220
—	—	—	59	—	154
1225	1245+	481	440	498	1155
303	310	155	125	161	290
204	211	83	92	91	230

A. Type *Paris Mus.*
B. *Otago Mus.* A14.31
C. *Otago Mus.* A24.69
D. *Otago Mus.*
E. *Dom. Mus.* 7
F. *Eom. Mus.* 416
G. *Dom. Mus.* 143
H. *Dom. Mus.* 1402
I. *Mus. Nac.* Bs. Aires
J. *S.R.N.M.* 21511
K. Flower 1868 R.C. 3
L. True
M. *Brit. Mus.* 1677G, 76.2.16.3
N. *Dom. Mus.* 614
O. *Brit. Mus.* 1949-8.A.1
P. *S. Aust. Mus.* M.5012

BERARDIUS BAIRDI (MILLIMETERS)

A. Type *U.S.N.M.* 30992
B. *U.S.N.M.* 49736
C. ? *U.S.N.M.* 49725
D. *U.S.N.M.* 49727
E. Bering Isl. *U.S.N.M.*
F. 33 ft. (Pike, 1953)
G. 29 ft. (Pike, 1953)
H. ? 34 ft. 5 in. (Slipp & Wilke, 1953)
I. 36 ft. (Omura, Fujino, & Kimura, 1955)

Key to the numbers, *1* to *20*, in the appendix tables of measurements.

1. Total length of skull; *2.* Length of rostrum; *3.* Tip of rostrum to posterior median margin of pterygoids; *4.* Height of vertex to pterygoids, vertical; *5.* Breadth between centre of orbits; *6.* Breadth between zygomatic processes; *7.* Breadth at maxillary notches; *8.* Breadth of rostrum at middle; *10.* Greatest breadth of premaxillaries, proximally; *11.* Greatest breadth of premaxillaries in front of anterior nares; *12.* Greatest breadth of anterior nares; *13.* Length of temporal fossa; *14.* Breadth between temporal fossae; *15.* Breadth of foramen magnum; *16.* Width of occipital condyles; *17.* Height of occipital condyle; *18.* Length of mandible; *19.* Length of symphysis; *20.* Greatest depth of mandible.

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EXPLANATION OF PLATES

PLATE I

Berardins arnouxi Duvernoy stranded in Pukerua Bay, New Zealand.
Photos E. Pain.

PLATE II

Old male of *Berardius arnouxi* Duvernoy.
Fig. 1. Stranded animal; Fig. 2. Head showing frontal bos, beak and gular grooves; Fig. 3 Blowhole and scarring; Fig. 4. genital and anal area; Fig. 5. Dorsal fin, new and old scars and wounds; note the parallel scars and possible shark teeth marks (left lower corner). Photos McCann.

PLATE III

Skull of adult *Berardius arnouxi* Duvernoy.
(See index to lettering, page 137).
Courtesy National Museum. Photos P. M. Hedgland.

PLATE IV

Skull of neonatal *Berardius arnouxi* Duvernoy.
(See index to lettering, page 137).
Courtesy National Museum Photos P. M. Hedgland.

PLATE V

Sagittal section of adult *Berardius arnouxi* Duvernoy.
Figs. 1. and 2. general aspect. Fig. 3. Narial region; note 'blind pit' (BP) in vomer.
(See index to lettering, page 137)
Courtesy National Museum Photos P. M. Hedgland.

PLATE VI

Posterior aspect of Skulls of *Berardius arnouxi* Duvernoy.
Fig. 1. neonatal; Fig. 2. adult.
(See index to lettering, page 137)
Courtesy National Museum Photos C. Hale Fig. 1. & P. M. Hedgland Fig. 2.

PLATE VII

Antorbital region of adult *Berardius arnouxi* Duvernoy.
(See index to lettering, page 137)
Courtesy National Museum Photos P. M. Hedgland.

PLATE VIII

Antorbital and aural region of neonatal *Berardius arnouxi* Duvernoy.
Fig. 1. Antorbital foramina and optic foramen; note only foramen No. 2 is visible at this stage. Fig. 2. aural area.
(See index to lettering, page 137).
Courtesy National Museum Photos P. M. Hedgland.

PLATE IX

Formation of Antorbital tubercle and associated bones in *Berardius arnouxi* Duvernoy (adult).
Fig. 1. Dorsal aspect; Fig. 2. ventral aspect; Fig. 3. orbital region.

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(See index to lettering, page 122).
Courtesy National Museum Photos P. M. Hedgland.

PLATE X

Adult *Berardius arnouxi* Duvernoy.
Fig. 1. Brain cavity; Fig. 2. Aural region.
(See index to lettering, page 122).
Courtesy National Museum Photos P. M. Hedgland

PLATE XI

Adult and neonatal tympanic bones contrasted.
A—adult; B—neonatal.
(See index to lettering, page 122).
Courtesy National Museum Photos P. M. Hedgland

PLATE XII

Teeth of *Berardius arnouxi* Duvernoy.
Upper set, inner faces; centre, outer faces of same set; lower, antero-posterior faces.
Courtesy National Museum Photos P. M. Hedgland

PLATE XIII

Scapulae of *Berardius arnouxi* Duvernoy.
Fig. 1. Dorsal aspect of adult and neonatal.
Fig. 2. Ventral aspect of same pair.
Courtesy National Museum Photos P. M. Hedgland.

PLATE XIV

Berardius bairdi Stejneger.
Fig. 1. Adult animal; Fig. 2. Extremity of rostrum; note *Conchoderena* attached to teeth; Fig. 3. Teeth of adult and of a 2,700 mm foetus; top row, anterior, bottom row, posterior.

Photos
Courtesy Dr. H. Omura.

PLATE XV

Adult skull of *Berardius bairdi* Stejneger.
(See index to lettering, page 122).

Photos
Courtesy Dr. H. Omura.

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KEY TO LETTERING AND FIGURES ON PLATES

Ac—Acromion.
ALS(AS)—Alisphenoid bone.
AN—Antorbital notch.
AOF—Antorbital foramen.
AT—Antorbital tubercle.
AU(auf)—Auditory foramen.
B(ty)—Tympanic bulla.
BOC—Basioccipital crest.
BP—' Blind pit ' in posterior wall of vomer (nares).
BS—Basisphenoid bone.
Ca—Carotid foramen.
CE—Condylar foramen.
Cor—Coracoid.
EO—Exoccipital bone.
ET(e)—Eustacian tube.
F—Frontal bone.
FC—Falx cerebri.
FM—Foramen magnum.
FO(fo)—Foramen ovale.
FP—Falciform process.
FS(fl)—Sphenoidal fissure.
J—Jugal process.
L—Lachrymal bone.
LRC—Lower rostral canal.
M—Malar bone (jugal).
MAS—Mastoid process.
MCF—Post maxillary crest foramen.
MD—Mandible.
ME(MES)—Mesethmoid bone.
MF—Mandibular foramen.
MP—Maxillary pit.
MRC—Median Rostral canal.
MRG—Mesorostral groove.
MX—Maxilla.
MXC—Maxillary crest.
MXF—Maxillary foramen.
N—Nasal bone.
NF—Narial foramen.
OBS—Orbito-sphenoid bone.
OC—Occipital condyle.
OF(OPF)—Optic foramen.
OS—Orbitosphenoid.
Pa—Parietal.
Pal.-Rid.—Palatine ridge.
PCF—Post crest foramen.
PE(per)—Periotic bone.
PL(Pl)—Palatine bone.
PMF—Post maxillary foramen.
PMX—Premaxillary.
PMXF—Premaxillary foramen.
PS—Presphenoid.
PT—Pterygoid bone.
S—Nasal septum.
SO—Supraoccipital bone.
SQ—Squamosal bone.
Ty(B)—Tympanic bulla.
Vo.—Vomer.
URC—Upper rostral canal.

Ear bones:
a—Posterior articular surface between bones.
a′—Anterior articular surface between bones.
af—Aquaduct of Fallopius.
al—Anterior lobe of periotic bone.
e—Eustacean tube.
eam—External auditory meatus.
epl—Exterior posterior lobe of tympanic.
fo—Fenestra ovalis.
fr.—Fenestra rotunda.
ipl—Internal posterior lobe of tympanic.
m—Mastoid process.
per—periotic bone.
pl—Posterior lobe of periotic.
ty—Tympanic bulla.

Numbers: Nos. 1, 2 and 3 refer to foramina in the antorbital region.

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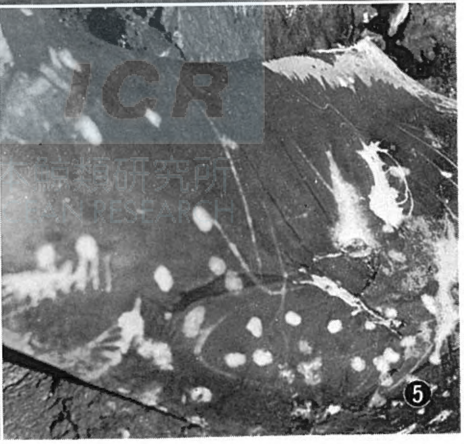
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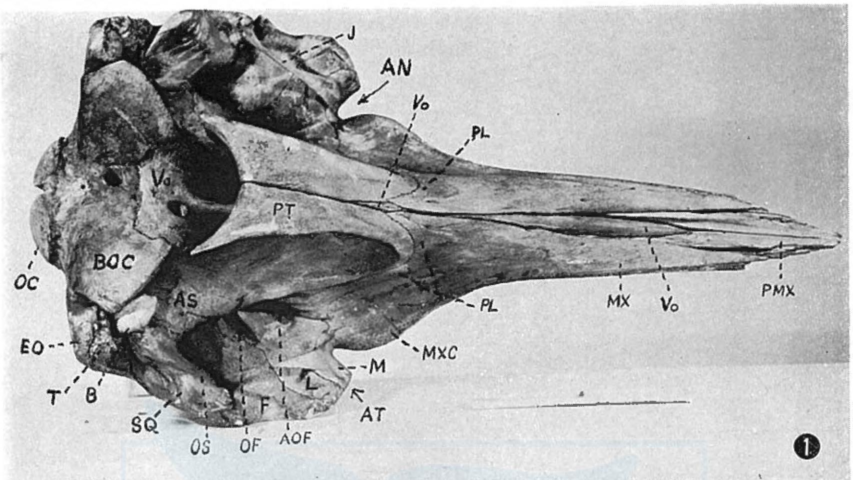
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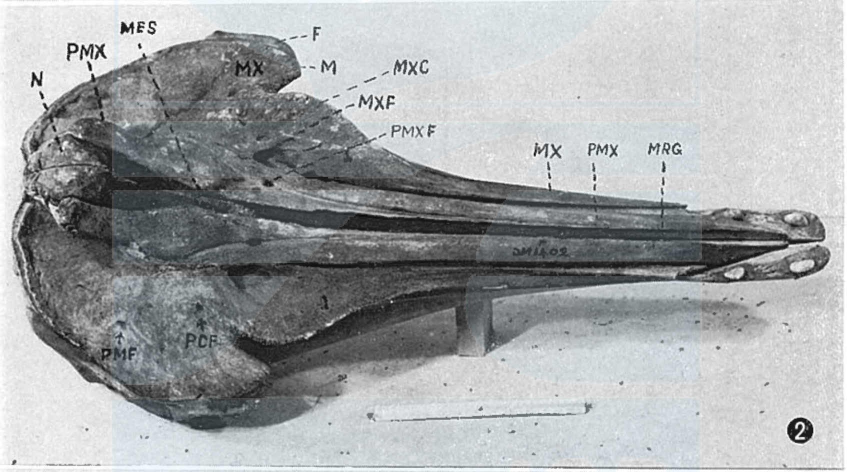
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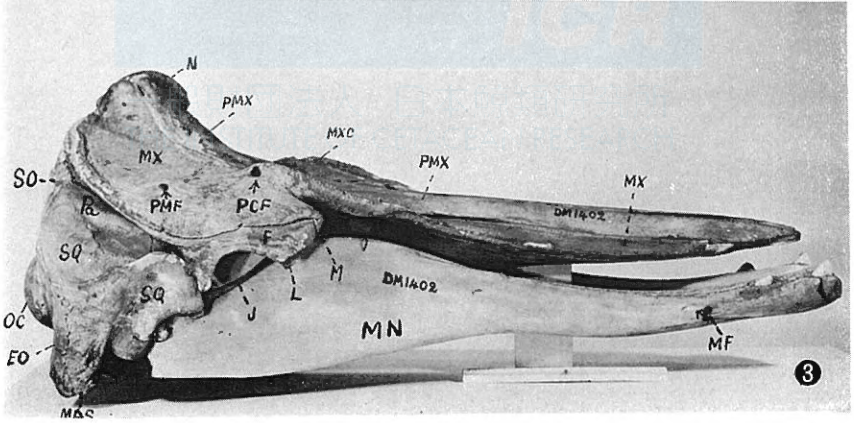
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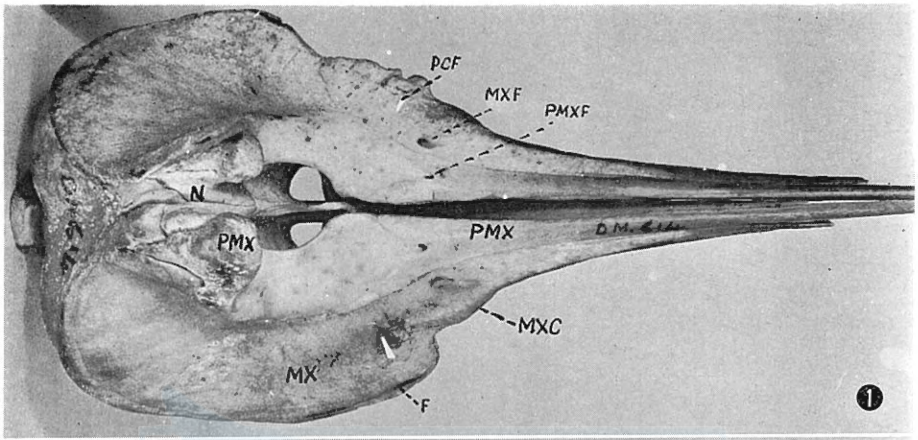
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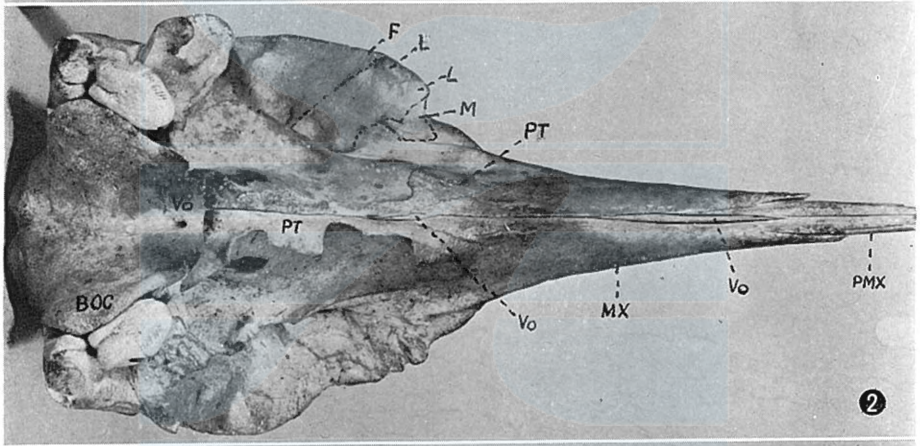
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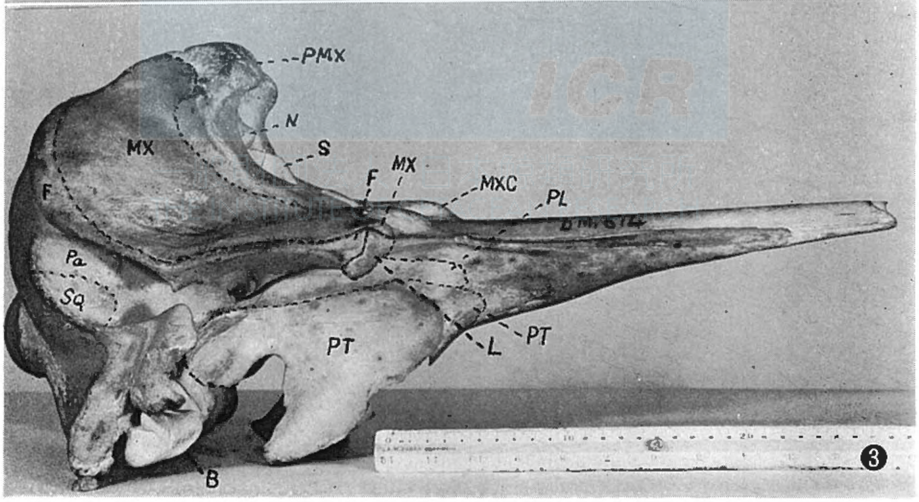
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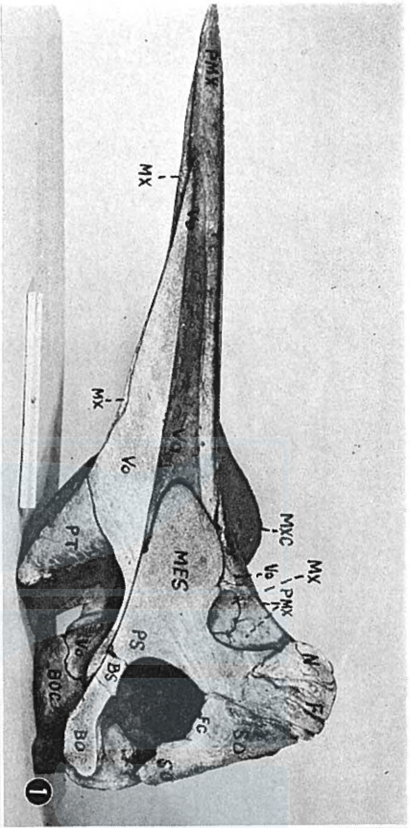
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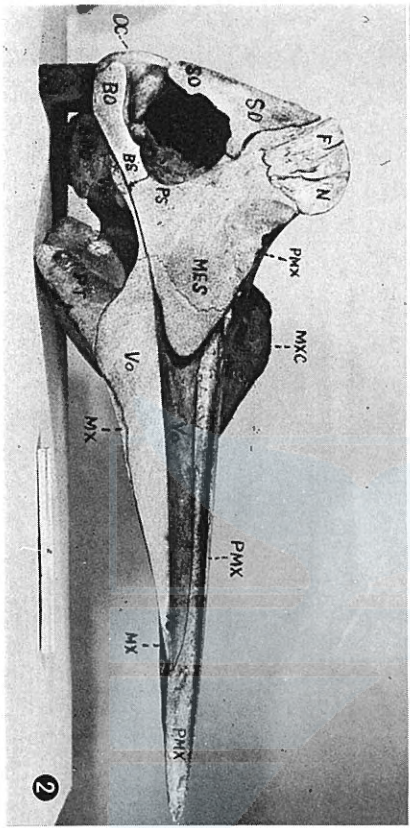
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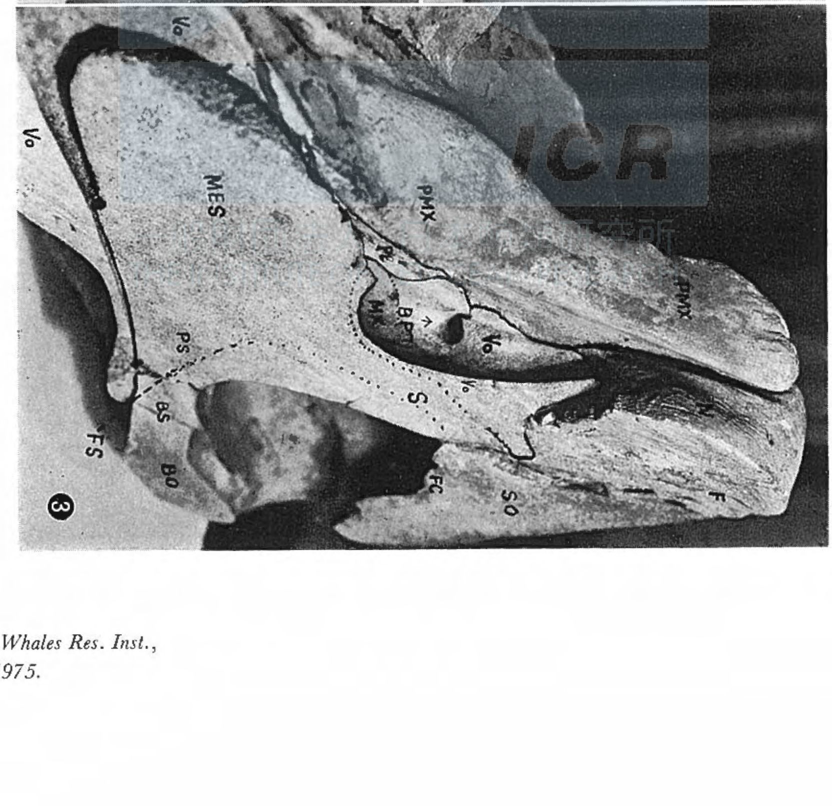
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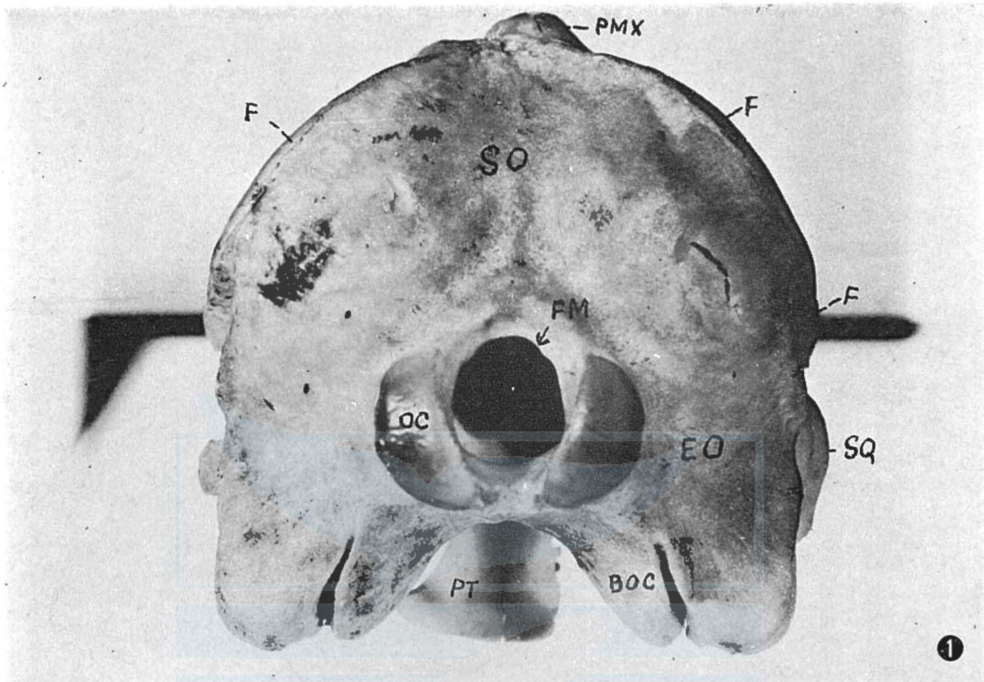
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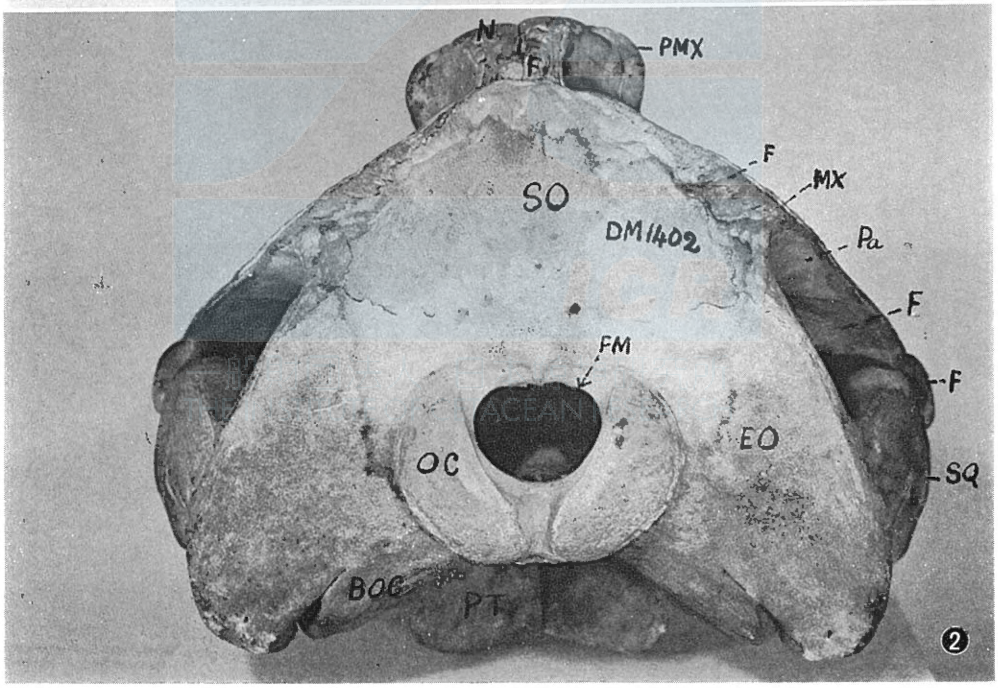
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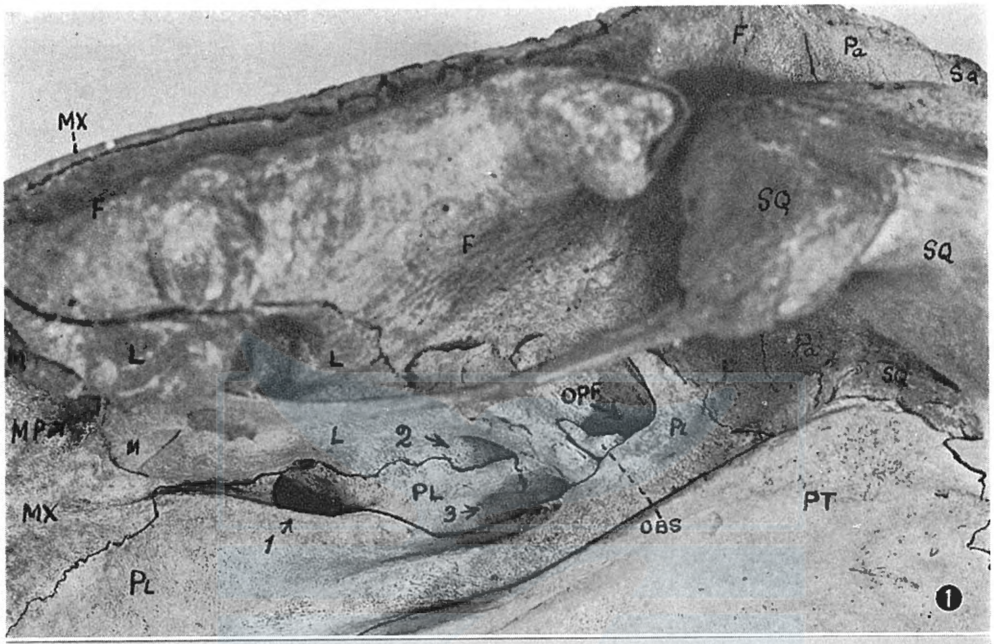
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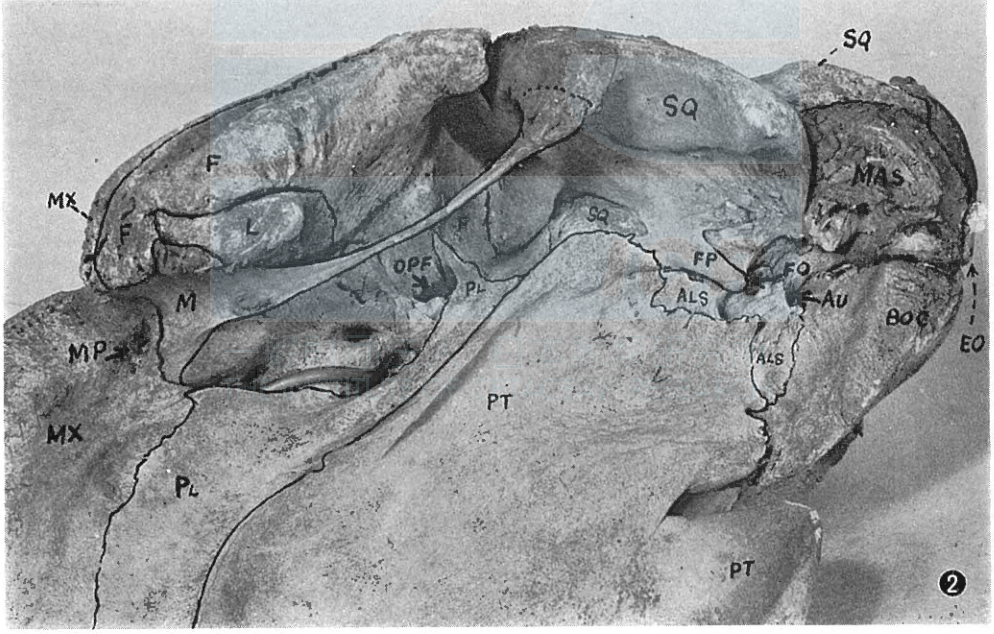
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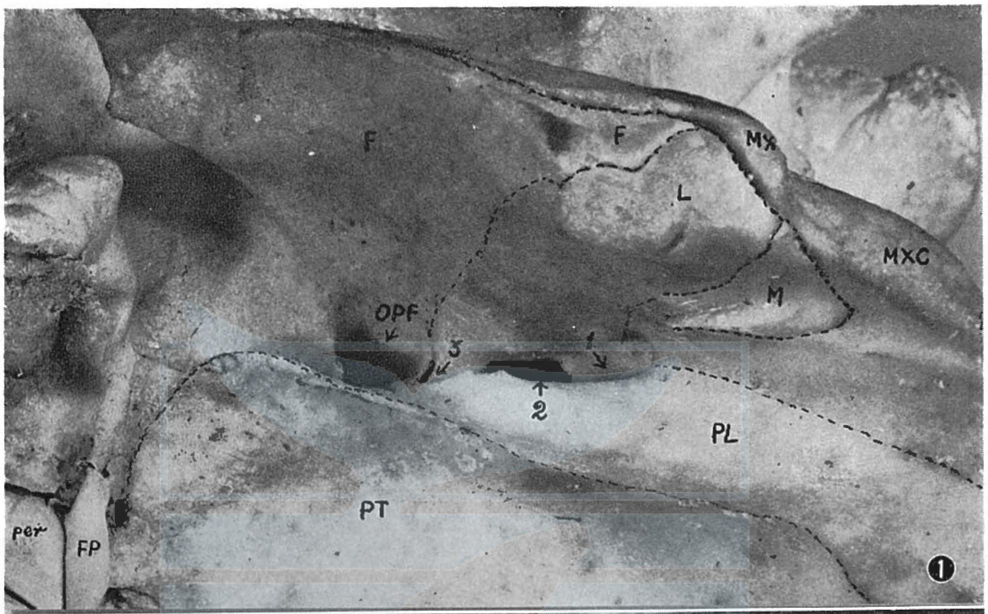
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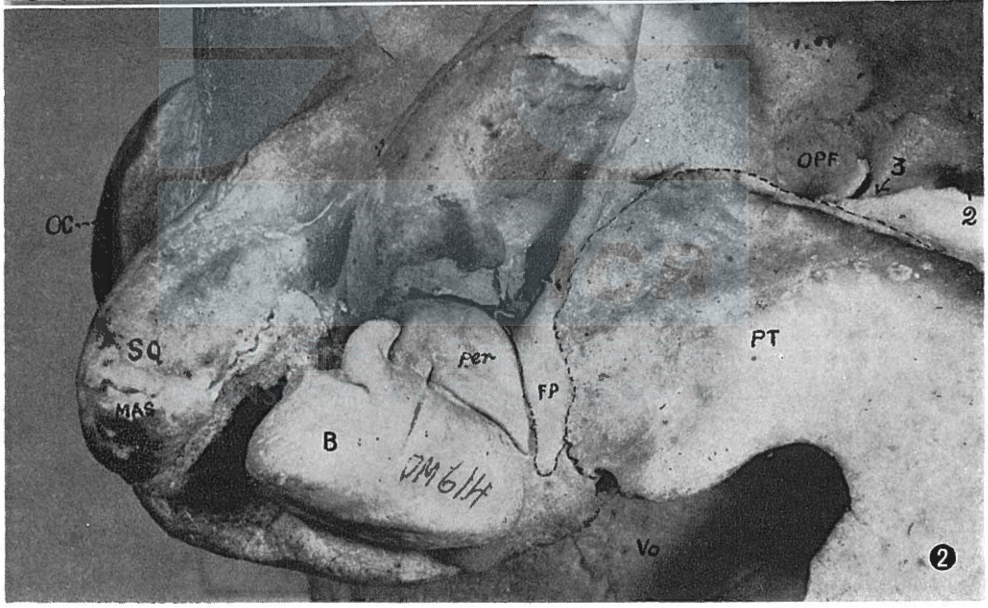
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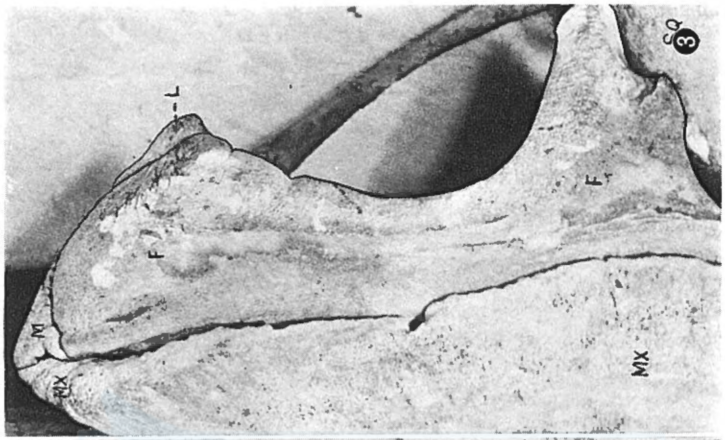
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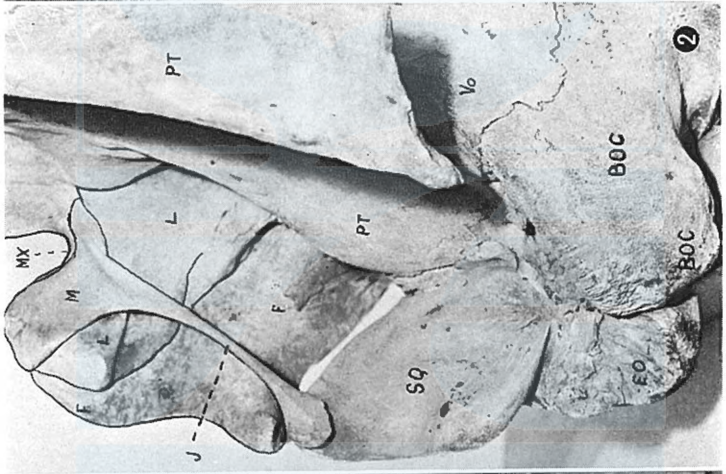
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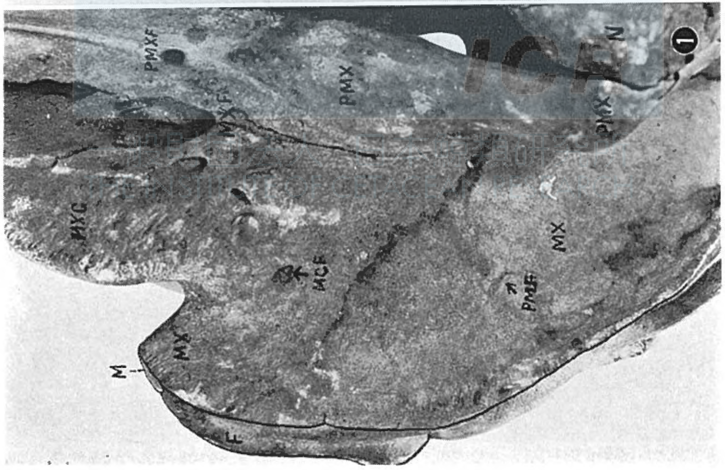
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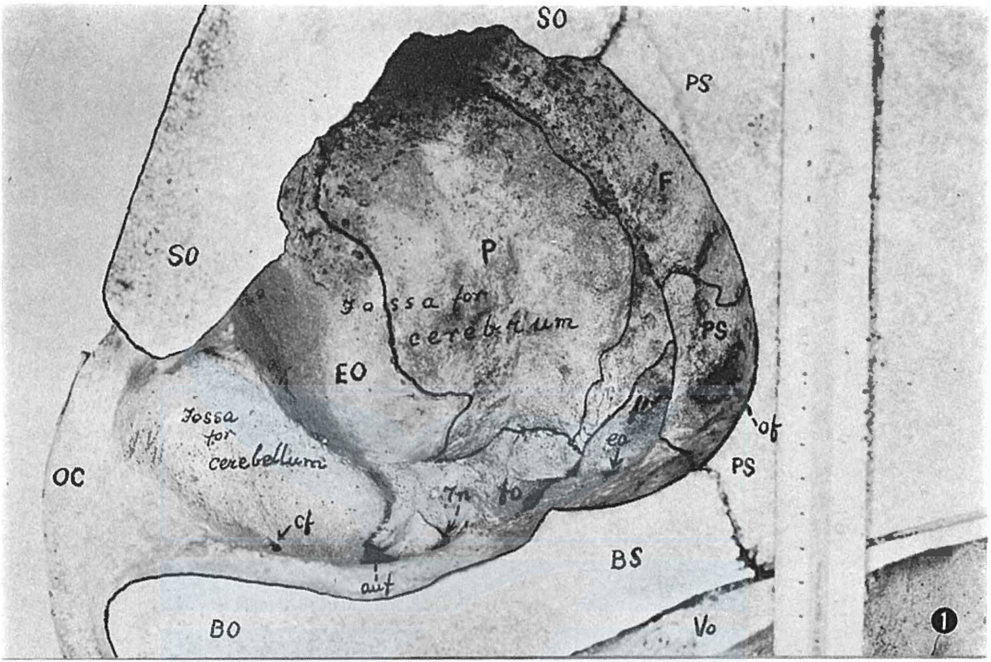
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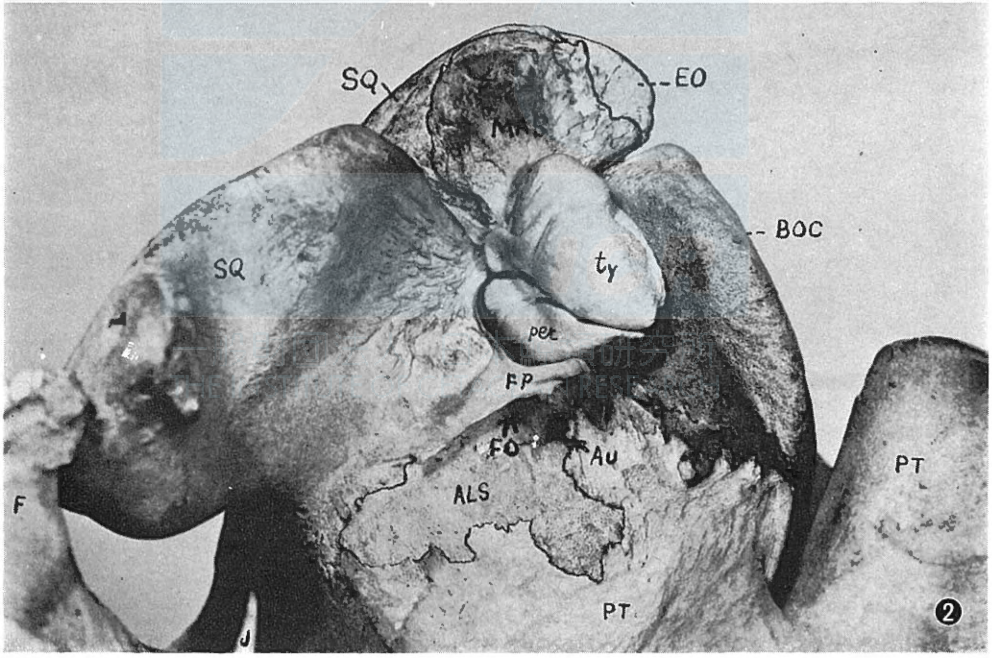
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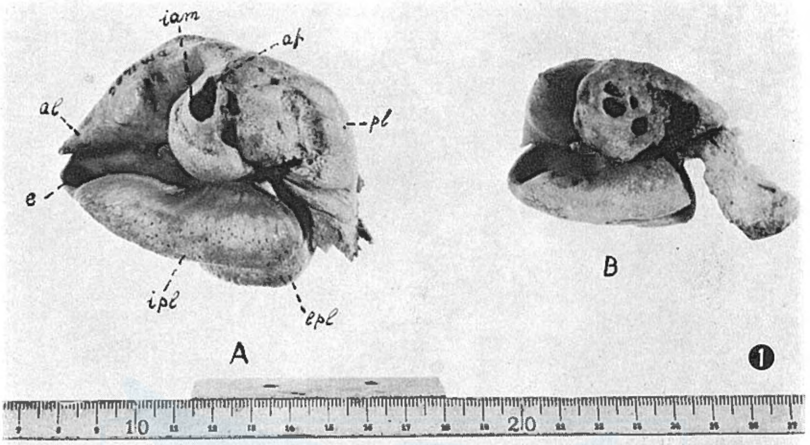
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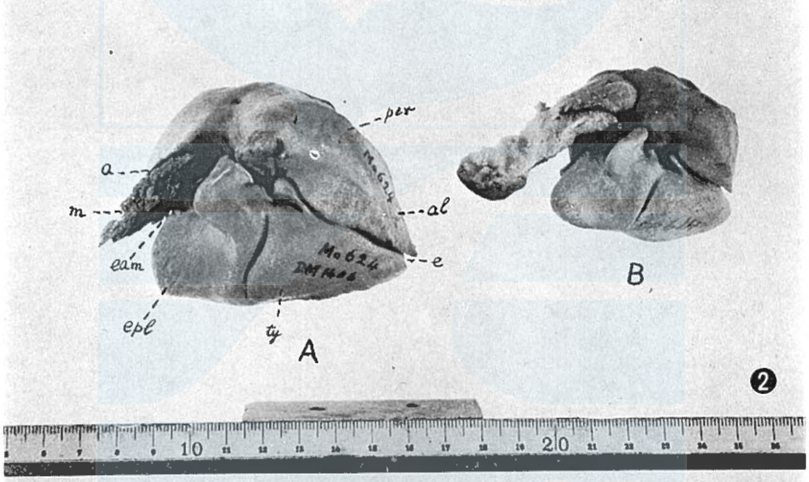
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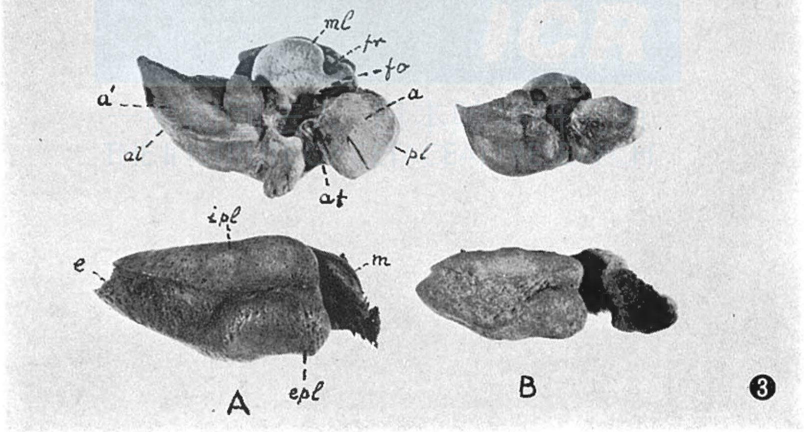
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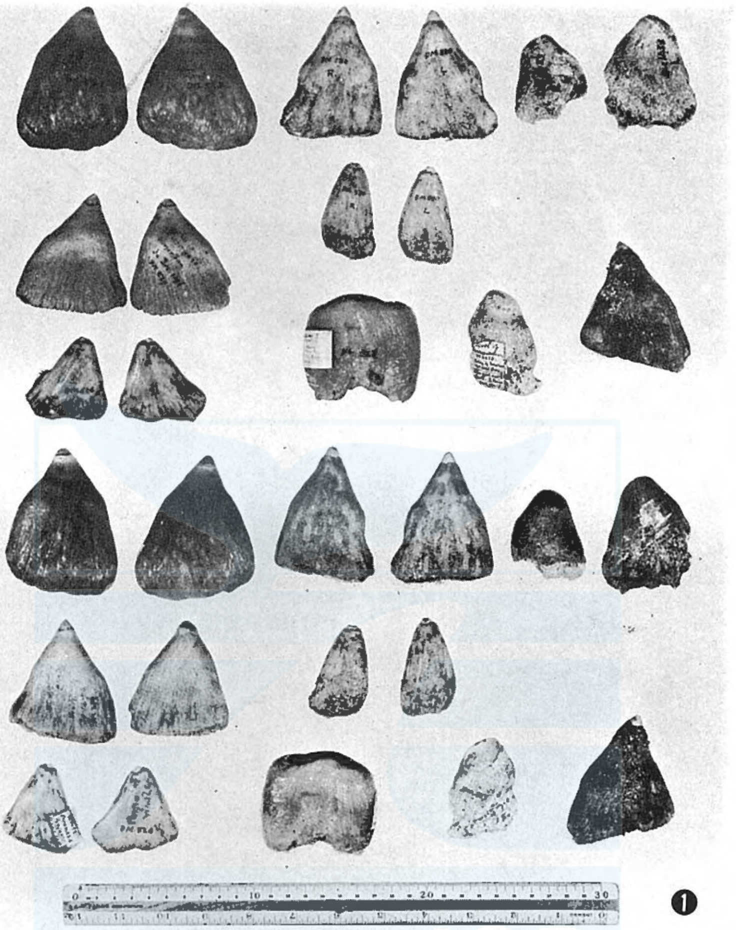

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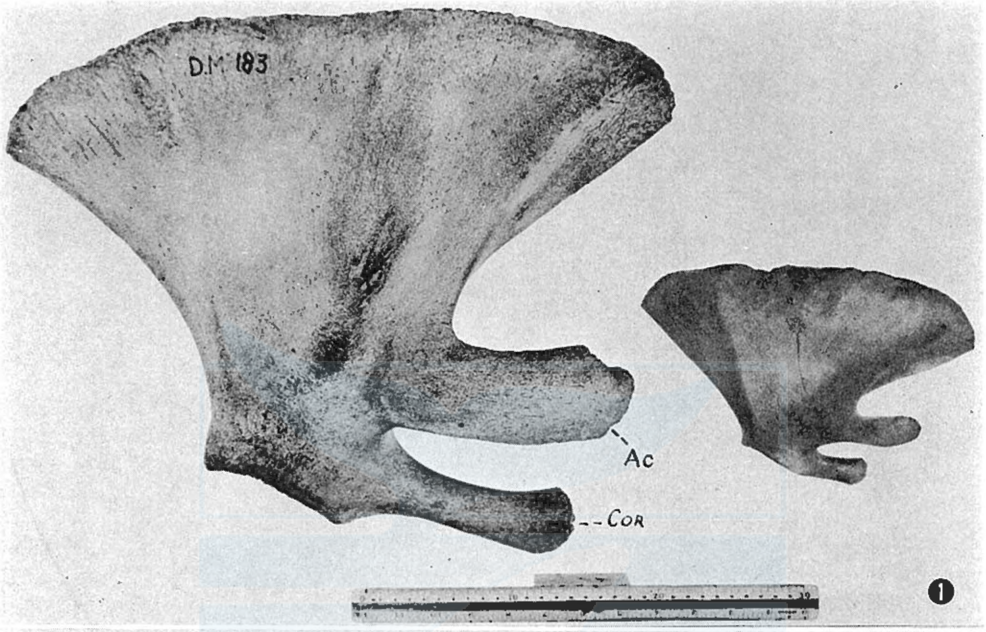

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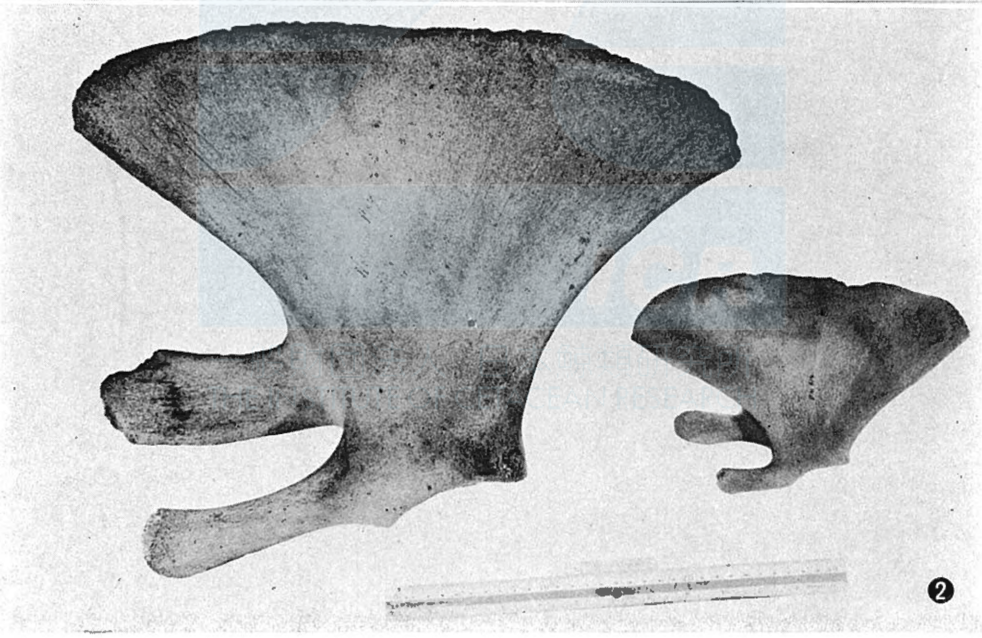

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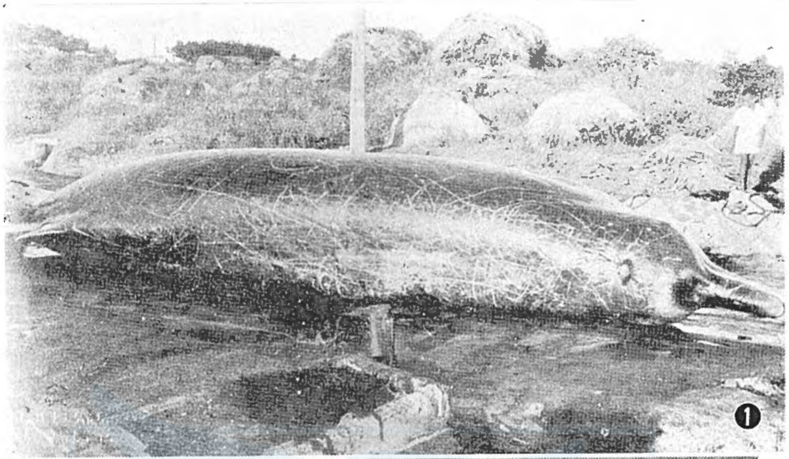

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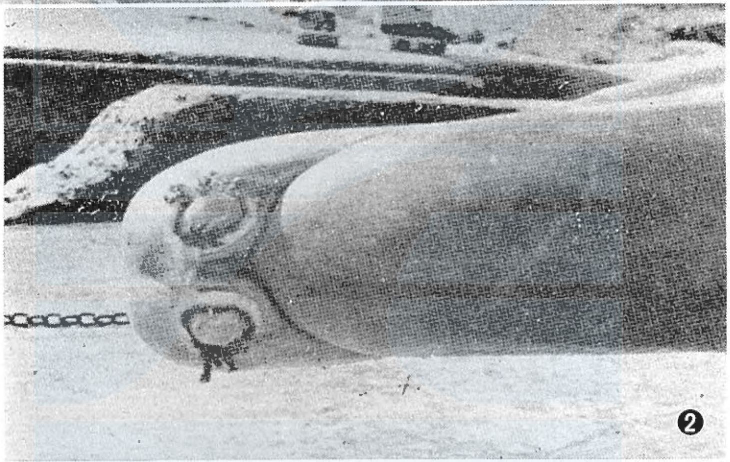

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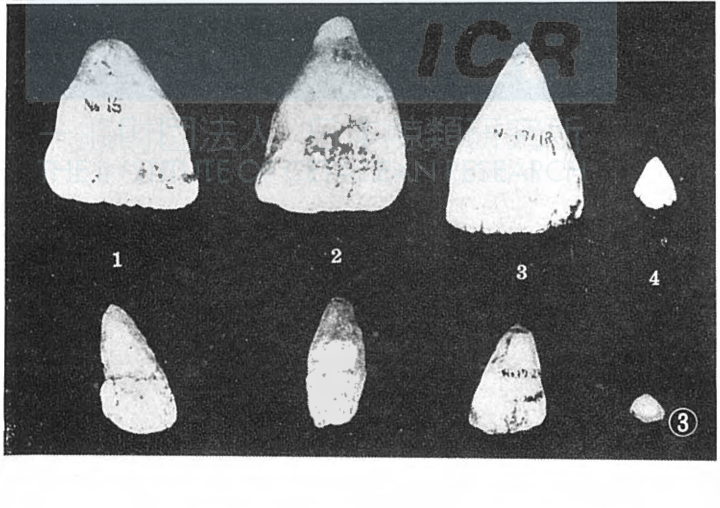

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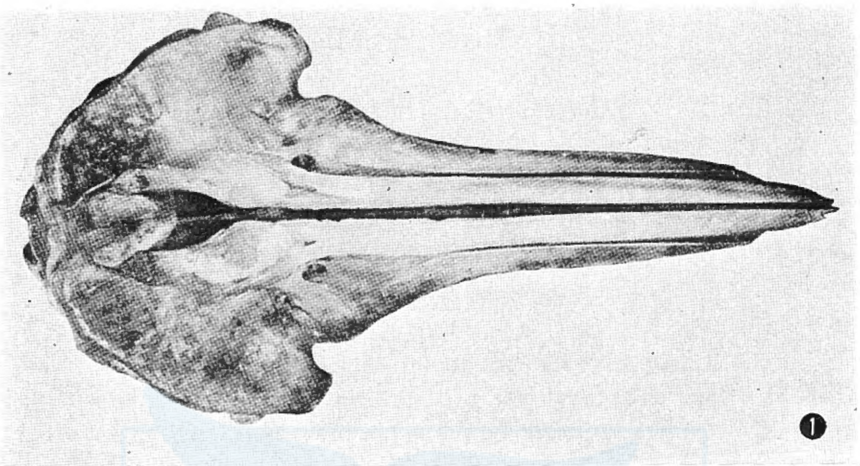

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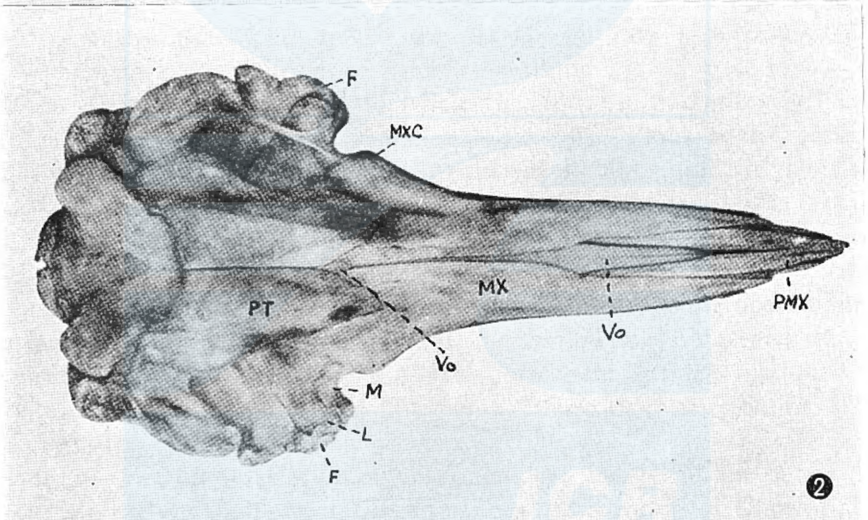

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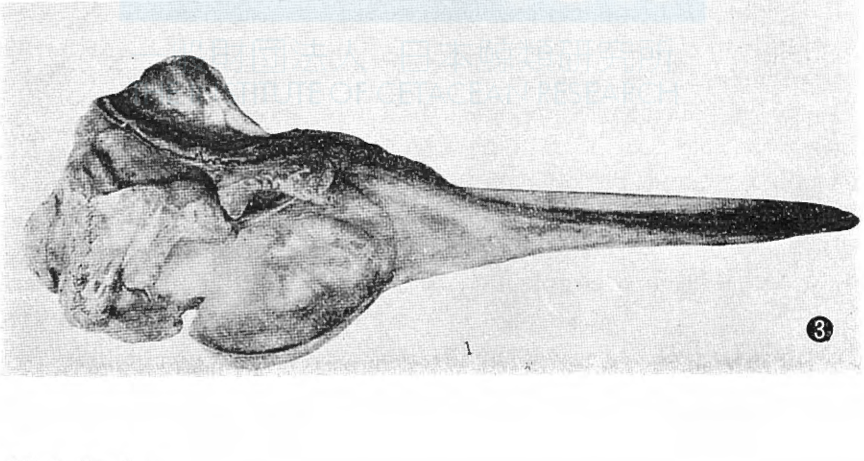

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STRANGE ORGAN IN THE ANAL REGION OF THE FINLESS PORPOISE

MASAHARU NISHIWAKI
University of the Rycckyus, Okinawa

AND

KAZUO KUREHA
Himeji City Aquarium, Himeji

The Himeji City Aquarium received a telephone call from Mr. Tsuda of Aioi Yacht Harbor on the morning of October 13, 1974 asking to take over a finless porpoise which had been caught by a member of the yacht club. The porpoise was found floating up and down the surface by a sailing crew near by Karani Is., one of the scattered islands about 20 km to the west of Himeji City 4 km distant from the beach. Then the crew hauled it with handy net.

When Kureha arrived at the harbor, the porpoise had already been dead. So, he carried the carcass back for examination. This 114 cm male specimen had a small hole in the genital aperture just inbetween the anus and the penis opening. Investigating with a surgical tool, the examiner felt the cavity was about 2 cm deep and had closed end. Then Nishiwaki was invited to join the examination. The opening hole was on the center line of ventral surface and looked like a small vagina. At dissection, it was found that the hole was the opening of a blind sac 3 mm in diameter and 24 mm in length inside. The sac narrows immediately at the close end and connected to the hind part of the urinary bladder with thin connective tissue. There was no organ such as uterus or ovaries besides it nor any gland found around the sac by naked eyes.

There has been a description on this opening. Dr. K. Mizue of the Nagasaki University studied on smaller cetaceans in the western waters of Kyushu about ten years ago. He reported on the finless porpoises caught in Tachibana Bay in his research report—XII that " naturally, males of this species has no nipple slits along the genital opening, but there is a blind sac just inbetween the genital opening and the anus." He had a interest on it and would study separately in future. Asked for further information, Dr. Mizue answered that he had seen 12 males at that research and seen this organ in every specimen. So, he thought it might be quite common, not a matter of drawing special attention nor he have kept any specimen of this portion. When he thought back, he was not sure whether all the twelve porpoises had this hole. Although he thought it was a degenerated nipple, now he thinks it was not.

Because there is only one specimen of this portion of finless porpoise, it might be better to leave histological study undone until more specimen will have found. Here the authors intend to report a finding of the strange sac and want to draw attention of scientific collegues to get further information and to know whether this is an aromatic or civet secretion gland or a harmaphroditic vagina.

REFERENCE

Mizue, K., K. Yoshida, and Y. Masaki, 1965. *Neomeris phocaenoides*, so-called Japanese " SUNAMERI ", caught in the coast of Tachibana Bay, Nagasaki Pref. Studies on the Little Toothed Whales in the West Sea Area of Kyusyu-XII. *Bull. Fac. Fish., Nagasaki University*, 18: 7–29.

EXPLANATION OF PLATE

Fig. 1. The 114 cm male specimen of the finless porpoise (*Neophocoena phocaenoides*).

Fig. 2. Ventral surface of the specimen. N: navel, P: penis opening, H: strange hole, A: anus.

Fig. 3. Dissected genital aparture of the specimen. T: testis, U: urinary bladder, R: rectum, P: penis, N: navel, A: anus, H: strange hole.

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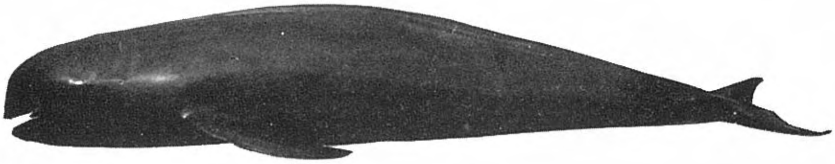

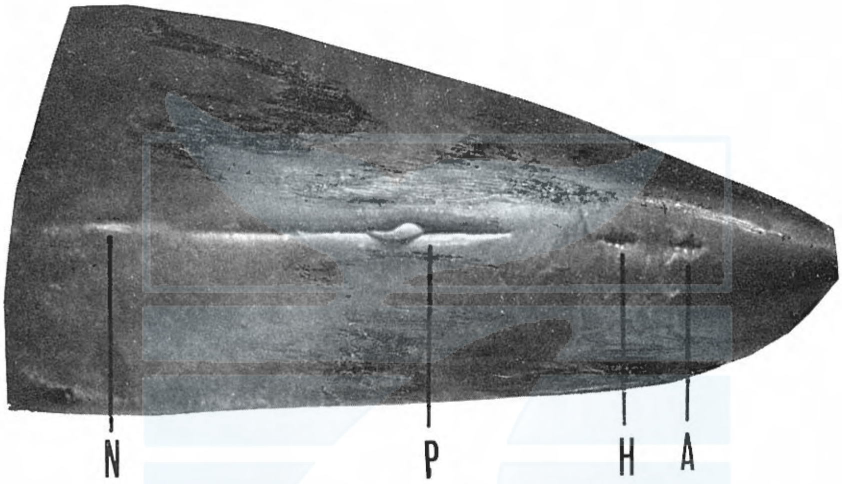

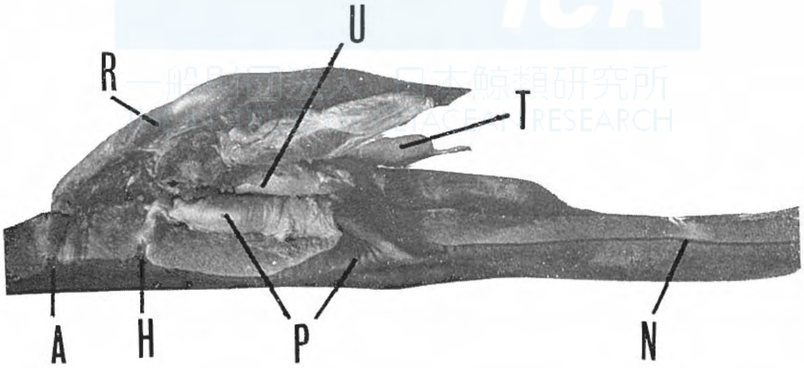

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DISTRIBUTION OF SPERM WHALE CATCHES IN THE SOUTHERN INDIAN OCEAN

SABURO MACHIDA*

Whales Research Institute, Tokyo

ABSTRACT

Over 6,000 sperm whales were caught by Japanese antarctic whaling expeditions in the southern Indian Ocean bounded by latitude 30°—50°S and longitude 20°—145°E on the way to and from the antarctic whaling grounds in the seasons of 1957/58–1972/73. Most catches were made intensively in November and December before the baleen whale seasons.

The distribution of the species in the area concerned is discussed in relation to the surface temperature field. The relationship between the heavy catches of the animals and the Subtropical Convergence was found. Sperm whale concentrations are restricted in the convergence region and in temperate waters north of it. They are distributed up to about 41°S in the southwestern, southcentral, and southeastern Indian Ocean and about 47°S south of Australia. Virtually no females occur in colder waters south of the convergence region.

INTRODUCTION

Sperm whales have been caught by Japanese antarctic whaling expeditions in middle latitudes in the southern Indian Ocean on the way to and from the antarctic region in the Antarctic Ocean since the 1957/58 season.

There are very few reports about the distribution of sperm whales in pelagic waters in the Indian Ocean. Especially in the southern part of the ocean only very small catches of the species were made by the American whaleships mainly in nineteenth century (Townsend, 1937) and only a few animals were observed by research and merchant vesseles (Brown, 1957; Slijper *et al.*, 1964). On the other hand we can see the distribution of the species in the area concerned in the charts by Kasuya (1964), Ohsumi and Nasu (1968), and Berzin (1972), which were mapped based on the materials from Japanese and Soviet antarctic whaling expeditions respectively. However, the practical study of the sperm whale distribution and the grounds for the species in relation to the oceanographic conditions is rather scarce.

In any programme of whale research aimed at the reasonable exploitation of a population a knowledge of the distribution of the animals concerned is invaluable. In this present report the distribution of the sperm whale catches in the southern Indian Ocean bounded by latitude 30°–50°S and longitude 20°–145°E has been

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* Present address: *Japan Marine Fishery Resource Research Center, Tokyo.*

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No. 27, 1975, 141–157.

described in relation to the surface temperature field, using the materials from Japanese antarctic whaling expeditions in the seasons of 1957/58–1972/73.

RESULTS

Japanese antarctic whaling expeditions had caught sperm whales heavily in middle latitudes in the southern Indian Ocean from 1957/58 to 1972/73 (Table 1). Though the sperm whale catches were made during the warmer months of November–April, most animals were actually caught in November before the baleen whale seasons. A few catches of the animals were also made at the beginning of December and from the end of March to April again after carrying out catching for baleen whales. During the mid summer (January–February), at the height of catching for baleen whales, only very few sperm whales were caught.

TABLE 1. THE SEASONAL AND MONTHLY CATCHES OF SPERM WHALES BY THE JAPANESE ANTARCTIC WHALING EXPEDITIONS IN THE SOUTHERN INDIAN OCEAN FROM 1957/58 TO 1972/73. RIGHT FIGURES: FEMALES

Season	Nov.		Dec.		Jan.		Feb.		Mar.		Apr.		Total	
1957/58	25	—	—		—		—		—		—		25	—
58/59	—		—		—		—		—		—		—	
59/60	—		—		—		—		29		—		29	—
60/61	—		—		—		—		1	—	29	—	20	—
61/62	62	7	1	—	—		—		64	—	76	—	203	7
62/63	391	187	18	—	46	—	10	—	60	—	105	36	630	223
63/64	1,750	960	—		—		—		48	2	—		1,798	962
64/65	1,194	684	—		—		—		5	—	—		1,199	684
65/66	254	7	—		1	—	—		159	—	—		414	7
66/67	309	47	8	5	3	—	14	—	83	—	—		417	52
67/68	20	—	22	—	27	—	—		—		—		69	—
68/69	—		—		—		—		—		—		—	
69/70	302	137	13	—	—		—		—		—		315	137
70/71	458	305	211	74	—		18	—	—		—		687	379
71/72	45	9	394	206	—		—		—		—		439	215
72/73	—		71	19	—		—		—		—		71	19
Total	4,810	2,343	738	304	77	—	42	—	449	2	210	36	6,326	2,685

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Fig. 1 shows the relation between the number of sperm whales and surface temperatures. It can be readily seen from the figure that the catches of the animals in November, when most catches were made, have relations with temperature. A large quantity of catches were made in the relatively limited range from 12° to 16°C with a peak at 14°C though the whales occur in the wide range of $-1°$ to 23°C. On the other hand, in other months, when few sperm whales were caught, the relationship between the catch and temperature can not be seen as well as that in November.

Fig. 2 shows the distribution of sperm whale catches in the southern Indian Ocean from November to April in the seasons of 1957/58–1972/73. Most of the catches were made in the central part of the area in November. The southern half of the favorite grounds is located in shallow waters around Newamsterdam Island (about 37°50′S and 77°30′E) and Saint Paul Island (about 38°40′S and 77°35′E). The second large catches of the species, which were almost carried out at the beginning of December, are made off southwestern Australia. In the western part of the area, the distribution of the catches are widely scattered and the extent of the favorite haunts were hardly encountered though the total number of sperm whale catches in the area concerned are rather large. In general a large quantity of catches of sperm whales was distributed in the warmer waters north of 40° to 41°S.

It is well known that the sperm whale has some social schools. We can not, of course, find out the accurate composition of the schools caught from the catch records but the catches of females, with which some large-scale social schools are composed, are available. As females have been also caught by Japanese antarctic whaling fleets in middle latitudes in the southern Indian Ocean the catch location are presented here.

The relationship between the nature of female sperm whales and oceanographic condition is shown in Fig. 3, which gives the one between the monthly catch of females and the surface temperatures. Though females were frequently encountered in 10°–23°C, the catches increased abruptly (from 19 to 277 animals) in temperate waters from 11° to 12°C. A large number of the female catches were made in November, and they occurred in waters between 12° and 19°C with a peak at 14°C. During December, probably at the beginning of the month, several females were caught was made in warmer waters (14° to 20°C) than during November. In addition only a few females were caught in warmer temperatures than 17°C in March–April.

Fig. 4 shows the distribution of the female catches, most of which were also captured in November to the beginning of December and a slight catch again in March to April. Furthermore most females were caught in the southcentral Indian Ocean and some animals also caught off southwestern Australia. No females were caught south of 42°S in the southern Indian Ocean except in the eastern extremity south of southeastern Australia, where several females were encountered as far south as about 47°S.

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DISCUSSION

Sperm whales are caught heavily in lower latitudes north of about 41°S (Fig. 2), especially in November, though the catches are carried out over the area concerned. The southern extremity of the heavy catch area seems to be corresponding with a certain oceanographic condition. In Deacon's (1937) chart the Subtropical Convergence, which is the boundary between the Subtropical and Subantarctic Surface Waters, was drawn between about 39° and 43°S in the southern Indian Ocean and between about 45° and 47°S south of Tasmania Island in the easternmost area of the ocean. According to Orren (1966) the convergence was found to lie at 42°S ±1° in the southwestern part of the ocean. In the southeastern Indian

Ocean the convergence region was shown in latitudes from about 39° to 42°S in Burling's (1961) chart. Rochford (1962) illustrated the South Transitional Zone schematically, that is the transitional zone between the Subtropical and Subantarctic Zones, which locates between about 35° and 40°S in the southeastern Indian Ocean. In addition the Japanese whaling fleet also crossed the convergence region in nearly same latitudes in the southeastern Indian Ocean (Machida, 1974, a, b, unpublished data). On the other hand, in the southcentral part of the ocean, according to Deacon (1937) the surface temperature observations by the rv Valdivia and Gauss show that the convergence lies between 40° and 41°S in about 76°E. The rv Anton Brunn crossed the Subtropical Convergence at about 40°S, 75°E in April (Uda and Nakamura, 1973). Deacon's (1963) examination of mean monthly temperatures of 1-degree squares by Döneke (1938), though little is reported about the seasonal variation of the convergence, suggests that its variations of the position are rather small, of the same order as these of the Antarctic Convergence. Taking account into these knowledge of the Subtropical Convergence it is evident that good catches of sperm whales are related to the convergence region.

According to Fig. 1 the relationship between the good catches of sperm whales and the Subtropical Convergence will be confirmed. A large quantity of the catches were made in the range from 12° to 16°C with a peak at 14°C during November, when is outside the baleen whale seasons. Deacon (1963) described that the Subtropical Convergence is generally given in a close distribution of the surface isotherms of 10°–14°C in winter and 14°–18°C in summer. Though he divided a year into two seasons, winter and summer, November should be rather grouped into the transitional season from winter to summer. There, however, are very few reports on the Subtropical Convergence except the summer season. In the southeastern Indian Ocean (around 40.5°S and 108°E) a Japanese antarctic whaling fleet crossed the convergence region from 13.5° to 10.4°C in the middle of November (Machida, 1974b). The range of temperature may be classified into the winter category according to Deacon's (1963) criterion. November, however, should be grouped into the warmer month or rather into the transitional season from winter to summer, i.e. spring. Simply taking account of the Deacon's (1963) general criterion about the Subtropital Convergence in the transitional season from winter to summer it probably lie in the range between 12° and 16°C, which are the meadian of the range corresponding with the convergence in winter and in summer respectively. In November a large number of sperm whales, as mentioned above, were caught in these temperatures.

On the other hand a slight catch at the beginning of December, of which the great majority of the catches were made off southwestern Australia, appears to be corresponding to warmer waters than 14°C. The warmer temperatures than 14°C are included into the summer category of Deacon's (1963) criterion of the Subtropical Convergence and coincident with the range which corresponds to the convergence region in December (Machida, unpublished data).

Though in the southern Indian Ocean only very small catches of sperm whales were made mainly in the nineteenth century (Townsend, 1937) and only a few animals were sighted by research and merchant vesseles (Brown, 1957: Slijper *et al.*, 1964), Kasuya (1964) and Ohsumi and Nasu (1968) illustrated the sperm whale distribution in pelagic waters of the southern Indian Ocean from catch records of Japanese antarctic whaling expeditions. In addition Berzin (1972) charted the distribution of the species in the area concerned based on the recent materials from Soviet pelagic whaling expeditions with previous works. In these charts it is evident that the heavy catches of sperm whales are located around the Subtropical Convergence in the southern Indian Ocean during October–March. He described furthermore that large concentrations were noted north of Newamsterdam and Saint Paul Islands. A heavy catch of the animals by Japanese fleets was also made from in shallow waters around both two islands to north. The large catches was also illustrated off southwestern Australia as the favourable grounds in the charts by Townsend (1937), Gilmore (1959), Mackintosh (1965), Berzin (1972), and others.

The southern extremity of the good catches of sperm whales seems to reflect the concentrations of the large-scale schools of the species. According to Gaskin (1970), Ohsumi (1971), and others the sperm whale has the distinct social structure of various types of school, i.e. the nursely schools, the harem schools, the immature mixed sex schools (the juveniel schools), the bachelor schools, the bull school (male pairs) and the lone bull (solitary bull). Of which the nursely, harem and juveniel schools are composed of a large number of females. In the short period before the baleen whale seasons catching for sperm whales will be occupied in waters inhabiting these schools. We can not, of course, find out the accurate category of the social structure of the species from the catch recrods but the females are recorded in the catch logs. It is quite possible to suppose the location of the large-scale schools from that of females, therefore. The distribution of the female catches shown in Fig. 4 may suggest the distribution pattern of the major schools of the species which are restricted in the Subtropical Convergence.

The females and the youngs are generally accepted being limited to the regions between about 40°N and 40°S (Slijper, 1962). Gilmore's (1959) charts show that females are limited by the isotherm of 20°C, which seems to be more or less the range as the convergence. Kasuya (1964), who charted the seasonal distribution of male and female sperm whales in the rectangles by latitude 1° and longitude 5°, using the part of the same materials as that in this report, assumed that the southern limit of the female distribution in the southern Indian Ocean is 40°–45°S in latitude and that the range is roughly corresponding with the Subtropical Convergence. On the other hand Nasu (1969) pointed out that the southern range of females was corresponding with the Australasian Subantarctic Front, which is located in the region between the Subtropical and Antarctic Convergences (Burling, 1961) based on the distribution of female sperm whales by Ohsumi and Nasu (1968). They charted the distribution of the female catches in ten degree squares by using the part of the same materials as that in Kasuya (1964) and in this report. Clarke (1972) studied the stomach contents of sperm whales caught off Durban (South Africa) and reported that few antarctic cephalopod beaks were found from females and small-sized males though larger males having antarctic cephalopod beaks in large number. From this fact he suggests that females and small-sized males do not go far south through the Subtropical Convergence. I may take that the southern range of female sperm whales in the southern Indian Ocean is corresponding with the Subtropical Convergence as far as I discuss the distribution of the female catches and the surface temperatures in Fig. 3 and 4.

On the other hand there is really several records that the female and young sperm whales occurred in higher latitudes beyond the Subtropical and Antarctic Convergences. Salvenson (1915) illustrated one female caught off South Gergia (about 55°S). In the southern Indian Ocean several schools of small-sized sperm whales, which seemed to be composed of females and youngs, were observed at the end of January at 59°S, 65°E and at 58°30′S, 71°E, respectively (Ivanov, 1972). Fourteen females were caught at the end of January south of Herd Island (about 56°S) (Ivashin and Budylenko, 1970). Though these observations and records suggests that some females and youngs are tolerable to cold waters south of the Subtropical Convergence and/or furthermore through the Antarctic Convergence, these are rather scarce and I may regarde them as strugglers.

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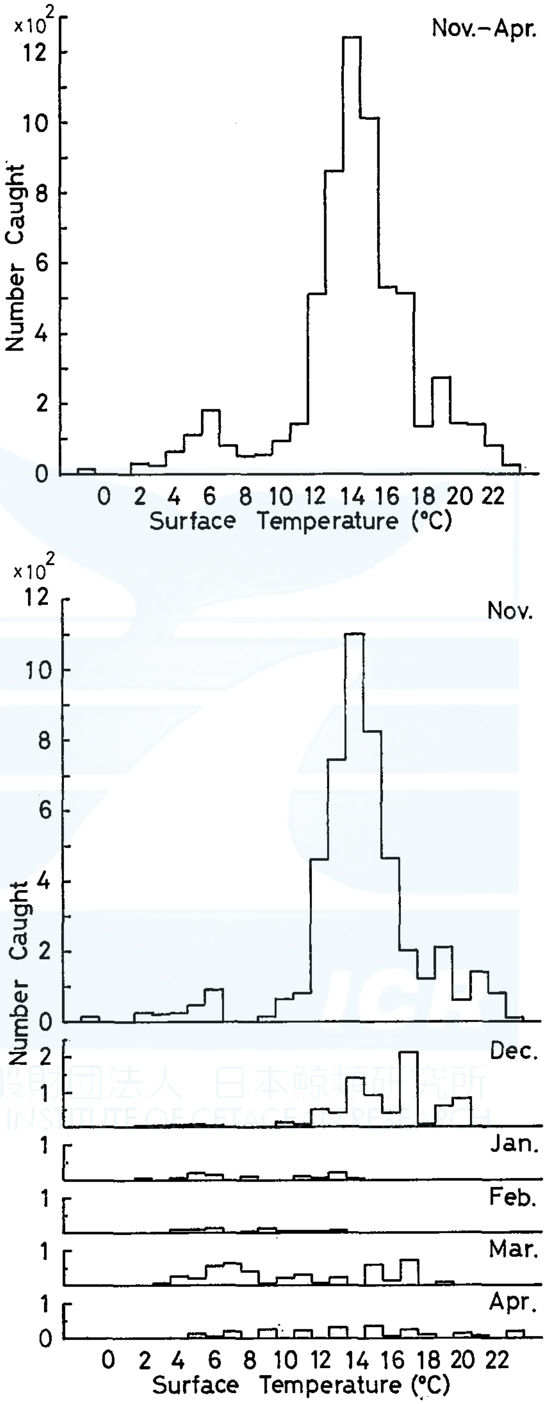

Fig. 1. Catches of sperm whales and surface temperatures in November—April (1957/58–1972/73)

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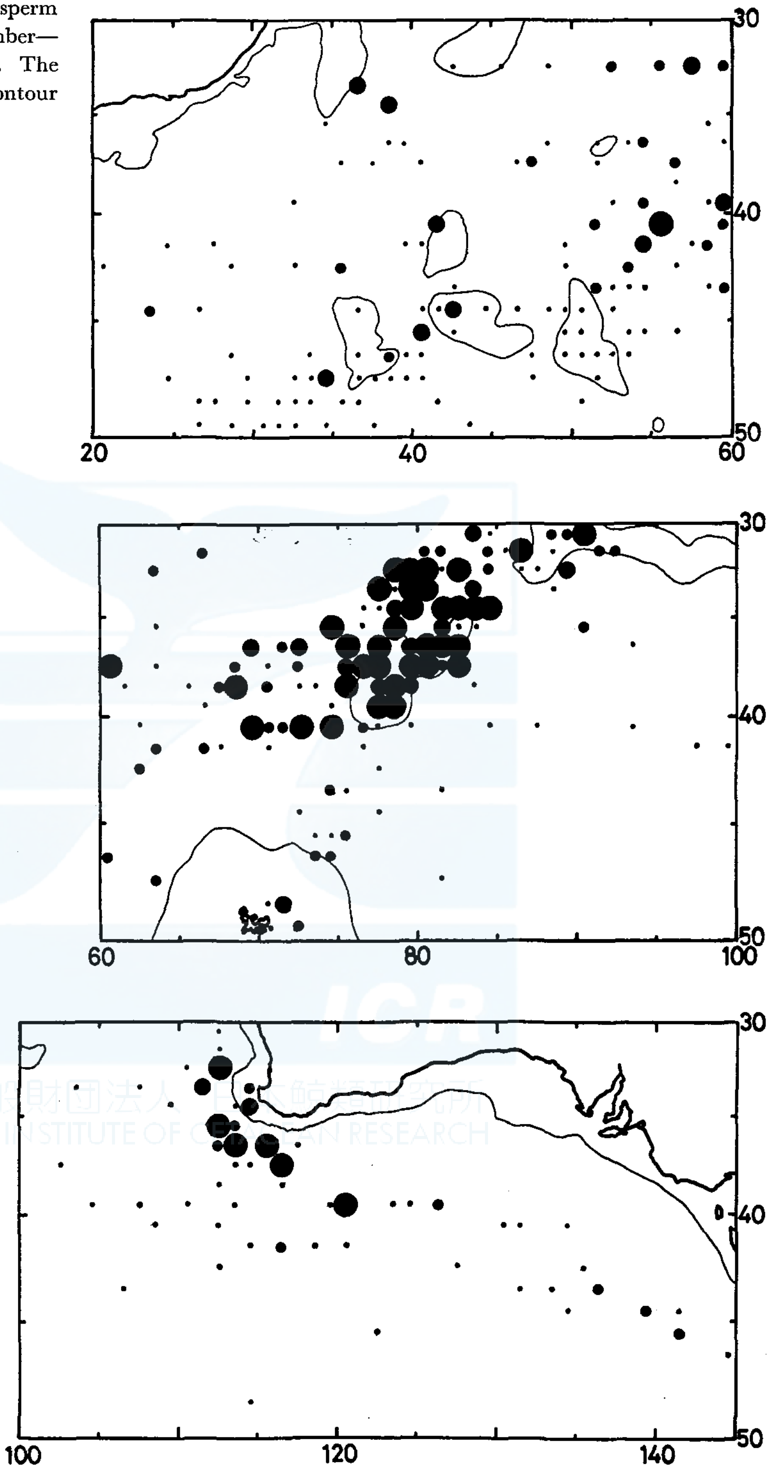
Fig. 2(a). Distribution of sperm whale catches in November—April (1957/58–1972/73). The fine line represents the contour of 1,500 fathoms.



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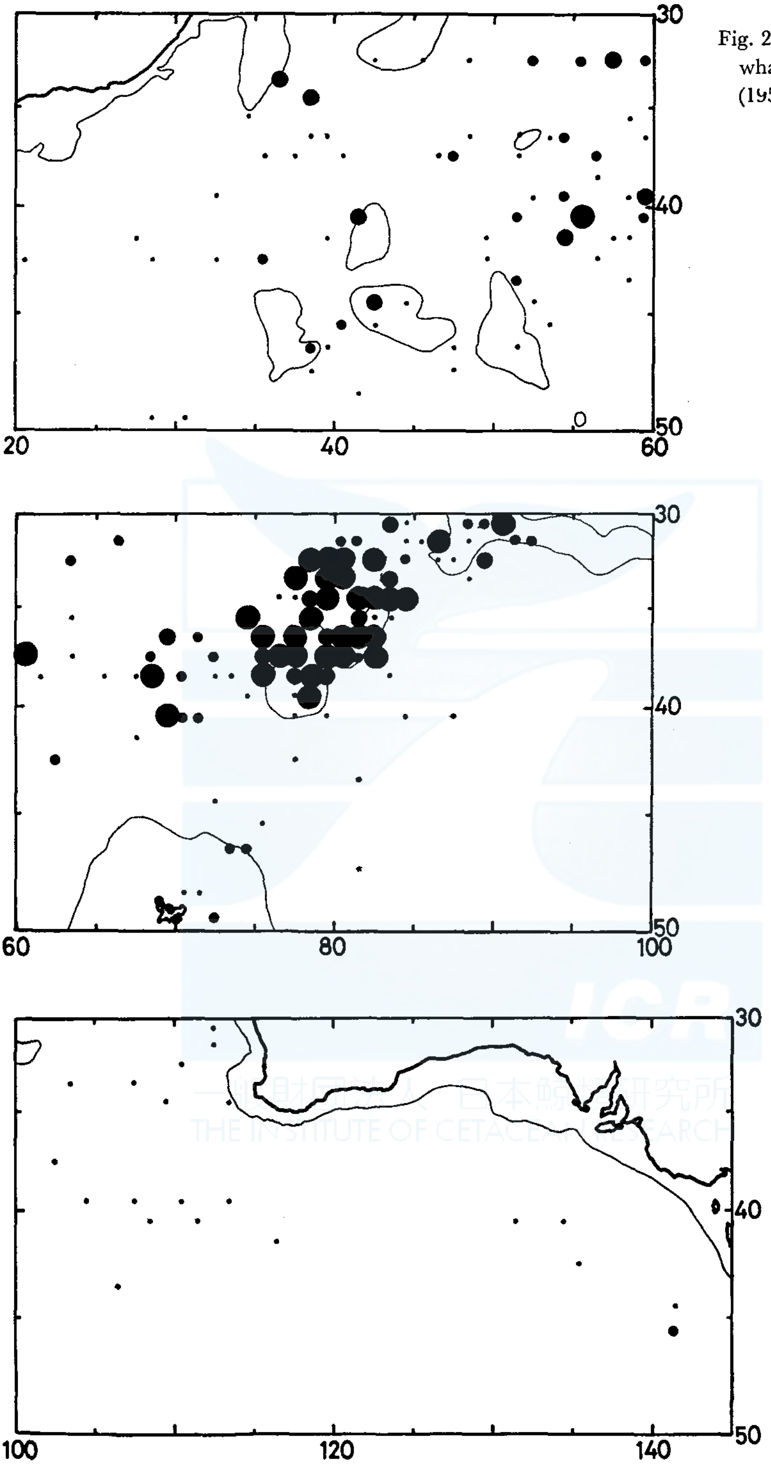

Fig. 2(b) Distribution of sperm whale catches in November (1957/88–1972/73).

Fig. 2(c). Distribution of sperm whale catches in December (1957/58–1972/73).

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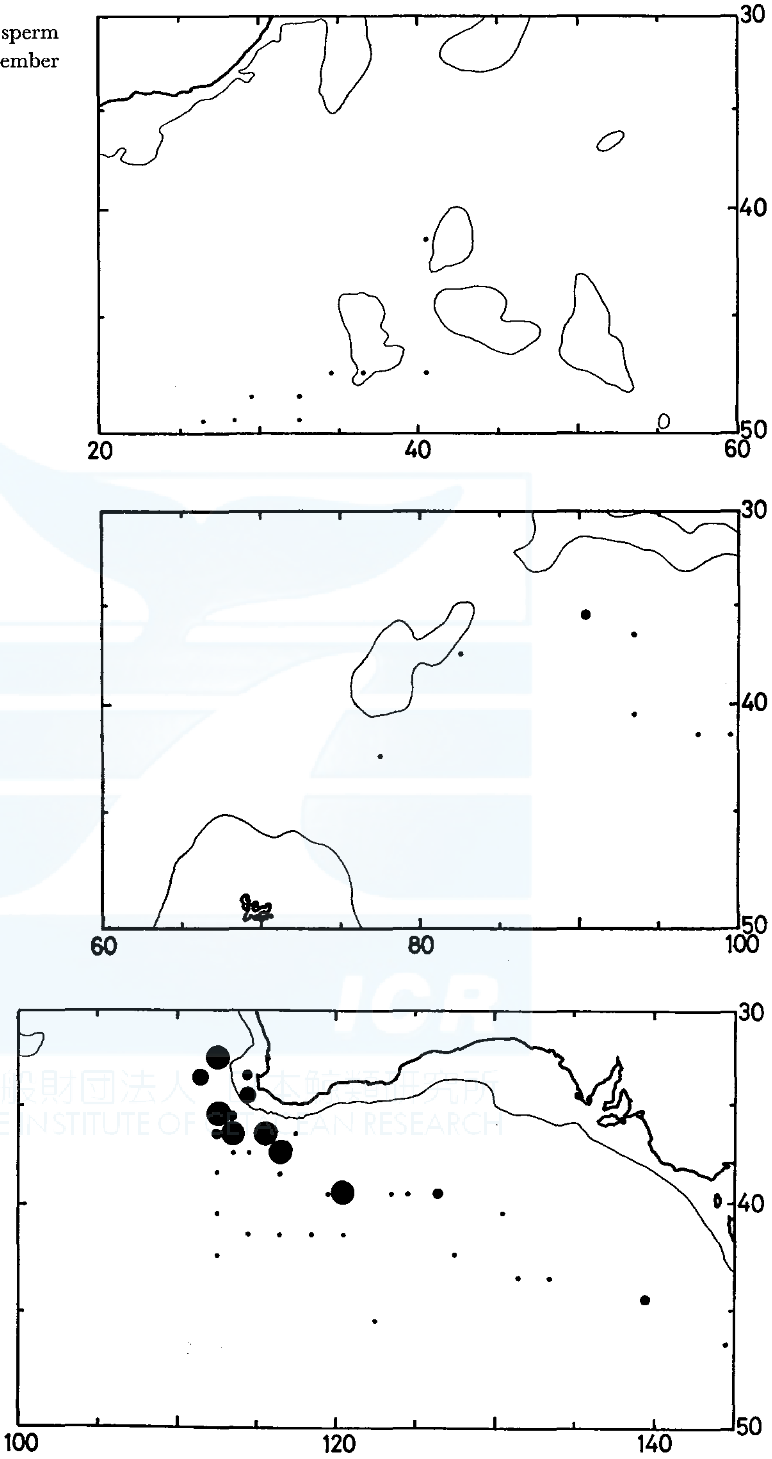

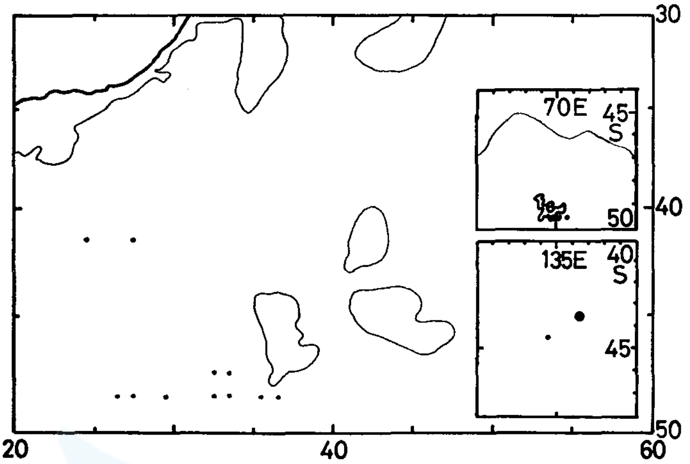

Fig. 2(d). Distribution of sperm whale catches in January (1957/58–1972/73).

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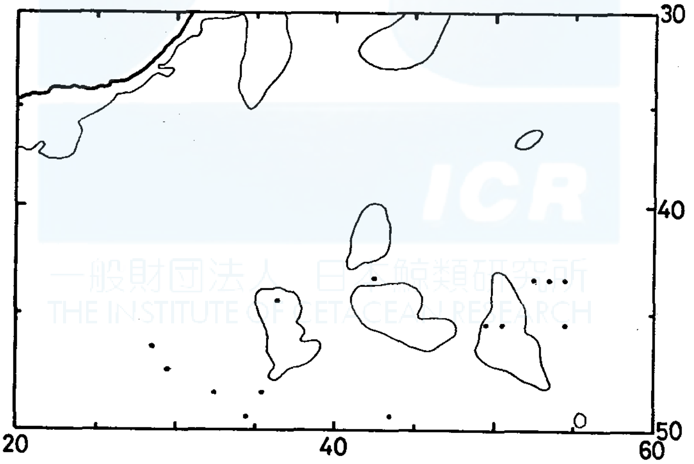

Fig. 2(e). Distribution of sperm whale catches in February (1957/58–1972/73).

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Fig. 2(f). Distribution of sperm whale catches in March (1957/58–1972/73).

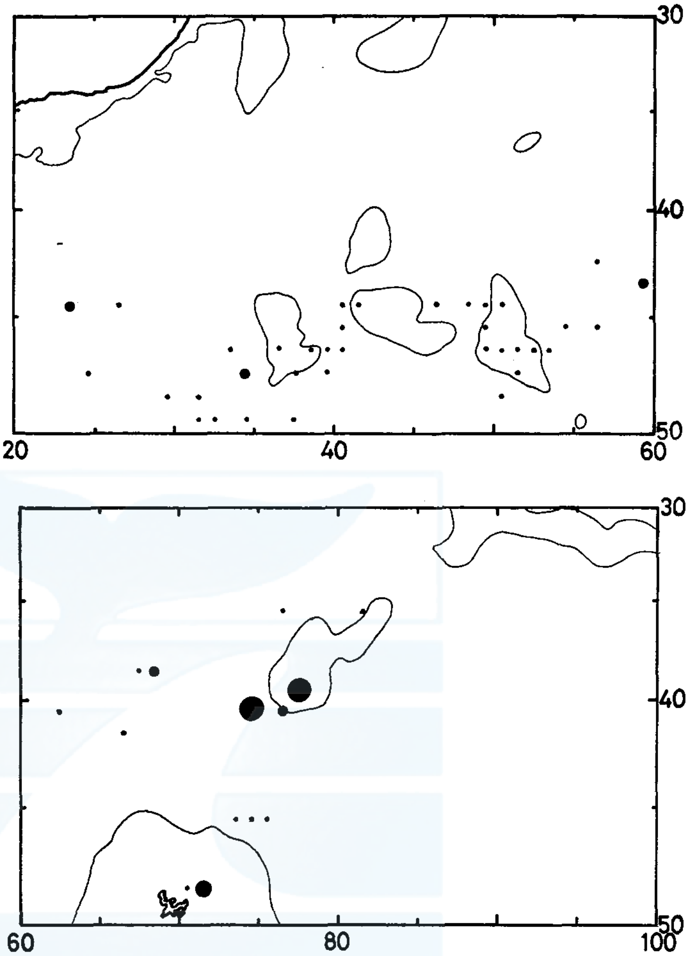
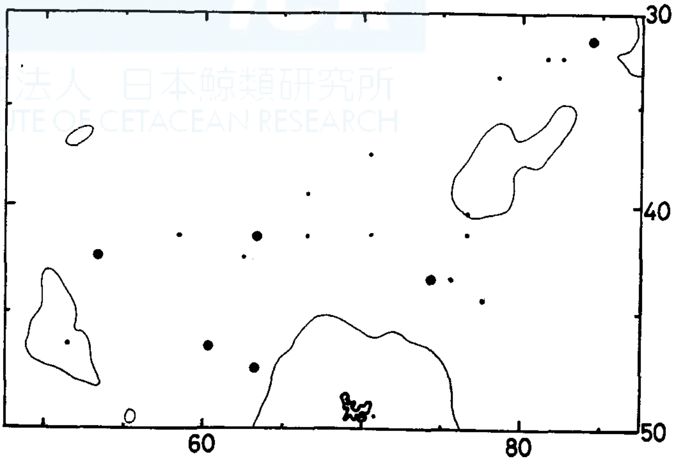


Fig. 2(g). Distribution of sperm whale catches in April (1957/58–1972/73).



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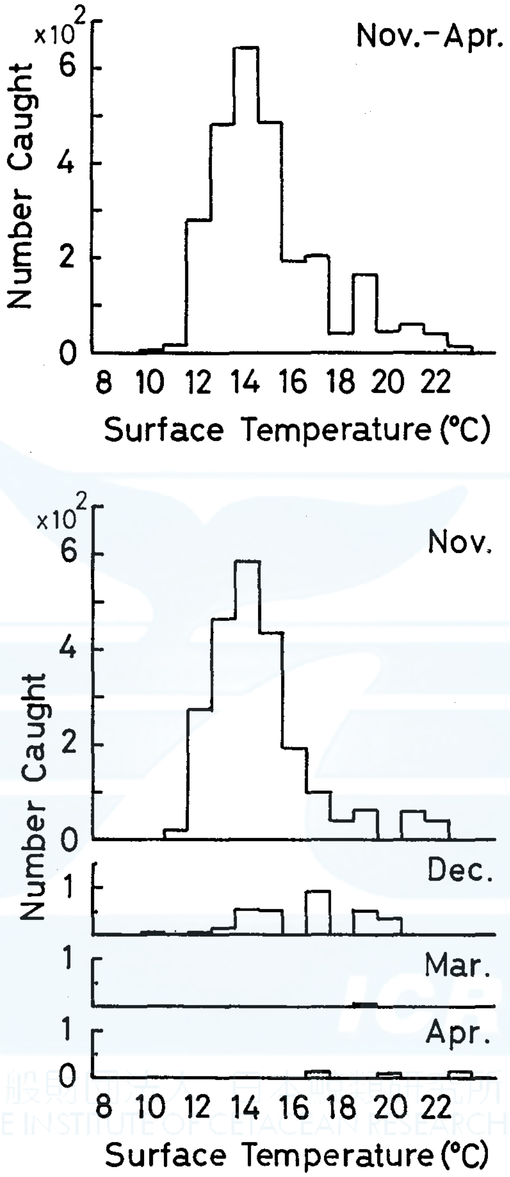

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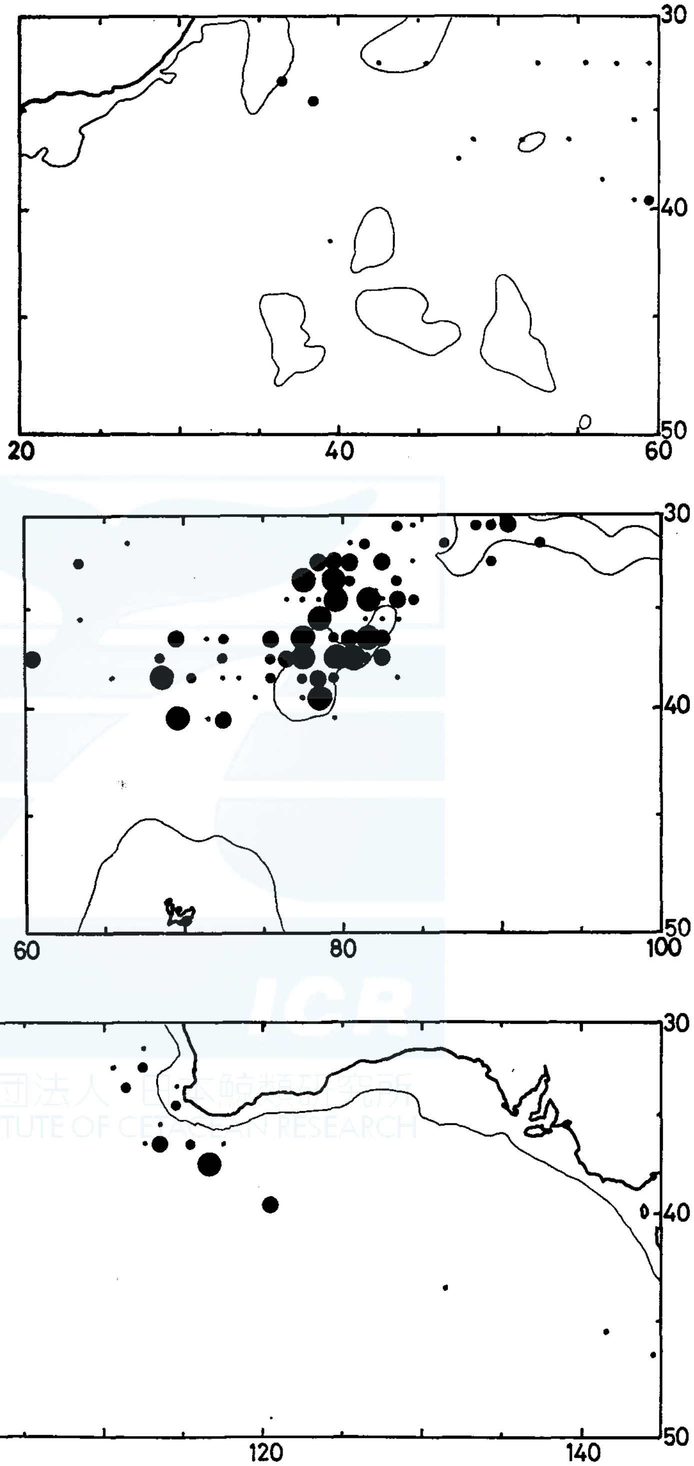
Fig. 3. Monthly catches of female sperm whales and the surface temperatures (1957/58–1972/73).

Fig. 4(a). Distribution of female sperm whale catches in November—April (1957/58–1972/73).



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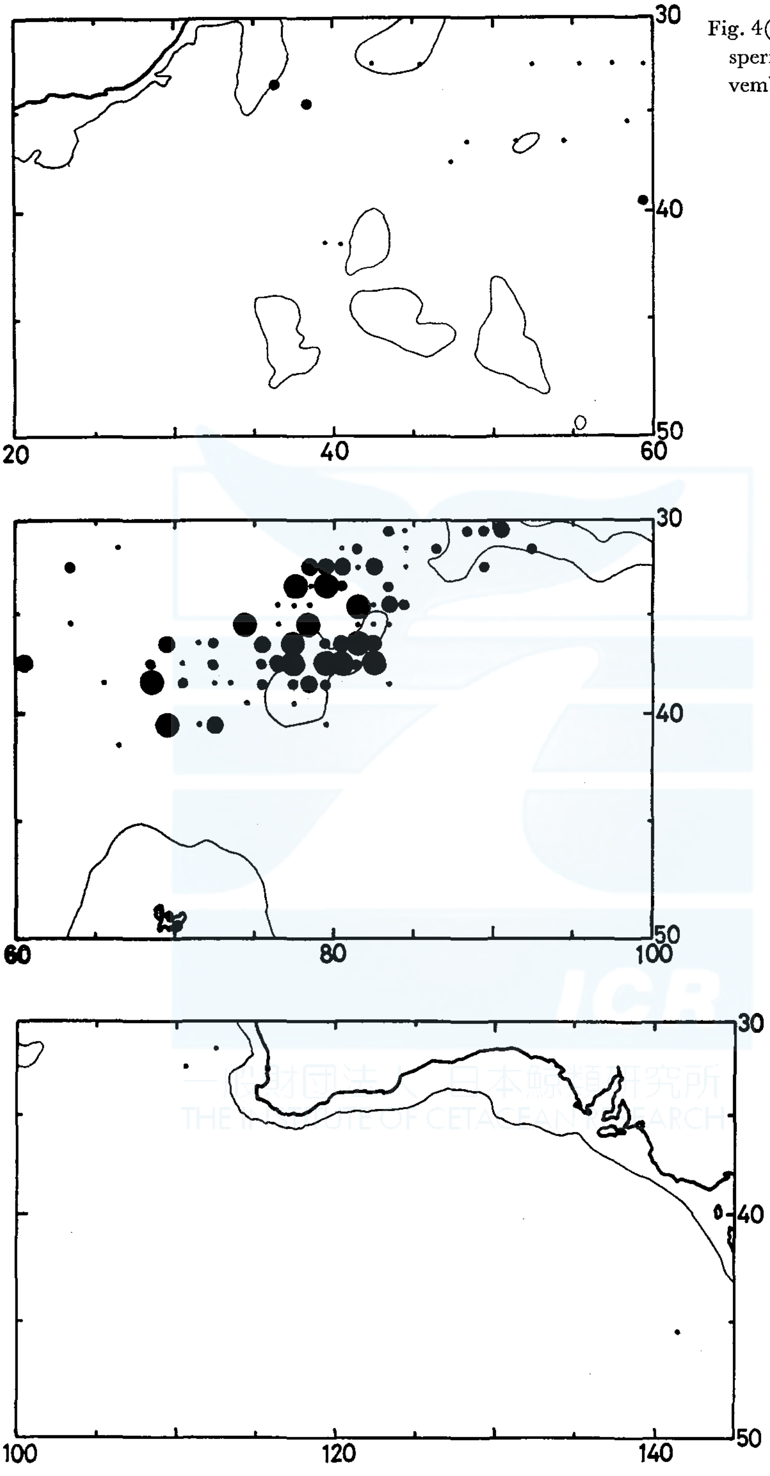

Fig. 4(b). Distribution of female sperm whale catches in November (1957/58–1972/73).

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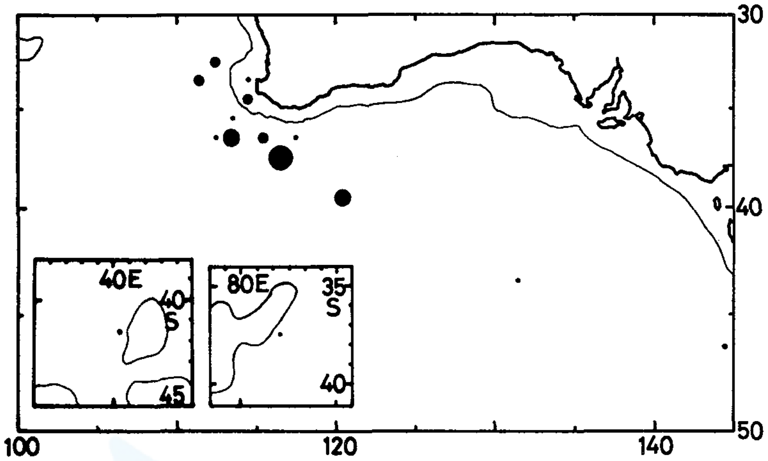

Fig. 4(c). Distribution of female sperm whale catches in December (1957/58–1972/73).

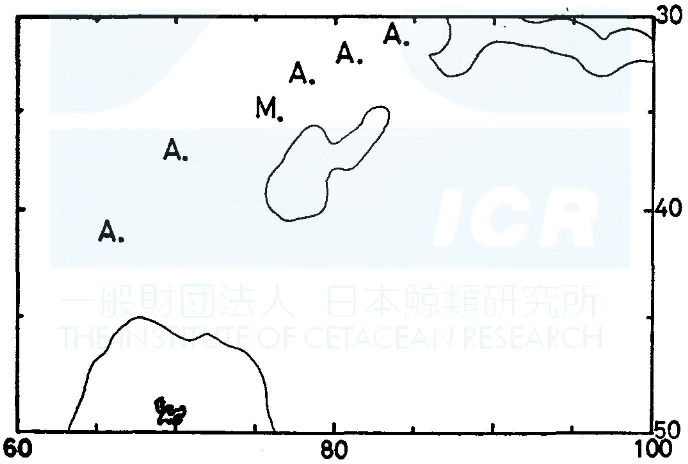

Fig. 4(d). Distribution of female sperm whale catches in March and April (1957/58–1972/73). M: March A: April

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