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NORTH PACIFIC RIGHT WHALE

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INTRODUCTION

It is generally accepted that the right whales or black right whales live in three isolated communities, i. e. in the North Atlantic, North Pacific and southern hemisphere, being separated by continental area and wide vacant tropical belt of water, mainly based on the chart showing distribution of whales as shown by logbook records of American whaleships, presented by Townsend (1935).

The Atlantic right whale has been studied, both from east and west sides, by various authors since the capture of a young example in the port of San Sebastian, Spain, in 1854. Outline of these studies are well summarized by True (1904), and in more historically by J. A. Allen (1908). True's account, however, contains an exhaustive summary of all the published accounts of the external and osteological characters of all the then known specimens, both European and American, and much original matter relating to several American examples not previously described. Since then Andrews (1908, 1909), Collett (1909), Turner (1913), and G. M. Allen (1916) contributed greatly to our knowledge of the North Atlantic right whale. And it is established that *Balaena nordcaper* Lacépède, *B. biscayensis* Eschricht, *B. cisarctica* Cope, *B. britanica* Gray, *B. tarentina* Capellini, etc. are all synoniums and they belong to a single species *Eubalaena glacialis* Bonnaterre, a distinct species from the Greenland or bowhead whale, *Balaena mysticetus* Linnaeus.

Very little is known about the southern right whale, *B. australis* of the South Atlantic and *B. antipodarum* and *B. novae-zelandiae* of the South Pacific. J. A. Allen (1908) describes, without comment, that two (possibly three) species of *Eubalaena* occur in the southern hemisphere, though he summarizes well the North Atlantic right whale. Harmer (1928) states that it seems probable that several species of southern right whale that have been described should all be referred to as a single species, which is closely allied to, but possibly distinct from, the Biscay whale [*Eubalaena glacialis*]. Matthews (1938) notes body proportions and other characters of five southern right whales observed by the Discovery staff at South Georgia and Cape Province, South Africa. Further he reports that a specimen was taken by special permission and brought into Leith Harbour, South Georgia, where its skeleton was prepared for the British Museum (Natural History). But this skeleton was unfortunately lost;

while awaiting shipment an avalanche from the nearby mountain overhelmed the old part of the whaling station at Leith Harbour where it lay. Since then no systematic study of this species has been appeared, as far as I am aware.

More less is known about the North Pacific right whale. Only scanty and fragmental reports have been appeared, because of lack of specimen, though hunting of this species was carried on vastly in the North Pacific by American whalers and a number was taken locally by the Russian and Japanese.

In the early days of nineteenth century the North Pacific right whale was called as " cullamach " or " kuliomoch " whale. Gray (1846) named this species *Balaena japonica* and later it was renamed *B. sieboldii* by him (1864). And the name *B. aleoutiensis* was given by Van Beneden (1865). But these were named without sufficient type specimen. True (1904) treats briefly in his account the North Pacific right whale under the name "*Balaena sieboldii* Gray (?), based mainly on an account by Scammon (1874) and the whalebone kept in the National Museum, Washington. He closes the chapter by quoting Van Beneden's opinion (1875) that the right whale of the coasts of Japan is a distinct species from that of the North Atlantic. His statement was commented by J. A. Allen (1908) as having not noticed to the attitude of Flower (1891) who describes that " This form [*Balaena australis*] inhabits the temperate seas of both northern and southern hemisphere, and is divided into several so-called species according to their geographical distribution :—*B. biscayensis* of the North Atlantic, *B. japonica* of the North Pacific, *B. australis* of the South Atlantic, and *B. antipodarum* and *B. novae-zelandiae* of the South Pacific ".

The distinction among the right whales from the North Atlantic, North Pacific, and southern hemisphere has not been established yet owing to the lack of the specimen and necessary measurements of the latter two, but Fraser (1937) uses the name " Black Right Whale " to include all of these, regarding, not as so many distinct species, but rather as local races of one species which is widely distributed. Recently Tomilin (1957) describes single species of *Eubalaena glacialis* and under this name three different sub-species. These are *E. glacialis glacialis* Bonnaterre from the North Atlantic, *E. glacialis sieboldii* Gray from the North Pacific, and *E. glacialis australis* Desmoulin from the southern hemisphere.

The hitherto-noted difference between the North Atlantic and North Pacific right whales is the color of baleen plates (Tomilin 1957). Matsuura (1936) made some statistical study of whales taken in the coasts of Japan. He (1942) also measured body proportions of two right whales taken by the " Tonan Maru " expedition in the waters south of Kamtchatka in 1941. This may be the first record of the North Pacific right whale whose body proportions were measured, but this report is not popular to cetologists of other countries, because it is written in Japanese and was not made public.

In 1956 two right whales were killed in the coastal waters of Japan by a special permission for scientific research under Article 8 of the International Convention for the Regulation of Whaling. These two whales were observed and measured of their external as well as internal characters by the staff of the Whales Research Institute. A brief report on the observation of these whales was made public by Omura (1957). In the present account these whales are treated in detail with other data hitherto obtained by ourselves including those by Matsuura, and comparing with those from different localities by various authors.

Followings are the catch particulars of the two right whales taken in 1956.

Date of catch	*Position of catch*	*Body length in feet*	*Sex*	*Where processed*
May 23, 1956	38°—33′N, 143°—40′E	38	F	Ayukawa
June 30, 1956	41°—46.8 N, 148°—59.5′E	41	M	Kirittapu

RECENT OCCURRENCE AND MIGRATION

Historical. In old days prior to the present century some North Pacific right whales were killed yearly in the coastal waters of Japan by nets fishing. These grounds were located on the south and west coasts of Japan and these hunting was carried out mainly in winter. At Senzaki, a small town located western side of Honshu and facing to the Japan Sea, a total of various kinds of about 15 whales in average were taken yearly in a period from 1802 to 1850. The right whale occupied about 20 per cent of the catch, and the rest were fins, humpbacks, and grey whales, etc. The catch lasted from December to March following, having its peak in January. At Taiji, a small town located southern-most part of Honshu, also such whaling had been conducted in winter until 1878, when it came to an end with a disaster. On December 24th 1878 almost all the fishing vessels engaged in whaling were sunk and about one hundred people were drown because of a sudden storm, while pursueing a big right whale.

The Norwegian whaling has been introduced to Japan at the beginning of this century and gradually the whaling had moved to northern grounds where whaling is operated mostly in summer. Matsuura (1936) summarizes the catches of the North Pacific right whale in ten years from 1925 to 1934. Table 1 is reproduced here from his account, slightly changed for clarification.

This table shows well the monthly distribution, hence migration, of the North Pacific right whale. In February it approaches to the Bonin Island, in March and April to the south-west coast of Honshu, during April and July to the north-east coast of Honshu, and from May until September it stays in the waters near Hokkaido. But in the line of Hokkaido in this table is included the catch in the Okhotsk Sea and in the waters around Kuril Islands. The best ground in these days was the coasts around Iturup and Urup Islands in the Kuril Islands.

TABLE 1. MONTHLY CATCH OF THE NORTH PACIFIC RIGHT WHALE IN JAPAN DURING 1925—34. (after Matsuura)

Locality	Feb.	Mar.	Apr.	May	Jul.	Aug.	Sept.	Total
Hokkaido1)	—	—	—	13	16	24	4	57
NE coasts of Honshu	—	—	1	2	1	—	—	4
SW coasts of Honshu	—	1	1	—	—	—	—	2
Bonin Island	3	—	—	—	—	—	—	3
Total	3	1	2	15	17	24	4	66

1) Including Kuril islands.

TABLE 2. RECORDS OF RECENT SIGHTINGS OF NORTH PACIFIC RIGHT WHALE BY JAPANESE WHALE CATCHERS.

Year	Coastal whaling					Pelagic whaling in the North Pacific						Total
	Apr.	May	Jun.	Jul.	Total	May	Jun.	Jul.	Aug.	Sept.	Total	
1941	—	—	—	—	—1)	—	2	4	—	—	6	6
1948	—	—	—	1	1	—	—	—	—	—	—2)	1
1949	—	—	—	—	—	—	—	—	—	—	—2)	—
1950	2	2	—	—	4	—	—	—	—	—	—2)	4
1951	4	7	—	—	11	—	—	—	—	—	—2)	11
1952	4	—	—	—	4	—	—	—	—	—	—1)	4
1953	—	5	1	—	6	—	—	—	—	—	—1)	6
1954	4	9	—	—	13	2	10	10	2	—	24	37
1955	2	—	—	—	2	—	3	5	—	—	8	10
1956	—	1	2	—	3	1	8	63	—	3	75	78
1957	21	22	1	1	45	—	10	15	—	—	25	70
Grand total	37	46	4	2	89	3	33	97	2	3	138	227

1) No record available.
2) Not operated.

Recent occurrence. As regards the recent occurrences of the North Pacific right whales I have collected records of sightings by Japanese whale catchers which are tabulated in table 2, separately by coastal and pelagic whaling and by months. In the column of the coastal whaling the data from 1948 to 1955 were collected from log-books of catchers and those for 1956 and 1957 were supplied from the whaling companies concerned, but not the all were informed. In the column of the pelagic whaling in the North Pacific the data for 1941 were taken from Matsuura (1942), and the rest were supplied from Mr. T. Kawakami of the Fisheries Agency of Japanese Government.

As shown in table 2 a total of 227 right whales were sighted by Japanese whale catchers during 11 years from 1941 to 1957. Number of sightings in each year differs considerably, from nil in 1949 to 78 in 1956. It seems that the sighting has increased in recent years, but we should put the fact in mind that in 1956, when a special permission for taking of right whales for scientific purposes was issued, catchers were requested to make full records of sightings of that species. Further it occurs without doubt that the same whale or the same school of whales be sighted by different catchers, thus increasing the numbers of sighting records considerably. It is obvious, therefore, that these data have little value for the study of relative abundance in different years. But these data are very useful for the study of distribution and migration of whales, when the positions of these sightings are plotted in chart according to the time observed (figs. 1).

Distribution and migration. Figure 1 shows the positions of the North Pacific right whales sighted in each month in these 11 years. In April right whales were only sighted in the waters east of Hokkaido and north-east coast of Honshu. In addition to these sightings two whales were observed in the coast of Taiji, southern-most part of Honshu, though these whales were not plotted in figure 1. We have no record of sighting in April in the waters north of 43° North Latitude. This may partly be due to the fact that the Japanese pelagic whaling begin in May and no catcher boat operating in these waters in April, but it is probable that the North Pacific right whale does not migrate so north in this month, judged from the chart showing the positions of monthly catch by American whalers by Townsend (1935), which coincides well with figure 1.

In May also the majority are sighted in the same area as in the previous month, but slightly they shifted to north and three were sighted between 45° and 47° North Latitude. None was sighted in and nearby the Bering Sea, though Japanese pelagic whaling had in operation generally from the middle of May there. Tomilin (1957) describes that the North Pacific right whale stays in the waters around Kamtchatka and in the Okhotsk Sea from the beginning of June to the end of October. His statement agrees with our observations, but according to Townsend (1935) a number of right whales were killed in old days in May in the south-east coast of Kamtchatka and some in the Bering Sea, and a few in the south-east coast of Hokkaido. This discrepancy may not be explained until further data are obtained in future.

In June the majority shifted further to north and approach very close to the Aleutian chain, Komandor Islands, and south-east coast of Kam-

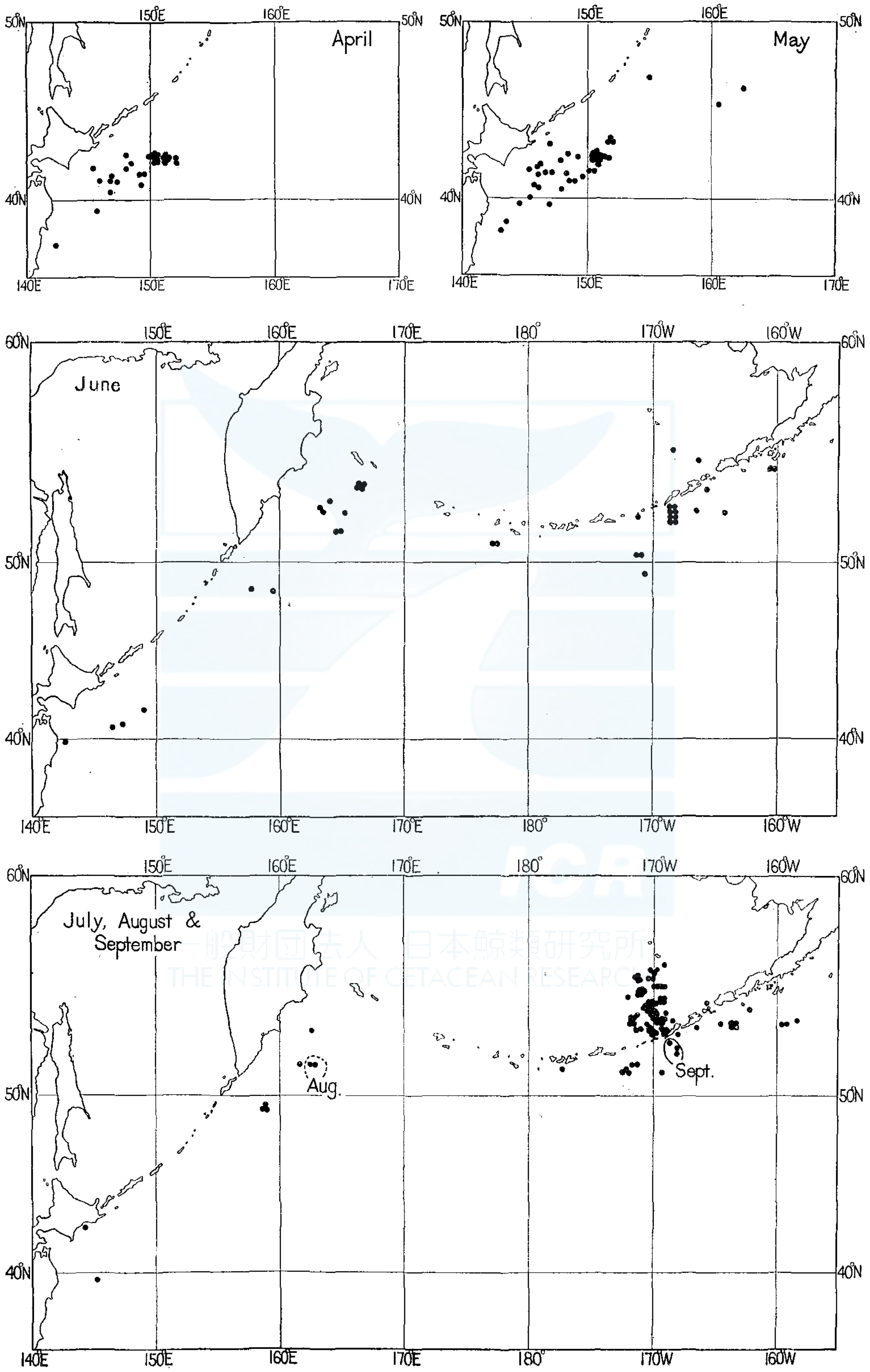


Fig. 1. Sighting of the North Pacific right whales in the years 1941–1957 by Japanese whale catchers.

tchatka, but only two were sighted in the Bering Sea, north of the Aleutian chain. We have no recent record of right whale sighted prior to this month in the west coasts of the North America by our catchers. It is well known, however, that another stock of right whales than the western stock occurs in the eastern coast of the North Pacific. Whales around the Aleutian chain in figure 1 are without doubt belong to the stock in the so-called "Kodiak ground" in the gulf of Alaska. Gilmore (1956) reports an observation of the North Pacific right whale from the coast of La Jolla, southern California, and presents a chart showing supposed distribution and migration of this stock.

In July most of the sightings were recorded in the Bering Sea around 170° West Longitude. Only a few records of sightings are observed in the waters west of 180° Longitude, but this may probably be explained by concentration of catchers in the former area in this month.

In August and September only a few numbers were sighted, two from the south-east coast of Kamtchatka in August and three in the waters south of Unimak Island of the Aleutian chain in September. None was sighted in the coastal waters around Japan after July.

From above it is concluded about the migration of the North Pacific right whales that they appear in the waters east of north-east localities of Honshu and south of Hokkaido in April, staying there in May and then they proceed to further north. In June they arrive in the Bering Sea and its nearby waters and staying there during the whole summer. According to the chart by Townsend (1935) the northern limit of migration of this species is lying west side of St. Lawrence Island.

As to the southern limit of migration we have no recent record of sighting, but three right whales were taken in February during 1925–34 as shown in table 1. Townsend (1935) reports that some whales were killed in the west coast of Formosa in February and March in the days of American whaling. It is supposed, therefore, that the southern limit of the migration of the North Pacific right whale, at least that of stragglers, is about or a little north of 20° North Latitude in the western side of the North Pacific.

We have no record of recent sighting of the North Pacific right whale in the Sea of Japan and Okhotsk Sea, though it was hunted intensively by American whalers in these waters too in the past.

In table 3 are shown the frequencies of the numbers of the North Pacific right whales in the schools, sighted by the Japanese whale catchers during the years 1941–1957. Of the 164 instances 111 or about 68 per cent of the total were met solitary, and 45 or about 27 per cent in double, including 6 cases recorded as female which accompanied by a calf. The highest numbers in a school is 4, but such occasions account

TABLE 3. FREQUENCIES OF THE NUMBERS OF NORTH PACIFIC RIGHT WHALES IN THE SCHOOLS ENCOUNTERED

Year	Coastal whaling			Pelagic whaling in the North Pacific				Total			
	Numbers in school			Numbers in school				Numbers in school			
	1	2	3	1	2	3	4	1	2	3	4
1941	—	—	—	3	—	1	—	3	—	1	—
1948	1	—	—	—	—	—	—	1	—	—	—
1949	—	—	—	—	—	—	—	—	—	—	—
1950	2	1	—	—	—	—	—	2	1	—	—
1951	9	1	—	—	—	—	—	9	1	—	—
1952	4	—	—	—	—	—	—	4	—	—	—
1953	4	1	—	—	—	—	—	4	1	—	—
1954	6	2	1	6	9	—	—	12	11	1	—
1955	—	1	—	8	—	—	—	8	1	—	—
1956	3	—	—	33	14	2	2	36	14	2	2
1957	24	9	1	8	7	1	—	32	16	2	—
Total	53	15	2	58	30	4	2	111	45	6	2
%	75.7	21.4	2.9	61.7	31.9	4.3	2.1	67.7	27.4	3.7	1.2

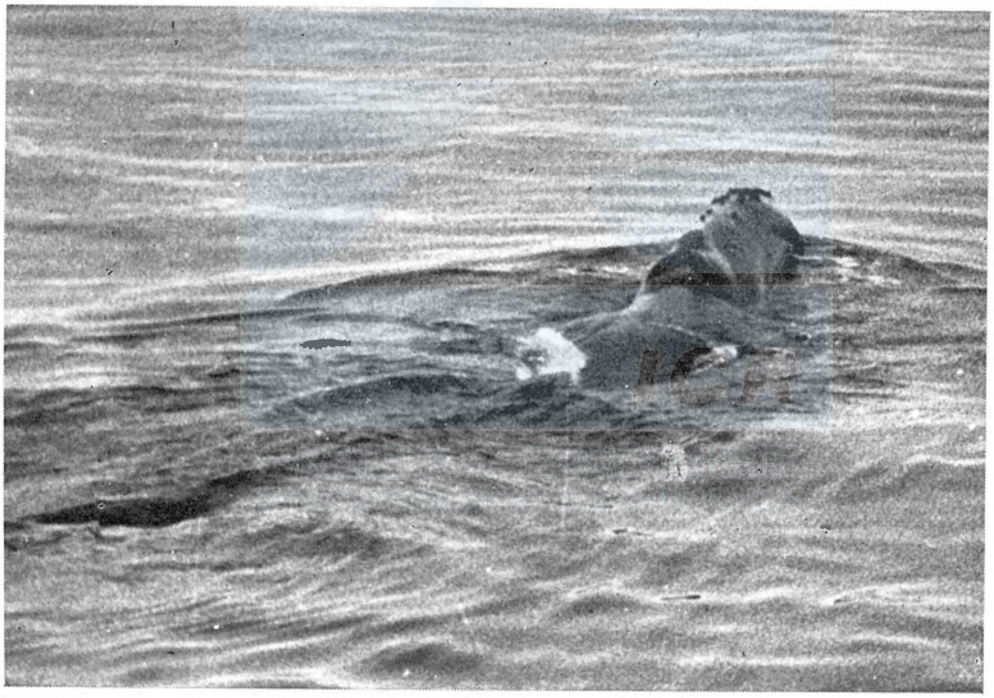


Fig. 2. North Pacific right whale.

Position. 51°12′N, 170°14′W
Date. 27th June 1956.
(Photo by Mr. S. Watase)

only 1.2 per cent of the total.

The North Pacific right whale shown in figure 2 was sighted solitary by a catcher boat on June 27th 1956 at 51°12′ North Latitude and 170°14′ West Longitude. This picture was taken by Mr. S. Watase of the Taiyo Gyogyo K. K., Tokyo, and referred to with the permission of the Japan Whaling Association, who has the copyright of this picture.

SIZE AND WEIGHT

Size. Scammon (1874) describes about the body length of the North Pacific right whale that " Its average adult length may be calculated at 60 feet—it rarely attains to 70 feet,—and the two sexes vary but little in size ". This statement was criticized by Tomilin (1957) as having been confused with Greenland whale (*Balaena mysticetus*), but I am not in favor of the Tomilin's opinion.

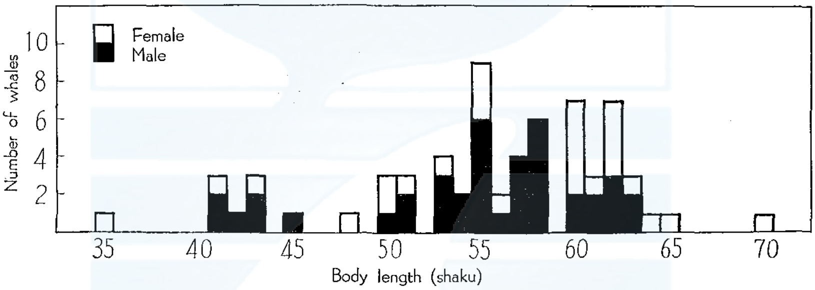


Fig. 3. Size distribution of North Pacific right whales taken in the years 1925-34. (1 Shaku ≒ 1 Foot)

(Based on the data of Matsuura (1936))

Matsuura (1936) presents size distribution of the right whales taken in the adjacent waters of Japan in ten years 1925-34, which is reproduced here in figure 3, in the form of histograms. This figure supports in some extent the above statement by Scammon. Since the Matsuura's account is based upon the catch reports from various whaling companies and he himself did not measured the body length of the whales taken, the body lengths in his account are not deemed as always correct. Nevertheless I don't think that there are great difference, say over 5 feet, from the correct length. Another evidence supporting Scammon's statement is the whale measured by Matsuura himself in 1941. In this year he went to the northern Pacific as an inspector on board the " Tonan Maru ". This expedition took three right whales in which two were measured of their body proportion by Matsuura. He also made some biological observations of the whales taken. These are included in his report briefly (1942). One of these whales was a immature male of 13.6 meter (44 feet 7 inches) long. But another one was a mature female of 17.8 meter (58 feet 5 inches) long. This is the biggest black right whale (*Eubalaena*) ever appeared in scientific papers. The body proportion of these whales are shown in table 7, in addition to two North Pacific right whales measured by ourselves and show a good coincidence to the latter. Hence I believe his measurement is correct. This whale is reported as having attained its sexual maturity, but it contained in its ovaries only one corpus albicans.

The biggest North Atlantic right whale ever recorded is the female captured off the southern coast of Long Island, New York, near the village of Amagansett and reported by Andrews (1908). The body length of this whale was measured by the whalers at the time of capture as 56 feet and 7 inches taken with a tape laterally, from the tip of the snout to end of the" flukes ". But later it was measured by Andrews as 54 feet (16.5 meter) from the tip of the snout to the notch of the flukes, along the mid-dorsal line. This whale was assigned as adult.

According to Collett (1909) the largest of all the North Atlantic right whales taken by Norwegians in the sea to the east of Iceland and around the Faroe Islands, the Shetlands and the Hebrides during the years 1889-1908 was a female taken in 1903 and measured 54 feet (16.4 meters). The average lengths of males and females were 45.8 feet (13.9 meters) and 47 feet (14.3 meters) respectively in 1907 and the corresponding figures in 1908 were 43.8 feet (13.3 meters) and 44 feet (13.4 meters) respectively. Hence larger body length of the North Pacific right whale than that in the North Atlantic is highly probable.

The largest one out of the four southern right whales reported by Matthews (1938) is a female which measured 15.23 meters (50 feet), and shows no remarkable difference in size from the North Atlantic right whale.

I have no sufficient data in relation to the average body length at which sexual maturity is attained in the North Pacific right whales. The body length of the two right whales takes in 1956 for scientific purposes were 11.65 meters (38 feet 3 inches) female and 12.4 meters (40 feet 8 inches) male. Both were sexually immature and no follicle was observed on the surface of the ovaries of the female. Matsuura (1942) reports that his third whale, which was also taken by the " Tonan Maru " expedition in 1941 but body proportion was not measured, as sexually mature. This was a male of 41 feet long. But I don't think his statement as to the sexual condition is correct. He conducted no microscopic examination of the testis of the said whale, nor recorded the weight or volume of the testes.

His 58-foot female had apparently reached its sexual maturity, because this whale contained one corpus albicans in its ovaries. One might imagine that more corpora albicantia be accumulated for this huge size, but we have no other evidence at present to judge whether or not this is an unusual case.

Weight. Weight of various parts of the body of the two North Pacific right whales are already shown in a brief report by Omura (1957). It is reproduced here in table 4.

TABLE 4. WEIGHT OF NORTH PACIFIC RIGHT WHALE

	Ayukawa 1,165cm ♀		Kirittapu 1,240cm ♂	
	Weight in kg	% of total weight	weight in kg	% of total weight
Meat	7,990	34.94	6,622	29.77
Blubber	8,259	36.11	10,030	45.08
Bone, total weight	3,166	13,84	2,921[4]	13.13
Skull	993	4.34	645	2.93
Mandibles	253	1.11	338	1.51
Ribs	368[1]	1.61	487[1]	2.19
Vertebrae	1,109[2]	4.85	935[2]	4.19
Flippers	337	1.47	383	1.73
Scapulae	106	0.46	128	0.58
Viscera, total weight	3,188	13·96	2,435	10.95
Heart	180	0.80	154	0.69
Lung	204	0.90	163	0.73
Liver	216	0.94	109	0.49
Kidney	68	0.29	24[5]	0.11
Stomach	105	0.46	77	0.35
Intestine	381	1.66	279[5]	1.25
Tongue	1,369	6.00	888	4.00
Others	665	2.91	741	3.33
Baleen plates	263	1.15	239	1.07
Total	22,866[3]	100.00	22,247[3]	100.00

1) Include weight of sternum.
2) Include weight of chevrons and innominate bones.
3) Blood is not included in the total weight.
4) Include weight of hyoid.
5) Decomposed heavily.

The Ayukawa whale was killed on May 23rd 1956 and was processed on the following day, in a good fresh condition. The Kirittapu whale was taken on June 30th 1956, but was not treated until June 2nd. Thus about 42 hours has elapsed from the time of killing to the commencement of the treating. Further two grenades exploded in the abdomen at the time of killing. Internal organs went to decay accordingly and meat was not suitable for food. Such difference in freshness should be borne in mind when comparing the weights of these whales.

Meat and blubber were weighed divided in many times after they were cut into pieces, and then these weights were added together according to these items. Bones were weighed separately but they were never sawed into pieces, because skeletons were to be prepared as specimen for later study of osteology. Also were weighed the internal organs separately. Blood was not weighed at all.

TABLE 5. WEIGHT OF NORTH PACIFIC RIGHT WHALE COMPARED WITH SPERM AND SEI WHALES OF SIMILAR SIZE

	Ayukawa specimen (1,165cm)	Sperm whale (1,220cm)	Sei whale (1,220cm)
Total weight in kg	22,866	17,030	10,550
Meat	34.9%	33.4%	57.7%
Blubber	36.1 〃	33.0 〃	17.8 〃
Bones	13.8 〃	9.9 〃	13.4 〃
Internal organs	14.0 〃	9.5 〃	9.1 〃
Others	1.2 〃	14.2 〃	2.0 〃

TABLE 6. THICKNESS OF BLUBBER OF NORTH PACIFIC RIGHT WHALE

Positions of the body measured	Ayukawa whale 1,165cm ♀		Kirittapu whale 1,240cm ♂	
	in cm	‰ of body length	in cm	‰ of body length
On the lateral line of the body				
at the level of earhole	13.5	11.6	—	—
〃 tip of flipper	—	—	13.0	10.5
〃 umbilicus	15.0	12.9	15.0	12.1
〃 reproductive aperture	—	—	15 0	12.1
〃 anus	13.0	11.2	14.5	11.7
On the ventro-median line of the body				
at the level of angle of gape	21.0	18.0	—	—
〃 umbilicus	17.0	14.6	—	—
〃 30 cm after anus	23.0	19.7	—	—

Total weights of the Ayukawa and Kirittapu whales are about 23 and 22 metric tons respectively, instead of the body length of the latter is longer than the former by 75 cm. Only blubber is heavier in the Kirittapu whale. This is possively due to the fact that blubber is affected very slowly by decomposition of the body. Lighter weight of bones in the Kirittapu whale is due one part to the fact that all meat had removed from the bones cleanly, and another to the lesser amount of oil contained in bones because of decomposition of the body. It is also possible that the weights of meat and internal organs of the Kirittapu whale are much lighter than the actual weight in fresh condition.

In table 5 the weight of the Ayukawa whale is compared with sperm and sei whales of similar size, calculated by Omura (1950). It is clear that the North Pacific right whale is much heavier than these species.

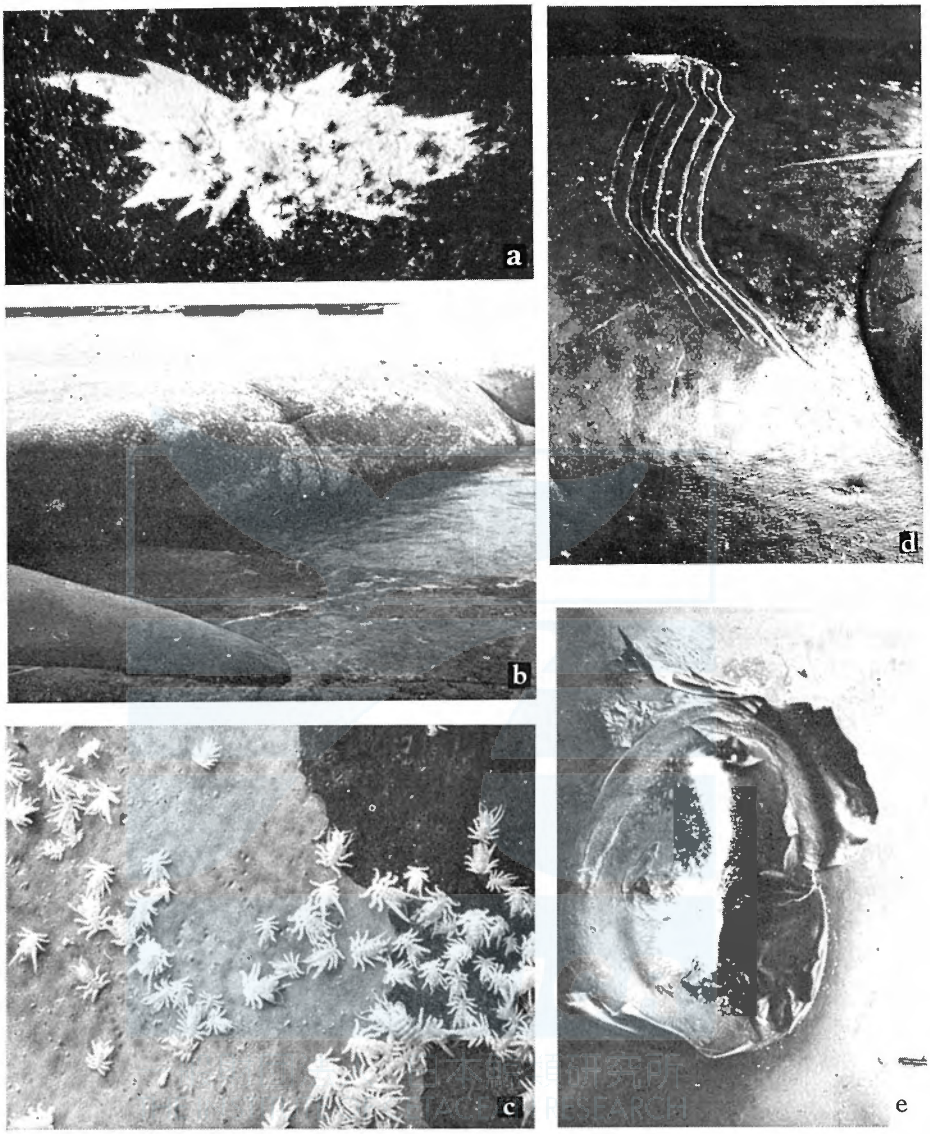


Fig. 4. a. White patch over the umbilicus of Ayukawa whale. Whale lice are also seen all over the skin. b. Ayukawa whale. Note the whale lice infecting all over the body. The transverse gloove across the genital aperture was caused by chain while towing by catcher. c. Amphipod crustaceans on the skin of the Ayukawa whale. d. White linear scars on the skin of the Ayukawa whale. Tip of the right flipper is seen on the right. e. Oval white scar on the left lip of the Kirittapu whale (long axis horizontal).

Thickness of blubber. Thickness of bubber was measured at various points, as shown in table 6. The thickness exceeds 1.0 per cent of the body length in any point where measurement was taken place. In blue and fin whales thickness of blubber accounts about 0.5 per cent of the body length, measured at the lateral side midway between the dorsal fin and the anus. It is obvious that the balaenid whales have much thicker blubber than the balaenopterid whales.

EXTERNAL CHARACTERS

Color. The Ayukawa and Kirittapu whales were both completely pigmented a dark blue-black except that the former had a white patch over the umbilicus (fig. 4a). The latter had uniform color throughout the body. True (1904) summs up the body color of the then known specimens of the North Atlantic right whale as follows: "Three specimens of the European Nordcaper are recorded as being entirely black, and the Iceland specimens were also black, with the exception of one young one, which was reported to the lighter colored on the belly. Of three American specimens, two are recorded as entirely black, and one (adult female) as having 'a great deal of pure white on its under side'". Collett (1909) describes that a uniform black must be considered to be the typical color, covering the entire body without any great differences of shade, but in some specimens more or less of the ventral surface is white. And according to him 20 per cent of 50 specimens captured in the course of the last three years (1906–1908) in the North Atlantic by Norwegians were white-bellied. He also presents a good photograph of white-bellied female. Andrews (1908) reports that his Amagansett whale was everywhere dense ivory-black with the exception of the flukes and flippers and the region immediately surrounding the genitalia, where there were numerous milk-white patches varying in diameter from two to fourteen inches. According to Matthews (1938) all three southern right whales whose color was noted at South Africa and South Georgia had conspicuous white marking on the belly, varying in shape and size. But he mentions that Lonneberg (1906) records white patches on two out of seven southern right whales examined at South Georgia.

The foregoing facts may lead to a conclusion that the typical color is uniform black, but some specimens more or less white-bellied, in the North Atlantic and probably also in the southern right whales.

The white patch on the umbilicus of the Ayukawa whale is an irregular ellipse in shape and rather small, its long and short axes being 45 and 21 cm respectively. This white patch is not possibly due to the alteration of the skin produced by parasitic cirripeds. We have no other recent record on the body color of the North Pacific right whale. Scammon (1874) describes however that the color is generally black, yet there are many individuals with more or less white about the throat and pectorals, and sometimes they are pied all over. Ohtsuki (1951) notes that the "Semi" or "Semi-kujira", North Pacific right whale, is black all over the body, except belly where white. He also published a figure of white bellied one. His book entitled "Geishiko" (On whales) was published in an early days of the nineteenth century and the exact date is unknown. It was reproduced, however, in 1951 by the Japan Whaling Association for the reference to the people concerned. These suggest that there may be a similarity of body color among right whales from the North Pacific, North Atlantic and southern hemisphere.

Scar. The Ayukawa and Kirittapu whales had white linear scars on their bodies. These scars were noted in the Ayukawa whale in groups of several lines at four different parts of the body. The most remarkable scars (fig. 4d) were on the skin just behind the right flipper. As shown in this figure these scars were consisted of six lines, running down parallel from the level of the axilla and obliquely forward at the belly. Other three groups were on the left side of the tail, also in groups of similar but shorter lines. In the Kirittapu whale these lines were observed almost all over the body. Collett (1909) also noted such white stripes on the skin in most, though not all, of the specimens of the North Atlantic right whale he observed, running in all directions, and measuring up to one meter in length and about 50 mm wide. He thought these stripes may have been produced by the rubbing of the animal against the bottom when following the plankton-crustaceans upon which it feeds. But it is thought more probable that these may be the scars caused by biting of killer whales, judged from figure 4 d. In addition to these linear scars the Kirittapu whale had a wound, incompletely healed, 150 cm in length and about 10 cm in depth, similar to that caused by a harpon, near the flank on the right side of the body.

The oval white scar which generally seen on the skin of the balaenopterid whales was not detected from these right whales, except one on the left lip of the Kirittapu whale (fig. 4 e).

External parasite. The Ayukawa and Kirittapu whales were thickly infected by whale lice, amphipod crustaceans (figs. 4 b, 4 c), but in lesser extent in the latter specimen. The body color of the former was looked as if having yellowish-brown pigment over the whole body at the first sight when it was hauled up through slip-way to the flensing platform of the landstation. Thus the whale was covered by lice almost whole body, but most thickly on the so-called "bonnet" and similar callosities on the lower jaw, and around the genital aperture. The Kirittapu whale was also infected thickly, but in lesser extent on the flank. The whale lice on the "bonnet" or other callosities of the Ayukawa whale were yellowish-white in color; elsewhere they were yellowish-brown. All of these lice on this whale were identified as *Cyamus ceti* by Mr. T. Nemoto of the Whales Research Institute. In addition to this species *C. ovalis* was also detected on the Kirittapu whale by him, but the gill of these specimens is said as somewhat different from published descriptions. Studies on these problems will be reported by somebody else.

No other external parasite, such as *Coronula*, *Conchoderma* or *Pennella* was detected from these whales, nor was diatom infection visible to the naked eye. No diatoms have so far been detected on samples of skin which were collected.

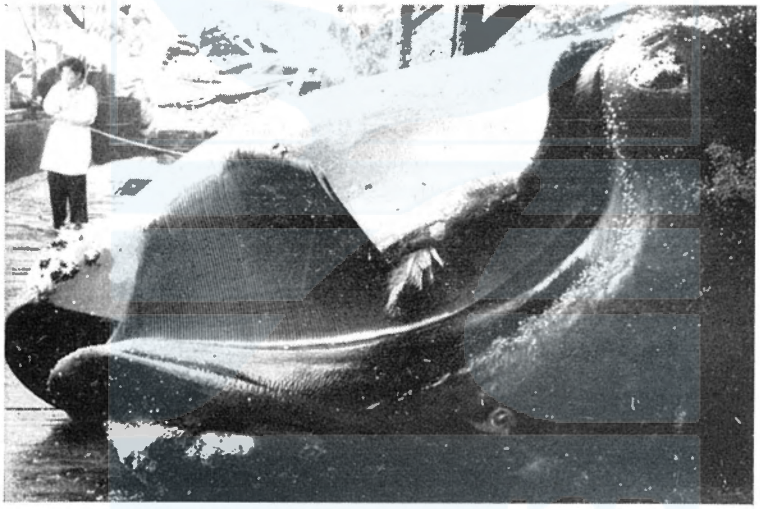


Fig. 5. Ayukawa whale. Bonnet and other callosities on the upper jaw.

Head. In the Ayukawa whale the "bonnet", the largest and most anterior callosity on the upper jaw, begins from a point 20 cm behind the tip of the upper jaw (fig. 5). It is oval in outline and its length is about 75 cm. A group of much smaller callosities occupies the mid-line of the rostrum between the bonnet and the blow-holes, behind which lies a pair (fig. 6). The region of the blow-holes is slightly elevated above the general level of the head. The blow-holes are 27 cm long along the curve, and diverging anteriorly 10 cm and posteriorly 37 cm (fig. 6).

The lower lip of this whale had a maximum depth of 117 cm. There was a further group of callosities in line on each side of the lower jaw, starting just behind the tip and running towards the gape. The most anterior one was the largest and irregularly outlined, long axis being

36 cm. A line of another three small callosities runs back towards the gape, their outlines being circle in the 2nd and 3rd and the 4th oval. Their lengths were 7, 6.5, and 7.5 cm respectively. Breadth of the 4th was 6 cm. The length from the tip of the lower jaw to the centers of the 1st, 2nd, 3rd, and 4th callosities, measured in straight line along the axis of the whale body, were 20, 32, 59, and 112 cm respectively. The 2nd situated just behind the 1st (figs. 7 a, b). In addition to these callosities there was another one callosity, nearly circular in shape, on each side of the head just above the eye (fig. 5). Its size is larger than those on the mandible, except the first, but smaller than the " bonnet ". All these callosities were thickly infected with cyamids of different sizes.

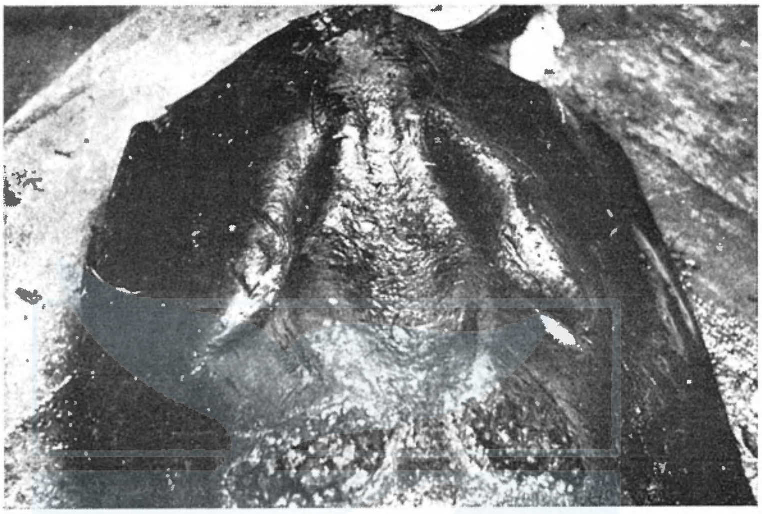


Fig. 6. Blow-holes of the Ayukawa whale. Obliquely posterior view. Note two callosities behind the nostrils.

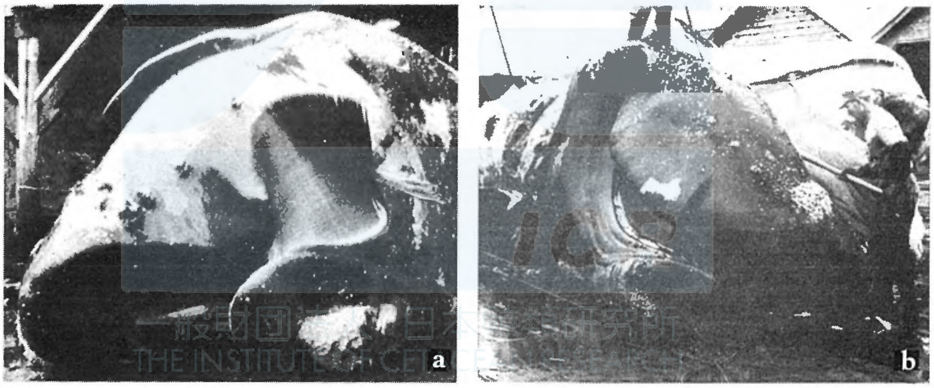


Fig. 7. a. Ayukawa whale. Note four callosities on the lower jaw. b. Kirittapu whale. Note five callosities on the lower jaw.

The anterior portion of the Kirittapu whale presented the same general appearance, except that the number of callosities on the mandible. There was one more callosity behind the 4th, on the same level, as shown in figure 7 b. This was similar in shape and size with others, except the first. These callosities were situated with more fairly constant distance from each other than the Ayukawa whale.

In the Ayukawa whale the distance from the 3rd to 4th is nearly the double of that from the 2nd to 3rd, measured in straight line along the body axis. It is possible, therefore, that the arrangement of these callosities with a fairly constant spacing, as seen in the Kirittapu whale, is typical and in the Ayukawa whale the 4th was lacking, being renumbered the present 4th as 5th.

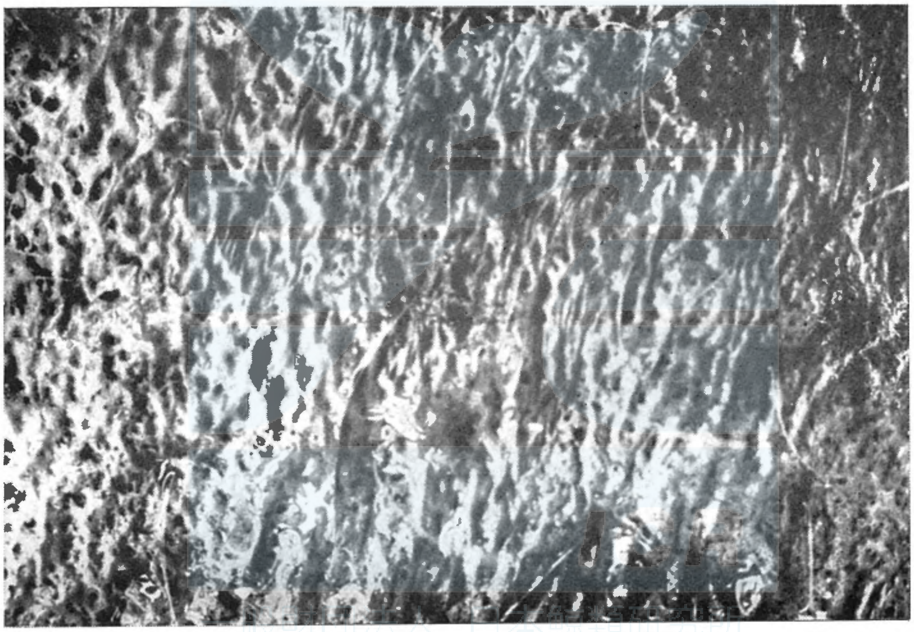


Fig. 8. Ayukawa whale. Hairs on the chin.

Hair occurred on the head of both whales, on the rostrum as well as on the mandible. In the Ayukawa specimen a group of about 160 hairs was observed on the chin (fig. 8), and each one in the center of the 2nd, 3rd, and 4th callosities on the mandible. In the Kirittapu whale hairs were observed as follows: 27 in front of the "bonnet", 11 just before the blow-hole, 20 after the blow-hole, 118 on the chin, 3 in the 1st callosity, and each one in the center of the other callosities on the mandible.

The "bonnet" and other callosities on the right whales from the North Atlantic and southern hemisphere had long been an object of speculations. The cause of the formation was thought as: an excreascence formed by the adhesion of *Coronula*, irritation of the whale louse, due to disease of the outer layers of integument, and produced by the animal rubbing itself against rocks in order to get rid of the barnacles. Ridewood (1901) concludes that the bonnet would appear to be a circumscribed area of skin, where, for some reason not apparent, the cornified layers fail to rub off at their normal rate, but remain and accumulate to produce a hard mass, projecting above the general surface of the epidermis as a kind of corn. This opinion, however, was proved not to be the case by Matthews (1938), after examining microscopic sections prepared from well-preserved material. He states further that on two occasions different members of the Discovery Staff, when examining right whales, noted that the callosities on the mandible "may have marked the position of hairs", and "their appearance suggested that they may have been occupying the position of hair follicles". Further he describes that the occurrence of fully developed callosities in whale No. 1020, a sucking calf, shows that they are congenital and not developed after adult life is reached.

The presence of hair in the mandibular callosities in our two specimens, sexually immature male and female, well supports the observations of the Discovery Staff. Further the arrangement of the "bonnet" and other callosities in our specimens is exactly similar in general to those in whales from the North Atlantic reported by Andrews (1909), and from the southern hemisphere reported by Matthews (1938).

Body proportion. The body proportions of the Ayukawa and Kirittapu whales were shown in table 7, in actual length in cm as well as percentages against the total body length. In this table also shown the body proportions of two North Pacific right whales taken by the "Tonan Maru" expedition in 1941 and reported by Matsuura (1942) for reference. Catch particulars of these whales are as follows:

Date of catch	*Position of catch*	*Body length in feet*	*Sex*
June 10 1941	48°27′ N, 157°51′E	58	F
June 11 1941	48°23′ N, 159°29′E	45	M

Only four North Pacific right whales shown in table 7 were measured of their body proportion until at present, though there are twelve specimens from the North Atlantic and five from the southern hemisphere to my knowledge. These are listed in table 8, arranged in the order of their body length and according to the geographical areas.

In figures 9, 10 and 11 are shown the body proportions of right whales from the North Pacific, North Atlantic, and southern hemisphere, by different symbols, which show percentages of each measurements against the body length of the respective whales. I calculated the percentages of the specimen reported by various authors, in case no proportion was given by the author.

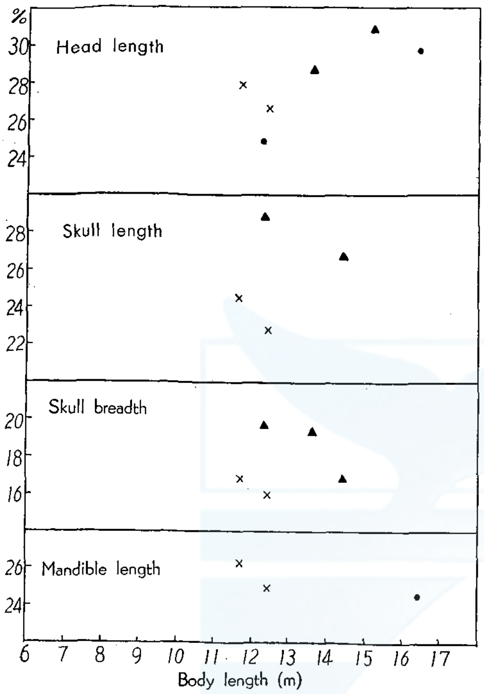


Fig. 9 a. Body proportion of right whale (1)

× North Pacific right whale.
● North Atlantic 〃 〃
▲ Southern 〃 〃

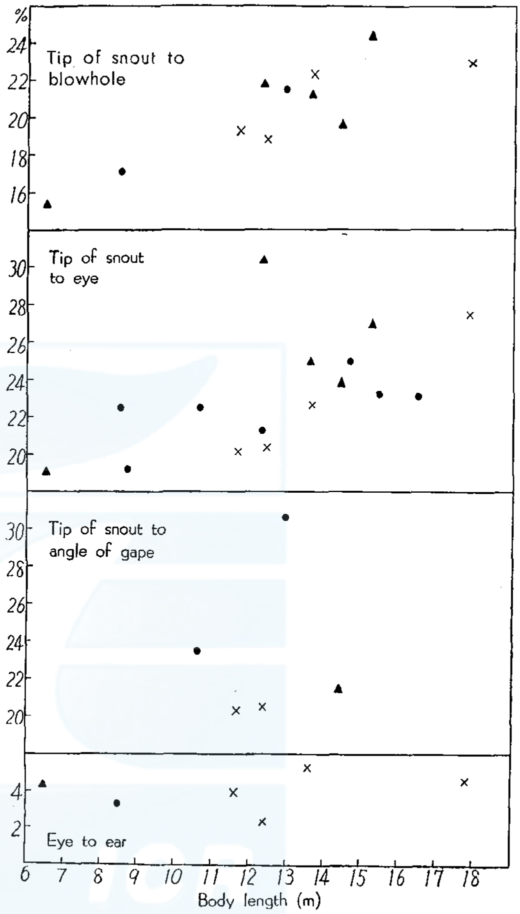


Fig. 9 b. Body proportion of right whale (2).

Proportions of various parts in the anterior portion of the body are given in figures 9. a and 9 b. Some abnormal value are seen in these figures, i. e. each one in the 2nd figure (tip of snout to eye) and the 3rd (tip of snout to angle of gape) from the top in figure 9. b. These are one from the southern hemisphere and one from the North Atlantic. Otherwise no significant difference is noted among whales from the three different oceans. Further it seems that the head length, lengths from tip of snout to blowhole and from tip of snout to eye increase their proportion according to the growth of body, as generally seen in the other species of whales.

Body proportions in the posterior portion of body are shown in figure 10 a, i. e. lengths from notch of flukes to umbilicus, from the same to anus, and anus to reproductive aperture, in three figures. Also some exceptional value are seen in these figures. But these are presented by single whale from the Southern Ocean, reported by Matthews (1938).

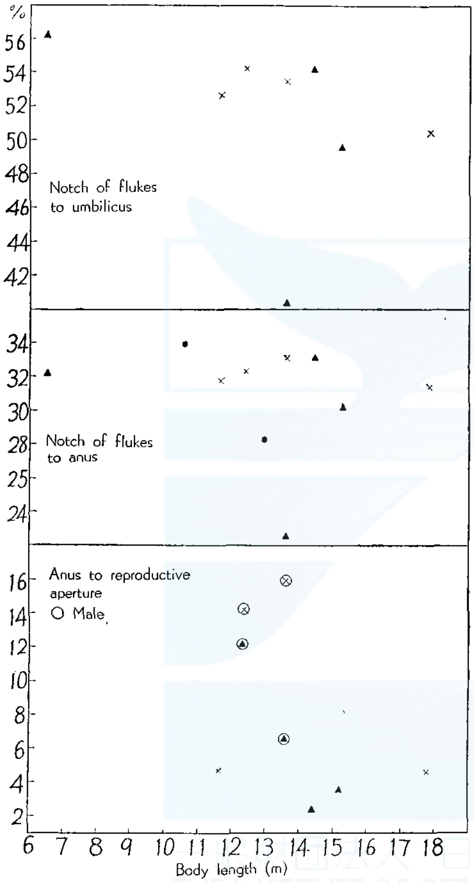


Fig. 10a. Body proportion of right whale (3).

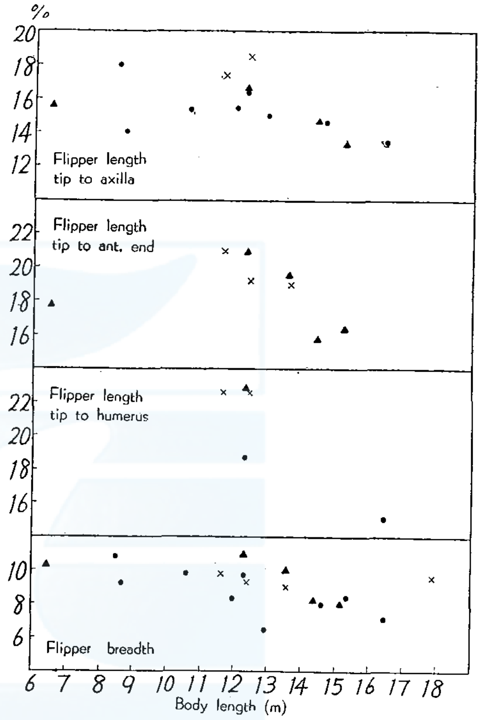


Fig. 10b. Body proportion of right whale (4).

× North Pacific right whale
● North Atlantic 〃 〃
▲ Southern 〃 〃

This is No. 503 whale, a male of 13.54 meters long, and was measured at South Georgia. This whale shows much lower value than other whales in these three parts, though in other parts no abnormality is noted. Excepting this whale, we may conclude that there is no difference of proportion in the posterior part of the body among right whales from three different oceans. Further it is probable that the proportion of the length from notch of flukes to umbilicus against total body length decreases according to the growth of the body, as seen in the other species

TABLE 7. BODY PROPORTION OF NORTH PACIFIC RIGHT WHALE.

Measurements	Ayukawa ♀ immature		Kirittapu ♂ immature		Tonan Maru[1] ♂ immature		Tonan Maru[1] ♀ mature	
	in cm	%	in cm	%	in cm	%	in cm	%
Total length of body	1,165	100.0	1,240	100.0	1,360	100.0	1,780	100.0
Lower jaw, projection beyond tip of snout	30	2.6	40	3.2	—	—	—	—
Tip of snout to blowhole (centre)	225	19.3	233	18.8	305	22.4	409	23.0
Tip of snout to angle of gape	237	20.3	256	20.6	—	—	—	—
Tip of snout to centre of eye	235	20.2	253	20.4	309	22.7	490	27.5
Tip of snout to anterior insertion of flipper	270	23.2	290	23.4	—	—	—	—
Tip of snout to axilla	347	29.8	340	27.4	—	—	—	—
Centre of eye to centre of ear	46	3.9	30	2.4	72	5.3	82	4.6
Notch of flukes to posterior emargination of dorsal hump	416	35.7	—	—	—	—	—	—
Notch of flukes to centre of anus	370	31.8	400	32.3	450	33.1	559	31.4
Notch of flukes to umbilicus	613	52.6	672	54.2	728	53.5	899	50.5
Centre of anus to centre of reproductive aperture	55	4.7	176	14.2	218	16.0	82	4.6
Width of flukes at insertion	125	10.7	—	—	—	—	—	—
Notch of flukes to the nearest part of the anterior margin of the flukes	112	9.6	115	9.3	—	—	—	—
Tail flukes, total spread	483	41.5	—	—	—	—	—	—
Tail flukes, tip to notch	237	20.3	245	19.8	—	—	—	—
Flipper, tip to axilla	203	17.4	229	18.5	—	—	—	—
Flipper, tip to anterior end of lower border	245	21.0	238	19.2	245[2]	18.0[2]	—	—
Flipper, tip to head of humerus	263	22.6	280	22.6	—	—	—	—
Flipper, greatest width	114	9.8	115	9.3	124	9.1	171	9.6
Head length, condyle to tip of snout	325	27.9	330	26.6	—	—	—	—
Skull length, condyle to tip of premaxilla	285	24.5	283	22.8	—	—	—	—
Greatest breadth of skull at orbits	197	16.9	198	16.0	—	—	—	—
Length of mandible (straight)	307	26.4	310	25.0	—	—	—	—
Circumference in front of flippers	676	58.0	746	60.2	—	—	—	—
〃 at umbilicus	686	58.9	780	62.9	—	—	—	—
〃 〃 anus	484	41.5	510	41.1	—	—	—	—
〃 〃 caudal terminus or "small"	170	14.6	184	14.8	—	—	—	—
Depth of body at umbilicus	175	15.0	258	20.8	—	—	—	—
〃 middle of insertion of flipper	209	17.9	—	—	—	—	—	—
〃 anterior insertion of flipper	—	—	245	19.8	—	—	—	—

1) Cited from Matsuura (1942). Lengths in cm were calculated from percentages.

2) Along the lower border.

of whales. The length from anus to reproductive aperture is much greater in male than female in the black right whales too.

TABLE 8. LIST OF RIGHT WHALES MEASURED BY VARIOUS AUTHORS

Body length (cm)	Locality and year		Sex	Authority
	Pacific Ocean			
1,165	Ayukawa, Japan.	1956	♀	Present author
1,240	Kirittapu, Japan.	〃	♂	〃
1,360	South of Kamtchatka.	1941	♂	Matsuura, 1942
1,780	〃	〃	♀	〃
	Atlantic Ocean			
848	Long Island, U.S.A.	1908	♀	Andrews, 1909
869	San Sebastian, Spain.	1853		Fisher, 1871[1]
1,059	Provincetown, U.S.A.	1909	♀	Allen, 1916
1,199	Taranto, Italy.	1877	♀	Capellini, 1877[1]
1,227	Wainscott, U.S.A.	1907	♀	Andrews, 1908
1,229	Charleston, U.S.A.	1880	♂	Manigault, 1885[1]
1,293	Cape cod, U.S.A.	1895	♂	Allen, 1916
1,318	East of Iceland.	1889	♀	Guldberg, 1891[1]
1,463	Egg Harbor, U.S.A.	1882	♀	Holder, 1883[1]
1,543	Ré Island, France.	1680	♀	Sequette, 1682[1]
1,615	Cape Lookout, U.S.A.	1894	♀	Brimley, 1894[1]
1,646	Amagansett, U.S.A.	1907	♀	Andrews, 1908
	Southern Ocean			
650	South Africa.	1926	♂	Matthews, 1938
1,232	South Georgia.	〃	♂	〃
1,354	〃	〃	♂	〃
1,440	〃	1931	♀	〃
1,523	South Africa.	1926	♀	〃

1) Cited from True (1904)

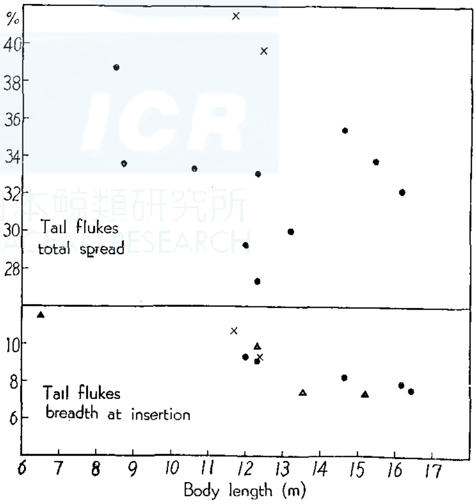


Fig. 11. Body proportion of right whale (5)

× North Pacific right whale
● North Atlantic ,, ,,
▲ Southern ,, ,,

Figure 10 b. concerns solely to proportions of flippers. The breadth shows fair coincidence each other. As regards to the length of flipper however it seems that the North Pacific specimens have greater value than those from the North Atlantic, if not to those from the Southern Ocean. Andrews (1908) published a photograph of inferior surface of left pectoral fin of the Amagansett whale, which is outlined in figure 12, compared with that of the Kirittapu whale.

It is obvious that the Kirittapu whale has a more pointed flipper at its distal end. The

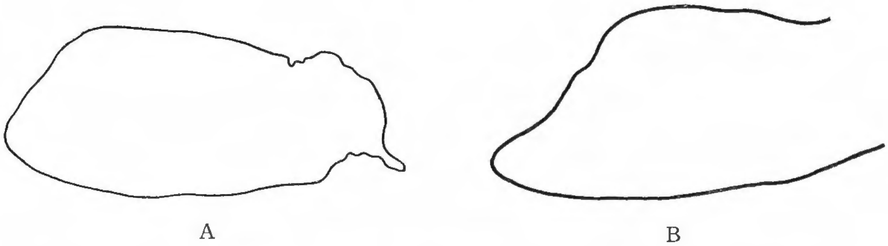
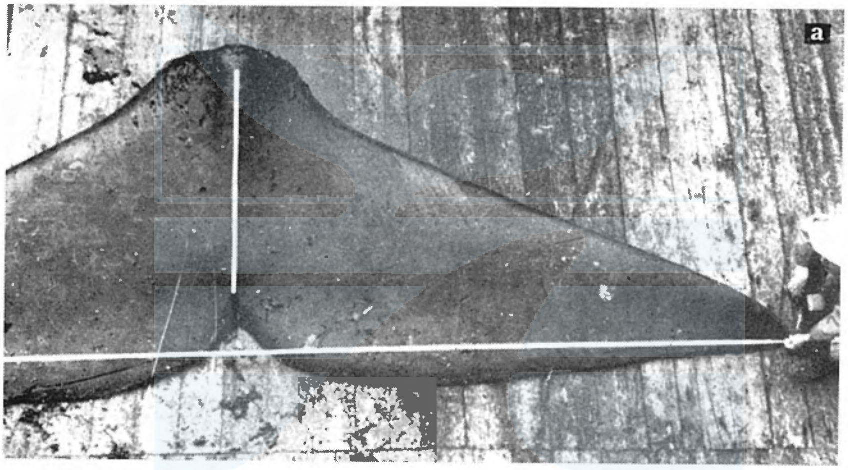


Fig. 12. Flipper of right whale. (Inferior view).

A. North Atlantic right whale. Outlined from photograph (Andrews, 1908)
B. North Pacific right whale. Kirittapu whale.



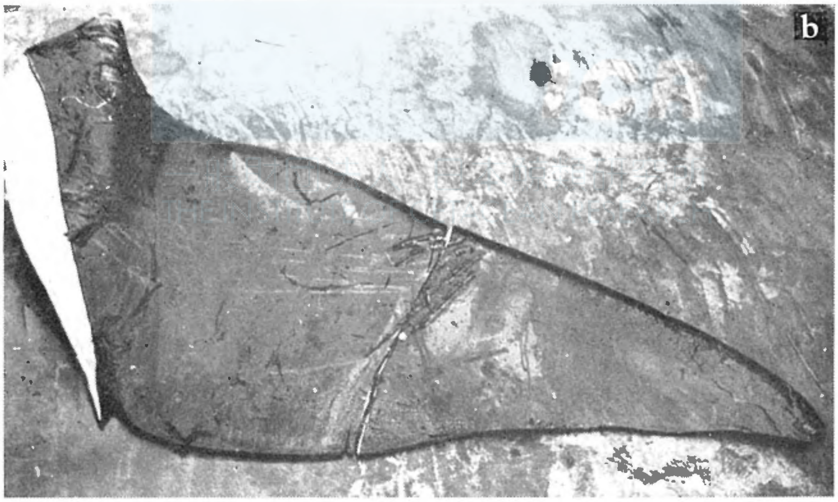


Fig. 13a. Tail fluke of the Ayukawa whale.

Fig. 13b. Right tail fluke of the Kirittapu whale.

Ayukawa whale presented the same general appearance in flipper as the Kirittapu whale. But according to photographs published by Collett (1909), a black-bellied male (plate XXV of his account) is suggested to have obtuse flipper as that of the Amagansett whale and a white-bellied female (plate XXVII of his account) pointed one as that of the Kirittapu whale. Matthews (1938) also presents a number of photographs of the southern right whale and his No. 3560 whale (plate XIII, fig. 2 of his report) is also suggested to have a pointed flipper. It is possible, therefore, that these shapes of flipper should not be deemed as a specific character, nor a difference according to the local race. It is thought that this is only an individual difference (or injured?) and further no correlation is observed according to sex.

Relative size of tail flukes against the total body length is shown in figure 11. The North Pacific specimens seem to have larger tail flukes than those from other oceans, judged from the upper figure in figure 11, which shows the total spread of tail flukes. But there is a wide individual variation and nothing particular may be drawn as to the difference among whales from three different oceans. The breadths at insertion of the tail flukes agree fairly well in the specimens plotted here and it is suggested that the proportion of this breadth decrease with growth of body. In figures 13 a and b are shown the photographs of the tail flukes of the Ayukawa and Kirittapu specimens.

BALEEN AND FOOD

Baleen. Baleen plates numbered 228 on the right side and 236 on the left in the Ayukawa whale and 257 on the right and 259 on the left in the Kirittapu whale. Matthews (1938) records two instances of the southern right whales whose number of plates were examined. These are 235 and 227 on one side. Hence there is no difference between the North Pacific and southern right whales in this respect.

In the Ayukawa whale the longest plate was 89 cm long, from the gum to tip along the outer edge, exclusive of the bristles, and 11.8 cm wide at the gum, and in the Kirittapu specimen the longest was 90 cm long and 14 cm wide. These lengths and widths were measured at the time of the treating of the whale body at the respective landstations. Then each one from each ten group in the row of baleen plates, i.e. 10th, 20th, 30th, etc., were preserved for further study, both from right and left sides for the both specimens. Later these baleen plates were measured at our laboratory, in the following three parts: a. length from the tip, exclusive of the bristles, to the insertion of gum on the inner edge; b. length from the same to a point on the outer edge cut by a line, drawn parallel with ridges of the plate from the insertion of gum on the inner side; c. width of plate between two points on the inner and outer edges mentioned above.

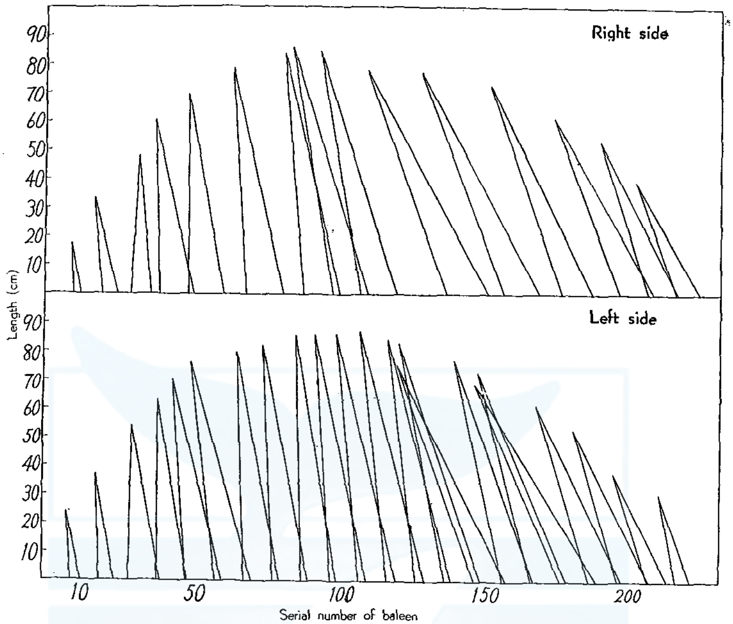


Fig. 14. Sizes of baleen plates selected one from each ten series. Ayukawa whale.

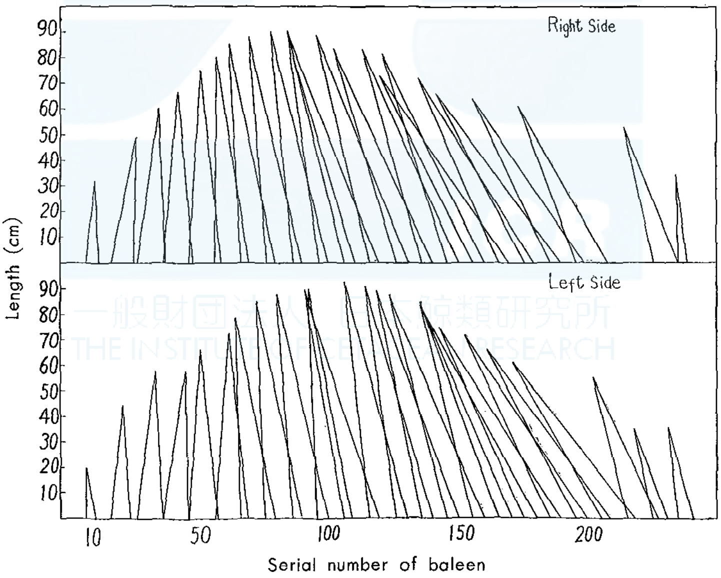


Fig. 15. Sizes of baleen plates selected one from each ten series. Kirittapu whale.

Figures 14 and 15 show the sizes of baleen plates of two specimens, based on these measurements, as well as the variation of sizes according to serial numbers.

Figure 16 a shows a photograph of the selected baleen plates of the Ayukawa specimen, and figure 16 b the Kirittapu specimen. As seen in these photographs some differences are noted between two specimens. In the Kirittapu specimen baleen plates in the anterior portion are bending inward and those in the posterior portion outward more strongly than the Ayukawa whale (compare the 20th and 170th plates in figures 16 a and b). It can not be concluded however, whether or not this is a difference according to sex for lack of more material.

Fig. 16 a. Left baleen plates of the Ayukawa whale. ♀
From left to right: formost one, 20th, 70th, 120th, 170th and two from after portion.

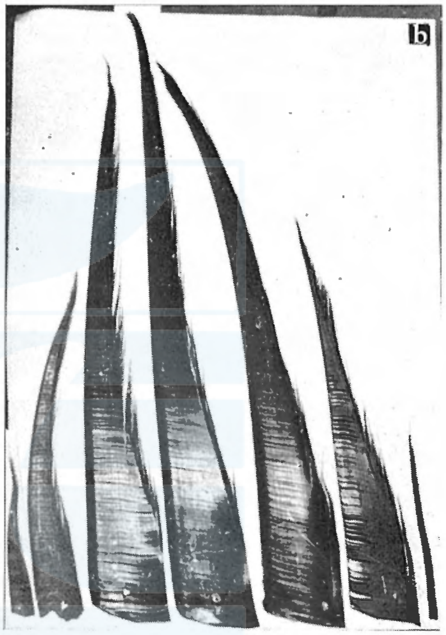


Fig. 16 b. Left baleen plates of the Kirittapu whale. ♂
Left to right: foremost one, 20th, 70th, 120th, 170th, 220th and aftermost one.

In the Ayukawa whale the largest plate among the baleen specimens preserved is the 100th of the right side which measures 101.5 cm long from the base to tip, exclusive of bristles, and its width at base 12.7 cm. In the Kirittapu whale the longest is the 120th of the left side which measures 106.6 cm long and 14.2 cm breadth. The thickness at base is 0.5 cm in both samples. The longest bristle measured 22.5 cm. True (1904) reports that four baleen plates which may be assigned to the North Pacific right whales are kept in the National Museum, Washington, and the longest among them measures 8 feet 6 inches (259 cm). This is much longer than our specimens and longer than any of the baleen plates reported from the North Atlantic right whales. This will support my opinion that the North Pacific right whale may bigger than that from the North Atlantic, mentioned in the item of size.

The color of the baleen plates are uniform grayish-black in both whales. True (1904) describes that the aforecited whalebone in the National Museum is entirely black. Tomilin (1957) also reports that his specimen from the North Pacific is blackish in color. According to Andrews (1908) the baleen of the Amagansett specimen, including both plates and bristles, was deep blue-black in color, with the exception of the anterior portion, where for a distance backward of 18 inches, the bristles and extreme bases of the plates were pure white. Collett (1909) also reports that in some specimens from the North Atlantic a few of the foremost plates were white. Such white coloration is not observed in our specimens, nor in literatures cited above. It may naturally be premature to conclude here that such white coloration never occur in the North Pacific right whale.

Food. The Ayukawa whale had an almost empty stomach, and what food remained was half-digested. Examined microscopically by Mr. T. Nemoto of our institute, the contents were considered to the largely *Calanus plumchrus* mixed with some *C. finmarchicus* and *Euphausia pacifica.* The stomach of the Kirittapu whale was almost empty also, and all that could be scraped out could just go into the palm of a man's hand. The scrapings were identified by him as a mixture of *C. plumchrus*, *C. cristatus* and *C. finmarchicus*, and most was *C. plumchrus.* Matsuura (1942) describes that among three right whales taken in 1941 by the " Tonan Maru " expedition in the northern Pacific two were empty and the third contained a small amount of *C. plumchrus* in its stomach. Collett (1909) states that the food of the North Atlantic right whale, both in the Hebrides and off Iceland, was found to be exclusively pelagic crustaceans (the " krill " of Norwegian whalers), a Euphausiid about half an inch long, probably *Boreophausia inermis.* According to Matthews (1938) one southern right whale was recorded as containing some fairly fresh food (krill, *Euphausia superba*) and a lot of darkish fluid. He (1932) also recorded how the southern right whale feeds on shoals of the pelagic *Grimothea* postlarva of *Munida gregaria* off the coast of Patagonia. It may be concluded, therefore, that the right whales from three different oceans are all live on planktonic crustaceans.

REPRODUCTIVE ORGANS

Only a little information was obtained on the reproductive organs from the Ayukawa and Kirittapu whales. The former specimen, a female of

38 feet in body length, was still sexually immature. The genital groove was closed and nothing could seen of the genitalia, but the presence of the virginal band was ascertained, running antero-posteriorly across the entrance to the vagina. In course of dismembering of the whale body a mass consisted of ovaries, uterine cornua, vagina, and ligamentum was put aside for preservation as sample for further study. But unfortunately this mass was thrown into cooker by somebody. It was observed however by myself that these ovaries are still immature and no follicle was seen on their surface.

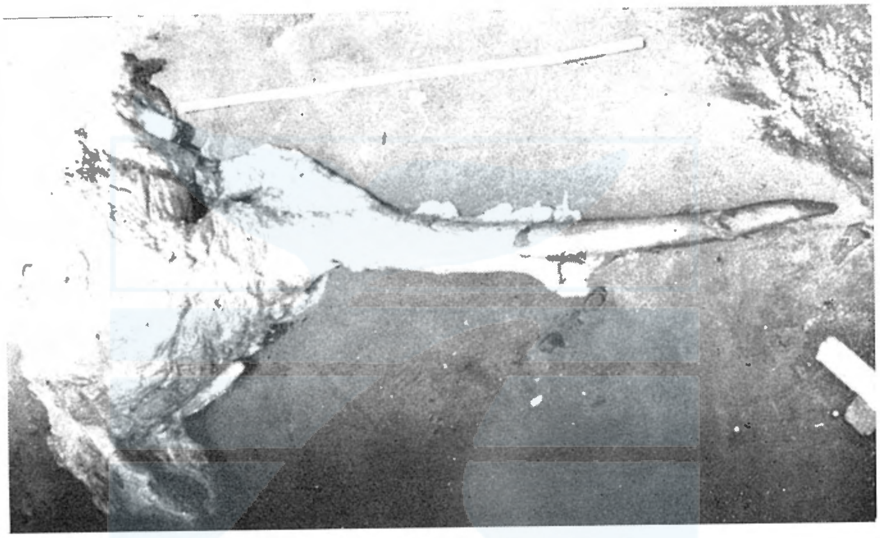


Fig. 17. Penis of the Kirittapu whale.

In the Kirittapu whale, a male of 41 feet long, the penis was completely withdrawn into the cavity within the genital groove. After flensing it was secured as sample (fig. 17). It was long and slender, being different in shape from those of balaenopterid or sperm whales.

Collett (1904) published a photograph of a male from the Hebrides (plate XXV of his account). Body length of this whale is not given in his account, but, it is possible that this whale is bigger than the Kirittapu specimen, judged from a man standing nearly to the whale in the picture. In this whale the penis is extruded of its major parts from the cavity and its shape is also long and slender, having a strong resemblance to that of the Kirittapu whale.

The penis of the Kirittapu whale was frozen and later was shipped from the landstation to Tokyo, but unfortunately it was decomposed because it was transported as a usual cargo by mistake.

The testes had already putrefied at the time of dismembering, so that histological examination was impossible, but they were judged as sexually immature by the staff of the Whales Research Institute examined.

OSTEOLOGY

Both skeletons of the Ayukawa and Kirittapu whales were preserved as specimen. All vertebrae, including chevron bones, of the former whale were however damaged greatly by mistake at the time of processing, being thrown into a cooker. Skull, ribs, scapullae and bones of flippers of this whale are now in the " Ayukawa Whale Museum ". A perfect set of skeleton was obtained from the latter whale, which has been kept at the " National Science Museum, Tokyo ". The skull of the Ayukawa whale is somewhat broken because of grenades which hit inferior part of the head at the time of killing. In this account, therefore, is dealt mainly the skeleton of the Kirittapu whale.

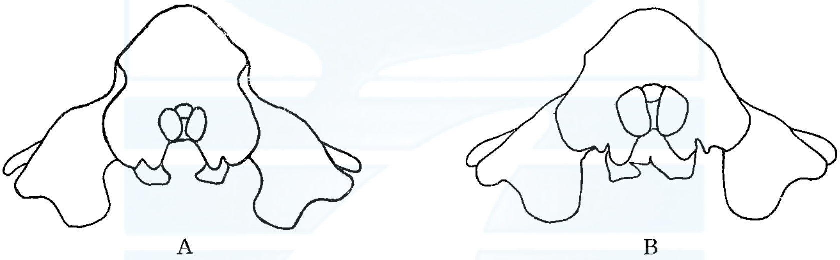


Fig. 18. Skull of right whale (Posterior view)
A. North Atlantic specimen. Outlined from drawing (Allen, 1908). Length 3,650 mm
B. North Pacific specimen. Kirittapu whale. Length 3,230 mm

Skull. The skulls of the two black right whales from the coast of Japan (pls. II–IV) resemble in general appearance to those from the North Atlantic. But there are some difference in visual comparison. The one is the direction of the mastoid processes of the temporals. J. A. Allen (1908) published a picture of occipital view of skull of the North Atlantic right whale (48 feet long) taken at Provincetown, Mass., in April, 1864. In this picture mostoid processes of right and left temporals are directed obliquely inward and two lines along each inner surface of the processes meet with an angle of about 50° (fig. 18 A). In the Ayukawa and Kirittapu specimens, however, the processes directing downward and two lines along each inner surface of the processes run nearly parallel from each other (pl. III and fig. 18 B). This is the most remarkable difference in visual comparison between specimens from two different oceans. But there is a possibility that this is only a difference according to age. Skull length of these three specimens are 3,650, 3,022 and 3,230 mm respectively.

In profile the Japanese specimen (pl. IV fig. 1) has less curved rostrum than two skulls presented by True (1904). But the Provincetwon specimen, cited above, has also less curved rostrum than the True's specimens. The shape of the rostrum of the Japanese specimen agrees with that of the Provincetown specimen in this point, but it seems that the latter is much slender, comparing the figure given by Allen and plate 4.

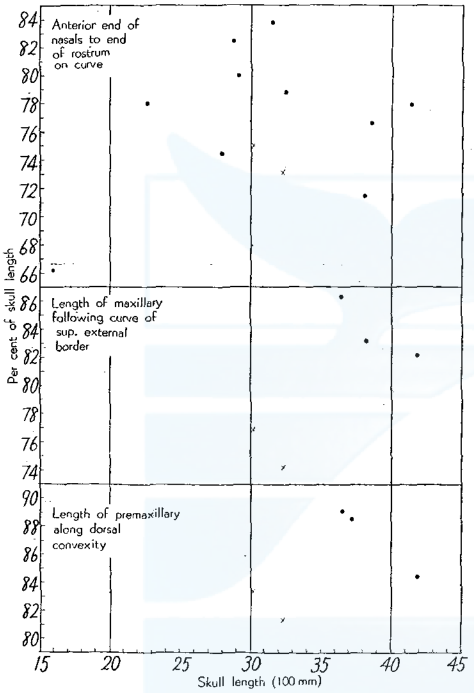


Fig. 19a. Measurements of skull of right whale (1).

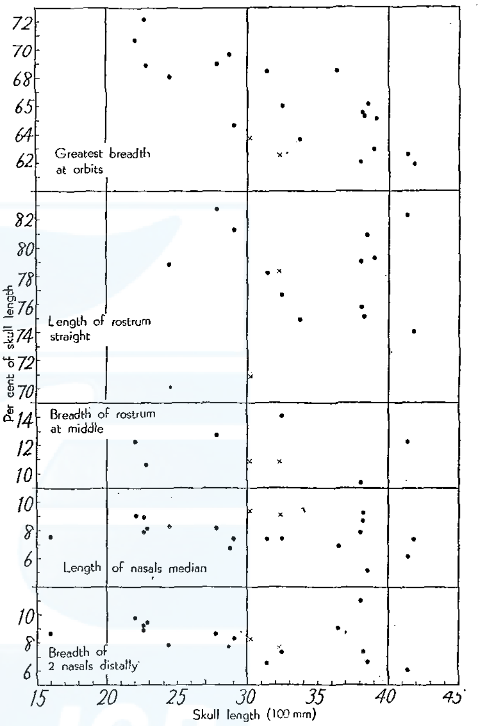


Fig. 19b. Measurements of skull of right whale (2).

× North Pacific right whale ● North Atlantic right whale

True (1904) states that the measurements of the American and the European skulls vary considerably among themselves. He further says it seems probable that the discrepancies are in part due to the shrinking and warping of the various bones of the skull, and the long, slender maxillae and premaxillae, the long orbital processes of the frontals and maxillae, seem quite easily subject to such distortion. It is quite natural, therefore, that there might occur some modification in the shape of the rostrum during the course of preservation. But it seems probable that the shrinking and warping of bones will affect in much lesser extent to the mastoid processes of the temporal. Hence the difference in the direction of the mastoid processes, noted above, should be deemed as important, if it is not a difference according to age and exist in all Atlantic specimens. The Kirittapu skeleton was shipped from the land-station to the "National Science Museum" in Tokyo as raw bones, and there it had been burried in the earth for about six months, during summer. The photographs and the measurements of this specimen were taken just after the excavation was took place. It is possible, therefore, that this skull was modified very little by the shrinking and warping of the various bones of the skull, if any, at least at the time of measurement and taking photographs.

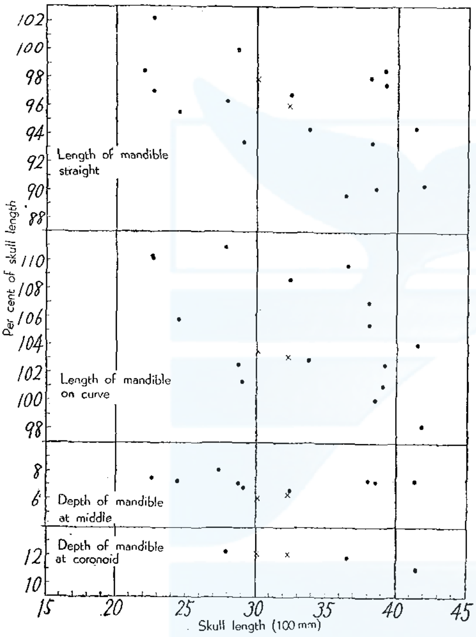


Fig. 20a. Measurements of skull of right whale (3).

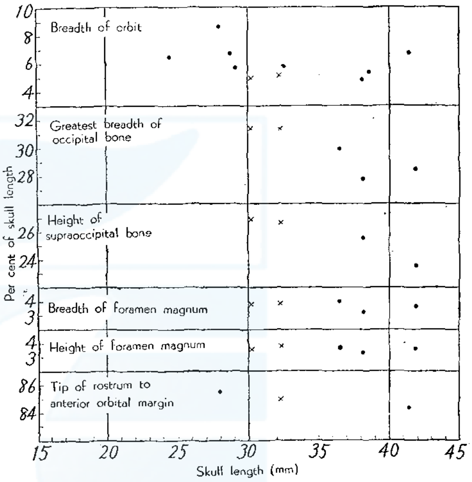


Fig. 20b. Measurements of skull of right whale (4).

× North Pacific right whale
● North Atlantic right whale

In table 9 are shown the measurements of the various parts of the skulls of both specimens from the coast of Japan, in actual measurements in millimeter and percentages against total length as well as percentages against greatest breadth of the skull. In order to compare these proportions to those of specimens from other localities I have cited measurements of the North Atlantic right whales by other authors as far as I can. List of these specimens are tabulated in table 10, arranged in the order of skull length.

All of these measurements are plotted in figures 19 and 20, their skull length being expressed on the horizontal axes and the proportion of various parts against the skull length on the vertical axes. Different symbols are used in these figures in order to make clear the Japanese specimens from those from the North Atlantic.

TABLE 9. SKULL MEASUREMENTS OF NORTH PACIFIC RIGHT WHALE

Measurements	Ayukawa specimen ♀, 1,165cm, imm.			Kirittapu specimen ♂, 1,240cm, imm.		
	in mm	% of length	% of breadth	in mm	% of length	% of breadth
Length of skull, straight	3,022	100.0	156.9	3,230	100.0	159.9
Length of maxillary at superior border, straight	2,190	72.5	113.7	R. 2,350 L. 2,325	72.8 72.0	116.3 115.1
〃 , following curve of sup. external border	2,320	76.8	120.5	R. 2,420 L. 2,370	74.9 73.4	119.8 117.3
Length of premaxillary, straight	2,415	79.9	125.4	R. 2,520 L. 2,500	78.0 77.4	124.8 123.8
〃 , along dorsal convexity	2,518	83.3	130.7	R. 2,630 L. 2,620	81.4 81.1	130.2 129.7
Length of rostrum, straight	2,143	70.9	111.3	2,530[3]	78.3	125.2
Anterior end of nasals to end of rostrum, on curve	2,265	75.0	117.6	2,360	73.1	116.8
Length from tip of rostrum to anterior orbital margin, straight	—	—	—	R. 2,670 L. 2,820	82.7 87.3	132.2 139.6
Length from tip of premaxillary to posterior end of pterygoid	2,801	92.7	145.4	R. 2,985 L. 2,975	92.4 92.1	147.8 147.3
Length from tip of premaxillary to post. end of palatines, median	2,740	90.7	142.3	2,900	89.8	143.6
Length from tip of premaxillary to ant. end of palatines, median	2,347	77.7	121.9	2,590	80.2	128.2
Length of nasals, median	281	9.3	14.6	R. 294 L. 288	9.1 8.9	14.6 14.3
Breadth of 2 nasals distally	247	8.2	12.8	247	7.6	12.2
〃 proximally	248	8.2	12.9	328	10.2	16.2
Greatest breadth of skull, orbits	1,926[1]	63.7	100.0	2,020	62.5	100.0
Breadth of skull at middle of orbits	—	—	—	1,960	60.7	97.0
〃 ant. and dist. ends of orbital processes of frontal	—	—	—	1,985	61.5	98.3
Breadth of skull at orbital processes of maxillaries	1,722	57.0	89.4	1,900	58.8	94.1
Breadth of skull at squamosals	1,798	59.4	93.4	1,950	60.4	96.5
Breadth of rostrum at middle, straight	326	10.8	16.9	350	10.8	17.3
Breadth of orbital process of frontal at distal end	R. 152 L. 151	5.0 5.0	7.9 7.8	R. 167 L. 166	5.2 5.1	8.3 8.2
Greatest breadth of occipital bone	950	31.4	49.3	1,010	31.3	50.0
Height of supraoccipital bone, from foramen magnum	813	26.9	42.2	861	26.7	42.6
Transverse breadth of occipital condyles	399	13.2	20.7	396	12.3	19.6
Height of occipital condyle	R. 283 L. 272	9.4 9.0	14.7 14.1	R. 275 L. 275	8.5 8.5	13.6 13.6
Greatest breadth of foramen magnum	116	3.8	6.0	122	3.8	6.0
Greatest height of foramen magnum	113	3.7	5.9	122	3.8	6.0
Length of mandible, straight	R. 2,958 L. —[2]	97.9 —	153.6 —	R. 3,100 L. 3,100	96.0 96.0	153.5 153.5
〃 , on curve	R. 3,125 —	103.4 —	162.3 —	R. 3,280 L. 3,380	101.5 104.6	162.4 167.3
Depth of mandible at middle	R. 182 —	6.0 —	9.4 —	R. 200 L. 210	6.2 6.5	9.9 10.4
〃 coronoid	R. 363 —	12.0 —	18.8 —	R. 385 L. 390	11.9 12.1	19.1 19.3
〃 condyle	R. 366 —	12.1 —	19.0 —	R. 382 L. 382	11.8 11.8	18.9 18.9
Breadth of mandible at condyle	—	—	—	R. 390 L. 392	12.1 12.1	19.3 19.4

1) Left side broken. Twice right 1/2. 2) Broken.

3) From fronto-maxillary sutures.

As shown in these figures no remarkable difference is noted between the specimens from the North Pacific and North Atlantic. The curved lengths of maxillary and premaxillary seem shorter in the North Pacific specimen, but few samples of the North Atlantic specimens were measured of these lengths (fig. 19 a, centre and bottom). Further there is a wide range of variation in the length from anterior end of nasals to end of rostrum, on curve (fig. 19 a, top). I can not conclude, therefore, that the North Pacific specimen has a shorter maxillary and premaxillary.

TABLE 10. LIST OF SKULLS OF RIGHT WHALES MEASURED BY VARIOUS AUTHORS

Skull length(mm)	Locality	Sex and age	Body length of whale	Authority
1,600	San Sebastian, Spain. 1854	jr.	24′ 10″	Gasco, 1879[1]
2,212	Taranto, Italy. 1877 (from Gasco's figure)	♀ —		True, 1904
2,268	〃	♀ imm.	39′ 4″	Gasco, 1878[1]
2,270	〃	♀ —		Capellini, 1877[1]
2,286	〃 (from Gasco's figure)	♀ —		True, 1904
2,451	New Jersey, U.S.A. (type *B. cisarctica*)	— jr.		True, 1904
2,794	Wainscott, Long Island, U.S.A. 1907	♀ jr.	40′ 3″	Andrews, 1908
2,880	Guetaria, Spain. 1878		34′ 3″	Graells, 1889[1]
2,908	Charleston, U.S.A. 1880	♂ —	40′ 4″	True, 1904
3,020	Ayukawa, Japan. 1956	♀ imm.	1,165cm	Present author
3,150	Amagansett, Long Island, U.S.A.			True, 1904
3,230	Kirittapu, Japan. 1956	♂ imm.	1,240cm	Present author
3,251	Long Island, U.S.A.			True, 1904
3,378	Iceland, 1891 (Capt. Berg, II)		42′±	Guldberg, 1894[1]
3,650	Provincetown, U.S.A. 1864		48′	Allen, 1908
3,810	Long Island, U.S.A.			True, 1904
3,820	Scotland.			Turner, 1913
3,828	Iceland. 1890		46′ 4″±	Guldberg, 1893[1]
3 861	Cape Lookout, U.S.A. 1874	♂ ad.	50′ 0″±	True, 1904
3,909	Iceland, 1891 (Capt. Berg, I)	♂ —	47′ 7″	Guldberg, 1893[1]
3,919	Iceland, 1891 (Capt. Berg, III)	♂ —	47′ 7″±	Guldberg, 1893[1]
4,140	Amagansett, Long Island, U.S.A. 1907	♀ ad.	54′	Andrews, 1908
4,190	Edinburg.			Turner, 1913

1) Cited from True, 1904.

The Ayukawa specimen seems to have a shorter rostrum than others (fig. 19 b 2nd figure from the top), but this is due to the different way of measurement. In the Kirittapu whale the length of rostrum was measured from the fronto-maxillary sutures on the dorsal surface of the skull, but in the Ayukawa whale this length was measured from the base, a point on the lateral edge of maxillary at middle of curve, hence smaller. Breadth of occipital bone and height of supraoccipital bone of the North Pacific specimens are greater than others (fig. 20 b), but again the measurements on these points are still scanty in order to get to any definite conclusion.

From these figures wide variations of proportion are observed mainly in: the length from anterior end of nasals to end of rostrum, the length of maxillary following curve of superior external border, the length of premaxillary along dorsal convexity, the greatest breadth at orbits, the length of rostrum in straight, the length of mandible in straight, and the same on curve. These are the portions of skull which are thought easily be affected by shrinking and warping. Further these measurements are probably subject to different methods of measurements. The proportions of skull, in these figures, other than listed above show much smaller ranges of variation according to individuals. These portion of the skull are hardly be thought to be affected greatly by modification of bones with elapse of time, if it is preserved properly. Also the method of measurement on these portion may not differ greatly by different authors. In these measurements the Japanese specimens agree quite well to that from the North Atlantic.

Fig. 21. Lachrymals (right and left) and malars (center) of the Kirittapu whale.

Lachrymals are long and flat, their lengths of right and left being 335 and 302 mm respectively. Malars are also long and thin and curved at their distal ends. The lengths of right and left malars are 382 and 381 mm respectively, measured in straight, and their straight portion articulate between lacrymal and maxillary (fig. 21)

In conclusion above there is no property which separates definitely the North Pacific right whale from the North Atlantic specimen as distinct, as far as the skull measurements are compared.

Vertebrae. The number of vertebrae of the Ayukawa and Kirittapu whales are different, the formulae of the both specimens being C7, D14, L11, Ca25=57 and C7, D15, L9, Ca25=56 respectively. The vertebral formula for the Kirittapu specimen is erroneously reported as having 10 lumbars and 24 caudals in the Omura's preliminary report (1957). It should be corrected as above.

The number of lumbars is fixed by the position of the first chevron. True (1904) states that the transition from the quite sharp inferior carina of the lumbar vertebrae to the paired inferior ridges of the caudals is not always abrupt, hence it is extremely difficult in many cases to determine correctly the number of lumbars. Andrews (1908) describes that although in both specimens (Amagansett and Wainscott whales) the posterior end of the inferior median carina was distinctly widened upon the 32nd vertebra, yet the 33rd vertebra was the first to bear a chevron and is thus denoted as the first caudal. The Ayukawa and Kirittapu whales were examined *in situ* at the landstations, the former specimen by myself and the latter by the staff of the Whales Research Institute. And it was ascertained that the first chevron was attached to the 33rd vertebra of the Ayukawa whale and 32nd in the Kirittapu whale.

In the Kirittapu specimen the posterior end of the inferior median carina of the 31st vertebra is abruptly thickened (pl. VI fig. 2), but no clear bifurcation is observed. The clear bifurcation is only observable upon the 32nd vertebra (fig. 22). Thus the 32nd vertebra was denoted as the first caudal.

The number of vertebrae of the North Atlantic right whales hitherto examined by various authors are shown in table 11. It will be observed from this table that in the North Atlantic specimens the number of dorsals is uniformly 14, the only one exception is in the San Sebastian (Spain) skeleton which has 13 pairs. According to True (1904), however, in this case Gasco thinks there may have been 14 pairs of ribs. The Ayukawa specimen agrees well in this respect, having 14 pairs of ribs, but the Kirittapu specimen has 15 pairs of ribs as stated later. This is only one exception in table 11.

The number of lumbars is uniformly 11 in the American specimens with one exception of the Long Island specimen (I), which numbers 10. In the European specimens 12 and 13 lumbars are reported by Guldberg and Gasco. True (1904) describes that it is obvious that the question of the real number of lumbars in the species cannot be authoritatively settled until the chevron bones are examined *in situ* in a number of adults and foetal specimens. His opinion is based on the question whether or not the first caudal are regarded as that in which a thickning of the posterior end of the inferior median carina first occurs. But it was ascertained by Andrews (1908), who observed both Amagansett and Wainscott specimens in the fresh, that the thickning of the inferior median carina first occurs upon the last lumbar. Thus the True's opinion that 11 lumbars may be regarded as the normal number, varying from 10 to 12, was confirmed by evidence observed *in situ*.

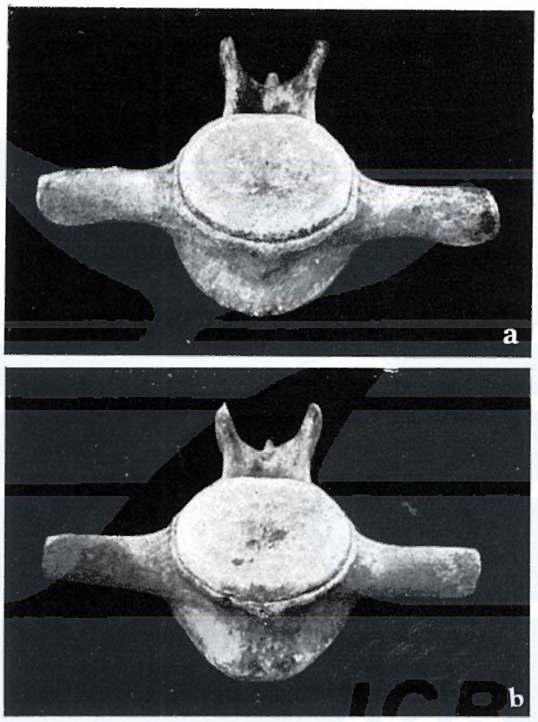


Fig. 22. Vertebrae of the Kirittapu whale.
a 31st. b 32nd.

In the Japanese specimens, the Ayukawa whale agrees well in this respect too, but the Kirittapu whale is exceptional, having only 9 lumbars. In the latter specimen the last lumbar bears a distinctly thickning of the inferior median carina at its posterior end, and further it was ascertained that the 32nd vertebra was the first to bear a chevron, as stated above.

The numbers of caudals are varying from 23 to 26 in the specimens listed in table 11. The Japanese specimens present no difference in this respect. Also in the total number of vertebrae nothing particular is observed between the specimens from the two different oceans.

The measurements of each vertebra of the Kirittapu whale are shown

TABLE 11. VERTEBRAL FORMULAE OF THE NORTH PACIFIC AND NORTH ATLANTIC RIGHT WHALES

Locality	Sex	Age	Author	C	D	L	Ca	Total
Taranto, Italy	♀	adol.	Gasco, 1878	7	14	12	23	56
〃 〃	♀	—	Capellini, 1877	7	14	— 36 —		57
San Sebastian, Spain	—	jr.	Gasco, 1879	7	13	13	23	56
Iceland (I)	—	—	Guldberg, 1893	7	14	12	21 (+3)	54 (+3)
〃 (II)	—	—	〃 〃	7	14	— 35 —		56
〃 (III)	—	—	〃 〃	7	14	— 35 —		56
Long Island (I), USA	—	—	True, 1904	7	14	10	26	57
〃 〃 (II), 〃	—	—	〃 〃	7	14	11	20+	52+
New Jersey, 〃	—	jr.	〃 〃	7	14	11	24	56
Charleston, 〃	♂	jr.	〃 〃	7	14	11	23	55
Cape Lookout, 〃	♂	ad.	〃 〃	7	14	11	22+	54+
Provincetown, 〃	—	—	〃 〃	7	14	11	24	56
Long Island (III), 〃	—	—	〃 〃	7	14	11	25	57
Amagansett, 〃	♀	ad.	Andrews, 1908	7	14	11	24	56
Wainscott, 〃	♀	juv.	〃 〃	7	14	11	23	55
Provincetown, 〃	—	—	Allen, 1908	7	14	11	24	56
Ayukawa, Japan	♀	jr.	Present author	7	14	11	25	57
Kirittapu, 〃	♂	jr.	〃 〃	7	15	9	25	56

TABLE 12. MEASUREMENTS OF VERTEBRAE OF NORTH PACIFIC RIGHT WHALE. KIRITTAPU WHALE (cont.)

(in mm)

Serial No.	Vertebral No.	Greatest breadth	Greatest height	Centrum		Neural canal			Remarks
				Breadth in front	Height in front	Length	Breadth	Height	
1	*C* 1	580	415	422	4) 325	240	116	119	4) articulating face
2	2	641	432	410					
3	3	572	428	284					
4	4	475	428	280					
5	5	473	2) 416+	263		22			2) breakage
6	6	554	2) 421+	242		28			
7	7		435	249	5) 220	53	165	131	5) aft.
8	*D* 1	534	459	251	212	79	172	128	
9	2	603	476	236	210	93	168	127	
10	3	588	506	237	207	107	174	128	
11	4	552	510	237	206	117	168	125	
12	5	540	520	231	205	121	167	123	
13	6	525	522	223	204	127	163	116	
14	7	1) 518	528	230	206	133	162	119	1) twice left half
15	8	538	3) —	239	212	140	160	119	3) S.P. broken
16	9	551	3) —	248	216	148	166	115	
17	10	585	526	255	220	155	167	109	

TABLE 12. MEASUREMENTS OF VERTEBRAE OF NORTH PACIFIC RIGHT WHALE. KIRITTAPU WHALE (cont.)
(in mm)

Serial No.	Vertebral No.	Greatest breadth	Greatest height	Centrum			Neural canal		Remarks
				Breadth in front	Height in front	Length	Breadth	Height	
18	11	616	512	265	222	158	172	105	
19	12	678	514	268	225	161	175	98	
20	13	765	505	275	227	167	177	97	
21	14	837	517	281	234	167	178	98	
22	15	845	541	284	243	176	176	96	
23	*L* 1	847	564	282	258	183	177	90	
24	2	825	572	283	271	180	174	86	
25	3	834	583	286	279	185	174	79	
26	4	840	592	293	275	190	172	78	
27	5	843	584	300	273	195	165	79	
28	6	830	588	296	276	190	154	85	
29	7	819	598	304	283	208	132	83	
30	8	782	597	297	291	209	126	81	
31	9	756	619	302	301	216	118	87	
32	*Ca* 1	721	605	305	305	212	115	84	
33	2	690	569	317	307	210	104	71	
34	3	678	553	312	306	214	90	72	
35	4	643	554	315	310	208	81	60	
36	5	615	545	318	315	206	74	54	
37	6	561	542	312	317	202	67	46	
38	7	507	533	326	325	205	64	46	
39	8	446	517	316	319	202	51	37	
40	9	415	487	316	320	196	35	36	
41	10	378	452	300	317	184	30	29	
42	11	350	428	297	309	181	28	26	
43	12	332	399	288	304	174	24	21	
44	13	313	370	272	276	164	—	—	
45	14	294	316	250	257	153	—	—	
46	15	250	263	223	228	134	—	—	
47	16	219	229	197	192	121	—	—	
48	17	200	198	160	156	112	—	—	
49	18	189	179	145	146	107	—	—	
50	19	179	159	132	128	102	—	—	
51	20	155	137	128	125	92	—	—	
52	21	140	119	114	108	82	—	—	
53	22	121	102	102	91	72	—	—	
54	23	98	82	84	74	66	—	—	
55	24	78	68	66	56	55	—	—	
56	25	55	54	—	—	47	—	—	

in table 12, in actual length of mm. The cervicals (pl. V) are all united into a solid mass, but viewed in profile the neural arches of the 5th, 6th and 7th are entirely free from the preceding ankylosed cervicals and among themselves. The diapophyses of the atlas and axis and those of the 6th and 7th are united and thickned at their extremities. In other cervicals the diapophyses are all free and very thin and much shorter than those united. The parapophyses are only developed on 2nd and 3rd. Each of the centra is separated from the others by well-

TABLE 13. MEASUREMENTS OF SKELETON. NORTH PACIFIC AND NORTH ATLANTIC RIGHT WHALES COMPARED

	Kirittapu	Amagansett[1]	Wainscott[1]
Total length of whale in cm	1,240	1,646	1,227
Length of skull in mm, straight	3,230	4,140	2,794
	% of skull length	% of skull length	% of skull length
Greatest breadth of atlas	18.0	18.4	21.3
〃 depth 〃 〃	12.8	10.4	15.4
Length of diapophysis of atlas	4.5	4.9	5.2
Height of neural spine of atlas	3.0	2.4	4.1
Greatest breadth of 1st dorsal	16.5[4]	16.8[5]	19.3[5]
〃 depth 〃 〃 〃	14.2[4]	13.8[5]	15.9[5]
Depth of centrum 〃 〃 〃	6.6[4]	5.5[5]	7.0[5]
Breadth 〃 〃 〃 〃 〃	7.8[4]	6.7[5]	9.1[5]
Length of diapophysis of 1st dorsal	6.2	6.7	5.9
Height of neural spine of 1st dorsal	3.6	3.3	2.9
Greatest breadth of 1st lumbar	26.2[4]	27.3[5]	30.0[5]
〃 depth 〃 〃 〃	17.5[4]	16.5[5]	17.5[5]
Depth of centrum 〃 〃 〃	8.0[4]	6.1[5]	7.5[5]
Breadth 〃 〃 〃 〃 〃	8.7[4]	7.6[5]	10.0[5]
Length of diapophysis of 1st lumbar	9.0	9.8	10.0
Height of neural spine 〃 〃 〃	6.7	7.6	5.9
Greatest breadth of 1st caudal	22.3[4]	22.0[5]	22.2[5]
〃 depth 〃 〃 〃	18.7[4]	18.4[5]	20.4[5]
Depth of centrum 〃 〃 〃	9.4[4]	7.9[5]	10.9[5]
Breadth 〃 〃 〃 〃 〃	9.4[4]	8.1[5]	11.1[5]
Length of diapophysis of 1st caudal	7.8	7.9	5.9
Height of neural spine 〃 〃 〃	6.6	7.3	7.2
Length of humerus[2]	17.0	13.4	17.2
Length of radius[3]	15.7	12.8	17.2
Length of ulna[3]	13.1	11.0	14.7
Neural spine ends on vertebra	No. 45 (Ca. 14)	No. 45 (Ca. 13)	No. 44 (Ca. 12)
First vertebra with transverse process perforated by vertical foramen	No. 39 (Ca. 8)	No. 39 (Ca. 7)	No. 38 (Ca. 6)
Transverse processes end on vertebra	No. 42 (Ca. 11)	No. 42 (Ca. 10)	No. 41 (Ca. 9)
Anterior zygapophysis first definitely separated on vertebra	No. 16 (D. 9)	No. 15 (D. 8)	No. 17 (D. 10)

1) Andrews, 1908
2) Including epiphyses
3) Excluding epiphyses
4) Anterior
5) Posterior

marked sutures in the lateral view, but in the inferior side the combined bone of atlas and axis extends backwards and covers up to 5th cervicals, thus making only the sutures 5-6 and 6-7 visible.

The posterior epiphysis of the 7th cervical is not fused to its centrum. The epiphyses of all vertebrae, other than cervicals, are not ankylosed to their centra, hence the whale is physically immature.

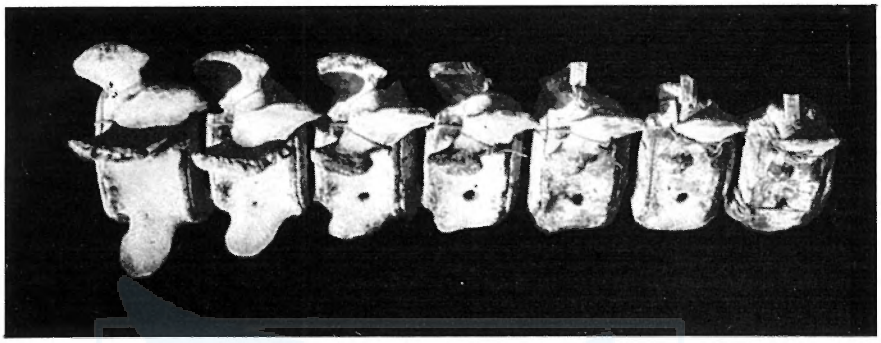


Fig. 23. Caudal vertebrae of the Kirittapu whale. Dorsal view. Note the vertical foramina on the transverse processes.
Left to right: 37th–43rd.

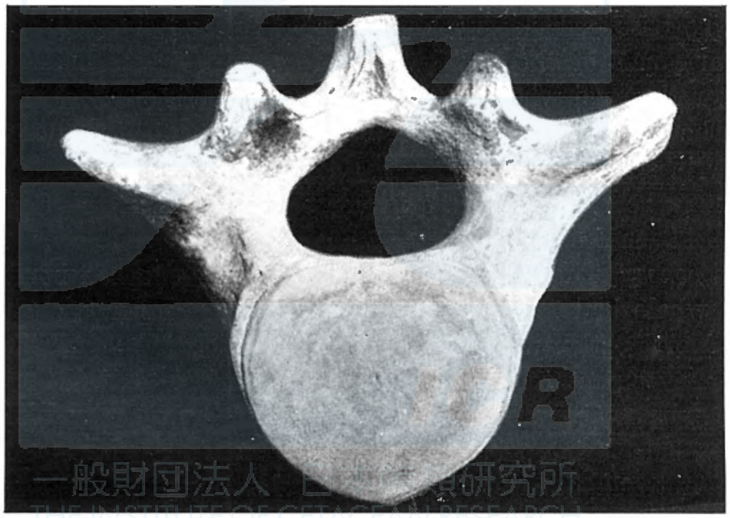


Fig. 24. 16th vertebra of the Kirittapu whale. Anterior view.

In table 13 are shown the measurements of the skeleton of the Kirittapu whale, reduced to percentages of the skull length, in order to compare with two specimens from the North Atlantic, reported by Andrews (1908). It will be observed from this table that there is no remarkable difference of the vertebrae between the specimens from two different oceans. Most of the measurements of the Kirittapu specimen fall in the range of variation of those of two specimens from the North Atlantic. The neural spine ends on the 45th vertebra in the Kirittapu and Amagansett specimens, and on 44th in the Wainscott specimen. The first vertebra with transverse process perforated by vertical foramen is the 39th in the former two specimens, and 38th in the latter. A quite similar case is the vertebral number on which transverse processes end. In the Kirittapu specimen appear the vertical foramina definitely on both transverse processes of the 39th vertebra, but there are sign of such foramen on the 38th and also on the 37th in lesser degree (fig. 23).

The first vertebra on which anterior zygapophysis definitely separated is different according to these three specimens, in the Kirittapu whale on the 16th (fig. 24) and in the two American specimens on the 15th and 17th respectively.

In figure 25 the vertebrae of the Kirittapu whale are compared with those of sei whale, a female of 43 feet long. The body length of this sei whale is longer only by 2 feet than the Kirittapu specimen of right whale. Its vertebral formula is C7, D14, L13, Ca22=56. This skeleton was sent to the Staatliches Museum für Naturkunde, Stuttgart, Germany, but I was able to measure the bones before shipment. Measurements of this specimen are also shown in figure 25.

It will be observed clearly from this figure that the vertebral bodies and neural canals of the right whale are much greater in diameter, but less thicker than sei whale. The spinous processes are longer in sei whale. The transverse processes too, especially in the dorsal region, are longer in sei whale.

These may be the differences in vertebrae between the balaenid and balaenopterid whales.

Chevron bones. The Ayukawa whale had 12 chevron bones and the Kirittapu whale had 15. The numbers of chevron bones ever recorded from the North Atlantic specimens vary from 9 to 12. This number, however, may suject to individual variation and has a little value for taxonomic purpose. In the Kirittapu specimen the right and left laminae of the 1st, 2nd and the last five chevrons are not united together (fig. 26). The first and the last five are considerably smaller than the rest. The fourth is the biggest.

It table 14 are shown the measurements of each chevron bone of the Kirittapu specimen.

Ribs. The number of pairs of ribs is uniformly 14 in specimens from the North Atlantic. The Ayukawa specimen has also 14 pairs of ribs, but the Kirittapu specimen has 15, being only one exceptional case ever recorded (pl. VII). The first rib is single headed in both specimens. The measurements of each rib are shown in table 15 for both specimens. The difference between the Ayukawa and Kirittapu specimens, other than the number, is the greater breadth of the first rib at its distal end in the former. This is clearly shown in plate VIII (fig. 1). The last rib is

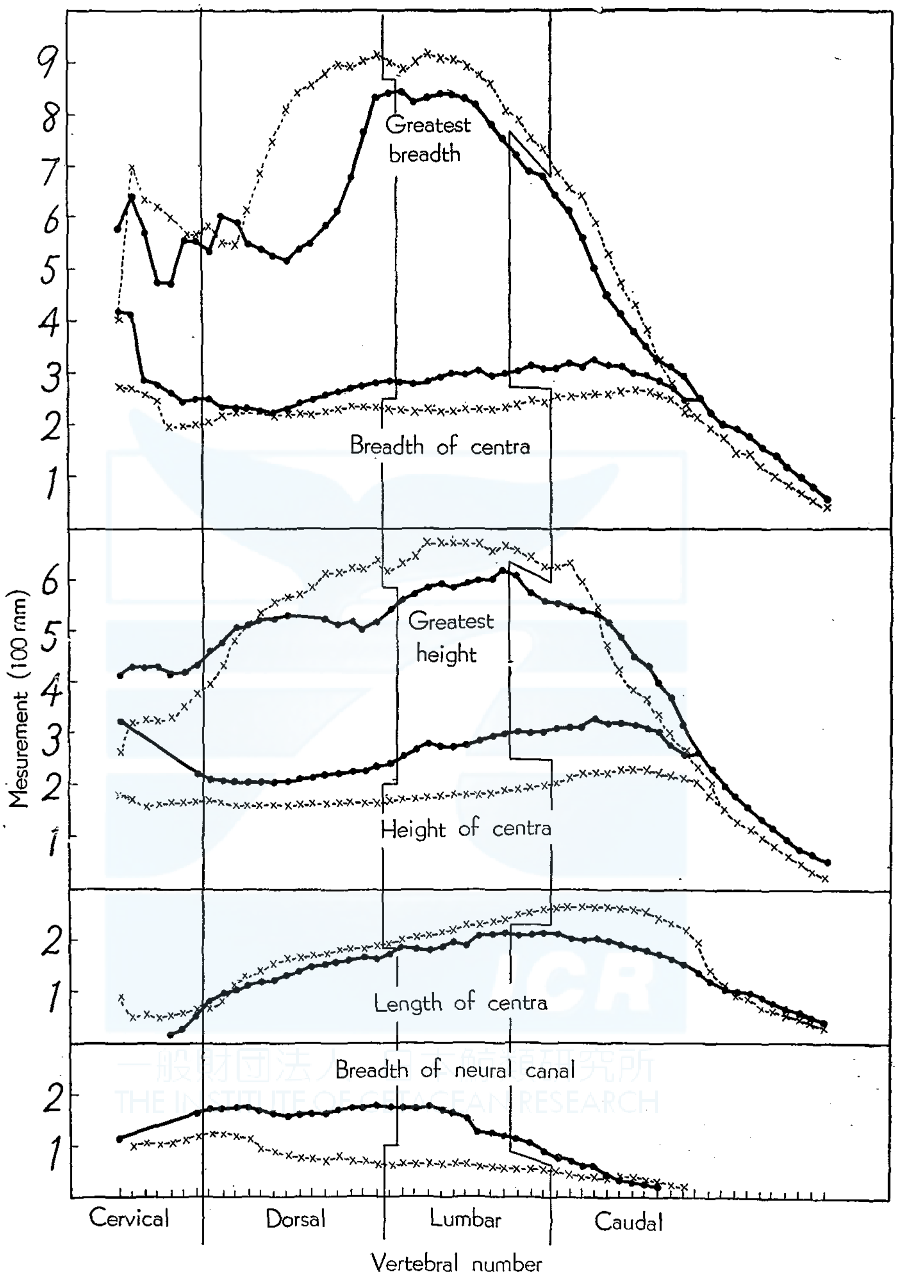


Fig. 25. Measurements of vertebrae of right whale compared with sei whale,
●—● Right whale ×—× Sei whale

TABLE 14. MEASUREMENTS OF CHEVRON BONES KIRITTAPU WHALE (in mm)

No.	Height	Breadth	Distance[1]	Remark
1	126 110	67 66	—	not united
2	184 197	120 105	—	〃 〃
3	217	150	187	
4	222	163	187	
5	222	147	183	
6	214	138	188	
7	183	140	190	
8	158	124	189	
9	142	116	183	
10	129	114	170	
11	112 —	98 —	—	not united right lamina missed
12	99 93	83 87	—	not united
13	60 57	64 61	—	〃 〃
14	—	—	—	broken
15	—	—	—	〃

1) Distance of 2 laminae at their superior margin (outside).

TABLE 15. MEASUREMENTS OF RIBS OF NORTH PACIFIC RIGHT WHALE (in mm)

Rib No.	Ayukawa				Kirittapu			
	Right		Left		Right		Left	
	Length[1]	Breadth[2]	Length[1]	Breadth[2]	Length[1]	Breadth[2]	Length[1]	Breadth[2]
1	1,025	228	1,036	234	1,107	144	1,067	124
2	1,419	136	1,385	129	1,422	152	1,386	128
3	1,561	120	1,545	121	1,674	116	1,637	104
4	1,610	106	1,609	113	1,737	102	1,732	105
5	1,640	104	1.647	105	1,776	98	1.761	94
6	1,650	101	1.644	97	1,799	97	1,784	94
7	1,581	79	1,587	76	1,769	91	1,754	88
8	1,532	68	1,541	68	1,654	69	1,674	65
9	1,471	68	1,482	67	1,599	69	1,597	62
10	1,409	63	1,422	64	1,514	65	1,535	67
11	1,346	58	1,363	55	1,474	64	1,487	67
12	1,239	57	1,238	57	1,421	66	1,430	67
13	1,148	54	1,111	55	1,310	52	1,343	59
14	541	40	590	35	983	37	971	42
15	—	—	—	—	653	31	604	43

1. Straight
2. At distal end

much shorter than that immediately succeeding in both specimens.

Sternum The Kirittapu whale has a sternum of rudely elongated heart-shaped, its height being 399 mm and its breadth 256 mm (fig. 27 a). Thickness of the sternum is 74 mm.

Only a few sterna have been recorded from the North Atlantic specimens, but they are all rudely heart-shaped. True (1904) reports that only the skeleton in the American Museum, New York, has the sternum of cruciform and says that one might almost believe that it did not belong to the skeleton to which it is attached. According to Allen (1908) however, this sternum is a restoration in wood, doubtless modeled after that of a fin whale, supplied by the preparator. Other sterna ever recorded are all more or less heart-shaped form, though there are great individual variation in the form. The sternum of the Kirittapu whale agrees in this point.

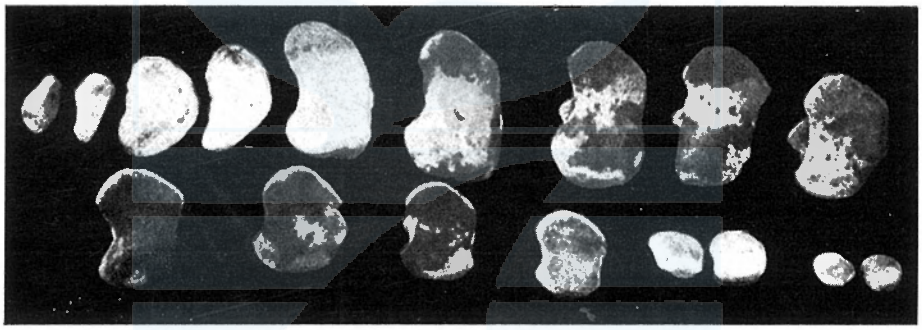


Fig. 26. Chevron bones of the Kirittapu whale. The last two are excluded because of breakage.
From left to right:
Upper; 1st (right and left), 2nd (right and left), 3rd, 4th, 5th, 6th and 7th.
Lower; 8th, 9th, 10th, 11th, 12th (right and left) and 13th (right and left).

Hyoid. The hyoid bones of the Kirittapu whale are shown in figure 27 b. The combined basihyal and thyrohyals is 573 mm in transverse diameter and 120 mm depth at median. Basihyal and thyrohyals are united completely, but the sutures are still visible. The median notch is rather shallow and wide. Length of the right and left stylohyals are 256 and 244 mm respectively.

The hyoid bones of the Ayukawa whale are similar in shape, but the basihyal and thyrohyals are not ankylosed into a mass.

Scapula. The scapula of the Ayukawa and Kirittapu specimens agrees well in general form with that of specimen from the North Atlantic (pl. VIII fig. 2). It is nearly symmetrically fan-shaped, the suprascapula border is regularly rounded. The glenoid border presents an oval outline, with the antero-posterior diameter greater than the transverse. The coracoid is undeveloped. The difference in the scapulae of both Japanese specimens are confined chiefly to the acromion. The length of the acromion of the Ayukawa specimen is about twice of that of the Kirittapu specimen. In the latter specimen the length of acromion is smaller than the breadth. Allen (1908) states that the average width of the acromion process is rather more than one-half of the length, hence the Kirittapu specimen may be exceptional.

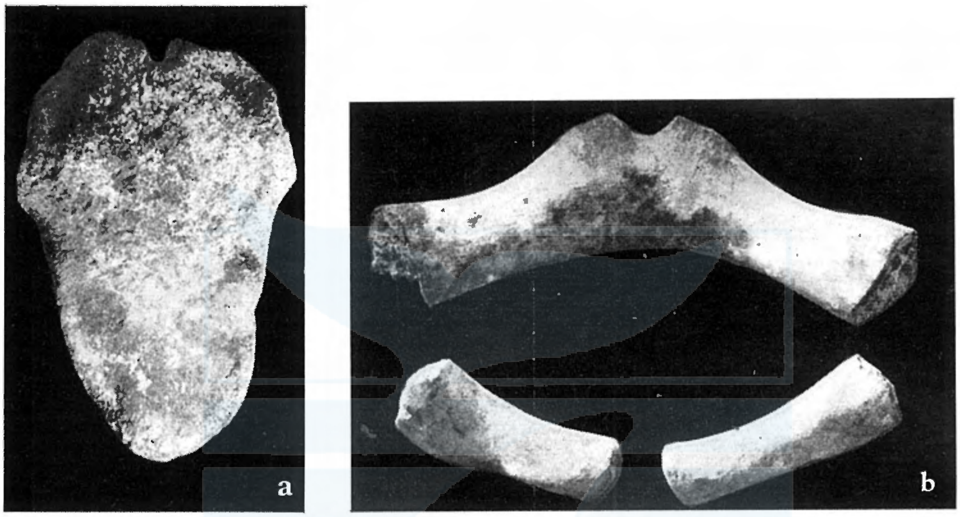


Fig. 27. Sternum and hyoid bones of the Kirittapu whale.
a. Sternum b. Upper: Combined bone of basihyal and thyrohyals.
Lower: Stylohyals.

TABLE 16. MEASUREMENTS OF SCAPULAE OF NORTH PACIFIC RIGHT WHALE (in mm)

Measurement	Ayukawa		Kirittapu	
	Right	Left	Right	Left
Greatest breadth	868	873	1,060	980
〃 height	689	697	779	775
Length of acromion	155	117+	65	65
Breadth of acromion	—	—	77	77
Breadth of glenoid fossa	330	328	343	344
Depth of glenoid fossa	245	251	278	276

The measurements of the scapulae of both Japanese specimens are shown in table 16.

Humerus, Radius and Ulna. The humerus, radius and ulna of the Kirittapu whale are shown in plate VIII. The humerus is a short and thick bone, constricted around the middle. The proximal and distal epiphyses of the humerus are all free and not united to their body. In the Ayukawa specimen also both epiphyses are not ankylosed. The radius is broad and flat distally, proximal end being much less expanded and much thicker. The ulna is fan-shaped in its distal portion and much constricted than the radius at middle. The proximal and distal epiphyses of the radius and ulna are all free in both specimens. The measurements of the humerus, radius and ulna of the Ayukawa and Kirittapu whales are given in table 17.

Carpals. In the right and left flippers of the Ayukawa specimen there are five carpal bones of different size. They are irregularly rounded in shape and the long and short diameters of the largest are 74 and 64mm, and the smallest 33 and 22 mm. In the Kirittapu specimen the carpal bones were still wholly concealed in the hardened cartilage, when the flippers were excavated from earth after six months of burying during the summer (pl. VIII).

TABLE 17. MEASUREMENTS OF HUMERUS, RADIUS AND ULNA OF NORTH PACIFIC RIGHT WHALE (in mm)

Measurement	Ayukawa		Kirittapu	
	Right	Left	Right	Left
Humerus1)				
Greatest length	500	492	556	549
Breadth at proximal end	349	343	375	404
〃 〃 distal end	303	302	316	307
Radius2)				
Length at middle	498	496	505	506
Breadth at proximal end	242	241	263	259
〃 〃 distal end	363	359	394	398
Ulna2)				
Length at middle	441	443	422	423
Breadth at proximal end	175	162+	185	185
〃 distal end	234	237	288	291

1) Including epiphyses 2) Excluding epiphyses

Phalanges. The formula for the phalanges of the Kirittapu specimen is I_3 II_5 III_6 IV_4 V_4. This is carefully confirmed by arranging the digits and cartilages, which were still remained at the time of examination. This formula correspond with the Ayukawa series, with one slight difference. The right flipper of the Ayukawa specimen agrees with this formula, but the left digit V has 3 phalanges, while others correspond. Andrews (1908) gives the formula I_1 II_4 III_5 IV_4 V_3 for the specimen from the North Atlantic, although this formula agrees with that of none of the skeletons in American Museums as shown by True (1904), which True himself has stated that the series of phalanges in all the mounted American skeletons is imcomplete.

According to Allen (1908), however, his Provincetown specimen has the phalangeal formula I_2 II_5 III_6 IV_4 V_3. It may be that, therefore, there is an individual difference in the number of phalanges. As already stated the shape of the flipper is deemed to subject to individual difference, and it is probable that this is a reflection of difference in number of phalanges. I should like to point out here again that the flippers of the Japanese specimen are more pointed at its distal end than that of the specimen presented by Andrews (1908) (fig. 12).

TABLE 18. MEASUREMENTS OF PHALANGES OF NORTH PACIFIC RIGHT WHALE. KIRITTAPU SPECIMEN (in mm)

Measurement	Right					Left				
	I	II	III	IV	V	I	II	III	IV	V
Length										
1st qhalanx	121	149	175	167	137	113	154	176	160	138
2nd 〃	127	171	189	162	133	134	173	189	156	128
3rd 〃	83+	156	176	128	112	95	154	177	133	110
4th 〃	—	130	148	63	69	—	135	150	62	70
5th 〃	—	91+	107	—	—	—	99	111	—	—
6th 〃	—	—	86	—	—	—	—	75	—	—
Proximal breadth										
1st phalanx	101	138	136	135	138	97	135	137	132	139
2nd 〃	75	122	136	97	88	75	125	136	93	88
3rd 〃	39+	109	130	70	58	45	111	130	68	58
4th 〃	—	83	100	49	34	—	86	102	52	37
5th 〃	—	59	77	—	—	—	59	74	—	—
6th 〃	—	—	48	—	—	—	—	45	—	—
Distal breadth										
1st phalanx	90	129	135	111	105	88	130	135	110	108
2nd 〃	56	128	144	85	73	57	132	143	81	73
3rd 〃	broken	96	113	57	44	16	93	111	56	43
4th 〃	—	70	83	26	20	—	69	82	30	20
5th 〃	—	31+	59	—	—	—	37	53	—	—
6th 〃	—	—	30	—	—	—	—	27	—	—

The measurements of phalanges of the Kirittapu specimen are shown in table 18.

Pelvic bones. The pelvic bones of the Ayukawa and Kirittapu whale have been preserved and now being under examination by other researchers.

CONCLUSIONS

Two black right whales, 38 feet female and 41 feet male, were killed in 1956 in the coasts of Japan by a special permission for scientific researches. The external and internal characters of the whales were studied. Records of recent sightings of the North Pacific right whales were also studied in relation to their migration. The results of these studies may be summarized as follows ;

1. The North Pacific right whales appear in the waters east of North-East Honshu and south of Hokkaido in April, staying there in May and then they proceed to further north. In June they arrive in the Bering Sea and its nearby waters and staying there during the whole summer. In these months a number of black right whales were also sighted in the eastern part of the Bering Sea.

Of the 164 instances of sightings of the black right whales about 68 per cent were met solitary. The highest numbers in a school was 4.

2. The North Pacific right whale may probably attains more longer body length than the North Atlantic right whale.

3. The total body weight of two black right whales were about 23 and 22 metric tons respectively, which are much heavier than sperm whale of similar size.

4. The body color of two whales was uniform dark blue-black, except a small white patch on the umbilicus of the female.

5. Both whales had white linear scars on their bodies. They were thickly infected by whale lice, amphipod crustaceans, and most remarkably on the "bonnet" and other callosities.

6. The size and location of these callosities showed no difference from those from the North Atlantic and southern hemisphere.

7. The body proportion of the North Pacific right whale has also showed no difference, compared with black right whales from different oceans.

8. Number of baleen plates were 228-259 on each side of the upper jaw. Color of baleen plates are uniform grayish-black and no white plate was observed.

9. *Calanus plumchrus, C. finmarchicus, C. cristatus and Euphausia pacifica* were found from the stomach of the two whales.

10. Both whales were sexually immature.

11. The skull measurements of the two whales provided no evidence as to the distinction of the North Pacific right whale from the North Atlantic right whale.

12. In the posterior view of the skull, however, the direction of the mastoid processes of the temporals differed from a skull of the North Atlantic right whale. But it is probable that this is a difference according to age.

13. The vertebral formulae for the two specimens are C7, D14, L11, Ca 25=57 and C7, D15, L9, Ca25=56. The former agrees to that reported for the North Atlantic specimens, while the latter exceptional.

14. The number of chevrons of both whales were 12 and 15 respectively.

15. The number of pairs of ribs of one specimen was 14, which is the uniform number in the North Atlantic specimens. But the other

specimen had 15 pairs of ribs. This is the single exception ever recorded.

16. The sternum, scapula, humerus, radius and ulna showed no special feature.

17. The phalangeal formula for two specimens was I_3 II_5 III_6 IV_4 V_4, and differed from the formulae reported for the North Atlantic specimens. The shape of the flipper, however, differs individually. Hence the numbers of phalanges may subject to individual variation.

18. From the foregoing statements it may be concluded that there is no specific distinction which separates definitely the North Pacific right whale from the North Atlantic right whale. The name *Eubalaena glacialis*, therefore, should be applied to the North Pacific right whale.

ACKNOWLEDGEMENTS

This work was enabled by a special permission for taking of two black right whales for scientific purposes granted by the Fisheries Agency of Japanese Government. Arrangements of the application were made by the Japan Whaling Association.

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I would like to thank the Ayukawa Whale Museum and the National Science Museum in Tokyo for the help of their staff in examination of skeletons.

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The data of recent sightings of the right whales were generously supplied by the Nihon Suisan K. K., Taiyo Gyogyo K. K., Kyokuyo Hogei K. K. and by two companies listed above. Mr. T. Kawakami of the Fisheries Agency has also kindly supplied the data which he himself collected during several years on board factory ships operated in the northern Pacific. Without their co-operation the present report may be obliged to change its contents.

The drawings were made by myself, but photographs were taken by the staff of the Whales Research Institute, including myself, except one shown in figure 2, which was taken by Mr. S. Watase of the Taiyo Gyogyo K. K.

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Fig. 1. North Pacific right whale. Ayukawa specimen. Female. 1,165 cm long.

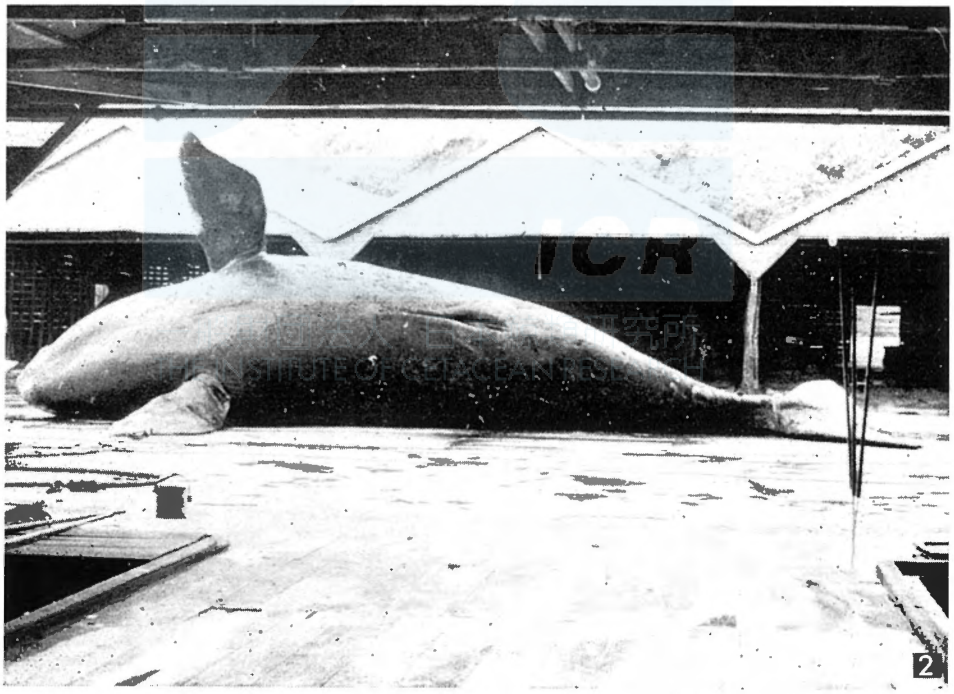

Fig. 2. North Pacific right whale. Kiritttapu specimen. Male. 1,240 cm long.

Fig. 1. Skull of North Pacific right whale. Kirittapu specimen. Dorsal view.

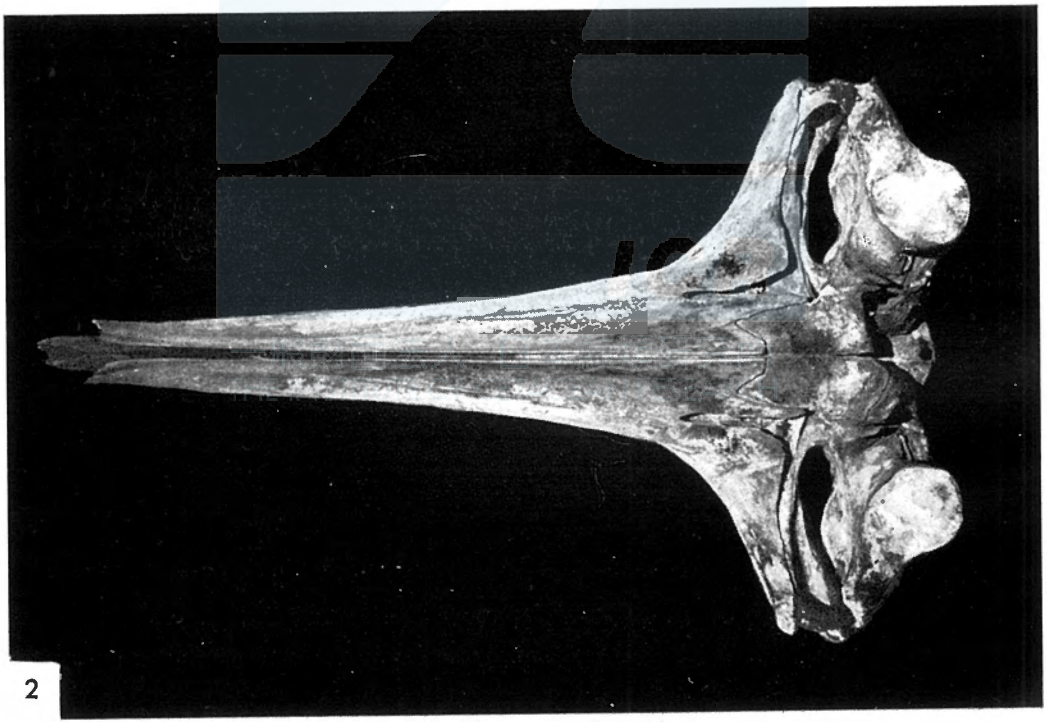

Fig. 2. The same. Ventral view.

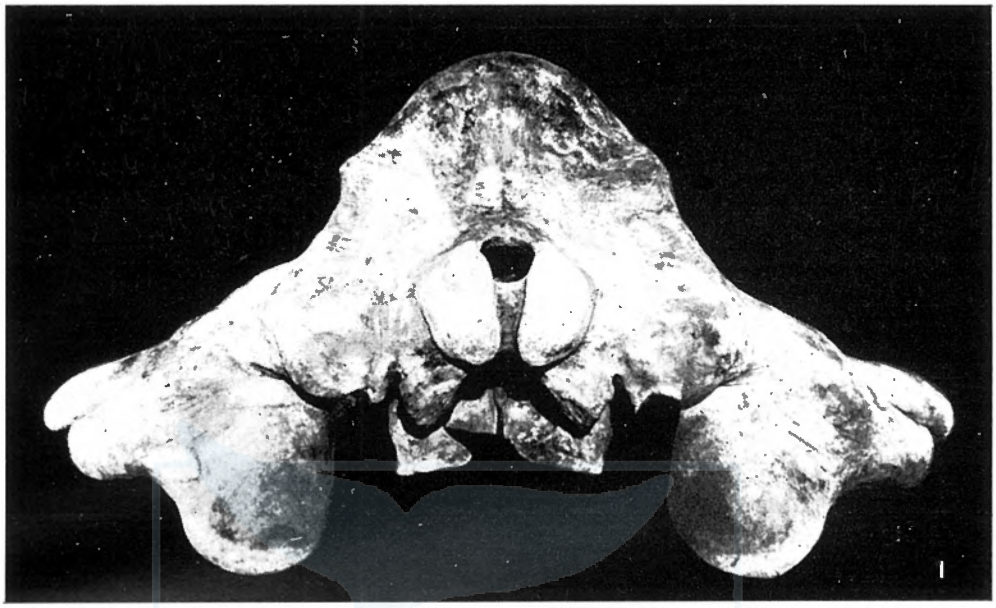

Fig. 1. Skull of North Pacific right whale. Kirittapu specimen. Posterior view.

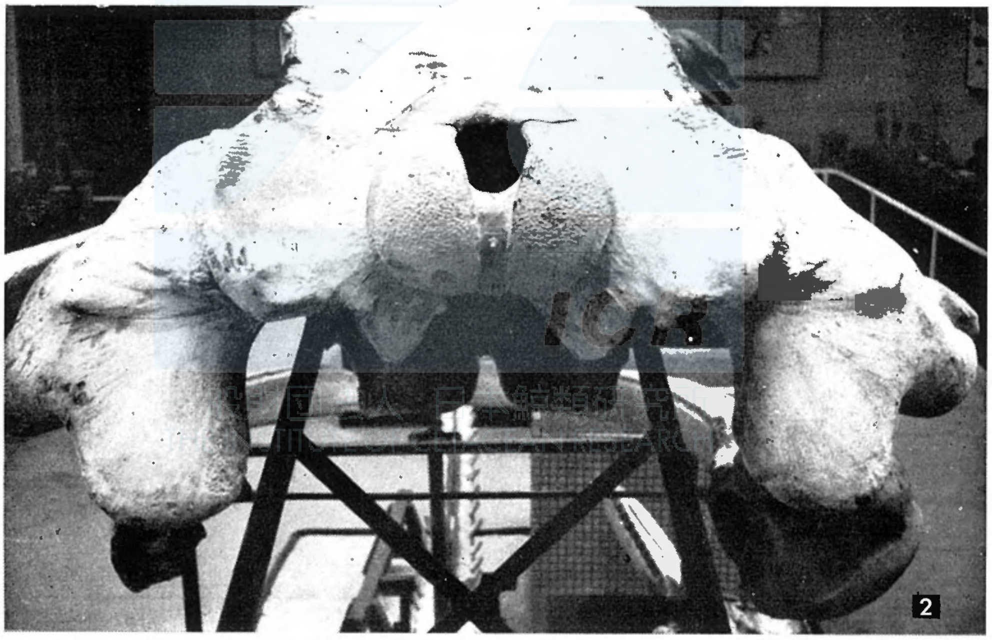

Fig. 2. Skull of North Pacific right whale. Ayukawa specimen. Posterior view.

Fig. 1. Skull of North Pacific right whale. Kirittapu specimen. Lateral view.

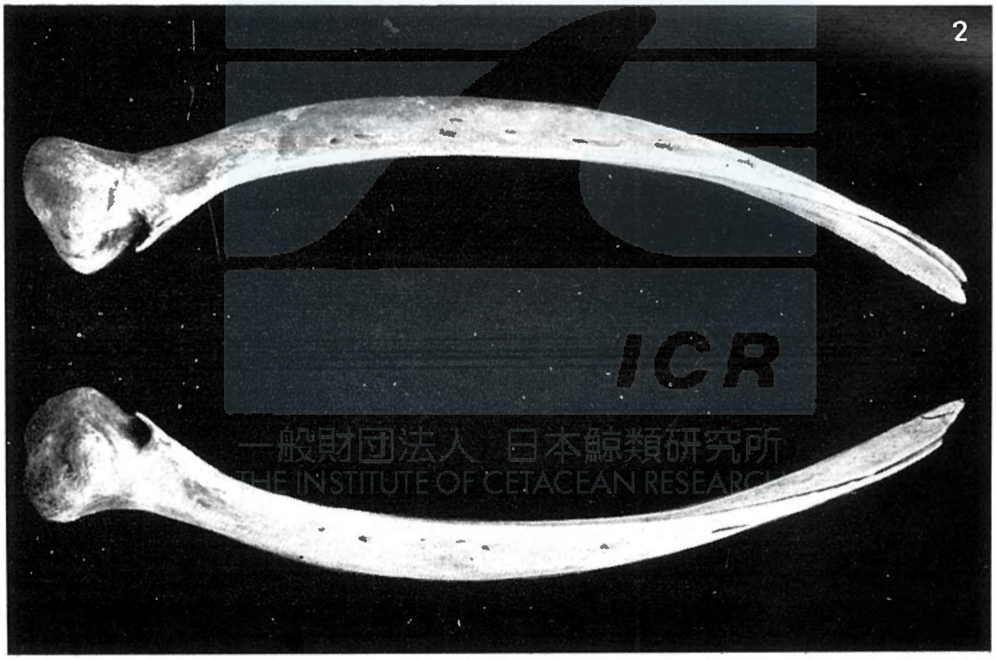

Fig. 2. Mandibles of North Pacific right whale. Kirittapu specimen. Dorsal view.

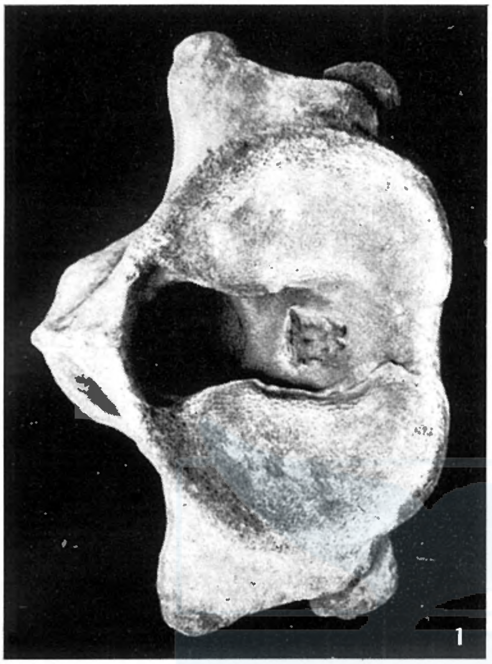

Fig. 1. Cervical vertebrae of the Kirittapu whale. Anterior view.

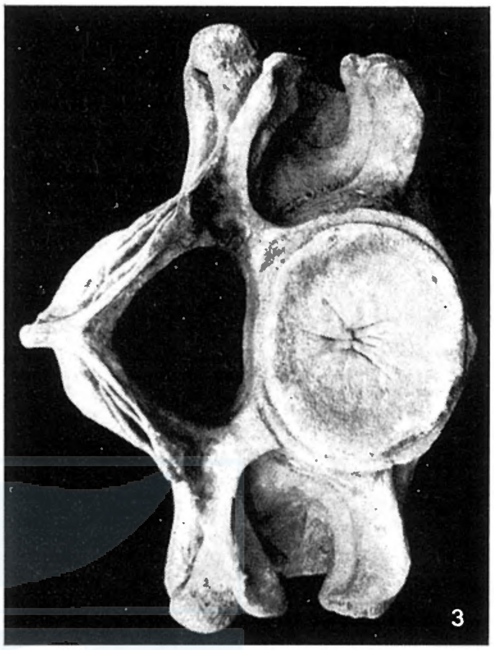

Fig. 3. The same. Posterior view.

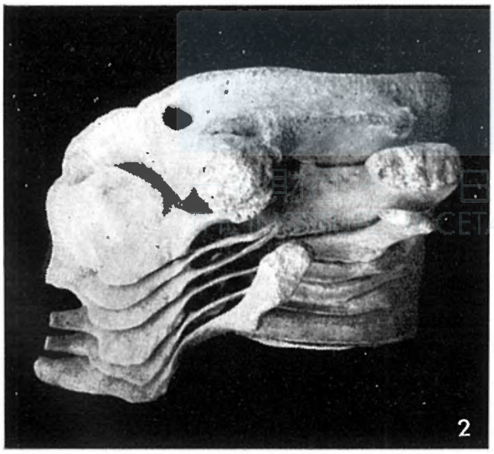

Fig. 2. The same. Lateral view.

Fig. 4. The same. Ventral view.

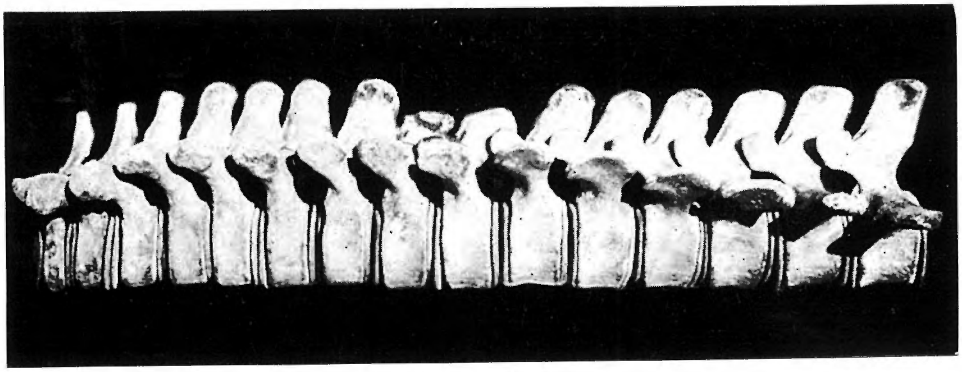

Fig. 1. Dorsal vertebrae of the Kirittapu whale.

Fig. 2. Lumbar vertebrae of the Kirittapu whale.

Fig. 3. Caudal vertebrae of the Kirittapu whale. 1st—11th.

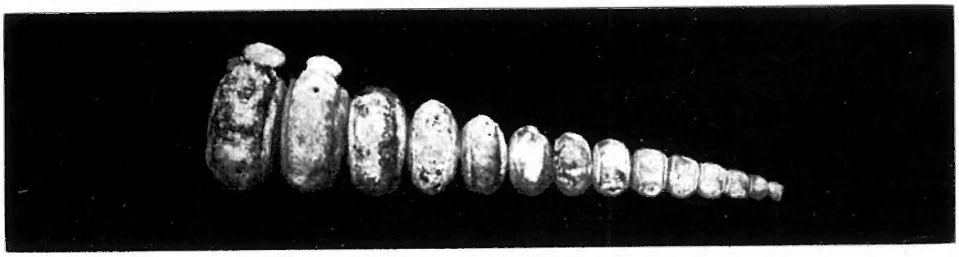

Fig. 4. Caudal vertebrae of the Kirittapu whale. 12th—25th.

Fig. 1. Right ribs of the Kirittapu whale.

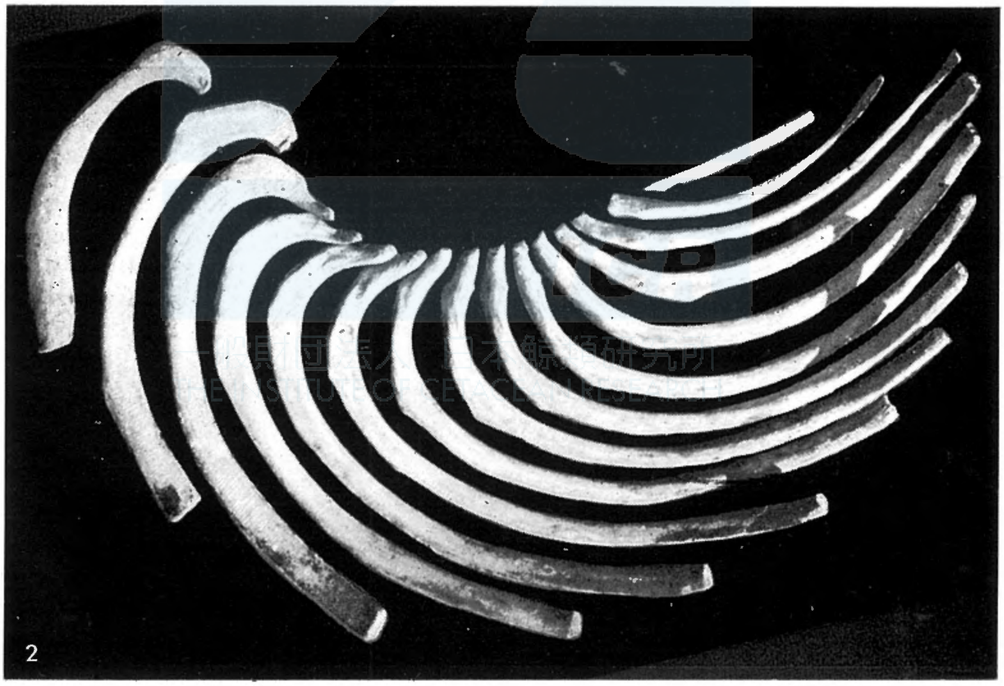

Fig. 2. Left ribs of the Kirittapu whale.

Fig. 1. 1st, 2nd and 3rd right ribs of the Ayukawa whale.

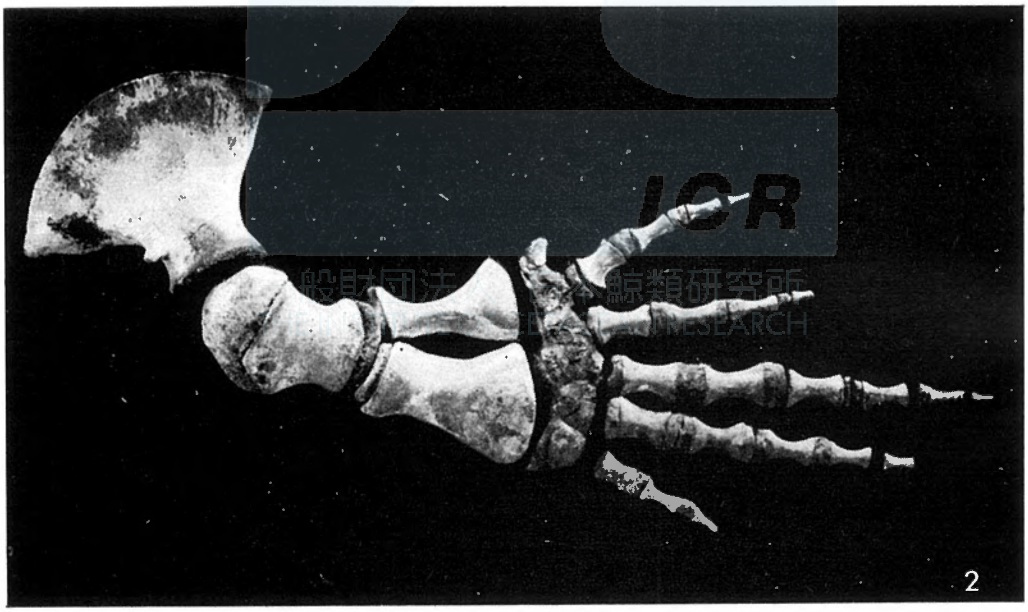

Fig. 2. Scapula, humerus, radius, ulna and phalanges of the Kirittapu whale. Left side.

A BEAKED WHALE *MESOPLODON* STRANDED AT ŌISO BEACH, JAPAN

MASAHARU NISHIWAKI AND TOSHIRO KAMIYA*

INTRODUCTION

The 23rd Sept. 1957 was the autumnal equinox. It was a holiday in Japan, so the senior author stayed at home. When he read the newspaper "Mainichi", a paragraph "Whaling on land" caught his eyes. The newspaper said as follows. "At 3 p.m. of the 22nd Sept. a whale dashed to land and wriggled on Ōiso Beach, Sagami Bay, near Tokyo. About 20 lads, who were playing base-ball on the shore, rushed all together upon the whale. But as the whale, which was about 5 meters long and about 1,500 kg in weight, got rowdy, the lads had to spring up and down into the sea water. Then they gave up to catch it alive, and each of them took a bat and beat to kill the whale. The lads sold the whale to a fishing company in Ōiso, but this company could not manage the huge body and transported it to the Yokohama Central Market". In Japan the whale meat, even though it may belong to the toothed whale, is used for human food. The newspaper said further that "it was a sei whale belonging to the smallest of the whalebone whale and living in the adjacent seas of Japan. This whale had followed perhaps

Fig. 1. The whale was carried from Ōiso Beach.

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migrating sardines so earnestly, that it might have erroneously stranded on the shore". And the newspaper published at the same time a photograph (Fig. 1) taken by Mr. M. Etoh, a student of the Nippon University, dwelling in Ōiso.

The senior author thought seeing this newspaper that the tail flukes shown in the photograph resembled neither those of the sei whale nor of the other whalebone whales, but that the whale might belong to the Ziphioids. Soon he telephoned to the Yokohama Central Market and asked about the whale. They replied that it had no baleens, but only one pair of the teeth on the mandible.

As stranding of a *Ziphius cavirostris* occurred on Kamakura Beach of Sagami Bay last year, the author thought at first it might also be a *Ziphius cavirostris*. This species is seen not so seldom in Japan, but as the Whales Research Institute has yet no specimen of *Ziphius*, he considered that it would anyway be some plus for the Institute to secure the skeleton. So he asked the manager of the market to deliver the remaining body to the Institute.

Fig. 2. The whale mostly deprived of the soft parts was brought to the University of Tokyo.

Before this date, many blue-white dolphins (*Stenella caeruleo-albus*) were captured on the 19th Sept. at Kawana, Shizuoka Prefecture. The senior author went to see them as soon as he was informed of it. From early morning of the 20th Sept. the examination was performed on them and a number of foetuses and newborn dolphins were collected. The collected materials were kept frozen in the store at Kawana. He returned to Tokyo and planned to visit Kawana again using a lorry motor-dray possessed by the Medical Faculty of the University of Tokyo on the 24th Sept. So he telephoned to Professor T. Ogawa and asked to let the lorry go to Kawana around the Yokohama Central Market.

Arriving at the market, the authors found the remains of the beaked whale. These are gathered loosely in a large wooden box, and at a glance of its head they were striken by the thought that it might belong to *Mesoplodon*. The rare whale, *Mesoplodon*, has hitherto been reported from many districts of the world. But in Japan, there has been only one precedent, namely that of Professor T. Ogawa, who reported the *Mesoplodon* caught on the 6th Jan. 1935 at Sotonoura, Miyazaki Prefecture, Kyushu (not in Ōsumi, Kyushu).

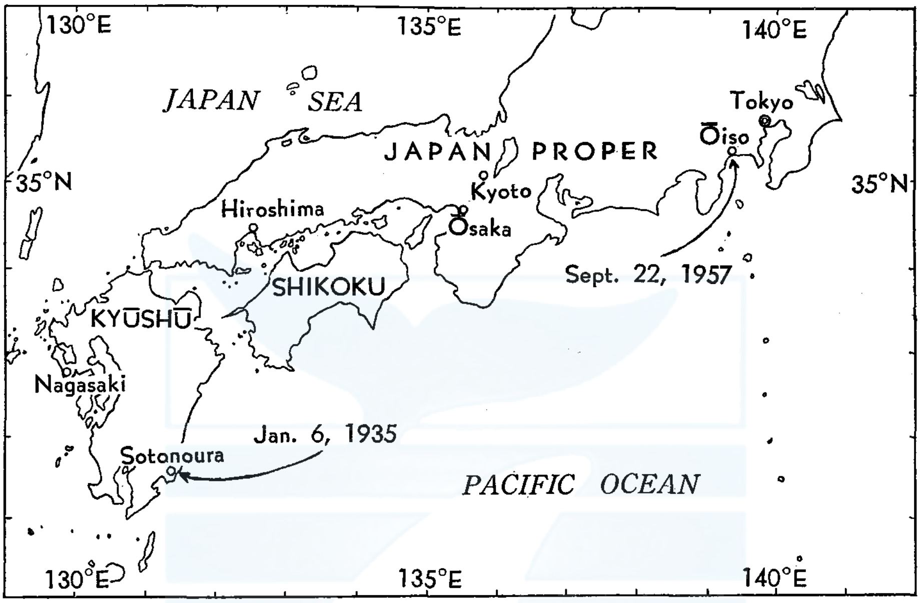


Fig. 3. Location of capture of *Mesoplodon* in Japan.

Therefore this specimen would possibly be the second one. The authors were very much satisfied to have obtained this precious specimen, but they continued the travel further to Kawana to bring home the materials mentioned above of blue-white dolphins and also the head of a false killer whale (*Pseudorca crassidens*). They brought all the materials to the Department of Anatomy, University of Tokyo late in the evening.

ACKNOWLEDGEMENT

The authors are indebted to Yokohama Maru-uwo Co. Ltd. for their kind presenting of the specimen, and thanks are also due to Mr. M. Etoh for lending his negative film of the specimen.

The authors would like to express their sincere thanks to Dr. F. C. Fraser of the British Museum, Dr. R. Kellogg of the United States National Museum, Dr. J. C. Moore of the American Museum of Natural History and Dr. Å. Jonsgård of the Norwegian State Institute for Whale Research.

Dr. Moore kindly discussed for this paper by many letters. Moreover he showed to the authors his manuscript "A beaked whale, from the Bahama Islands, and comments on the distribution of *Mesoplodon densirostris*"

and also many photographs of *Mesoplodon* species. Dr. Kellogg let us know his opinion minutely and gave us many valuable photographs for *Mesoplodon* studies. Dr. Fraser also showed his opinion on the distriction between *M. bidens* and the present whale and kindly spent time together with Dr. Omura for photographing *Mesoplodon* specimens preserved in the British Museum. Dr. Jonsgård too offered much kindness for this study. Sincere thanks are also due to Messrs. of the British Council, especially to Mr. W. R. McAlphine, Deputy Representative of this Council in Tokyo, for introducing the authors to Dr. Fraser.

The authorities of the American Museum of Natural History, the Smithonian Institution, the British Museum of Natural History, the Zoological Society of London, the Fisheries Research Board of Canada and Putnam Co. Ltd. were given the permissions for reproduction of the photographs in their publications to us. The authors should be grateful thanks to their courtesies.

The authors are deeply grateful to Dr. I. Amemiya, Dr. T. Ogawa and Dr. H. Omura; they gave a lead in this study.

Particularly Dr. Ogawa examined the present specimen together with the authors and gave agreement for altering the scientific name of the first *Mesoplodon* specimen in Japan.

NOTES ON THE EXTERIOR

The head was covered still with blubber, but was cut off at the V-shaped groove of the throat. So the existence of the V-groove was ascertained but the whole shape of the groove could not be seen. The colour of the body was entirely black, even on the rear sides of flippers and tail flukes. In the photographs taken by Mr. Etoh, some white flecks were observed, but they might represent scars, which usually appear on the whale body. The whole vertebrae were obtained, but unfortunately they were cut by saw instead of separation at the articulations. The tail flukes were cut off from the trunk at the insertion. When the whale body reached the market, both ends of the tail flukes and a little part of its hinder margin near the median line had already been cut away. As shown in Fig. 5, the shape of tail flukes was quite different from the usual cases of whales or dolphins. After careful examination, some slight depression was ascertained at the middle part of the hinder margin of the tail flukes, instead of a notch. At a glance, it seemed rather projected at the middle part.

All of these separated parts were arranged in order on the floor and the outline of the body was measured.

It was very disappointing from the situation mentioned above that the form of the whale body was not really observed. The authors arrived at the Yokohama Market, after the dissection had finished. The left flipper, both scapulae, pelvic bones and some parts of the ribs were lost, as they had been sold with soft parts (fresh meat, blubber, viscera, etc.) utilizable to the consumers.

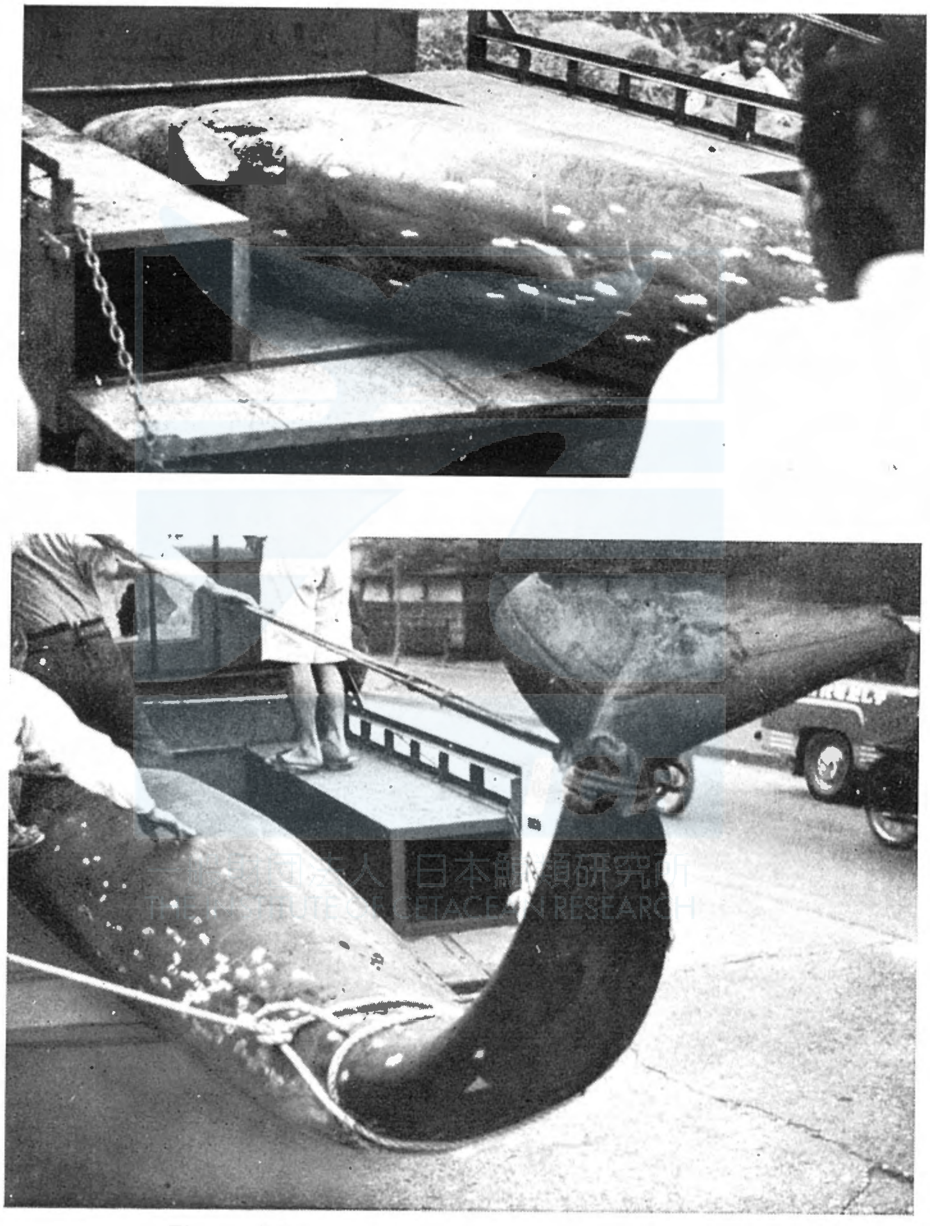


Fig. 4. White scars were observed on the whale body.

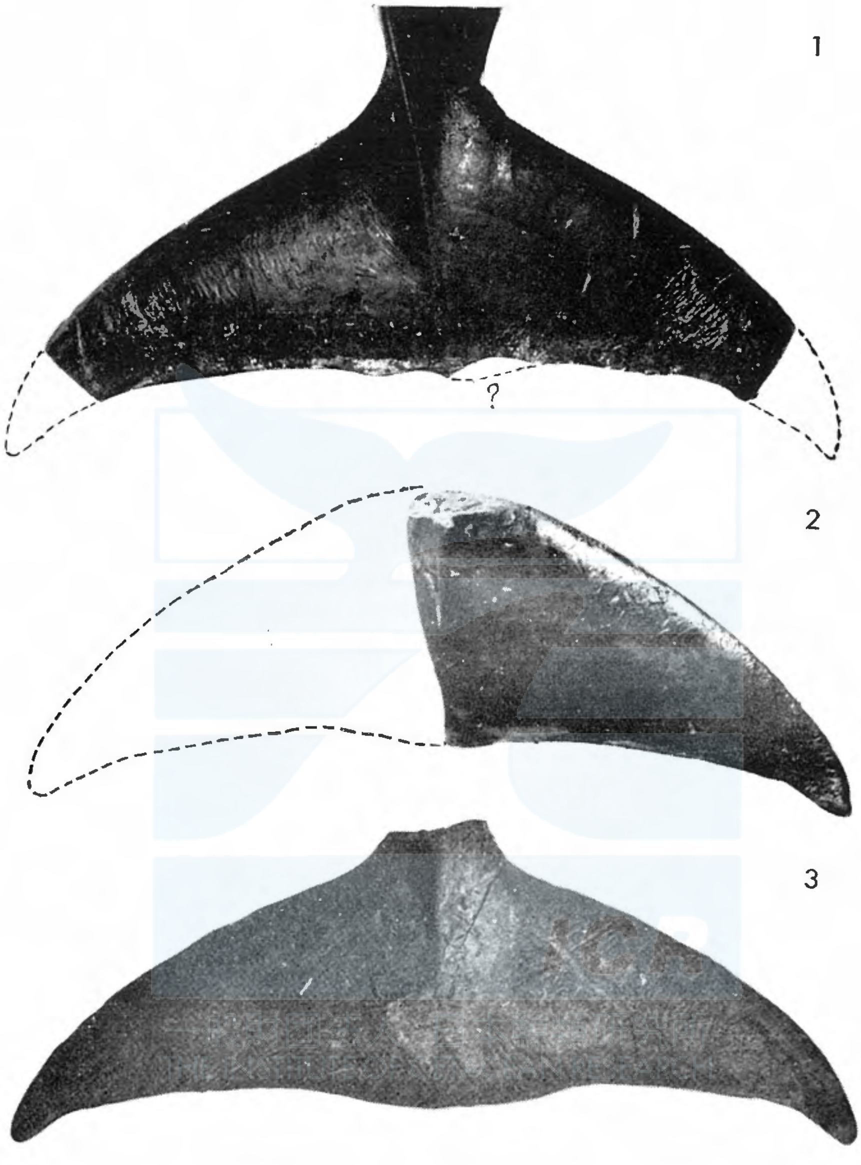


Fig. 5. Tail flukes of the present specimen (upper), compared with the first *Mesoplodon* specimen in Japan (middle) and *M. bidens* (British Museum, lower) (dorsal views).

Some measurements on the exterior, so far as the results could be gained, are given below :

Body length	ca.	472.0 (cm)
Head, occipital condyles to the tip of the snout		80.0
——, greatest width (opposite to the eyes)		43.0
Projection of the lower jaw beyond the snout		2.5
Tip of the lower jaw to the teeth		20.5
Tip of the snout to the angle of gape		40.0
—— to the center of eye		51.0
—— to the blowhole		49.0
Breadth of the blowhole		8.0
Distance between conical apices of both teeth		11.5
Flipper, axilla to the tip		33.0
——, anterior border to the tip		51.0
——, greatest width		13.0
Tail flukes, total breadth	ca.	112.0
——, middle point of the hinder margin to the tip (average)	ca.	57.5
——, minimum distance between the middle point of the hinder margin to the anterior border		42.0

OSTEOLOGY

Skull. Skulls have been measured in various species of *Mesoplodon* by a number of scientists. For the purpose of comparison with those reports, the present authors measured the skull of this specimen as many points as they could determine. The results are given in the next table, and the lateral, dorsal and ventral views of the skull are shown in Plates III and IV. The explanation upon these dimensions and figures will be mentioned later.

Vertebrae. The total number of the vertebrae amounts to 48, with the formula of C: 7, D : 10, L : 10, Ca : 21. This formula is slightly different from precedent reports upon *Mesoplodon*. The first three cervical vertebrae are ankylosed

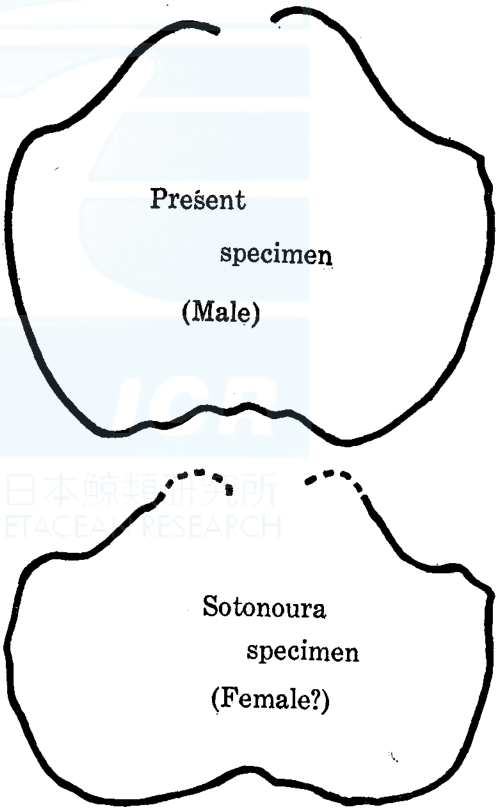


Fig. 6. Outline of the transversely sectioned middle part of the rostrum. Natural size.

TABLE 1. SKULL DIMENSIONS OF THE NEW SPECIMEN

		mm	percentage to the length	percentage to the breadth
1.	Total (condylo-basal) length	779	100.0	218.8
2.	Length of rostrum (median)	435	55.8	122.2
3.	Breadth of rostrum at base	151	19.4	42.4
4.	Breadth of rostrum at middle	64	8.2	18.0
5.	Breadth of rostrum at the position just above the teeth	46	5.9	12.9
6.	Breadth of rostrum at the highest point of anterior palatine suture	90	11.6	25.3
7.	Breadth of rostrum between the antorbital notches	205	26.3	57.6
8.	Depth of rostrum at middle	54	6.9	15.2
9.	Depth of rostrum at the position just above the teeth	56	7.2	15.7
10.	Depth of rostrum at the highest point of anterior palatine suture	74	9.5	20.8
11.	Length of premaxilla*	640	82.2	179.8
12.	Breadth of premaxillae at middle of rostrum	47	6.0	13.2
13.	Breadth of premaxillae at expanded proximal ends	150	19.3	42.1
14.	Breadth of premaxillae in front of anterior nares	116	14.9	32.6
15.	Breadth of premaxillae opposite premaxillary foramina	69	8.9	19.4
16.	Breadth of premaxillae opposite maxillary foramina	75	9.6	21.1
17.	Greatest breadth of premaxillae opposite anterior nares	112	14.4	31.5
18.	Least breadth of premaxillae opposite anterior nares	108	13.9	30.3
19.	Least distance between the postero-dorsal margins of the maxillary foramina	89	11.4	25.0
20.	Least distance between the postero-dorsal margins of the premaxillary foramina	36	4.6	10.1
21.	Least distance between the maxillary foramina and premaxillary foramina*	22	2.8	6.2
22.	Distance from posterior border of maxillary foramina to anterior extremity of maxillary protuberance	L: 63 R: 53	8.1 6.8	17.7 14.9
23.	Length of nasal suture line	37	4.7	10.4
24.	Greatest breadth of nasals	52	6.7	14.6
25.	Greatest breadth of superior nares	53	6.8	14.9
26.	Diameter of orifice of posterior nares immediately behind pterygoid processes	115	148.0	32.3
27.	Distance from tip of rostrum to bottom of maxillary notches	L: 473 R: 475	60.7 61.0	132.9 133.4
28.	——— anterior end of vomer	160	20.5	44.9
29.	——— anterior end of presphenoid	L: 370 R: 369	47.5 47.4	103.8 103.7
30.	——— anterior margin of superior nares	578	74.2	162.4
31.	——— nasal vertex	607	77.9	170.5
32.	——— medial suture line of posterior end of pterygoides	554	71.1	155.6
33.	——— line joining antero-lateral processes of maxillaries	463	59.4	130.1

TABLE 1. SKULL DIMENSIONS OF THE NEW SPECIMEN (Cont.)

			mm	percentage to the length	percentage to the breadth
34.	——— occipito-frontal vertex		616	79.1	173.0
35.	——— posterior median end of maxillae on palate		645	828.8	181.2
36.	——— bottom of tubal notch (median)		458	58.8	128.7
37.	——— most anterior point of the palatines		368	47.2	103.4
38.	Length of vomer visible on palate		306	39.3	86.0
39.	Breadth across middle of orbits		334	42.9	93.8
40.	Diameter of orbit (antero-posterior)	L:	115	14.8	32.3
		R:	112	14.4	31.5
41.	Greatest breadth across supra-orbital plates of maxillae		316	40.6	88.8
42.	Greatest breadth across post-orbital processes		356	45.7	100.0
43.	Breadth across zygomatic processes		202	25.9	56.7
44.	Breadth across posterior margins of temporal fossae		218	28.0	61.2
45.	Greatest breadth of cranium at parietal region in temporal fosseae		228	29.3	64.0
46.	Length of temporal fossae	L:	109	14.0	30.6
		R:	103	13.2	28.9
47.	Depth of temporal fossae	L:	53	6.8	14.9
		R:	52	6.7	14.6
48.	Length of tympanic bone	L:	41	5.3	11.5
		R:	42	5.4	11.8
49.	Greatest breadth of tympanic bone*		30	3.9	8.4
50.	Breadth of occipital condyles		126	16.2	35.4
51.	Breadth of foramen magnum		47	6.0	13.2
52.	Length of occipital condyle	L:	80	10.3	22.5
		R:	81	10.4	22.7
53.	Height, vertex to inferior border of pterygoids		293	37.6	82.3
54.	Length of mandible (median)		665	85.4	186.8
55.	Length of mandibular ramus	L:	666	85.5	187.1
		R:	672	86.3	188.8
56.	Distance from anterior end of mandible to coronoid process		625	80.2	175.6
57.	Length of symphysis		184	23.6	51.7
58.	Distance from anterior end of mandible to anterior end of alveolus	L:	180	23.1	50.6
		R:	183	23.5	51.4
59.	Distance from anterior end of mandible to posterior end of alveolus	L:	277	35.6	77.8
		R:	282	36.2	79.2
60.	Depth of mandible at posterior margin of tooth	L:	90	11.6	25.3
		R:	94	12.1	26.4
61.	Depth between angle and coronoid process	L:	121	15.5	34.0
		R:	122	15.7	34.3
62.	Minimum depth of mandible between tooth and coronoid process	L:	72	9.2	20.2
		R:	71	9.1	19.9
63.	Breadth across mandibular condyles*		328	42.1	92.1
64.	Greatest height of mandible at coronoid process	L:	118	15.1	33.1
		R:	119	15.3	33.4
65.	Length of tooth	L:	91	11.2	24.4
		R:	92	11.6	25.3
66.	Breadth of tooth (antero-posterior at crown)*		99	12.7	27.8
67.	Breadth of tooth (transverse)*		16	2.1	4.5

* equal on both sides

together at the bodies as well as at the neural arches. And the 4th and the 5th cervical ones are also ankylosed each other.

The spinous precesses of the 2nd, 3rd and 4th lumbar vertebrae show some pathological changes of the bones. Generally in the Cetacea the last rib is not jointed with the corresponding vertebra. As the authors could not attend the dissection of the whale body, they were not certain in determining the last rib. But in other beaked whales the shape of the last rib is usually very short and thick, and is buried in the muscles. The last (10th) rib of this specimen is different from this shape. It is not inconceivable therefore, that the 11th ribs were present but lost in this case. But in the present work according to the number of ribs actually observed, the number of the dorsal vertebrae is counted as 10. Accordingly the number of lumbar vertebae becomes 10. The first caudal vertebra was determined by the existence of the first chevron. The first and second chevrons are separated into halves. All the chevrons are 11 in number and were collected without any damage.

The last 8 of the caudal vertebrae existed in the region of the tail flukes. Dimensions of the vertebrae are shown in Table 2, and the photographs of them are shown in Plate VI. The vertebrae of this specimen compared with the *Mesoplodon densirostris* reported by Raven are given in Fig. 8. Both were aged and of about the same size. The figure shows clearly some difference of the body form. The authors wish to compare further with other species, but they have no data available on hand.

Ribs and sternum. The ribs and the sternum were cut by saw as mentioned above, and some parts of them were lost. Only the first ribs were intactly collected. Dimensions are given below:

Greatest breadth proximally	77 (mm)
Greatest length	317

Of the sternum were obtained only the parts that were jointed with the cartilage of the first rib. So it was difficult to estimate the whole shape and the number of these bones. The ribs and sternum are made of so porous and thick bony substance that they seem to contain plenty of fat. Among 10 pairs of the ribs, the anterior 7 pairs were two-headed. According to previous authors the two-headed ribs of *Mesoplodon* are said usually 8.

It was to regret that detailed measurements could not be achieved, because of loss of too many bones.

Raven showed that one pair of the cervical ribs existed in *M. densirostris*. In the present specimen the epiphyses of all the vertebrae are fused to the diaphyses, which tells evidently for the physical maturity.

TABLE 2. DIMENSIONS OF THE VERTEBRAE (mm)

Number of vertebrae	(1)	(2)	(3)	(4)	(5)	(6)	(7)
C 1st	28	48	122	124	202	42	59
2nd					178		
3rd					132		
4th	26	48	79	102	91	42	42
5th		57	74	106	95		44
6th	14	58	72	117	89	56	48
7th	18	58	76	145	95	56	55
D 1st	26	54	72	186	105	57	59
2nd	36	50	62	230	103	59	56
3rd	47	53	62	248	110	59	55
4th	54	49	62	272	110	60	53
5th	62	48	62	291	111	61	48
6th	67	52	64	307	95	61	46
7th	74	55	67	307	78	57	45
8th	81	59	70	313	144	54	44
9th	86	63	74	328	223	51	39
10th	93	72	78	331	262	44	34
L 1st	98	75	84	357	296	43	34
2nd	104	80	84	351*	298**	45	33
3rd	107	80	87	365*	306	46	33
4th	116	86	91	871*	307	45	33
5th	112	81	90	387	307	45	33
6th	121***	82	90	375	302	39	28
7th	127	86	90	390	296	28	25
8th	133	87	92	390	293	23	22
9th	139	87	95	391	286	19	19
10th	140	90	93	382**	285	18	17
Ca 1st	141	91	97	377	285	12	15
2nd	137	90	98	370	279	9	14
3rd	133	93	100	354	255	8	10
4th	123	93	99	330	227	8	10
5th	117	89	99	298	205	8	10
6th	112	90	95	265	181**	8	10
7th	105	92	93	235	151	8	9
8th	100***	92	95	206	123	7	8
9th	93	92	93	180	99	6	7
10th	88	92	82	149	85	6	7
11th	78	93	77	125	78	5	5
12th	60	83	75	92	75	2	2
13th	45	69	71	70	74	—	—
14th	38	55	65	59	68	—	—
15th	31	46	58	48	62	—	—
16th	35	42	52	45	56	—	—
17th	33	55	45	40	51	—	—
18th	30	27	39	32	45	—	—
19th	27	22	32	23	36	—	—
20th	24	16	25	17	28	—	—
21th	14	12	15	13	15	—	—

C7+D10+L10+Ca21=48

(1)=Length of body at center
(2)=Height of body at front end
(3)=Breadth of body at front end
(4)=Total height from anterior bottom
(5)=Breadth of transverse processes
(6)=Greatest height of neural canal
(7)=Greatest breadth of neural canal

* with some pathological change.
** has some deficit.
*** with scar caused by saw.

The authors thought the possibility of very small cervical ribs, which might have already been fused to the vertebra. But in reality they could not see the cervical ribs at all, as shown in the Fig. 7; no impression of it was attained, in spite of the elaborate examination. There were probably no cervical ribs in this case.

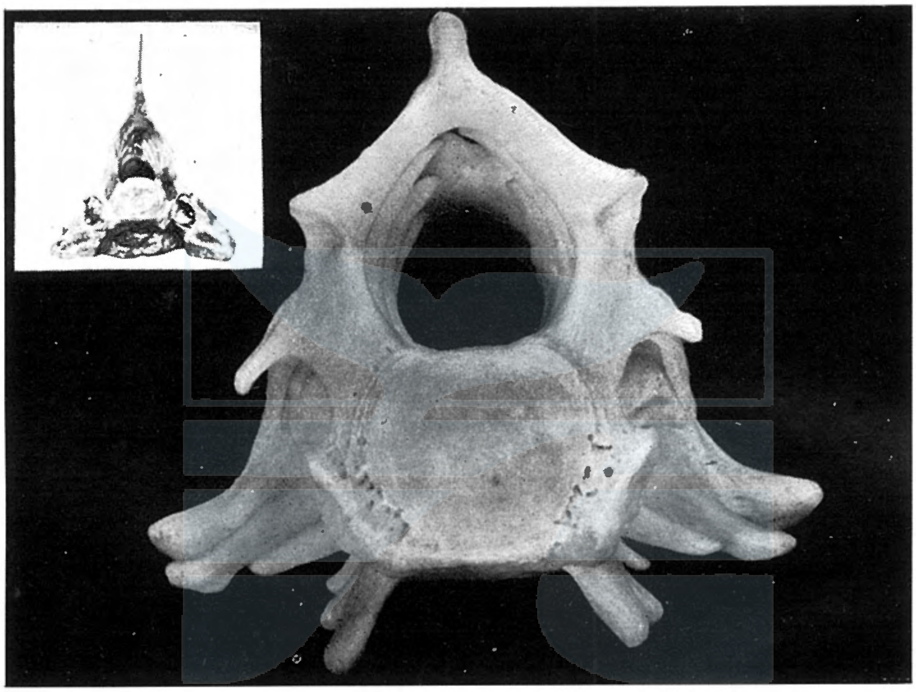


Fig. 7. Cervical vertebrae, caudal view. Upper left is the corresponding picture of *M. densirostris* after Raven.

TABLE 3. DIMENSIONS OF CHEVRON BONES

Number of chevron	Greatest length (antero-posterior)	Greatest breadth (transverse)	Greatest height (supero-inferior)
1. L	41	11	12
R	31*	12	12
2. L	57	18	46
R	52	19	38
3.	78	55	110
4.	107	56	112
5.	106	60	117
6.	99	60	110
7.	92	57	82
8.	85	57	68
9.	81	52	48
10.	69	35	39
11.	30	30	19

* has some deficit.

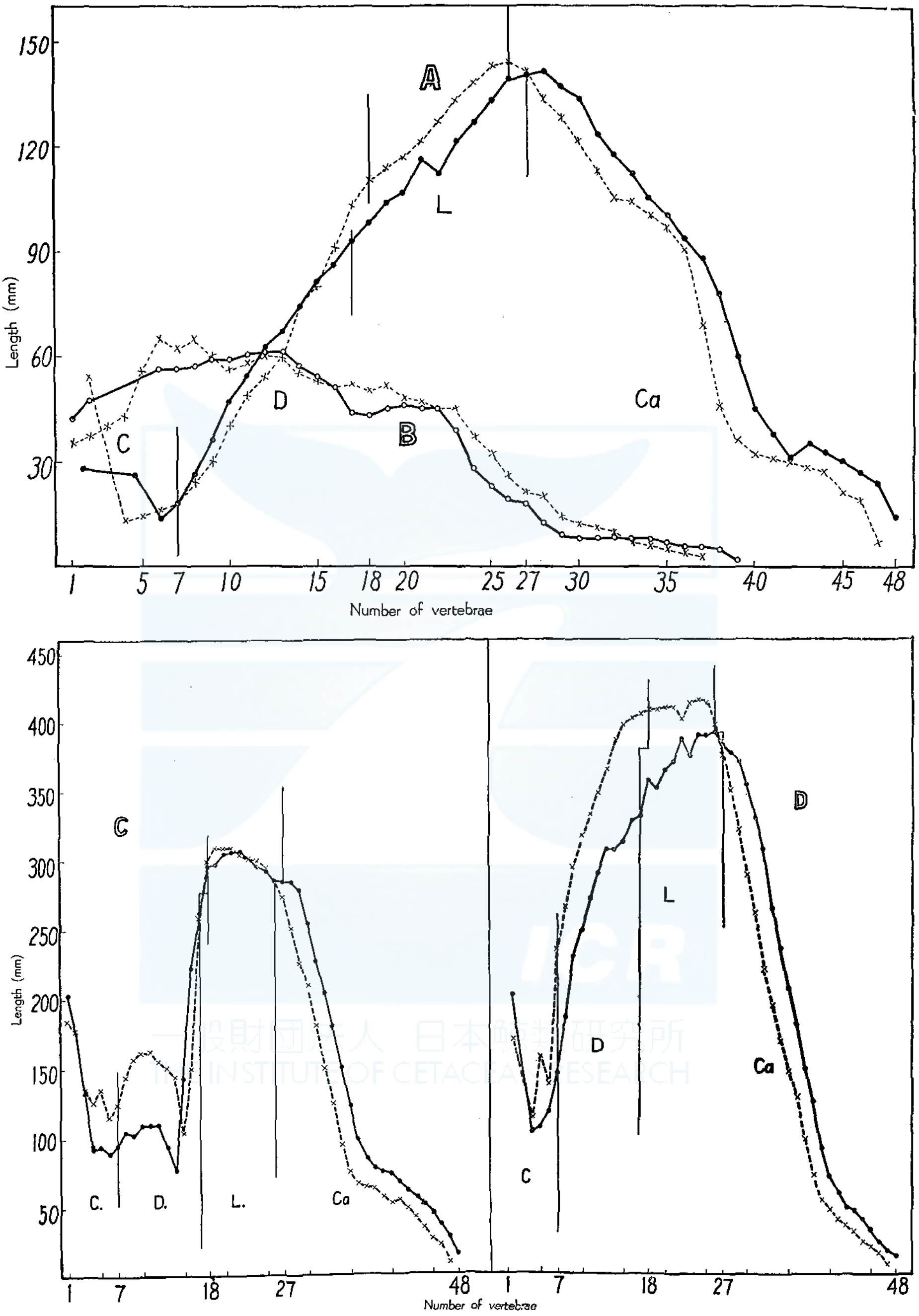


Fig. 8. Dimensions of the vertebrae of *Mesoplodon*. The present specimen compared with the data of Raven.
A: Length of centrum with epiphysis. B: Greatest height of neural canal.
C: Greatest width across transverse processes. D: Greatest height in midline.
C: cervical, D: dorsal, L: lumbar and Ca: caudal vertabrae.
—.—: present specimen. ---×---: *M. densirostris* (after Raven).

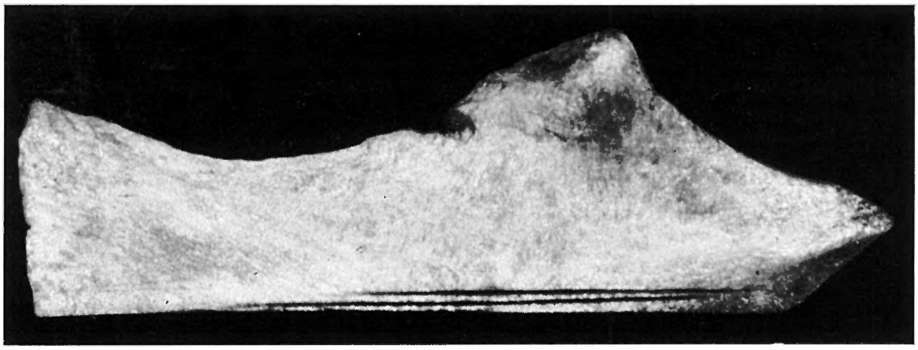


Fig. 9. A part of the 1st sternum.

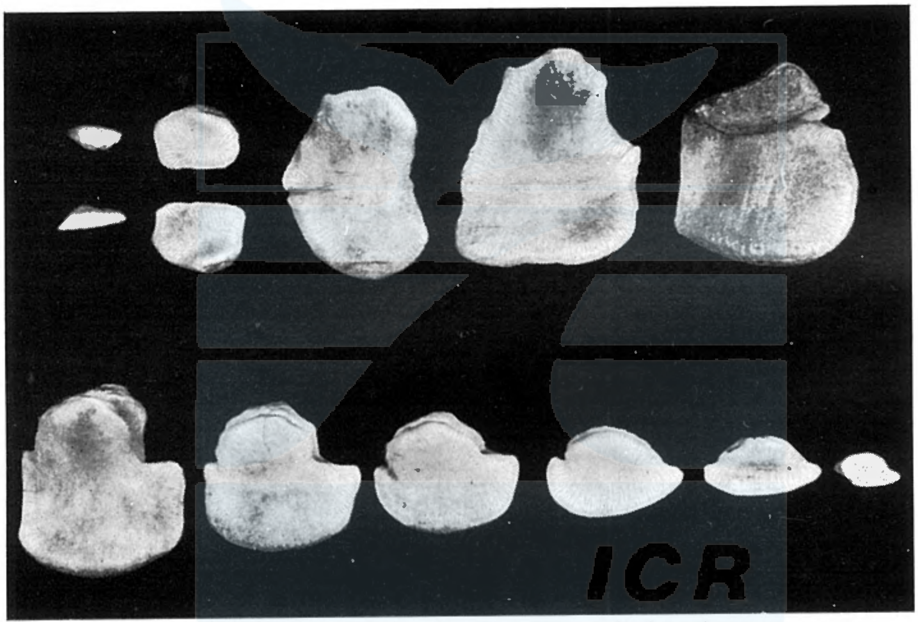


Fig. 10. Chevrons. Anterior 2 show ununited laminae.

TABLE 4. DIMENSIONS OF THE RIGHT PECTORAL LIMB BONES

Length of humerus	129 (mm)
Breadth of humerus at distal end	56
Depth of humerus at distal end	36
Breadth of humerus head	61
Height of humerus head	50
Length of radius	162
Breadth of radius at distal end	49
Depth of radius at distal end	24
Length of ulna	167
Breadth of ulna at distal end	38
Depth of ulna at distal end	19

Pectoral limb. Only the right flipper was examined and its X-ray photograph was taken (Plate IX). Dimensions of the bones of the pectoral limb are given in the above Table 4.

The phalangeal formula including the metacarpals is as follows. I : 1, II : 6, III : 5, IV : 5, V : 3. This formula shows some difference from previous reports upon *Mesoplodon.*

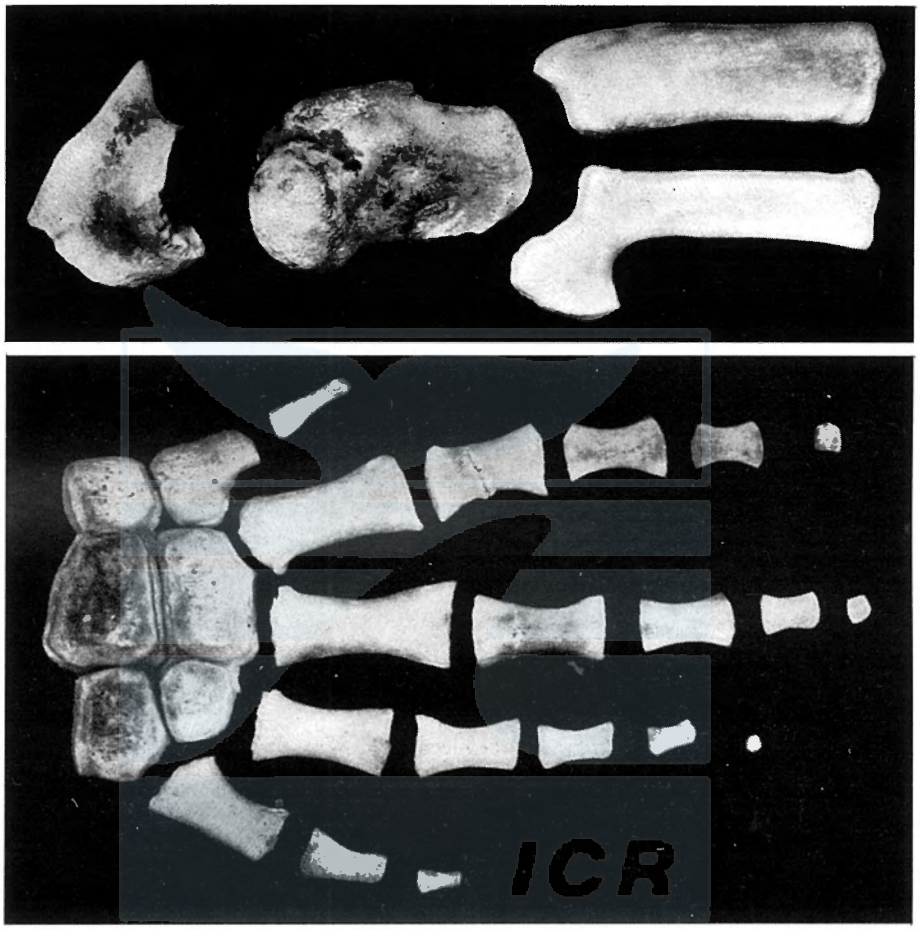


Fig. 11. Bones of the right pectoral limb, dorsal view. Phalanx distalis of II was lost (dissolved ?).

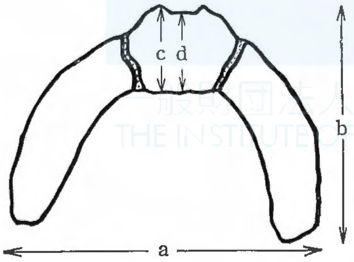
Pelvic bone. The vestiges of the pelvic bones were perhaps sold with the fresh meat, any way were missing, when the authors arrived.

TAXONOMICAL POSITION OF THE PRESENT SPECIMEN

Whales belonging to the *Mesoplodon* have been reported from various parts of the world. At first *Mesoplodon bidens* was found in 1804 by Sowerby. Since then, many species of the *Mesoplodon* have been known. and at present 9 species (*M. mirus, M. hectori, M. europaeus,** *M. grayi,* *M. bidens*, *M. layardi*, *M. stejnegeri*, *M. bowdoini* and *M. densirostris*) are commonly known. Dimensions of the skulls and distinctive characters of them (taken from the type specimens as possible) are shown in Tables 5 and 6 respectively. For easy understanding, the photographs (and the figures) are reproduced in the Plates.

Fig. 12. Hyoid bone. Basihyal and thyrohyals are not fused.

DOMINATION OF BASIHYAL, THYROHYALS AND STYLOHYALS



a-176 (mm)
b-130
c- 55
d- 50

The greatest length and breadth of stylohyals

L	163	37 (mm)
R	159	36

Four distinctive character seem to be present in classifying the species of *Mesoplodon*. The first is the relative position of the premaxillary and maxillary foramina. Raven described upon this character as follows. "The relative position of the maxillary to the premaxillary foramen is apparently a constant character in a given species. The conspicuous maxillary foramen which affords an exit for the principal branch of the nervus infraorbitalis is situated close to the lateral border of the premaxillary bone, where the latter is constricted at the base of the rostrum. The premaxillary foramen in *Mesoplodon* is always located at the rostral border of the very slight depression that marks the site of the ventral spiracular, or premaxillary sac. In some species of *Mesoplodon* the premaxillary foramen is in advance of the adjacent maxillary foramen, in other species behind the maxillary foramen. This depends upon the size and shape of the sac ". According to the position of these foramina, the species with the premaxillary foramen situated more rostrally than the maxillary foramen must be *M. europaeus* (=*M. gervaisi*), and *M. bidens*. And the present specimen agrees with them in this respect. The species name of *M. europaeus* is used by some scientists as synonym to *M. gervaisi*. The present authors prefer the name *M. europaeus*. *M. pacificus* is taken for a sub-species of *M. mirus*, that is *M. mirus pacificus* in the present work.

The second character is the presence or absence of the lateral basirostal groove, which was especially noticed by Flower. Raven described this character as follows: " Flower used the lateral basirostral groove as an important character in separating the various species of *Mesoplodon* into two groups. This lateral basirostral groove of Flower is synonymous and homologous with the maxillary alveolar groove of less specialized mammals. The species of *Mesoplodon* having this groove frequently retain a number of small peg-like upper teeth. It is also analogous to the alveolar groove in the mandible. Flower described it as a groove at the base of the rostrum, commencing posteriorly in a blind pit below the tubercle of the maxillary, situated in front of the antorbital notch and bounded above and below by sharply defined prominent ridges, both formed by the maxillary ".

The lateral basirostral groove was definitely found in *M. grayi* as a deep and conspicuous groove. According to Raven the groove in question is absent in *M. stejnegeri* and *M. bowdoini*. But the present authors are of the opinion that the groove is remarkably present in both of these species. By this instance it becomes evident that the problem on the existence or the absence of the lateral basirostral groove is influenced very much by subjective factor and the individual variation seems to play some part. Anyhow, this groove has been found most clearly in *M. grayi* (=*M. australis*), also in *M. layardi*, then in *M. densirostris*, *M. stejnegeri* and *M. bowdoini*. The present specimen does not show this groove at all. To the species of *Mesoplodon* which do not show the lateral basirostral groove are counted *M. mirus*, *M. hectori* (but instead a prominent ridge is present), *M. europaeus* and *M. bidens* as indicated in Table 6.

TABLE 5. COMPARISONS OF THE SKULL DIMENSIONS

1**Total (condylo-basal) length
2 Length of rostrum (median)
3 Breadth of rostrum at base
4 Breadth of rostrum at middle
6 Breadth of rostrum at the highest point of anterior palatine suture
7 Breadth of rostrum between the antorbital notches
8 Depth of rostrum at middle
10 Depth of rostrum at the highest point of anterior palatine suture
12 Breadth of premaxillae at middle of rostrum
13 Breadth of premaxillae at expanded proximal ends
15 Breadth of premaxillae opposite premaxillary foramina
16 Breadth of premaxillae opposite maxillary foramina
17 Greatest breadth of premaxillae opposite anterior nares
18 Least breadth of premaxillae opposite anterior nares
19 Least distance between the postero-dorsal margins of the maxillary foramina
22 Distance from posterior border of maxillary foramina to end of maxillary protuberance
23 Length of nasal suture line
25 Greatest breadth of superior nares
26 Diameter of orifice of posterior nares immediately behind pterygoid processes
27 Distance from tip of rostrum to bottom of maxillary notches
30 Distance from tip of rostrum to anterior margin of superior nares
32 Distance from tip of rostrum to median suture line of posterior end of pterygoids
33 Distance from tip of rostrum to line joining antero-lateral processes of maxillaries
35 Distance from tip of rostrum to posterior median end of maxillae on palate
37 Distance from tip of rostrum to most anterior point of the palatines
38 Length of vomer visible on palate
39 Breadth across middle of orbits
40 Diameter of orbit (antero-posterior)
41 Greatest breadth across supra-orbital plates of maxillae
42 Greatest breadth across post-orbital processes
43 Breadth across zygomatic processes
46 Length of temporal fossa L:
R:
48 Length of tympanic bone
49 Greatest breadth of tympanic bone
50 Breadth of occipital condyles
51 Breadth of foramen magnum
53 Height, vertex to inferior border of pterygoids
54 Length of mandible (median)
55 Length of mandibular ramus L:
R:
57 Length of symphysis
58 Distance from anterior end of mandible to anterior end of alveolus L:
R:
60 Depth of mandible at posterior margin of tooth
61 Depth between angle and coronoid process L:
R:
62 Minimum depth of mandible between tooth and coronoid process
64 Greatest height of mandible at coronoid process L:
R:
65 Length of tooth L:
R:
66 Breadth of tooth (antero-posterior at crown)
67 Breadth of tooth (transverse)

* It is not measured at crown.
** Numbers are same with Table 1.

IN VARIOUS KNOWN SPECIES OF *MESOPLODON*

M. mirus (Female) (after Raven)	*M. hectori* (after Flower)	*M. europaeus* (Male) (after Raven)	*M. australis* (after Flower)	*M. grayi* (after Flower)	*M. bidens* (Female) (after Fraser)	*M. bidens* (Male) (after Fraser)	*M. stejnegeri* (after Orr)	*M. bowdoini* (Male) (after Orr)	*M. densirostris* (after Raven)	Sotonoura Specimen (Female?) (after Ogawa)	The present specimen (Male)
(810)	(567)	(765)	(770)	(770)	(758)	(768)	(630)	(806)	(770)	(699)	(779)
100	100	100	100	100	100	100	100	100	100	100	100
—	56.4	—	65.9	66.2	65.4	63.4	51.1	—	—	59.7	55.8
—	—	—	—	—	—	—	18.6	28.9	—	24.5	19.4
7.4	6.5	—	5.7	5.2	5.5	5.5	7.1	7.3	9.1	9.0	8.2
—	—	—	—	15.7	—	—	—	—	—	—	11.6
25.9	23.8	—	24.3	23.5	23.5	24.1	—	—	24.9	27.3	26.3
—	—	—	—	—	4.4	4.8	6.5(+)	12.7	8.6	6.4	6.9
—	—	10.1	—	—	—	—	—	—	—	11.2	9.5
—	—	—	—	—	—	—	—	—	6.5	6.3	6.0
14.6	18.9	—	14.4	13.4	12.1	13.5	—	—	12.2	—	13.9
8.4	—	—	—	—	15.3	16.0	—	—	—	8.4	8.9
17.5	20.6	—	17.7	17.9	—	—	—	—	15.8	—	19.3
—	20.1	—	15.2	14.4	—	—	—	—	—	16.2	14.4
—	—	—	—	—	—	—	—	—	9.1	10.0	9.6
11.4	—	—	—	—	—	—	—	—	6.5	11.3	11.4
7.8	—	—	—	—	—	—	—	—	8.4	17.6	L:12.7, R:12.1
—	—	—	—	—	6.2	6.5	—	—	—	—	4.7
6.9	9.0	7.2	6.8	6.9	—	—	—	8.0	8.7	6.3	6.8
—	—	12.2	—	—	—	—	—	—	—	11.7	14.8
61.2	—	62.7	—	—	—	—	—	61.0	64.3	—	67.7
—	—	71.9	—	—	—	—	78.4	78.5	—	—	74.2
—	—	—	—	—	—	79.2	66.8	76.6	—	75.1	76.8
—	—	56.2	—	—	—	—	—	—	—	—	59.4
—	78.0	—	78.6	80.0	—	—	—	—	—	—	82.8
—	—	48.4	—	—	—	—	—	—	—	—	47.2
20.0	—	—	—	—	—	—	—	—	—	—	39.3
42.6	45.7	—	38.1	36.6	37.2	37.2	43.6	48.6	42.2	28.7	25.9
40.1	41.4	—	36.8	34.8	35.4	35.9	44.1	49.0	42.6	41.5	42.9
—	—	—	—	—	—	—	42.0	—	—	41.6	40.6
—	42.5	48.4	36.1	34.3	—	—	44.0	49.8	—	43.5	45.7
—	—	—	—	—	—	—	12.5	11.8	—	R14.2	L:14.4, R:14.8
—	—	—	—	—	13.1	11.5	—	—	—	16.5	14.0
—	—	—	—	—			—	—	—		13.2
—	9.5	—	6.4	6.6	—	—	—	—	—	—	L: 5.3, R: 5.4
—	—	—	4.2	4.5	—	—	—	—	—	—	3.9
16.3	16.2	—	12.9	12.3	—	—	15.9	16.2	14.0	15.6	16.2
—	—	—	—	—	5.0	6.5	—	—	—	6.3	6.0
37.2	—	—	—	—	31.9	34.1	41.3	42.6	48.0	39.6	37.6
82.5	—	—	—	—	88.7	88.9	—	—	88.7	85.1	85.4
—	85.4	86.9	—	85.7	—	—	—	—	—	—	85.5
—			—		—	—	—	86.0	—	—	86.3
23.8	26.5	16.3	—	27.8	30.6	34.6	—	—	24.0	18.3	23.6
—	—	9.6	—	—	—	—	—	—	—	—	23.1
—	—		—	—	—	—	—	18.5	—	—	23.5
—	—	—	—	—	—	—	—	9.1	22.1	L7.3	11.6
—	14.6	—	—	13.6	—	—	—	—	—	15.9	15.5
—		—	—		—	—	—	15.6	—	—	15.7
—	—	—	—	—	—	—	—	8.1	—	L7.3	L: 9.1, R: 9.2
14.4	—	—	—	—	—	—	—	—	16.9	15.6	15.1
	—	—	—	—	—	—	—	—		—	15.3
—	—	—	—	—	12.3	7.4	—	—	—	—	11.2
—	—	—	—	—			—	16.6	—	5.6	11.6
—	—	—	—	—	9.6*	5.3*	—	7.6*	—	6.4*	12.7
—	—	—	—	—	1.6	1.0	—	1.8	—	0.9	2.1

TABLE 6. A LIST OF SKULL AND MANDIBULAR CHARACTERS

Genus	*Mesoplodon*				
Species		*M. mirus* True, 1913.	*M. hectori* Gray, 1871	*M. europeaus* Gervais, 1852.	*M. grayi* Von Haast, 1876.
Synonym (or sub-species)		*M. mirus mirus* *M. mirus pacificus*	*Berardius arnuxi* *M. knoxi*	*M. gervaisi* Deslongchamps, 1866	*M. australis* *M. haasti*
Type locality		Beaufort Harbor, Carteret County, N.C., U.S.A.	Titai Bay, New Zealand.	English Channel.	Chatham Islands (east of New Zealand), New Zealand, Australia.
Approximate distribution		Ireland, Outer Hebrides; North Carolina north to Nova Scotia.		Also New Jersey, Florida, New York, Long Island, U.S.A.	A specimen stranded in Holland.
Vertebral formula	C7+D9-10+L10-11+Ca19-20=46 to 48. Atlas and axis fused, sometimes also third.	C7+D10+L11+Ca18=46 (Raven)		C7+D9+L11+Ca20=47 (Raven). C7+D10+L10+Ca20=47 (True, Raven). first three of C. ankylosed.	C7+D10+L11+Ca20=48: grayi (Flower). C7+D9+L11+Ca20=47: australis (Flower).
Ribs	Eight ribs two headed. Sternum of four or five pieces.				
Phalangeal formula	I: 1, II: 6, III: 6, IV: 3, V: 2 (Beddord) I: 2, II: 4, III: 4, IV: 3, V: 2 (Raven)	I: 2, II: 4, III: 4, IV: 3, V: 2 (Raven)		I: 2, II: 6 or 7, III: 6, IV: 4(+1?), V: 4 (True) I: 2, II: 5, III: 5, IV: 4, V: 3 (Raven).	
Premaxillary foramina situated to maxillary foramina		in level or caudal	on a level	markedly rostral (Raven)	caudal
Lateral basirostral groove		absent	absent (but a prominent ridge instead)	absent (but a prominent ridge instead)	present deep and conspicuous
Position of mandibular teeth	Single pair of larger or smaller functional teeth in lower jaw, embedded in mandible at or near middle.		not compressed	at middle of mandibular symphysis (opposite symphysis)	near hinder edge of mandibular symphysis
Shape of the teeth				compressed	*M. haasti* is only known from a rostrum and a mandible. But the peculier formed (triangular with a conical point) and large size of teeth seem to mark it out. This tooth has very close resemblance to present new from.
Mental foramen		single	multiple		
Rostrum		very elongated, shallow and margined, with a prominent flange.	broad at base	broad at base	narrow at base
Other characters	Skull with mesoethmoid ossified; the nasals are sunk between the upper ends of the premaxillae. Size: moderate = 15 – 17 feet.	When total length of skull of adult over one meter, in habits the Pacific Ocean. . . . *M. mirus pacificus*, against *M. mirus mirns*.	Distance from occipital condyle to premaxillary foramen about equal to greatest width of skull.		*M. australis* of Flower is same as M. hectori in part (Beddard). Mr. H. O. Forbes seeks to unite with *M.grayi*, Haast, Sir W. Flower's species, *M. australis* and *M. haasti*. In *M. australis* the palatines lie altogether outside the pterygoids.

ON THE VARIOUS SPECIES OF *MESOPLODON*

M. bidens Sowerby, 1804.	*M. layardi* Gray, 1865.	*M. stejnegeri* True, 1885.	*M. bowdoini* Andrews, 1908.	*M. densirostris* Blainville, 1817.	Present specimen
Z. sowerbiensis *sowerbyi* *Aodon dalei* *Delphinus micropterus*	*Callidon guntheri* *Dolichodon traversii* *floweri*			*M. seychellensis*	
Coast of Elginshire, Scotland.	Cape of Good Hope.	Bering Island, Commander Islands, Bering Sea.	New Brigton Beach, Canterbury Province, New Zealand.	Unknown.	Ōiso Beach, Sagami Bay, near Tokyo, Japan.
Recorded from France, British Isles, Holland, Belgium, Germany, Norway, Sweden, Italy, and off eastern U.S.A.	New Zealand, Australia, South Africa, the Falkland Islands.	Bering Island off Eastern Siberia and coast of Oregon, U.S.A.	New Zealand north to eastern North Pacific (near La Jolla).	Madeira, Eastern United States north to Canada, South Africa, Seychelles off East Africa, Lord Howe Island (east of Australia).	
C7+D10+L10+Ca19 =46 (Van Beneden). C7+D10+L9+Ca20 =46 (〃).	C7+D10+L10+Ca19 =46 (Haast).			C7+D11+L8+Ca21 =47 (Raven). C7+D10+L11+Ca18 =46 (Andrews). C7+D10+L11+Ca17 =45 (van Beneden & Gervais).	C7+D10+L10+Ca21 =48
					Number of two-headed ribs are 7.
I: 1, II: 6 or 5, III: 5 or 6, IV: 4 or 5, V: 3 or 4 (True) I: 0, II: 6, III: 5, IV: 3, V: 2 (metacarpa exclude, Kükenthal)			I: 0, II: 4, III: 3, IV: 3, V: 2 (metacarpa exclude, Andrews)		I: 1, II: 6, III: 5, IV: 5, V: 3. (I: 1, II: 5 (+1?), III: 5, IV: 5, V: 4, Ogawa: the first *Mesoplodon* specimen in Japan)
on a level (Beddard) markedly rostral (Raven)	on the same level on a level	in level or caudal (one behind the other)	in level or caudal	caudal or in level	markedly rostral
absent	absence (Flower) present shallow and inconspicurous (slightly developed) (Raven)	absent (Raven) present	absent (Raven) present	present (Beddard) shallow and inconspicarous	absent
near hinder edge of mandibular symphysis (situated caudal to symphysis)	near hinder edge of mandibular symphysis	situated entirely behind the symphysis symphysis is short	symphysis is short	Tooth with vertical apex, near hinder edge of mandibular symphysis. (like as *M. stejnegeri*).	Situated entirely behind the symphysis.
compressed 1/3.5	very large, The singular growth of the strap-shaped teeth finally grow round the jaw.	hardly compressed >1/7 very large	compressed 1/3–1/4 very large	compressed, 1/2–1/3 very large	hardly compressed, over 1/6 teeth profile is closely resembled to leaf shape of ginkgo tree.
	single		single	multiple	single
broad at base	narrow at base vertical height less than width at middle			narrow at base, vertical height greater than width at middle.	breadth of rostrum at base: moderate. (34.7% of rostal length).
	Maxillary protuberance and ridge scarcely distinguishable.	Distance from occipital condyle to premaxillary foramen much less than greatest width of skull. An unusually large brain case (half the length of the skull).	Maxillary protuberance and ridge very pronounced. Distance from occipital condyle to premaxillary foramen much less than greatest width of skull.		The epiphyses of the vertebrae were fully ankylosed their centrum. The extent of cöossification of the presphenoid and the vomer occupied relatively large space in the mesirostrum.

The third character to be considered is the position, where the teeth are situated in the mandible. This character is perhaps more important. A single pair of teeth are situated at the tip of mandible in *M. mirus* as in *Ziphius cavirostris*. In *M. hectori* the teeth are located close to the apex of the mandible. In *M. europaeus* the teeth stand at the place opposite to the mandibular symphysis, while *M. grayi* has the teeth near the hinder edge of the symphysis.

Forbes tried to unite with *M. grayi*, Haast (Sir W. Flower's species), *M. australis* and *M. haasti*. Of *M. haasti*, however, only a rostrum and a mandible are known. So some difficulty lies in taking it for an independent species. But it should be mentioned here especially that the peculiar form (triangular with a conical point) and the large size of the tooth seem to mark it out. Consulting Flower's figure, the lateral view of its tooth resembles closely the present specimen. The premaxillary foramen of *M. haasti* is situated more caudally than the maxillary foramen in the latter. This relative position of the foramina is the most remarkable difference between *M. haasti* and the present specimen.

In *M. layardi* the teeth are situated near the higher edge of the mandibular symphysis, and grow finally strap-shaped around the upper jaw. In *M. bidens* and *M. bowdoini* the teeth are connected to the hinder edge of the mandibular symphysis.

In the present specimen the teeth are situated posterior to the symphysis, similarly to the case in *M. stejnegeri*. But from the location of the teeth, these four, *M. bidens*, *M. bowdoini*, *M. stejnegeri* and the present specimen, are difficult to discriminate from each other. In *M. densirostris* the teeth with vertical apex are situated entirely caudal to the mandibular symphysis.

The fourth character is the shape of the teeth. This problem hitherto has not aroused much discussion. The form of the dentine may be more useful than the whole shape of the teeth for separation of the species. However, it is impossible that one peels off their cement from the teeth, even though on one side of the specimen. From these considerations, the ratio between the transverse thickness and the antero-posterior breadth at the place of insertion into the mandibular alveole gives an important key for this problem. The directions, in which the root of the teeth was formed and the coronal apex of the teeth was pointing, show the way, in which the layer of the odontoblasts retreated in the formation of the teeth. Therefore, the directions of the root and the apex of the teeth can be useful in determining the species. There remain only two, *M. bidens* and the present specimen, which are adequate for the first three characters mentioned above (from the first to the third).

Hereby, the fourth character comes necessarily into special consideration. About the teeth of other species, Table 6 is given, but the explanation is omitted for the purpose of avoiding confusion. In *M. bidens*, the ratio of thickness to antero-posterior breadth of the teeth seems to be 1 : 3.5 and the root of the teeth is directed extremely forewards. On the other hand, in the present specimen the ratio of thickness to antero-posterior breadth of the teeth is 1 : 6 and the rounded root of the teeth is directed slightly forewards. From this point of view no species has ever been known, which shows the teeth of a shape analogous to the present specimen.

Fraser sent recently to the senior author a suggestion upon the present specimen that, " I am quite certain that *M. bidens* is not concerned ". Fraser and Moore suggested from the photographs, that the present specimen might be *M. stejnegeri* or *M. bowdoini*. However, the present authors think the premaxillary foramina in *M. stejnegeri* or *M. bowdoini* seem to be situated on a level equal or more caudal to the maxillary foramina, and in the present specimen this relation is quite reverse. Raven concluded the absence of the lateral basirostral groove in *M. stejnegeri* and *M. bowdoini*, but the present authors can see this groove though vaguely in some photographs of these species. The present specimen does not show this groove at all.

Kellogg suggested, perhaps justly, that " The presence or absence of a lateral basirostral groove may possibly be an age character in some forms ". He said also on the teeth of a *M. stejnegeri* specimen that was found in 1927 on Egg Island, that " The root is expanded anteriorly and posteriorly and resembled the tooth from the Sagami Bay specimen". Considering these suggestions and moreover comparing the dimensions of the skull, the authors can not identify the present specimen to any one of the previously known species. Kellogg suggested further to the senior author, that " all of the specimens of *Mesoplodon* that I have examined present interesting problems and it would appear that the diagnostic characteristics of some of the species have not as yet been determined with any degree of certainty. As yet, a sufficiently adequate series of specimens is not available to determine the limits of variation ". The present authors take this important suggestion deeply into heart. On the steps of classification of the genus *Mesoplodon*, however, because the present specimen shows some characters, which have been thought worthy of separation of the species, it might be better recognized as an independent species also.

The present authors devised with their confidence a key for differentiating the species of *Mesoplodon* based on the distinctive characters mentioned above. The key is shown in Table 7.

TABLE 7. KEY TO THE SPECIES OF *MESOPLODON* BASED ON DISTINCTIVE CHARACTERS OF SKULL AND MANDIBLE

1_1 Premaxillary foramina in level or caudal to maxillary foramina	
2_1 Lateral basirostral groove present	
3_1 Lateral basirostral groove deep and conspicuous	*M. grayi*
3_2 Lateral basirostral groove shallow and inconspicuous	
4_1 Mandibular symphysis moderate; tooth situated caudal to angle of mandible; tooth pointed backward; tooth compressed in the rate of $^{1}/_{2}\sim{}^{1}/_{3}$	*M. densirostris*
4_2 Mandibular symphysis short; tooth situated near angle of mandible; tooth pointed forward	
5_1 Tooth compressed in the rate of $^{1}/_{3}\sim{}^{1}/_{4}$ between its thickness (transverse) and breadth (antero-posterior) at crown	*M. bowdoini*
5_2 Tooth hardly compressed in the rate of ca. $^{1}/_{7}$ between its thickness (transverse) and breadth (antero-posterior) at crown	*M. stejnegeri*
2_2 Lateral basirostral groove absent; tooth not compressed, situated at or near tip of mandible	
6_1 Distance from occipial condyle to premaxillary foramen about equal to greatest width of skull; mental foramen multiple	*M. hectori*
6_2 Distance from occipital condyle to premaxillary foramen much less than greatest width of skull; mental foramen single	*M. mirus*
7_1 Total length of skull of adult under one meter, inhabits Atlantic	*M. mirus mirus*
7_2 Total length of skull of adult over one meter, inhabits Pacific	*M. mirus pacificus*
1_2 Premaxillary foramina rostral to maxillary foramina	
8_1 Lateral basirostral groove present; vertical height of rostrum less than its width	*M. layardi*
8_2 Lateral basirostral goove absent	
9_1 Tooth situated opposite symphysis	*M. europaeus*
9_2 Tooth situated caudal to symphysis	
10_1 Tooth compressed in the rate of $^{1}/_{3}\sim{}^{1}/_{4}$ between its thickness (transverse) and breadth (antero-posterior) at crown	*M. bidens*
10_2 Tooth hardly compressed in the rate of ca. $^{1}/_{7}$ between its thickness (transverse) and breadth (anteroposterior) at crown	*M. ginkgodens*

The authors ventured to settle a new species for this specimen and nominated it as *Mesoplodon ginkgodens*. This species name is chosen from the fact that the lateral view of the teeth of the present specimen resembles closely the shape of a leaf of the ginkgo tree (*Ginkgo biloba* LINNAEUS). Ginkgo tree is very common in Japan; it is cultivated for the handsome foliage. Its correct Japanese name is ginkyo or ichō. But it was introduced to the scientific world of Europe under the perhaps mistaken nomination of Ginkgo. The name Ginkgo is now commonly used in English language and scientific circles, so the authors were obliged to adopt the rather false ginkgo against the correct ginkyo.

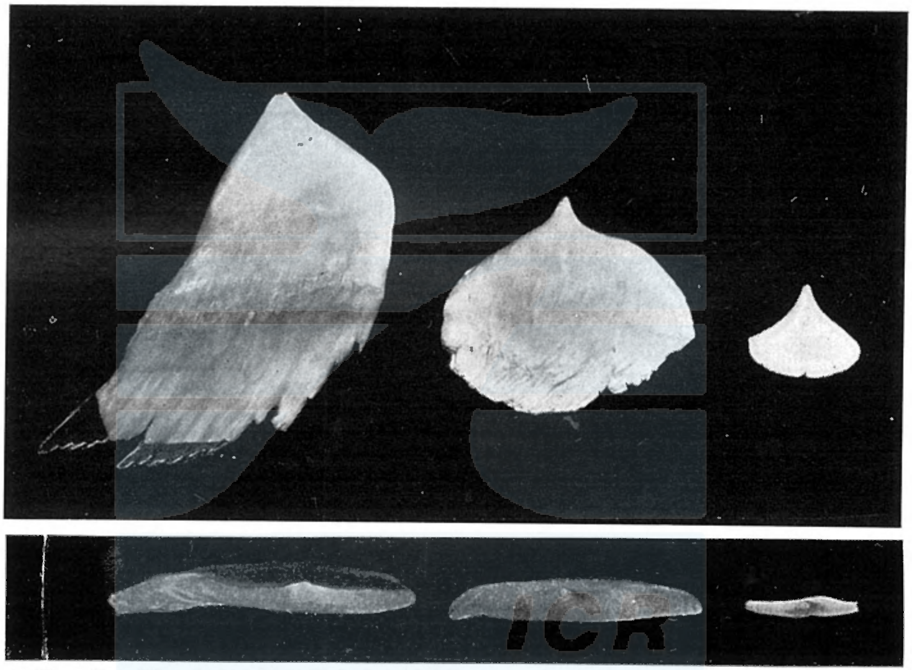


Fig. 13. The right side tooth (middle) compared with *M. stejnegeri* (left) and the first *Mesoplodon* specimen in Japan (right).

It is a very difficult problem to classify the whales of the genus *Mesoplodon* into species, because of the scarcity of them caught or found, examined and exactly reported. Somebody will in the future, several years or several ten years later, adjust the various species of *Mesoplodon*. But at present, there seems to be no other means than to take the present specimen for a new species from the distinctive characters. The authors designate the present specimen which stranded on Ōiso Beach, Sagami Bay, near Tokyo, as the type specimen of *Mesoplodon ginkgodens*. The skeleton, though incomplete, will be preserved at the National Science Museum in Tokyo, where also the first *Mesoplodon* specimen in Japan is preserved.

POSITION OF THE FIRST SPECIMEN OF *MESOPLODON* FROM JAPAN

The first specimen of *Mesoplodon* from Japan was reported in 1935 by Ogawa at the annual meeting of the Japanese zoological society. At that time he was puzzled to decide the species name of that *Mesoplodon*, and though it showed characters not completely corresponding to any of the known species, he ventured to identify it to *M. densirostris* rather than to *M. bidens*. But his opinion was not so conclusive, because of insufficiency of the references. It was taken by N. Kuroda in his "List of the Japanese Mammals" (1938) with the new Japanese name "Oogihakujira". Kuroda did not examine himself the specimen, but only recorded it in his catalogue.

The senior author revised at this occasion this first specimen, and he could read also the Raven's article "On the structure of *M. densirostris*, a rare beaked whale". The senior author already stated this specimen as *M. bidens* in "A List of Marine Mammals found in the Seas adjacent to Japan" (in Japanese, 1957). This specimen has been preserved in the National Science Museum of Tokyo. For detailed examination it was borrowed for a while to the Department of Anatomy, Faculty of Medicine, University of Tokyo.

From the key mentioned above upon the species of *Mesoplodon*, this (first) specimen may also belong to *M. ginkgodens*, equally as the present (second) specimen. Indeed, four distinctive characters are coincident between the first and the second specimen. The premaxillary foramina are situated evidently rostral to the maxillary foramina as shown in Plate. At that time Ogawa recognized this relation rightly, but he did not take this character so seriously, and attached importance rather to the position of the teeth on the mandible.

The position of the teeth is very much similar to that in *M. densirostris*. But the shape of the teeth is quite different. The teeth of the first specimen resemble very much a leaf of the ginkgo tree, as Ogawa justly said. The ratio of thickness to antero-posterior breadth of the teeth is thinner in the first specimen than in the second. This difference will be explained by assumption that the first specimen was a younger individual and perhaps a female. After all, the present authors would identify the first specimen neither to *M. densirostris* nor to *M. bidens*.

But some doubtful points remain when the two specimens are compared. The length of the skull is larger in the second specimen than in the first, but the length of the rostrum is larger in the latter than in the former. It is considered in *Mesoplodon* that the body length of the female is generally larger than the same-aged male. The first specimen was estimated as a young individual and probably as female. On the contrary, the second specimen is an old full-grown male. Moreover, it is to consider that the rostrum of the first specimen had been broken before Ogawa found it.

By synthetizing various points of view, the authors are of the opinion that the first specimen might belong to the same species as the present specimen, viz. *Mesoplodon ginkgodens*.

SUMMARY

1. A beaked whale that belongs to the genus *Mesoplodon* was stranded on the 22nd Sept. 1957 at Ōiso Beach, Sagami Bay, near Tokyo.

2. The whole shape of the body could not be examined, as it had been cut. The colour of the body was entirely black, even on the rear sides of flippers and tail flukes.

3. Skull, vertebral column and chevrons were collected in the complete set, but ribs and sternum were cut by saw, and some parts of them were lost. The right flipper without scapula was obtained. Pelvic bones were lost. Vertebral formula is ; C : 7+D : 10+L : 10+Ca : 21=48. 8 caudal vertebrae were contained in the tail flukes. Phalangeal formula is ; I : 1, II : 6, III : 5, IV : 5, V : 3.

4. Four distinctive characters are taken into special consideration in classifying the species of *Mesoplodon*. The first is the relative position between the premaxillary and the maxillary foramina. The second is the presence or absence of the basirostral groove. The third is the position of the teeth on the mandible. The fourth is the shape of the teeth. Considering these characters and comparing the dimensions of the skull with those of the known species, the authors could not identify the present specimen to any one of previously reported species.

5. A key to the species of this genus was summarized basing on the distinctive characters above mentioned. And the authors concluded to settle for this specimen a new species and nominated as *Mesoplodon ginkgodens*.

6. The first specimen of *Mesoplodon* from Japan was reported by Ogawa and said as *M. densirostris*. It was examined again in the present work. After all this first specimen belongs neither to *M. densirostris* nor to *M. bidens*, but perhaps to the same species as the present specimen, viz. *Mesoplodon ginkgodens*.

7. The authors designate the present specimen which was taken from Ōiso Beach of Sagami Bay as the type specimen of *Mesoplodon ginkgodens*. It will be preserved at the National Science Museum in Tokyo, where also the first *Mesoplodon* specimen in Japan is preserved.

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EXPLANATION OF THE PLATES

PLATE I

Dorsal, lateral and ventral views (top to bottom) of head of *Mesoplodon* from Ōiso Beach.

PLATE II

Front views of head and skull of *Mesoplodon* from Ōiso Beach.

PLATE III

Skull of *Mesoplodon* from Ōiso Beach with mandible attached; lateral, dorsal, anterior and posterior views (top to bottom).

PLATE IV

Lateral, dorsal and ventral views (top to bottom) of skull of *Mesoplodon* from Ōiso Beach.

PLATE V

Lateral, dorsal and reversed lateral views of mandible of *Mesoplodon* from Ōiso Beach.

PLATE VI

Lateral views of vertebrae of *Mesoplodon* from Ōiso Beach; cervicals and thoracics, lumbars, caudals 1-7, and caudals 8-21 (top to bottom). Vertebral formula is C7+D10+L10+Ca21=48.

PLATE VII

Cranial, dorsal and caudal views (top to bottom) of cervical vertebrae of *Mesoplodon* from Ōiso Beach; from left to right 1-4, 5-6 and 7th of cervicals.

PLATE VIII

Medial view of left and right sides vertebral ribs of *Mesoplodon* from Ōiso Beach.

PLATE IX

Dorsal view, X-ray photograph and ventral view of right flipper of *Mesoplodon* from Ōiso Beach. Phalangeal formula is I: 1, II: 6, III: 5, IV: 5, V: 3.

PLATE X

Dorsal, caudal, lateral and ventral views of left tooth of *Mesoplodon* from Ōiso Beach (natural size).

PLATE XI

Dorsal, caudal, lateral and ventral views of right tooth of *Mesoplodon* from Ōiso Beach (natural size).

PLATE XII

Skulls of various species of *Mesoplodon*; dorsal views.

Fig. 1. *M. mirus* (from Raven H.D.: Amer. Mus. Nov., No. 905, 1937).
Fig. 2. *M. hectori* (from Flower, W.H.: Trans. Zool. Soc. London, X, part 11, 1878).
Fig. 3. *M. europaeus* (from Raven H.C.: Amer. Mus. Nov., No. 905, 1937).
Fig. 4. *M. grayi* (from Flower, W.H.: Trans. Zool. Soc. London, X, part 11, 1878).
Fig. 5. *M. bidens* (No. 1727, Mus. Comp. Zoology, Harvard College; Courtesy of Smithsonian Institution).
Fig. 7. *M. stejnegeri* (No. 21112, USNM; Courtesy of Smithsonian Institution).
Fig. 8. *M. bowdoinis* (No. 31756, AMNH.; Courtesy of American Museum of Natural History).
Fig. 9. *M. densirostris* (from Raven, H.C.: Bul. AMNH., Vol. 80, 1942).
Fig. 10. *M. ginkgodens* (the present specimen).
Fig. 11. *M. ginkgodens* (the first specimen of *Mesoplodon* from Japan, Ogawa, T.: Arb. Anat. Inst. Kaiserl. Japan. Univ. Sendai, Heft 21, 1938).

PLATE XIII

Skulls of various species of *Mesoplodon*; lateral views.

Fig. 1. *M. mirus* (The specimen of Hatteras Island Beach, North Carolina; Courtesy of Smithsonian Institution).
Fig. 2. *M. hectori* (from Flower, W.H.: Trans. Zool. Soc. London, X, part 11, 1878).
Fig. 3. *M. europaeus* (No. 23346, USNM.: Courtesy of Smithsonian Institution).
Fig. 4. *M. grayi* (=*M. australis*: from Flower, W.H.: Trans. Zool. Soc. London, X, part 11, 1878).
Fig. 5. *M. bidens* (No. 1727, Mus. Comp. Zoology, Harvard College; Courtesy of Smithsonian Institution).
Fig. 6. *M. layardi* (*Ziphius Layardii*; from Gray, J.E.; Cat. Seals, Whales, Brit. Mus. 1866).
Fig. 7. *M. stejnegeri* (No. 143132, USNM.; Courtesy of Smithsonian Institution).
Fig. 8. *M. bowdoini* (No. 31758, AMNH.; Courtesy of American Museum of Natural History).
Fig. 9. *M. densirostris* (from Raven, H.C.: Bul. AMNH., Vol. 80, 1942).
Fig. 10. *M. ginkgodens* (the present specimen).
Fig. 11. *M. ginkgodens* (from Ogawa, T.: Arb. Anat. Inst. Kaiserl. Japan. Univ. Sendai, Heft 21, 1938).

PLATE XIV

Mandibles of various species of *Mesoplodon*; lateral views.

Fig. 1. *M. mirus* (from Norman, J.R. and Fraser, F.C.: Giant Fishes, Whales and Dolphins, 1937; Courtesy of the authors and Putnam & Co. Ltd.)
Fig. 2. *M. hectori* (from Norman. J.R. and Fraser, F.C.: Giant Fishes, Whales and Dolphins, 1937; Courtesy of the authors and Putnam & Co. Ltd.)
Fig. 3. *M. europaeus* (from Norman, J.R. and Fraser, F.C.: Giant Fishes, Whales and Dolphins, 1937; Courtesy of the authors and Putnam & Co. Ltd.)
Fig. 4. *M. grayi* (from Flower, W.H.: Trans. Zool. Soc. London, X, part 11, 1878).

Fig. 5. *M. bidens* (from Norman, J.R. and Fraser, F.C.: Giant Fishes, Whales and Dolphins, 1937; Courtesy of the authors and Putnam & Co. Ltd..)
Fig. 6. *M. layardi* (from Norman, J.R. and Fraser, F.C.: Giant Fishes, Whales and Dolphins, 1937; Courtesy of the authors and Putnam & Co. Ltd.)
Fig. 7. *M. stejnegeri* (No. 143132, USNM.; Courtesy of Smithsonian Institution).
Fig. 8. *M. bowdoini* (No. 31759, AMNH.; Courtesy of American Museum of Natural History.)
Fig. 9. *M. densiroitris* (from Raven, H.C.: Bul. AMNH., Vol. 80, 1942).
Fig. 10. *M. ginkgodens* (the present specimen).

PLATE XV

Mandibles of various species of *Mesoplodon*; dorsal views.

Fig. 1. *M. mirus* (from Raven, H.C.; Amer. Mus. Nov., No. 905, 1937).
Fig. 3. *M. europaeus* (No. 23346, USNM.; Courtesy of Smithsonian Institution).
Fig. 5. *M. bidens* (No. 1727, Mus. Comp. Zoology, Harvard College; Courtesy of Smithsonian Institution).
Fig. 5′. *M. bidens* (from Sergeant. D.E. and Fisher. H.D.: J. Fish. Res. Bd. Canada, Vol. 14, No. 1, 1957; Courtesy of Fisheries Research Board of Canada).
Fig. 8. *M. bowdoini* (No. 31757, AMNH.; Courtesy of American Museum of Natural History.)
Fig. 9. *M. densirostris* (male) (from Raven, H.C.: Bul. AMNH. Vol. 80, 1942).
Fig. 9′. *M. densirostris* (female) (from Raven, H.C.: Bul. AMNH. Vol. 80, 1942).
Fig. 10. *M. ginkgodens* (the present specimen).
Fig. 11. *M. ginkgodens* (from Ogawa, T.: Arb. Anat. Inst. Kaiserl. Japan. Univ. Sendai, Heft 21, 1938).

PLATE XVI

Skulls of various species of *Mesoplodon* with mandibles attached; lateral views.

Fig. 1. *M. mirus* (from Raven, H.C.: Amer. Mus. Nov., No. 905, 1937).
Fig. 3. *M. europaeus* (from Raven, H.C.: Amr. Mus. Nov., No. 905, 1937).
Fig. 4. *M. grayi* (from Flower, W.H.: Trans. Zool. Soc. London, X, part 11, 1878).
Fig. 5. *M. bidens* (from Sergeant, D.E. and Fisher, H.D.: J. Fish. Res. Bd. Canada, Vol. 14, No. 1. 1957; Courtesy of Fisheries Research Board of Canada.)
Fig. 6. *M. layardi* (from Norman, J.R. and Fraser, F.C.: Giant Fishes, Whales and Dolphins, 1937; Courtesy of the authors & Putnam Co. Ltd.)
Fig. 7. *M. haasti* (=*M. grayi*) Dorsal view of a part of skull, lateral view of a part of skull and left mandible (top to bottom). (from Flower, W.C.: Trans. Zool. Soc. London, X, part 11, 1878).
Fig. 10. *M. ginkgodens* (the present specimen).

PLATE XVII

Teeth of three species of *Mesoplodon*.

Fig. 5. *M. bidens* (from Fraser. F.C.: Rept. Brit. Mus. Nat. Hist., No. 11, 1934) A.: male of 14 ft. 6 inch, B.: female of 15 ft. 6 inch; Courtesy of British Museum of Natural History).
Fig. 7. *M. stejnegeri* (No. 143132, USNM.; Courtesy of Smithsonian Institution).
Fig. 9. *M. densirostris* (No. 143910, AMNH.; Courtesy of American Museum of Natural History).
Fig. 9′. *M. densirostris* (from Raven, H.C.: Bul. AMNH., Vol. 80, 1937 upper: male, lower: female. A.: lateral views, B.: caudal views).

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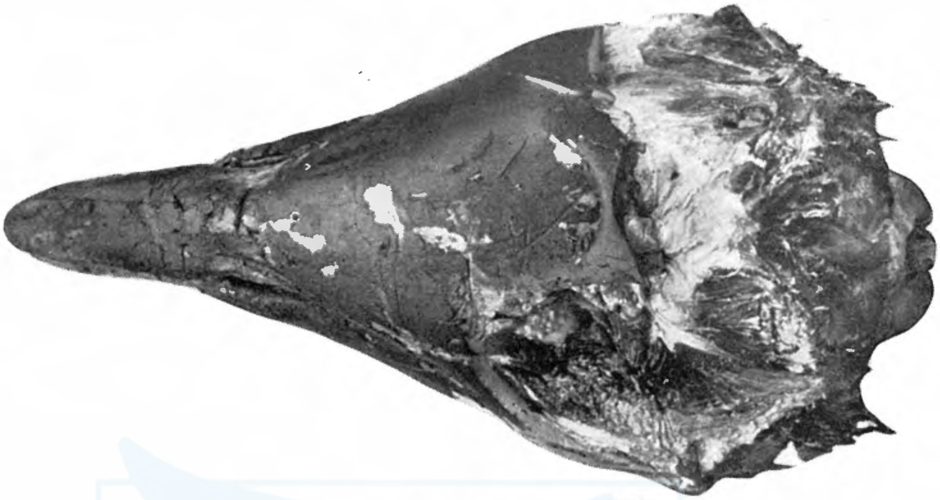
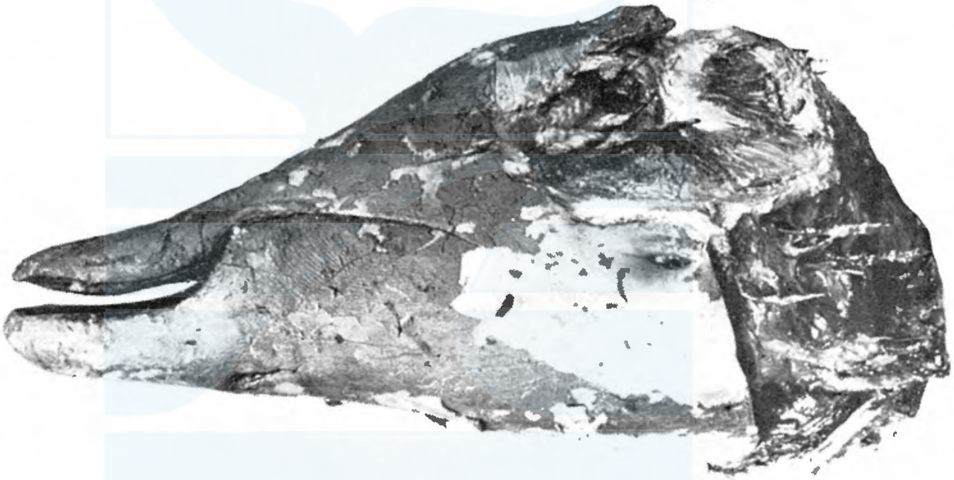
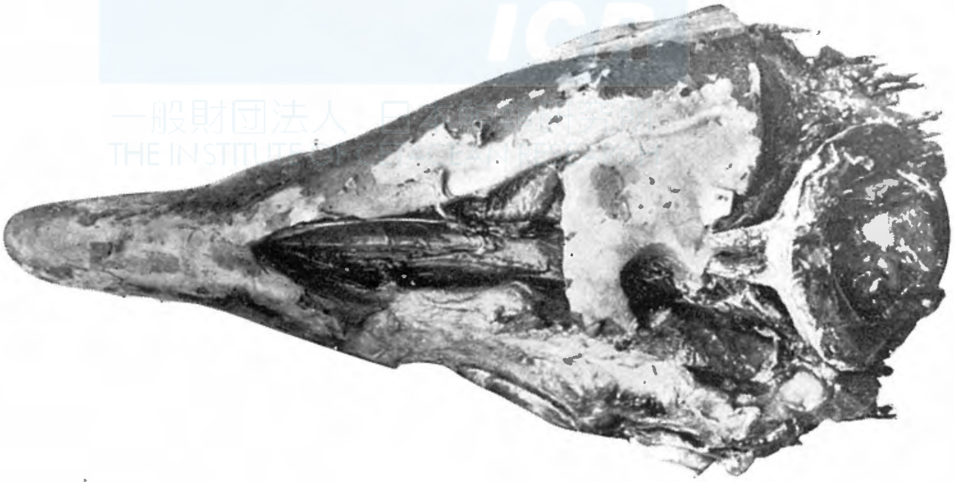






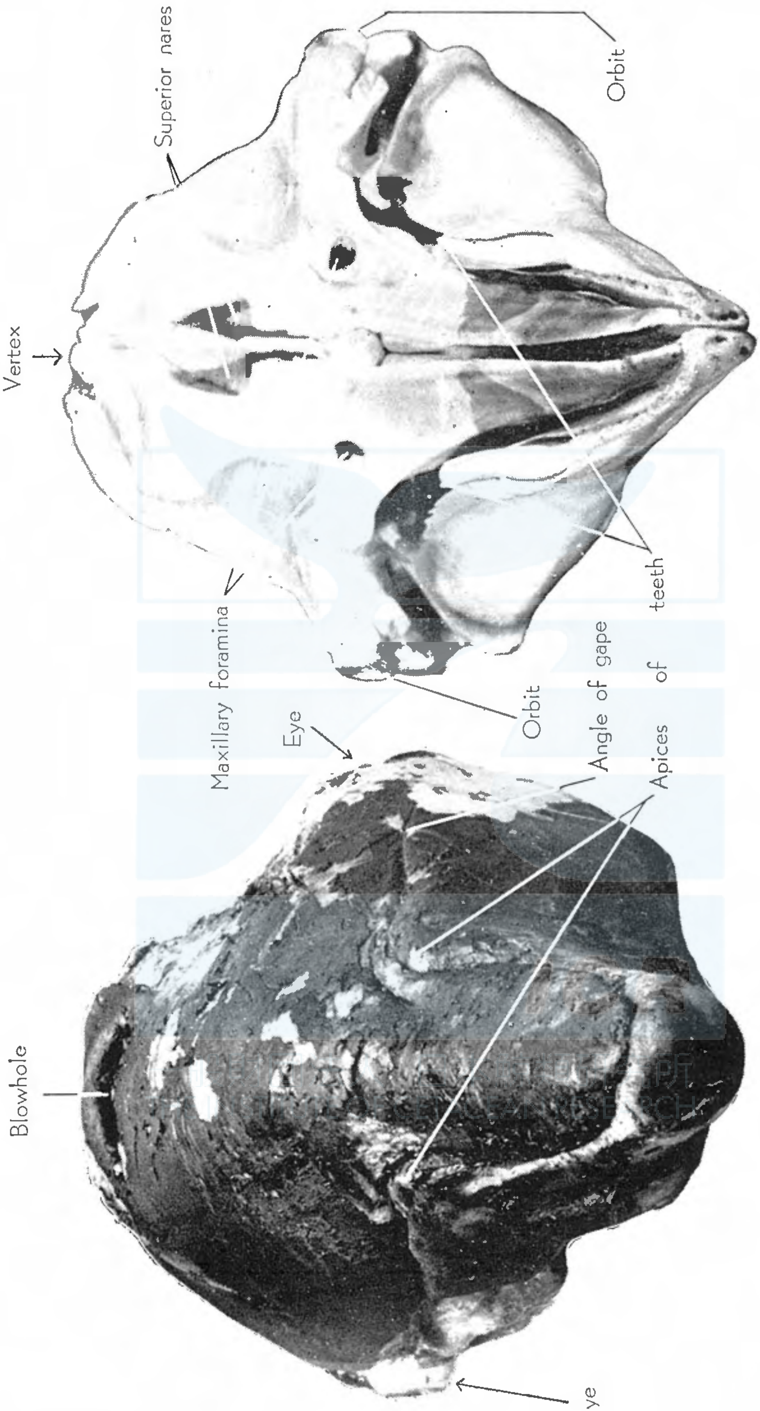
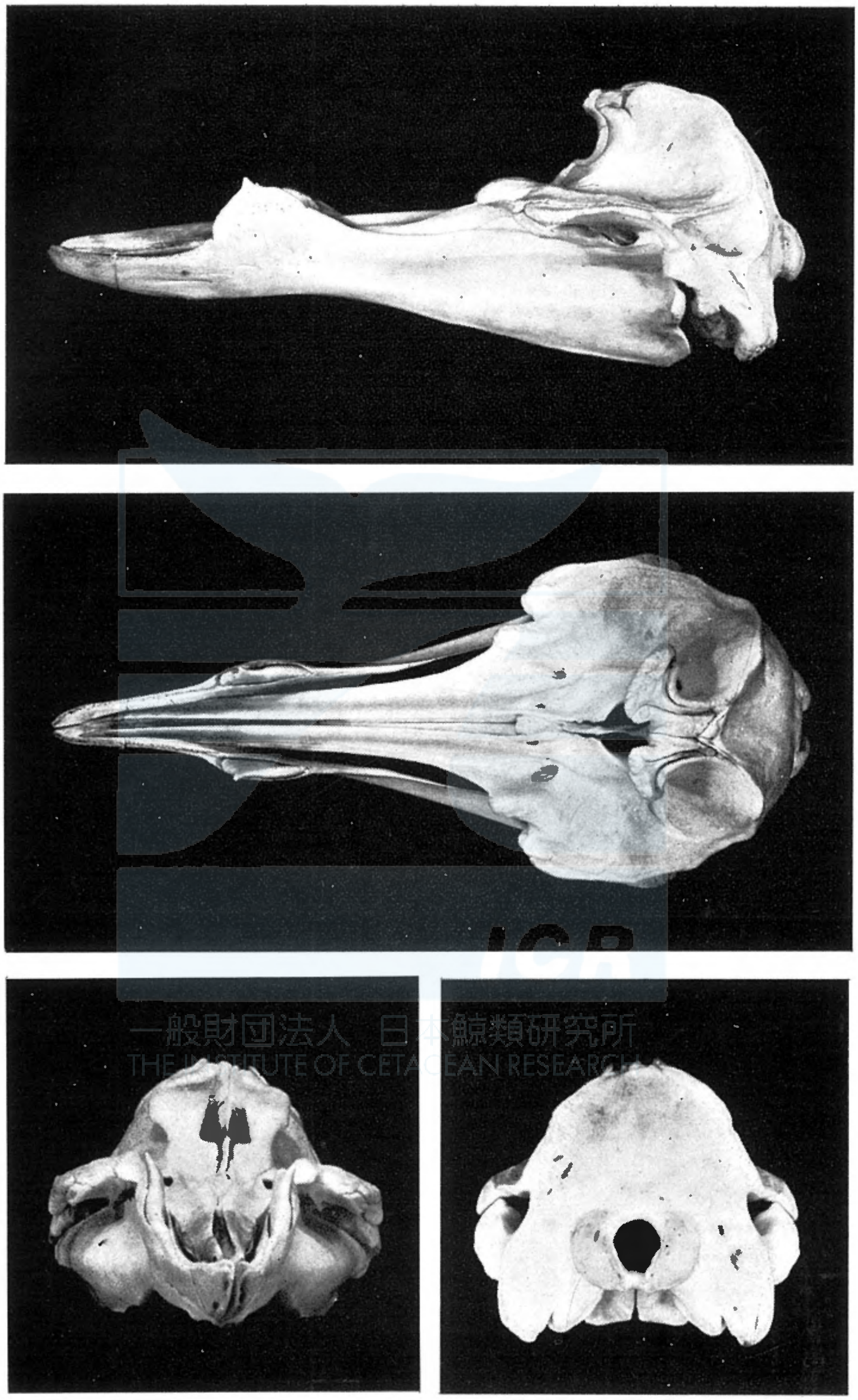
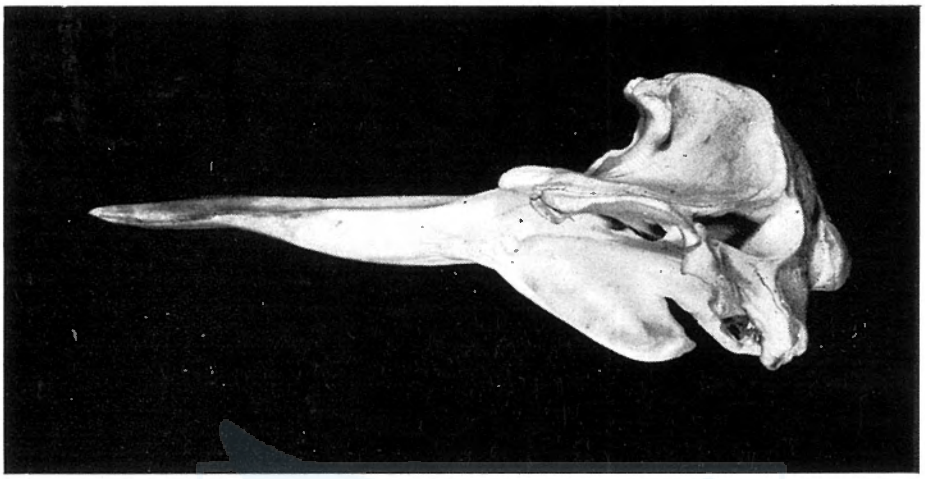
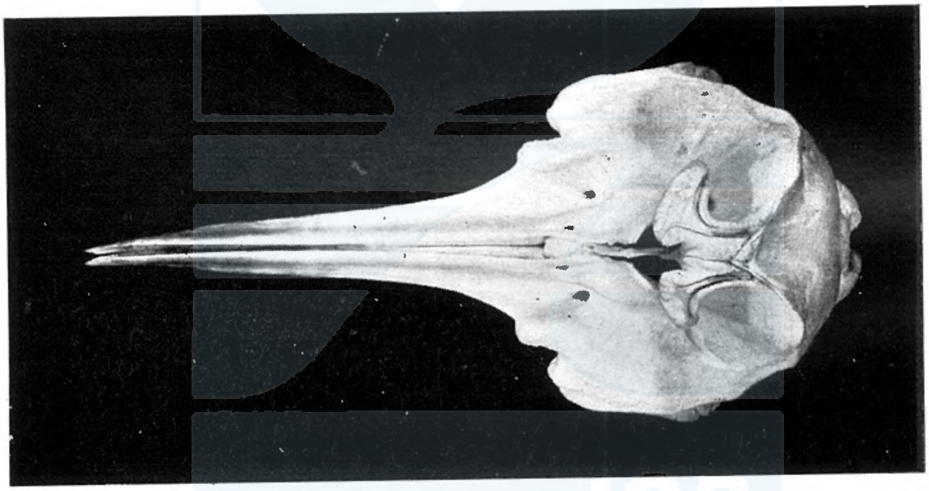
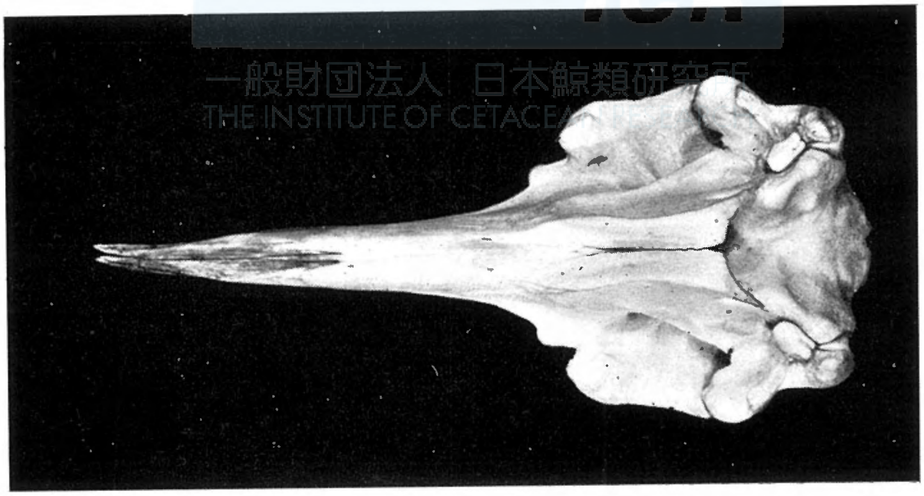

Superior nares
Orbit
Vertex
Maxillary foramina
teeth
Apices of teeth
Angle of gape
Orbit
Eye
Blowhole
Eye

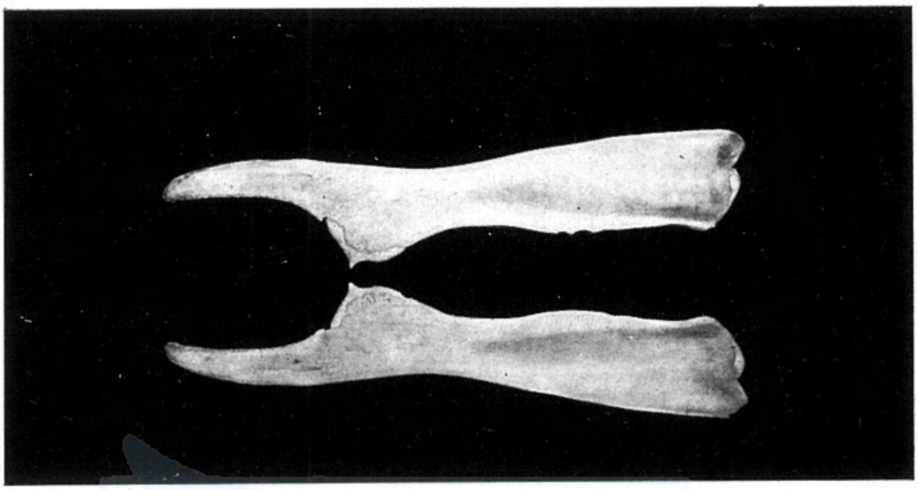
PLATE III

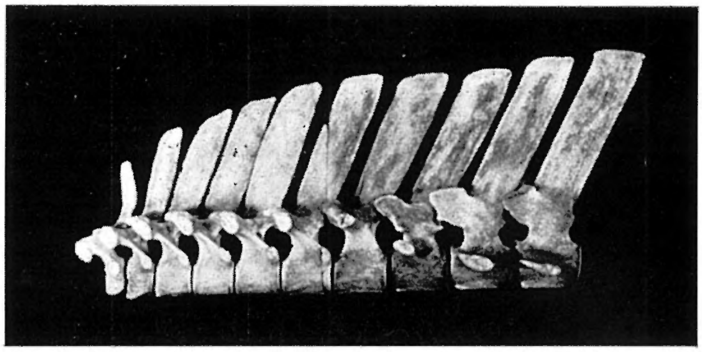


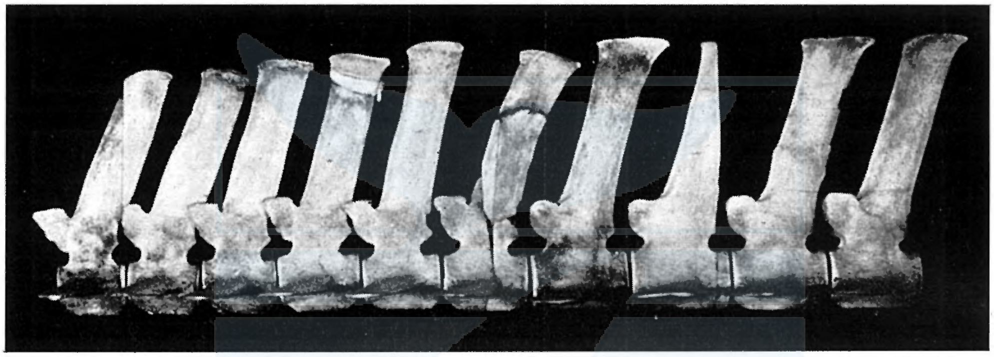


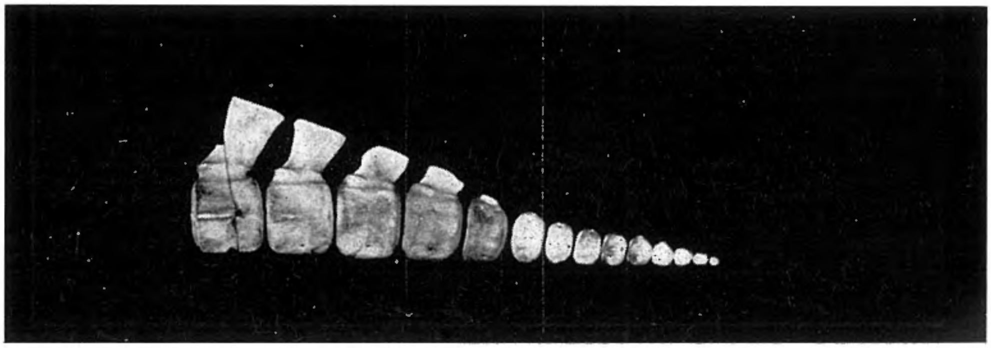


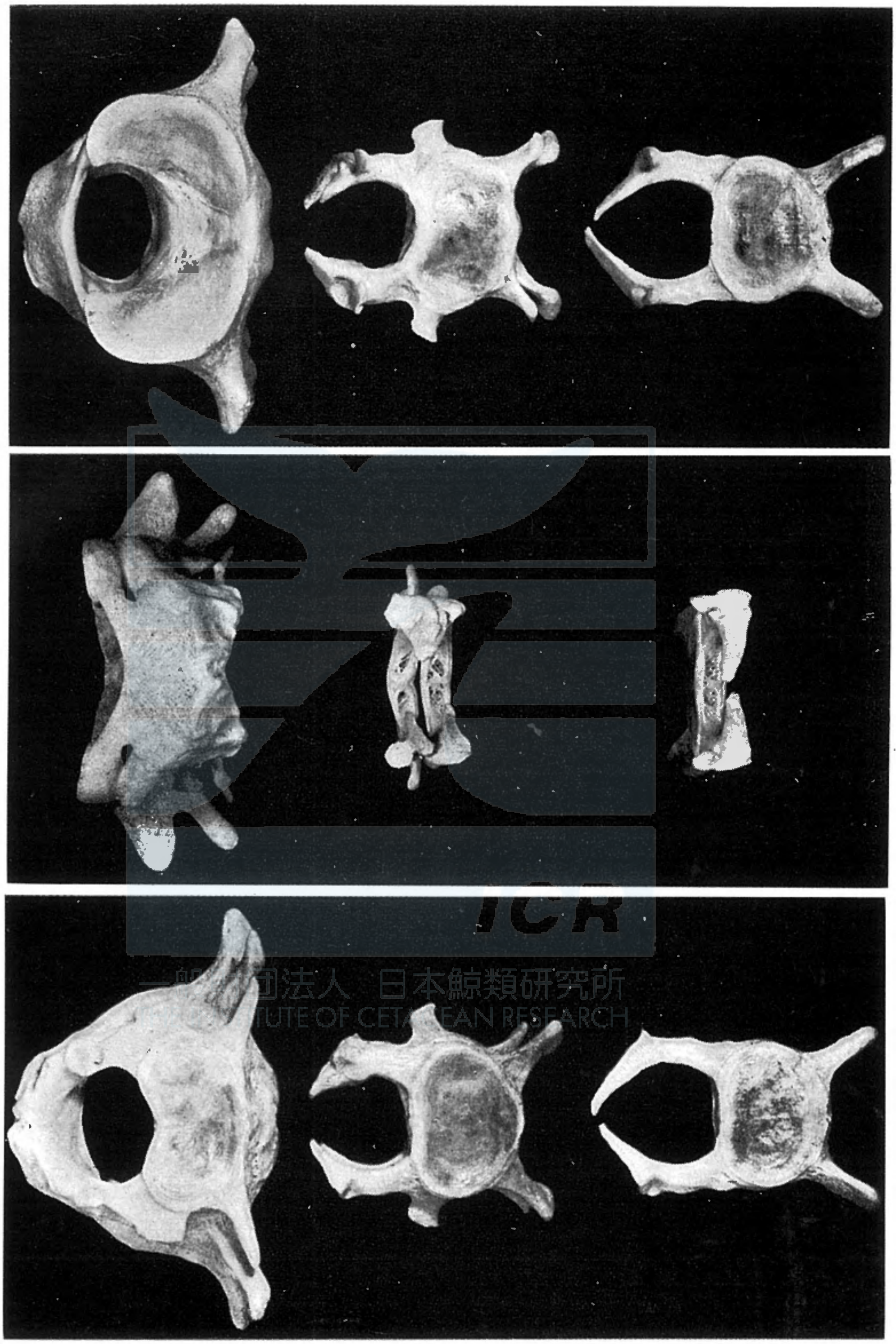


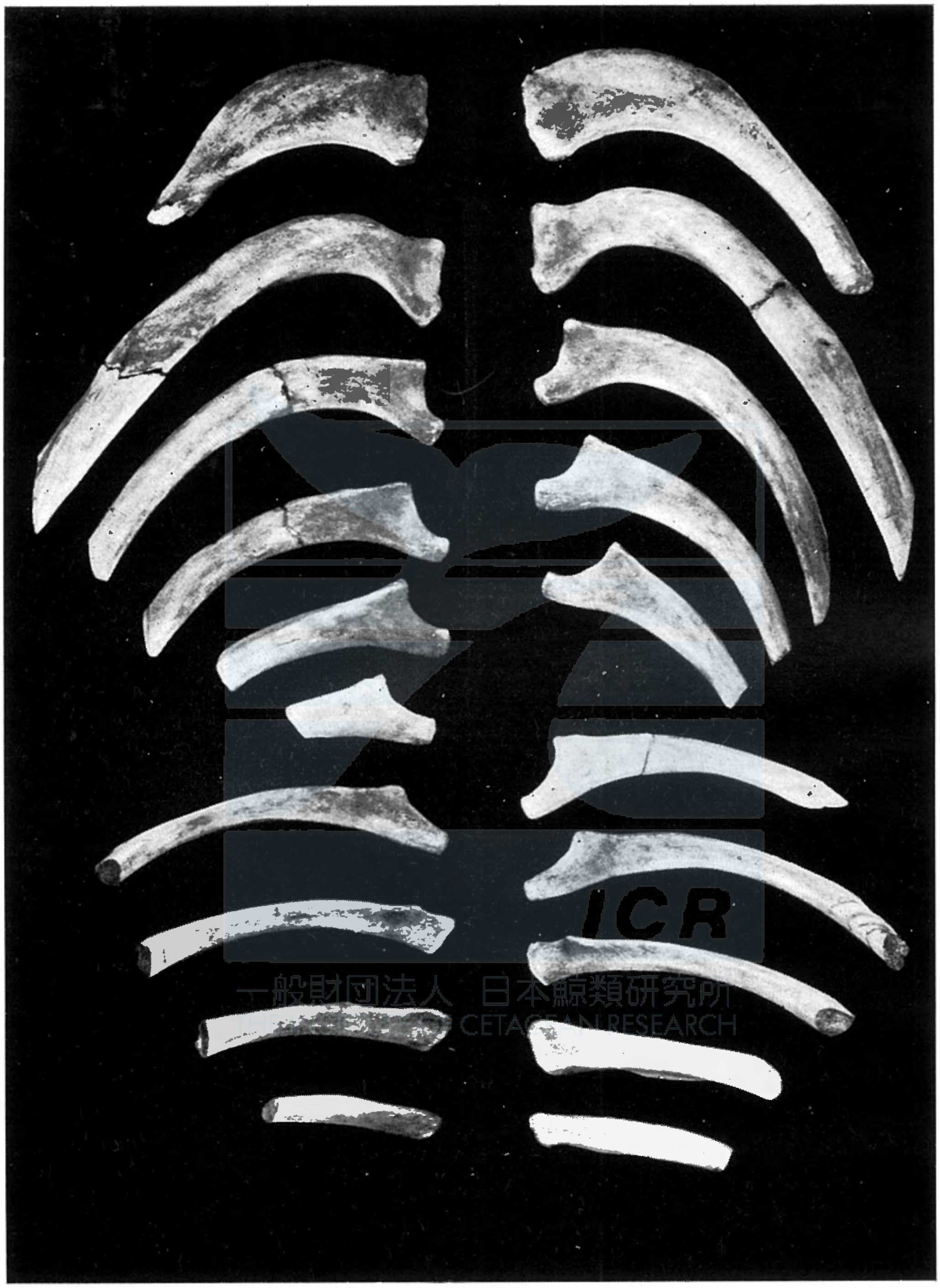


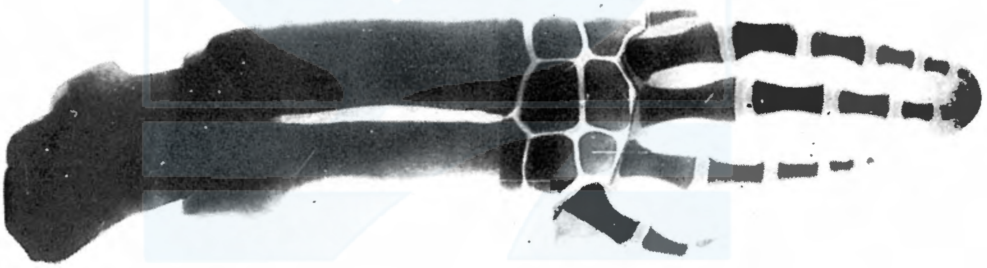


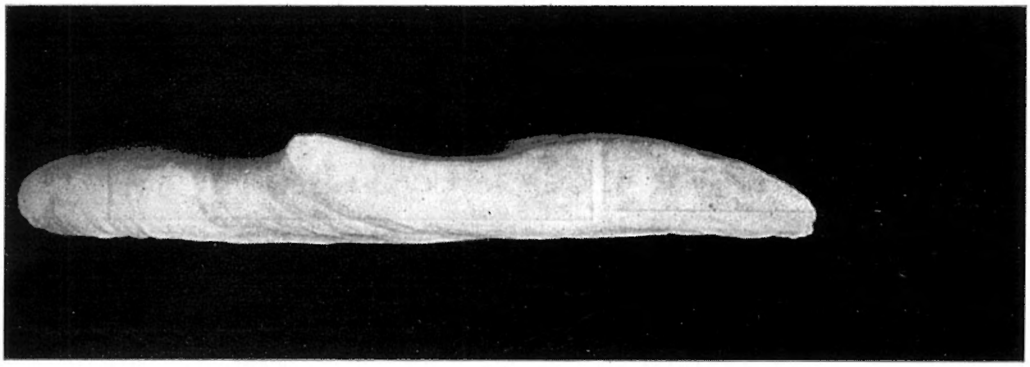


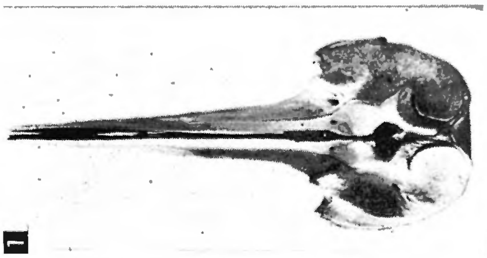








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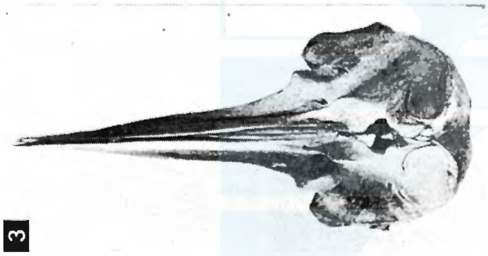
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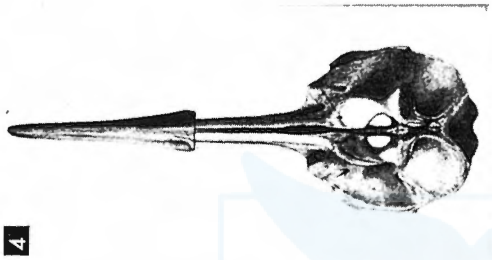
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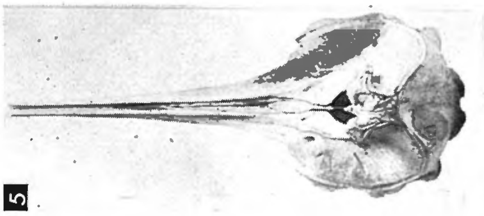
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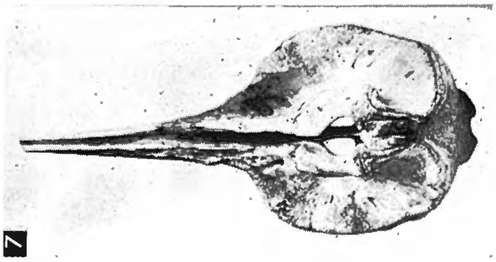
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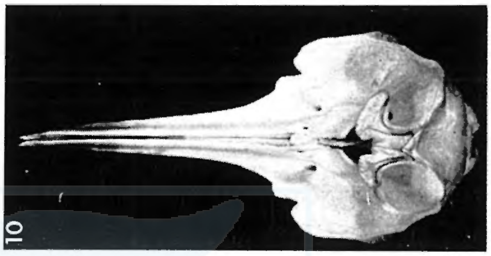
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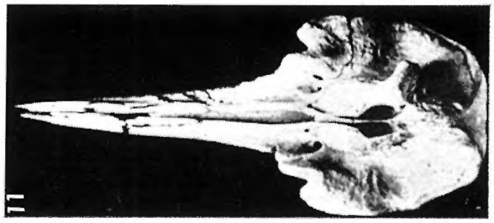
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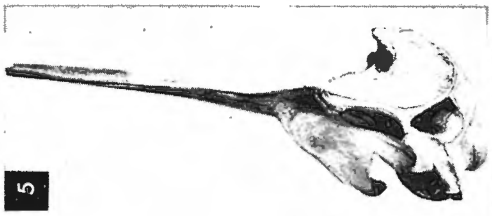
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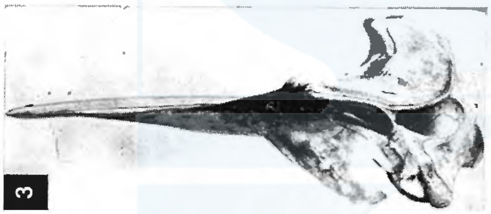
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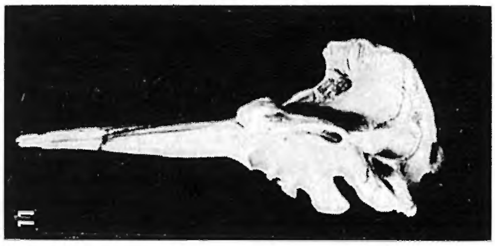
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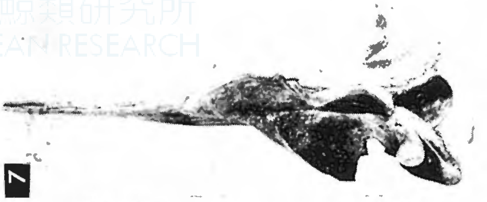
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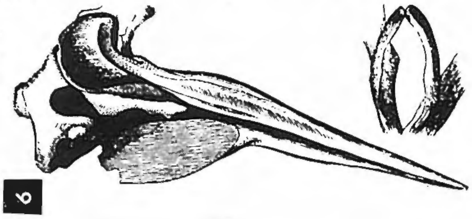
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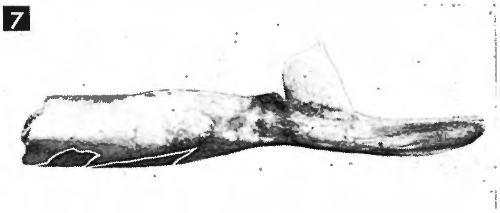

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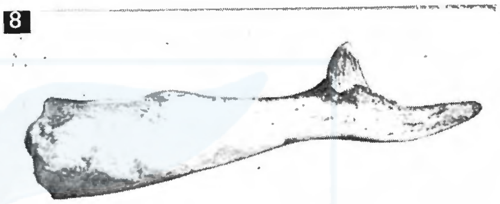

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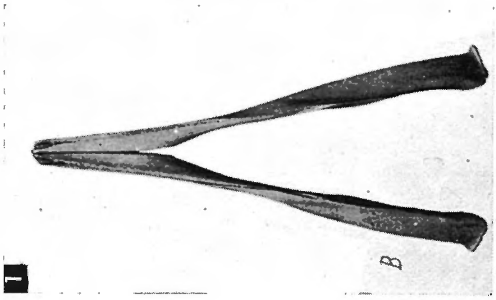
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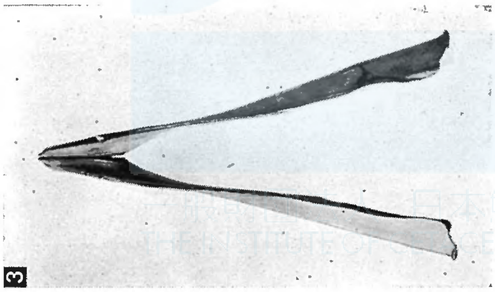
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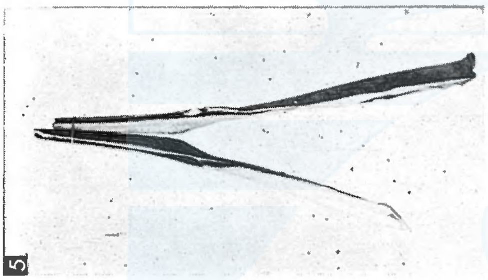
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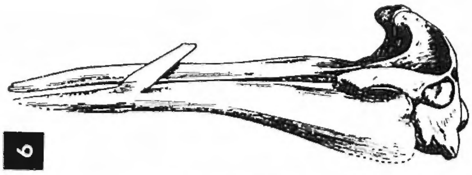
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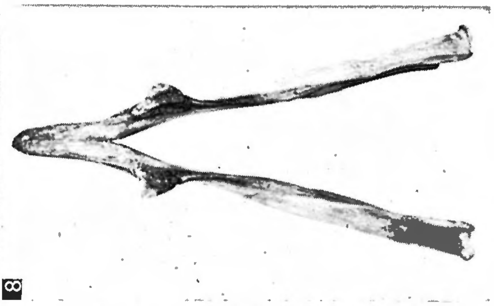
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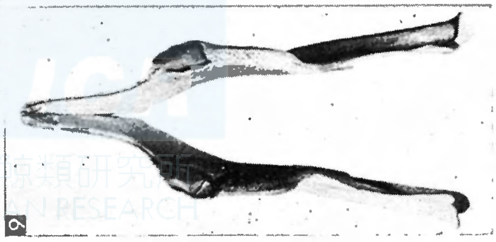
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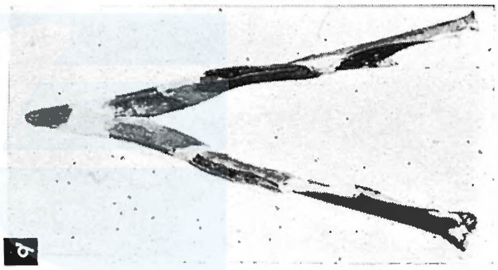
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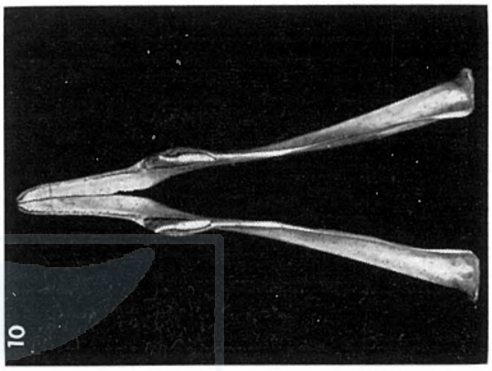
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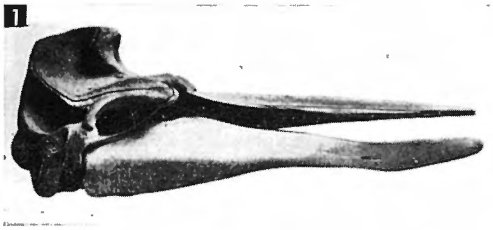

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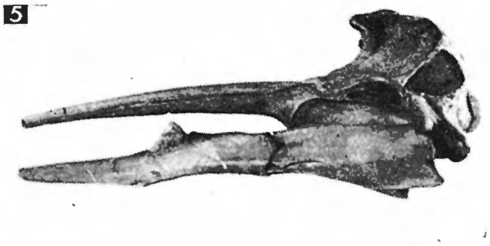

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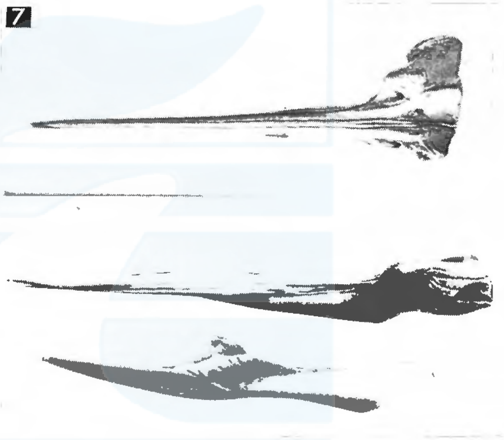

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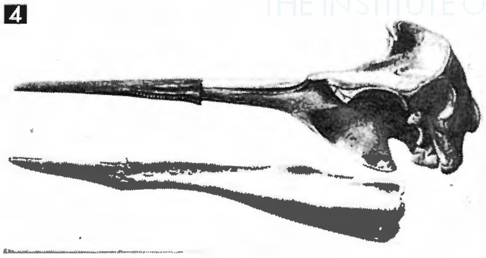

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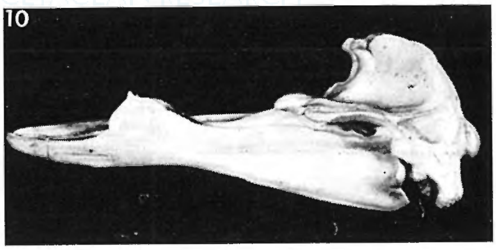

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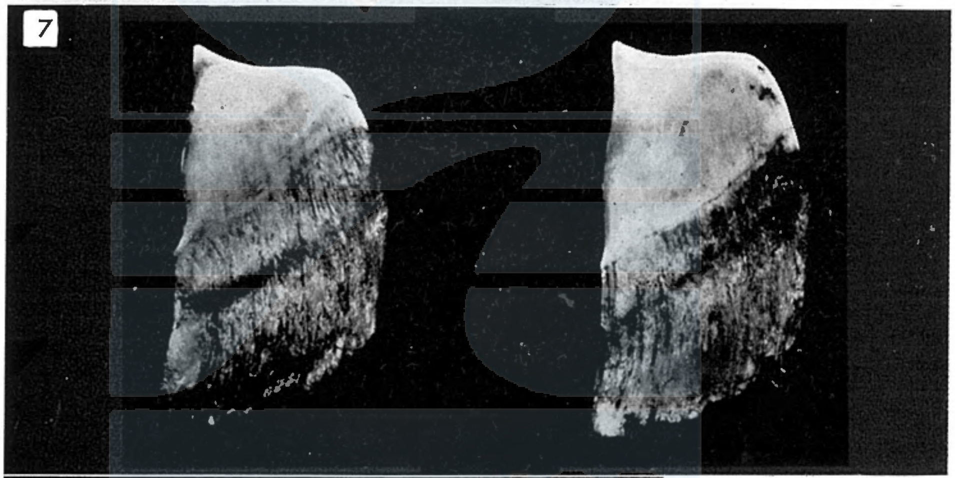

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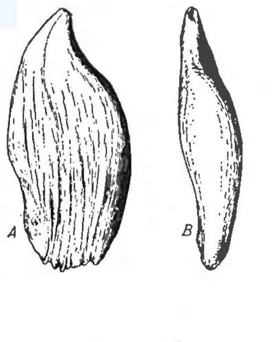

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KILLER WHALES CAUGHT IN THE COASTAL WATERS OFF JAPAN FOR RECENT 10 YEARS

MASAHARU NISHIWAKI
AND
CHIKAO HANDA*

Killer whales, wearing the characteristic form which can be easily distinguished even at a glance, live in any sea and ocean of the whole world. It is generally believed that they give damages to fishing, whaling and sealing. Pike pointed out that they are the powerful enemy to salmon fishery and others in the Canadian waters. In the waters adjacent to Japan, they also give many damages and menaces to us. In the case of tuna long-line fishery (haenawa fishery) at the Indian Ocean, it is not rare that the most of the lined fishes are lost by killer whale. The study on these damages must be interesting but not be described in the present report.

From the taxonomical view point, there seems to be a problem in definition of the scientific name of this animal, although different scientific names are habitually used in the Pacific and the Atlantic Ocean. So the authors have studied on the dimension of skeleton of the species but do not report it this time, because this should be discussed separately.

In spite of the damage by this animal, there is no hunting for expulsion or utilization of this species in the world. In the coastal waters off Japan, the small cetacean whaling happen to catch killer whales to take toothed whale oil from their blubbers and bones and meat for the local consumption for food.

The gun used for the small cetacean whaling in Japan is 50 mm in diameter. That is one of the best type gun for minke-whale and Baird's beaked whale hunting. Until Sept. of 1952, the bore of the small cetacean whaling was standardized by regulation at 40 mm calibre, but since that year Gooernment has sanctioned to use 50 mm gun.

The present report is based on the catch records which had been sent to Fisheries Agency for recent 10 years.

ACKNOWLEDGEMENT

Grateful thanks are due to the members of the whaling inspection group of Fisheries Agency for offering the data of these catch reports. The

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* The Tokyo University of Fisheries.

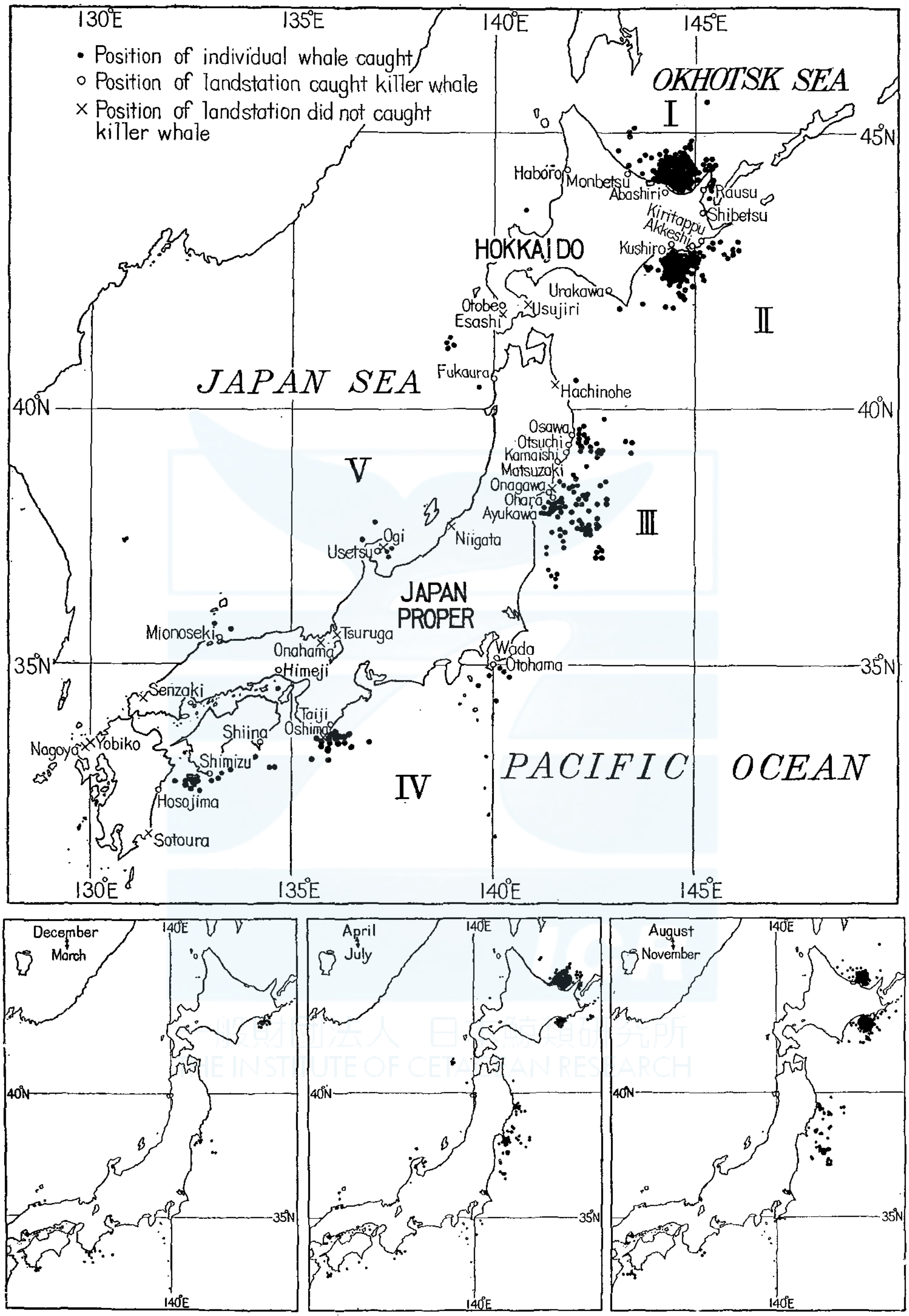


Fig. 1. Position of catch of killer whale in Japan, 1948-1957. Upper one: position of total catch and location of landstation. Lower three: seasonal movement of catch in every four months.

authors wish to express their sincere thanks to Professor I. Kubo of the Tokyo University of Fisheries, Dr. H. Omura, Mr. S. (Kimura) Ohsumi and Mrs. K. Morita of the Whales Research Institute for their kind guidance and cooperation.

BIOLOGICAL COMPOSITION OF CATCH

Annual catch Localities where killer whale were caught for recent 10 years is shown in Fig. 1 which shows five whaling areas. Area I is Okhotsk sea, Area II is the southern waters off Hokkaido and Area III is the eastern waters off Sanriku, north-eastern part of Japan proper. Area IV is the south-western part off Japan proper, from Inubo-saki to Sata-misaki of Osumi peninsula and Area V is Japan sea.

TABLE 1. ANNUAL CATCH OF KILLER WHALES IN DIFFERENT AREA, 1948–1957.

Years	Sex	Areas						Sex ratio
		I	II	III	IV	V	Total	
1948	Male	9		2	1		12	44.4
	Female	13		2			15	55.6
	Total	22		4	1		27	
1949	Male	5		10	4		19	44.2
	Female	15		5	4		24	55.8
	Total	20		15	8		43	
1950	Male	4	1	5	1		11	61.1
	Female	2	1	2	2		7	38.9
	Total	6	2	7	3		18	
1951	Male	9	17	9	4	1	40	59.7
	Female	7	11	6	3		27	40.3
	Total	16	28	15	7	1	67	
1952	Male	7	15	6	3	2	33	60.0
	Female	4	8	4	3	2	21	40.0
	Total	11	23	10	6	4	54	
1953	Male	9	18	12			39	60.0
	Female	5	7	11	2	1	26	40.0
	Total	14	25	23	2	1	65	
1954	Male	36	24	4	1	1	66	60.4
	Female	31	12				43	39.6
	Total	67	36	4	1	1	109	
1955	Male	11	20	5	4	3	43	55.8
	Female	20	4	5	3	2	34	44.2
	Total	31	24	10	7	5	77	
1956	Male	8	9	1	4		22	57.9
	Female	6	5	3	2		16	42.1
	Total	14	14	4	6		38	
1957	Male	8	16	7	3	1	35	50.7
	Female	15	6	11	2		34	49.3
	Total	23	22	18	5	1	69	
Total	Male	106	120	61	25	8	320	56.4
	Female	118	54	49	21	5	247	43.6
	Total	224	174	110	46	13	567	
	Sex ratio							
	Male	47.3	69.0	55.5	54.3	61.5	56.4	
	Female	52.7	31.0	44.5	45.7	38.5	43.6	

Area VI is the waters off Western Kyushu, the East China-sea. According to reports, however, no killer whale has been caught in this area.

TABLE 2. MONTHLY CATCH OF KILLER WHALES IN DIFFERENT AREA, 1948-1957

Month	Sex	Areas I	II	III	IV	V	Total	Sex ratio
Jan.	Male			1	2		3	50.0
	Female			1	2		3	50.0
	Total			2	4		6	
Feb.	Male				1		1	33.3
	Female			2			2	66.7
	Total			2	1		3	
Mar.	Male		3	3	2	1	9	64.3
	Female		1	1	3		5	35.7
	Total		4	4	5	1	14	
Apr.	Male	11		6	2	2	21	55.3
	Female	12		3		2	17	44.7
	Total	23		9	2	4	38	
May	Male	11	4	9		4	28	53.8
	Female	11	2	8	1	2	24	46.2
	Total	22	6	17	1	6	52	
June	Male	10	3	4	4		21	39.6
	Female	19	1	7	4	1	32	60.4
	Total	29	4	11	8	1	53	
July	Male	19	12	8	4	1	44	53.7
	Female	24	5	5	4		38	46.3
	Total	43	17	13	8	1	82	
Aug.	Male	12	12	22	3		49	62.8
	Female	9	8	9	3		29	37.2
	Total	21	20	31	6		78	
Sept.	Male	10	16	6	1		33	55.0
	Female	8	6	11	2		27	45.0
	Total	18	22	17	3		60	
Oct.	Male	9	31	1	2		43	53.1
	Female	20	16	2			38	46.9
	Total	29	47	3	2		81	
Nov.	Male	24	32	1			57	67.1
	Female	15	12		1		28	32.9
	Total	39	44	1	1		85	
Dec.	Male		7		4		11	73.3
	Female		3		1		4	26.7
	Total		10		5		15	
Total	Male	106	120	61	25	8	320	56.4
	Female	118	54	49	21	5	247	43.6
	Total	224	174	110	46	13	567	

The division of area is largely arbitural, for it is based on the geographical separation and the number of whales killed there. Biologically speaking, Area II and Area III, for instance, should have been considered as one area. As shown in the Fig. 1, however, the localities of catch we apparently concentrated in the waters both off the southern Hokkaido and off the east side of Sanriku. So these water are considered as separated.

The concentration of catch locality in the coastal waters is mostly caused by the restriction in the area to be covered by the catcher boats. The size of the boat used for the small cetacean whaling is restricted to be less than 30 tons by regulation and the average tonnage of the working boats is about 15 tons. In addition to the small size of the boats, their activity is more or less limited by the distance from landstation. These annual catch and their sex ratio are also shown in Table 1. There is no special description.

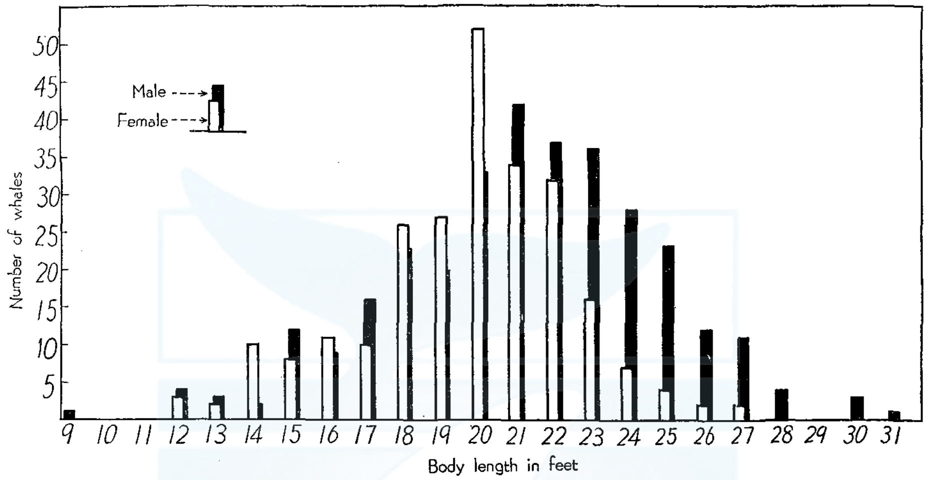


Fig. 2. Size distribution of killer whale, total of 10 years inclusive.

TABLE 3. AVERAGE LENGTH OF KILLER WHALE CAUGHT IN 10 YEARS

	Male	Female
1948	19.4	18.6
49	21.6	18.3
50	22.5	20.9
51	21.9	19.1
52	21.8	20.7
53	21.7	21.7
54	22.5	21.3
55	20.2	19.8
56	21.0	21.0
57	21.2	18.4
Total	21.5	20.0

TABLE 4. MONTHLY AVERAGE LENGTH OF KILLER WHALE CAUGHT IN 1948-1957

	Male	Female
Jan.	19.0	18.7
Feb.	21.0	18.0
Mar.	23.8	21.0
Apr.	20.4	20.5
May	22.3	19.1
June	19.2	19.1
July	19.4	20.0
Aug.	23.0	20.3
Sept.	22.2	18.9
Oct.	21.7	20.0
Nov.	21.2	20.9
Dec.	20.9	21.3
Total	21.5	20.0

Monthly catch Monthly catch of killer whales is shown in Table 2 in the same manner to Table 1. This is the sum of the recent 10 years catch. In the under part of Fig. 1. The seasonal difference of catch are shown as three small figures. Very poor catch was shown in December-March. In April the catch increases suddenly, especially in the area I (Okhotsk sea). This is the time when the whaling boats are beginning to work. On the contrary, December till March is the pause of whaling, so that the working boats are few and the catch is very scanty. From August to November considerable amount of killer whales is shown in the area I and II where many catcher boats operated in these areas.

In spite of their fierceness, killer whale has an ardent passion for their children and their comrades, and they strongly co-operate against any enemies or foods. So that they do not readily disperse. When a member of their group is killed, it is possible to catch others without moving the catcher boat far away from the place when the first one was killed. In some cases a carcass of the dolphins or another whale are left to the killer whale to hunting range.

TABLE 5. AVERAGE LENGTH OF KILLER WHALE IN DIFFERENT AREA

Area	Male	Female
I	21.6	21.2
II	21.3	20.7
III	21.5	18.4
IV	19.6	18.6
V	21.4	20.3
Total	21.5	20.0

TABLE 6. AVERAGE LENGTH OF KILLER WHALE IN DISTANCE FROM LANDSTATION

Area	Sex	Distance	
		1–30 miles	31–60 miles
I	Male	22.1	20.8
	Female	20.6	18.4
II	Male	20.8	22.0
	Female	20.3	20.5
III	Male	20.6	23.4
	Female	18.9	20.0

TABLE 7. NUMBER OF WHALES CAUGHT IN DISTANCE FROM LANDSTATION

Distance from landstation	1–30 miles	31–60 miles	over 60 miles	unknown	Total
Number of whales	391	101	36	39	567
Percentage	69.0	17.8	6.3	6.9	100.0

The difficulty of the capture of killer whale is influenced by water temperature and quantity of food. For instance they are very active in warm water (20–25°C) which makes it difficult to catch them, but they become dull and whaling boat can approach to within shooting range in 10–15°C waters. This is a reason why more killer whales are caught in northern waters than in the southern waters of Kinkasan (in the area III) in Japan.

Size Distribution Size distribution of killer whale are shown in Fig. 2. This is also the sum of catch for recent 10 years. In Fig. 2, there is a peak at 21 feet for males and at 20 feet for females.

The smallest length of killer whale caught is 9 feet. The largest length is 31 feet for males and 27 feet for females. However, it seems that the some mistakes are involved in discerning sex. Because these data were reported by members of whaler but not by biologists or inspectors. In Table 3 the average length of annual catch are shown, and in Table 4 the average length of monthly catch are given. The largest average length appears in March and October for male and in April and November for female. But it is not appropriate to consider that the largest average length is closely related with migration. In Table 6 and 7 is shown the number of whales caught and their average length by distance of every 30 miles from landstations. 69% of total catch are observed in 1–30 miles distance area, this fact are explained that the activities of the catcher boats are not so extensive. No other noticeable trend is found in these tables.

REPRODUCTION

Judging from the number of catch, more foetuses should expected. But the data used for this report are very scanty. These are shown in Fig. 3. Three different dots plotted in this figure were from the report by Mr. Y. Matsuura. Judging from the figure, it seems vaguely that the pregnant period of killer whale would be more than one year. It may be 16 months. The body length in parturition might be about 9 feet. Because the smallest killer whale which has been caught is 9 feet long and the largest foetus is also 9 feet in length. The breeding season is not clear if considered from the growth curve of foetuses. Peak of breeding season is not apparent through the year or twice in a year. But principally the peak might be in May-July. In other hand the

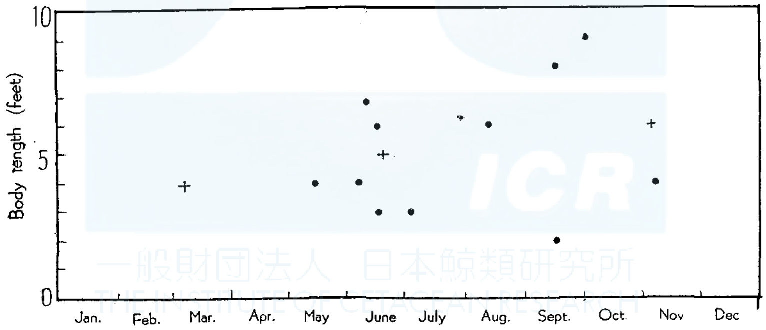


Fig. 3. Length of foetuses of killer whale plotted against the date of found.

photograph of killer whale in mating is shown as Fig. 4. This photograph was taken from airplane in June 22, 1957 by Mr. S. Takashima of the Kaiyo Aviation Company.

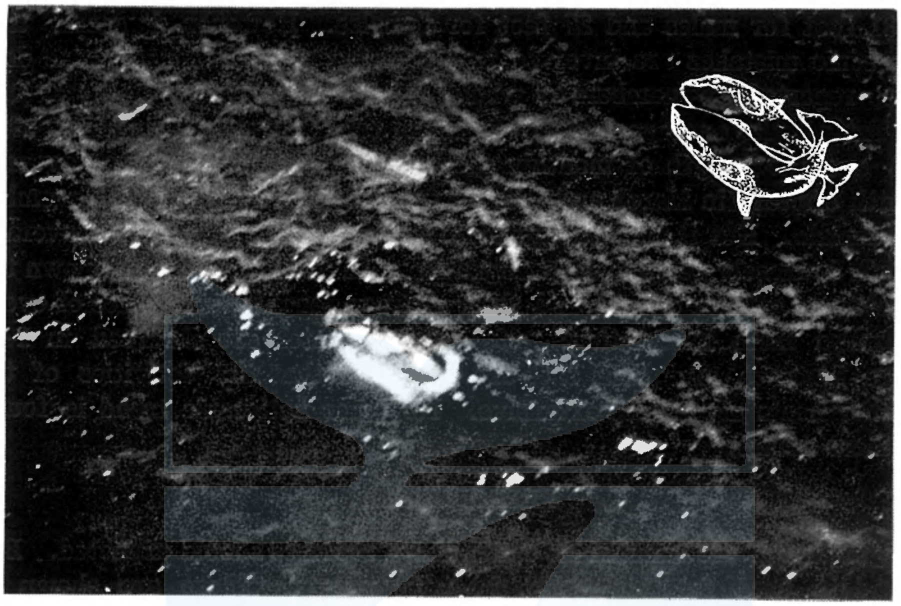
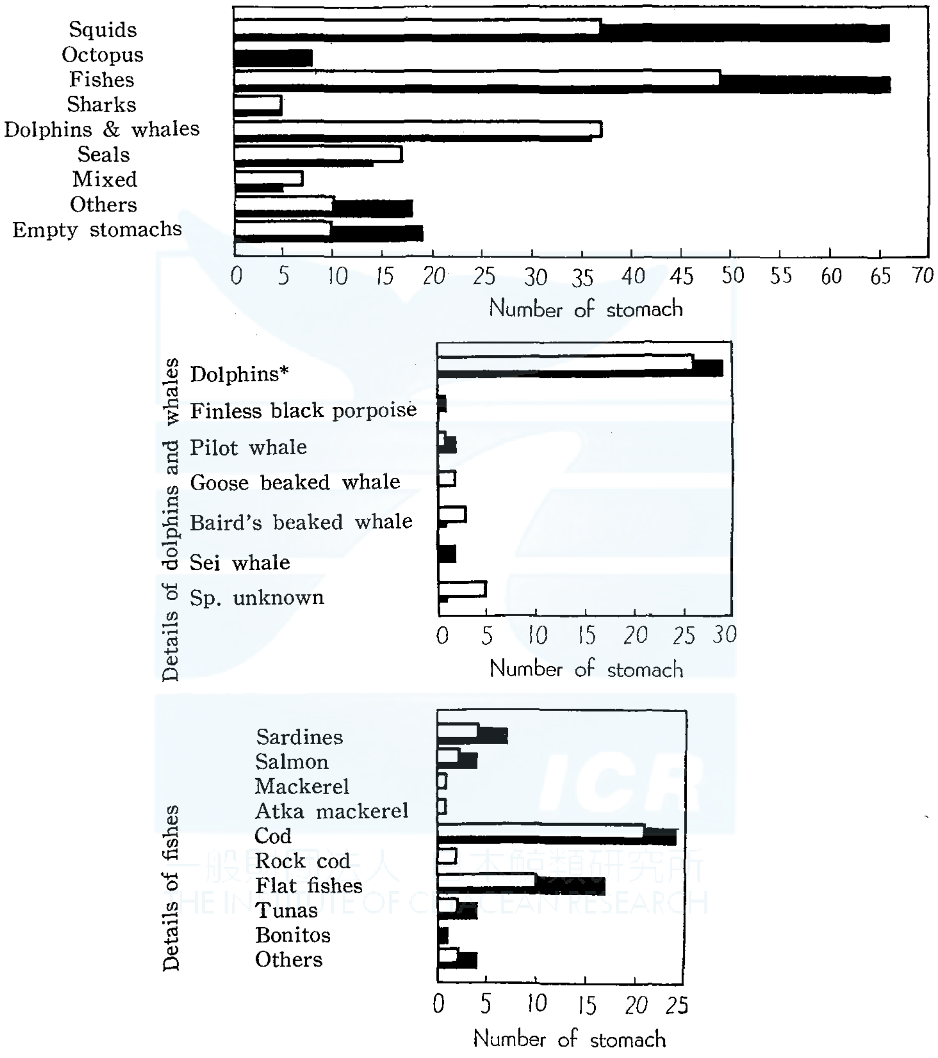


Fig. 4. Killer whale in mating (airial view)

FOOD

According to the famous report by Eschricht about the feeding habits of killer whale, 13 dolphins, 14 seals were found in the stomach and a seal was in his throat of the whale with 22 feet long. It is also reported that an amount of 60 calves of fur seal was observed in a stomach of this animal. Such avaricious feeding habits of killer whale have been collected and reported here. As explained in Fig. 5, the fishes, including sharks, are the dominant food and squids come second, then dolphins, whales and seals in this order. The details of these food items are given below. Dall's (Phocaenoides dallii dallii) and True's (Phocaenoides dallii truei) porpoises are mostly appeared in killer whales killed in the area I, II and V, and Blue-white (Stenella caeruleo-albus) dolphin in the area III and IV. The frequency of these food items accords to the distribution of dolphins and porpoises. Beaked whales and sei whale are also reported as the food of killer whale. When killer whales are flenced, many pieces of whale meat are only left in stomachs but in usually crew of whaling boats have seen killer whale attacking those species before they are caught. The most of seals were found in the area I and II. They are mostly the small sized seal, Phoca vitulina or Pusa hispida.

As to the items of fish, cod is most dominant, second comes bottom flat fish, and then comes sardine. From these figures it is recognized that killer whale eats many kinds of food.



* Dolphins are mainly True's or Dall's porpoises in area II, III and V.

Fig. 5. Kinds of stomach contents of killer whale.

Food items are shown in Fig. 6 according to body length of killer whale. The group of small (young) whales less than 14 feet long is supposed to be in the weaning period of just after weaning. They eat fishes or squids in the younger stage, and according to their growth, they can eat dolphins or any others. It seems that they can eat any kind of food if their mother break it to piece for them. According to their growth, quantity of fishes in stomach never changed perticuraly, but their catch of dolphins, whales and seals become many times. The quantity of fishes observed in stomach is rather constant regardless their size, but the larger foods as whales or dolphins can be seen only in the older animal.

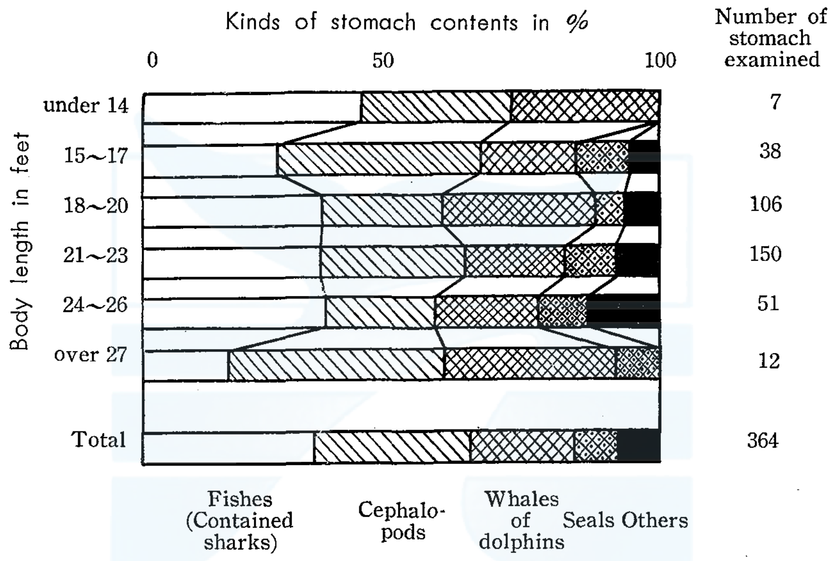


Fig. 6. kinds of stomach contents in different size of killer whales

UTILIZATION

Flencing method is not so different from that of other whale. Killer whale is utilized as well as the little piked whale and other small toothed whales (Baird's beaked whales, pilot whales etc.) in Japan.

The oil is obtained from their blubber and bones. The chemical property of this oil is roughly shown in Table 8. The killer whale oil has same market value to the sperm whale oil in Japan. The killer whale oil are utilized similar to the sperm whale oil.

Fresh meat is used for human food, The viscera and old meat are used for fertilizer or bait after boiled, cutted, chopped and dried.

TABLE 8. NATURE OF THE OILS TAKEN FROM MANY SPECIES OF THE TOOTHED WHALE

Species	Specific gravity $15\ d_4$	Refractive index (20°C)	Acid Value	Saponification Value	Iodine Value	Unsaponificable matter
Sperm whale (Spermaceti)	0.8808 ≀ 0.8848	1.4610 ≀ 1.4633	—	147.1 ≀ 148.5	71.4 ≀ 74.2	36.0 ≀ 38.6
(Blubber oil)	0.8733 (30 d_4)	1.4620 (30°C)	1.2	131.6	82.4	36.4
Baird's Beaked whale	0.8752	1.4645	1.8	114.9	86.0	43.2
Dolphin	0.9286	1.4717	—	217.2	125.3	—
Common porpoise	0.9258	—	—	195.0	119.4	—
Pacific White Sided Dolphin	0.9289	1.4670	0.6	233.9	92.2	1.9%
Pilot whale	0.9250	—	1.5	195.4	100.5	—
Finless black porpoise	0.9360	1.4624	0.5	260.3	83.0	1.67
Killer whale	—	—	0.63	211.9	86.4	—

(After Y. Matuura: Marine-Mammales)

SUMMARY

1. In adjacent waters of Japan about 60 of killer whale were caught annualy.
2. Killer whales were caught mostly in Okhotsk and the southern waters off Hokkaido, because many small cetacean whaling ships are working in these area. In addition to it, killer whale is caught easily in the waters of low temperature.

   They are very active in the waters of more than 20°C where it is rather difficult to catch them.
3. Average body length of killer whale is 21 feet for male, 20 feet for female. Maximum length is 31 feet for male, 27 feet for female.
4. Peak of breeding season of killer whale seems in May-July, and their pregnant period seems over one year. The body length in parturition is about 9 feet.
5. The most favorable food of killer whale is fishes, and squids, dolphins, whales, and seals come in this order.
6. According to their growth, chance of attack to dolphins, whales or seals is getting frequent.
7. The killer whale oil is sold almost by the same price of the sperm whale oil in Japan. The utilization of killer whale oil are also similar to sperm whale oil. Fresh meat is used for human food. The viscera and old meat are used for fertilizer or bait.

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GROWTH OF FIN WHALE IN THE NORTHERN PACIFIC

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On the growth of the fin whales (*Balaenoptera physalus*, Linn.), Mackintosh & Wheeler (1929) reported first in detail for the southern stock At that time, however, available age characters were not yet known. Therefore, chiefly on the age of the whale, their paper was incomplete. They pointed out the possibility of the number of ovulations and ossification of vertebral column as age characters. Wheeler (1930) developed this method and classified several groups by means of the number of ovulations. Peters (1939) calculated the number of ovulations in each breeding season.

Ruud (1940, 1945) discovered the age determination for whales by means of baleen plates. And then Tomilin (1945), Nishiwaki (1950, 1951a) and Utrecht (1956) advanced this method. Furthermore Nishiwaki (1951b) showed the colourlation of crystalline lens as an age character.

These age characters, however, are somewhat incomplete. In 1955, Purves discovered lamination in the core of the ear plug. This is now regarded as the best age character for baleen whales. Then, Laws & Purves (1956) and Nishiwaki (1957) studied the age of baleen whales chiefly fin whales using the number of the laminations.

On investigations of life history for the southern fin whales, many reports have been presented. On the other hand, the studies of growth for the northern fin whale have been relatively scanty. The reason will be that the whales caught in northern hemisphere have been relatively rare and so we have not been blessed with chances of investigation of whales. On the growth of the fin whale in adjacent waters to Japan, Tago (1922), Matsuura (1935), Omura (1950), Kasahara (1950), Mizue & Jimbo (1950), Sakiura, Nozawa & Ozaki (1953), Mizue (1956) and Mizue & Fujino (1957) reported. Pike (1953) reported on the fin whale from the coast of British Columbia. Papars of Matsuura & Maeda (1942), Omura (1955) and Sleptsov (1955) were described on the fin whale in the northern part of the North Pacific. On the growth of the fin whale in the North Atlantic, there are some papers by Ruud (1945), Jonsgård (1952) and Laws & Purves (1956). We shall discuss the above papers in the following chapters.

Since 1952 Japanese whaling in the fleets have operated in northern part of the North Pacific. The area includes the Pacific northern 48°N and

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Bering Sea. Inspectors and biologists on board have been engaged in biological investigations on each whale pulled up on deck. The purpose of the present paper is to describe the growth and age of the fin whale in the northern part of North Pacific. Although according to the investigation of blood groups by Fujino (1956), the northern fin whales are distinguished into east and west populations, the result of the marking investigation shows the intermixture between west and east groups in the northern Pacific. Therefore, in the present paper we study the growth representing the total northern Pacific fin whale.

We don't think this paper shows the growth of the fin whale in total North Pacific. In the North Pacific, several stocks of the fin whale will be existed. For instance, Mizue & Fujino (1957) and Ichihara (1957) describe that the fin whale caught in the East China Sea should be regarded as a independent stock because of a shape of baleen plates, body proportion, body length at sexual maturity and so on. Much less, we never think our paper will deduce the northern fin whale, for the fin whale in the North Atlantic is thought as a different stock in the northern hemisphere.

We devide the process of growth into the following stages.

1. *Fertilization*
2. *Birth*
3. *Weaning*
4. *Prepuberty*
5. *Sexual maturity*
6. *Physical maturity*

In above stages, we have very little data on the weaning. So this stage is substituted for the growth of calf.

We wish to express our thanks to inspectors and biologists and to Kyokuyo Hogei Co., Taiyo Gyogyo Co. for the investigations and sampling of our material. We are indebted to Mr. Tadayoshi Ichihara of the Whales Research Institute for his kind help to sampling and reading laminations in ear plug. We are also indebted to Mr. Takehiko Kawakami of the Fisheries Agency for giving us the data of marking whales in the northern Pacific.

MATERIAL AND METHOD

The material for the present study is based on the data of the biological investigation of fin whales mainly caught in the northern part of the North Pacific for the six years from 1952 to 1957. The inspectors and the biologists who pursued the investigation are as follows.

1952 Haruyuki Sakiura, Katunari Ozaki, and Kazuo Fujino.
1953 Yasutake Nozawa, Iwao Takayama, and Tahahisa Nemoto.

1954 Setsuo Nishimoto, Tamenaga Nakazato, Takehiko Kawakami, Ikuyo Hasegawa, Kazuo Fujino, and Seiji Kimura.
1955 Yasutake Nozawa, Saburo Ikeda, Ken-ichi Iguchi, and Kazuo Fujino.
1956 Heihachiro Kawamura, Sumio Matono, Sadao Ishii, and Seiji Kimura.
1957 Yasutake Nozawa, Takehiko Kawakami, Itaru Chihara, and Tadayoshi Ichihara.

The items of the investigation used in the present paper are date caught, sex, body length, thickness and condition of mammary gland, number of corpora lutea and albicantia in ovaries, weight of testes and collection of their samples, sex and body length of foetuses, condition of ossification of vertebral column and the collection of ear plugs.

On the lactation it was judged whether white milk was secreted or not. The thickness of the mammary gland was measured in the thickest portion of the gland, and then the maturity of the gland was judged by the condition of the gland. The immature mammary gland was thin and white or pink in colour, but the mature gland was thick and brown.

TABLE 1. NUMBER OF FIN WHALES CAUGHT AND INVESTIGATED BY JAPANESE EXPEDITIONS IN THE NORTHERN PACIFIC

Year	Males	Females
1952	104	109
1953	238	232
1954	675	641
1955	710	650
1956	755	657
1957	736	668
Total	3218	2957

The numbers of the corpora albicantia and lutea were counted with naked eye by slicing the right and left ovaries. The right and left testes were weighed in 0.1kg unit with spring balances after cutting off the epididymis. Thereafter a small piece was cut off from each testis and was directly fixed with the 10% formalin. The fixed samples were cut into the sections 10 micron thick by the paraffin method, double-stained with haematoxylin-eosin, and subjected to the microscopic examination.

On the ossification of the vertebral column, it was cut along the axis with a bone-saw and the presence of cartilaginous layer between the epiphysis and the centrum was examined with naked eyes. Conditions were classified as follows.

N: Not ankylosed. Thick cartilage.
n: Not ankylosed. Thin cartilage.
a: Ankylosed. Join visible.
A: Ankylosed. No sign of Join.

The samples of ear plugs were collected in 1956 and 1957, After fixation with 10% formalin, the samples were grinded down to the level of the longitudinal axis, and laminations in core were counted with naked eyes or by means of a dissecting-microscope.

THE BIRTH

THE GROWTH OF FOETUSES

The foetuses investigated in the northern Pacific from 1952 to 1956 consisted of 461 males, 461 females, 4 of indistinct sex because of a small size, and 4 couples of twins. In the twins, three couples of dizygotic (♂ ♀, ♂ ♀,♂ ♂) and one couple of monozygotic twins (♂ ♂) were included. Frequency of the twins was 0.43 per cent in the total foetuses. According to Kimura (1957), the frequency of multiplets in southern fin whales was 0.872 per cent.

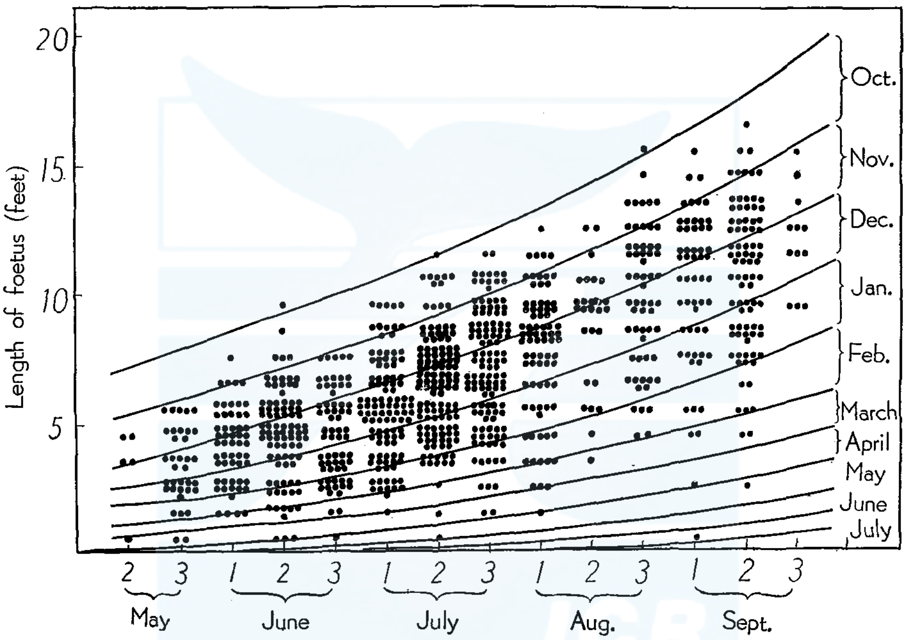

Fig. 1. Growth of fin whale foetuses from the northern part of the North Pacific.

Figure 1 shows the length and date (by the interval of ten days) of killing of each foetus. The whaling season usually sets in the middle of May and closes by the end of September in the northern Pacific. It is regrettable, therefore, that the growth of foetuses of the fin whales cannot be investigated throughout the year.

It is obvious from this figure the length of foetuses disperse at any time. This means that the pairing season is prolonged considerably, and there is also an individual variation in the growth. According to Kimura (1957), the difference of body length of two foetuses in a couple of twins increases usually with the growth, and it will be about two feet at birth.

The average length of our material in each ten-day period shows in figures 2 and 3. The growth of foetuses shows nearly parabolic curve.

The growth equation in this stage is represented by the following formula.

$$L=0.329M^{1.61}$$

L: Body length in feet. M: Time in month.

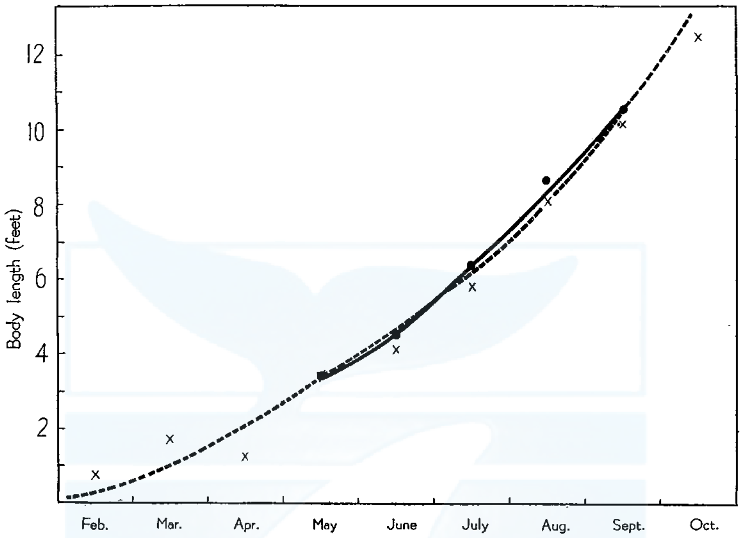

Fig. 2. Mean growth curve of fin whale foetuses from the northern Pacific, adjacent waters to Japan and the North Atlantic. Dotted line: adjacent water to Japan (Mizue, 1950). Solid line: northern Pacific. Cross: the North Atlantic.

TABLE 2. LENGTH OF FOETUSES IN THE MIDDLE OF EACH MONTH AND THEIR CONCISE CALCULATION

Month	Body length in feet	Concise calculation
1st	0.1	1×1×0.1
2nd	0.6	2×3×0.1
3rd	1.5	3×5×0.1
4th	2.4	4×6×0.1
5th	3.5	5×7×0.1
6th	4.8	6×8×0.1
7th	6.3	7×9×0.1
8th	8.2	8×10×0.1
9th	10.4	9×12×0.1
10th	13.4	10×13×0.1
11th	16.7	11×15×0.1
12th	20.5	12×17×0.1

Table 2 shows the body length of foetuses at the middle of each month and the easy method of calculating it. In the growth curves of both sexes we did not notice any variation. From figure 2 it is clear that the growth curve of the fin whale foetuses in the northern Pacific is almost similar to that in the coastal region of Japan and the North Atlantic. Thus, it is supposed that the growth curves of the fin whale foetuses are similar in all regions of the northern hemisphere. As shown in figure 3, if the growth curve of foetuses in the northern Pacific is removed just six months, it coincides closely with the curve of the southern fin whale foetuses. This means that in gestation period the growth rate of fin foetuses is similar all over the world.

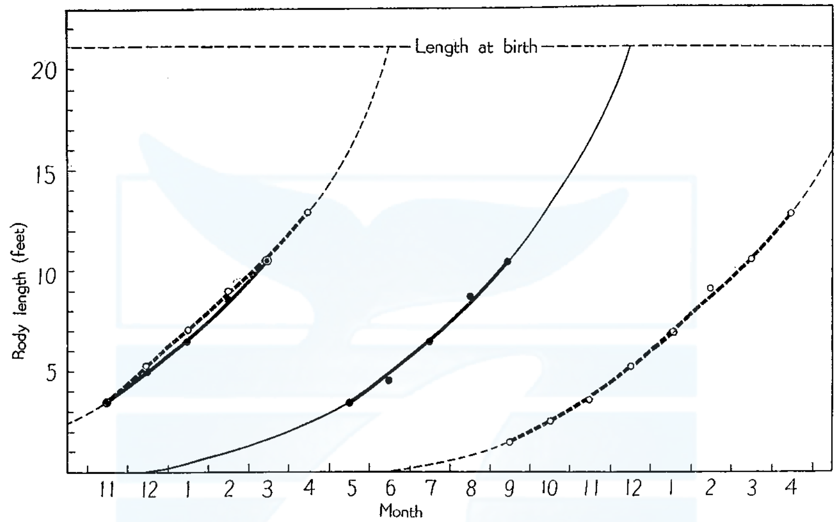

Fig. 3. Growth curve of the fin whale foetus from the northern Pacific and the Antarctic. Solid line: northern Pacific. Dotted line: Antarctic. Left solid line: northern Pacific, slided down six months.

BODY LENGTH AT BIRTH

The largest foetus of our materials is 16 feet 4 inches (497 cm) long. It was caught in the middle of September. But it is too short for a foetus at full term. Tago (1922) reported a 22 shaku (one shaku≒one foot) long calf which seemed to have been just born in the eastern sea of Korea in winter. Matsuura (1935) estimated that the body length of the fin whale at birth was about 6.0m (19 feet 8 inches). Kasahara (1950) estimated also that the fin whale was born at the length from 18 to 21 shaku. According to Mackintosh & Wheeler (1929), the fin whales were born at about 6.5m (21.3 feet) on the average. Table 3 shows the size of maximum foetuses, minimum calves and maximum adult whales in the North Pacific in each year since 1910, and summarized data from the Japanese Whaling Statistics from 1910 to 1945. The maximum foetus is 20 feet and minimum calf is 20 feet in the table.

According to the International Whaling Statistics, the maximum foetus is 22 feet 10 inches long and there are two 20 feet foetuses of the fin whales in the North Atlantic. We have suggested in above section that the mean growth curves of foetuses in various grounds of the world are similar with each other. And discussing the previous papers and the present data, we conelude that the body length at birth of the fin whale in the northern Pacific is estimated to be from 20 to 22 feet long and 21 feet long in an average.

TABLE 3. THE MAXIMUM AND MINIMUM BODY LENGTH OF THE NORTH PACIFIC FIN WHALES IN EACH YEAR (1910-56)

Year	Maximum length		Minimum length		Maximum foetuses	
	Males	Females	Males	Females	Sex and length	Date
1936	72feet	72feet	42feet	48feet	—	
1937	71	68	46	48	M. 10′-6″	3/8
1938	66	69	50	50	F. 10-1	26/8
1910-45*	75	76	20		? 20	?/7
1946	65	70	50	41	F. 7-8	22/7
1947	66	72	50	50	F. 13-3	20/8
1948	68	69	50	47	M. 13-6	1/10
1949	70	69	50	49	M. 14-3	22/8
1950	75	70	37	47	M. 13-0	3/8
1951	73	73	41	46	M. 16-6	14/9
1952	70	71	48	48	M. 14-3	14/9
1953	69	72	45	43	F. 15-8	10/10
1954	69	73	40	47	F. 16-5	12/9
1955	77	74	44	49	F. 17-2	10/9
1956	74	74	45	45	M. 13-4	4/9

* Coast of Japan

BREEDING SEASON

Owing to the limitation of whaling season (from May to September), we do not know much about the breeding season of the northern fin whales.

Thus we must assume the breeding season by means of length of foetuses in the whaling season.

In figure 1, each curve indicated the mean growth curve of foetuses shifted to lateral intervals of one month so as to include all the points plotted. If all foetuses grew at an equal speed, the foetuses measured would be conceived within the term from September to July.

Figure 4 shows the pairing season which is obtained by counting the number of plotted points between two parallel curves in figure 1. Majority of pairings take place between November and January, the maximum falling about in the middle of December. On the duration of pairing season, we found a very small foetuses 2.0cm long in the beginning of September.

In figure 3, it is found that the growth is very similar to that of southern fin whales being just six months behind. According to Mackintosh & Wheeler (1929), May, June, July and August are the months which the majority of pairing take place, the maximum falling at about the end of June or beginning of July. Tago (1922) stated that pairing season is not constant (he observed a copulation of fin whales in the middle of March), but he assumed that pairing season of the fin whales in the coast of Japan was the early spring. Kasahara (1950) assumed that the season of pairing and parturition is winter.

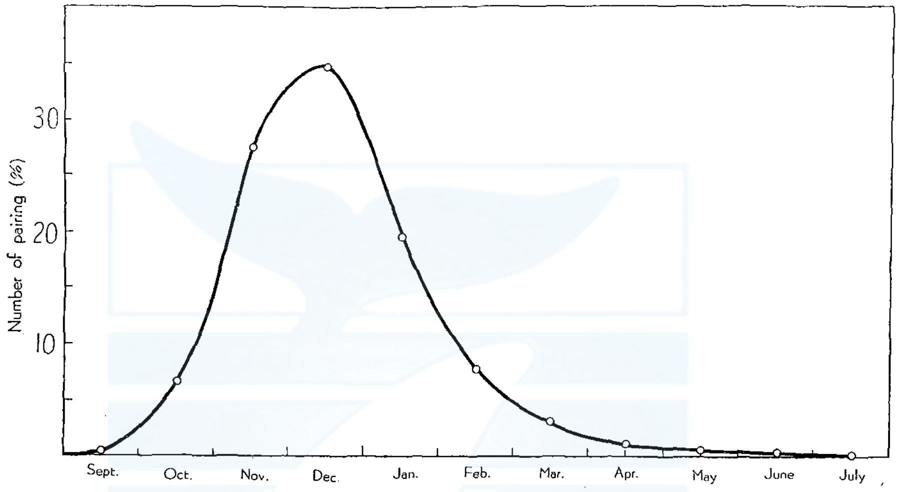

Fig. 4. Frequency curve of pairing for the fin whales from the northern part of the North Pacific.

We have no data on the gestation period and the season of parturition. According to the Japanese whaling statistics a calf which is 20 feet long is caught in December in the coast of Japan. In the International Whaling Statistics on the North Atlantic fin whales, a large foetus which is longer than an 18 feet foetus occur mostly in October, November and January. But a foetus of 22 feet 10 inches have been once caught in June. Mackintosh & Wheeler estimated that the midseason of parturition is the middle of June and the period of gestation is eleven months and a half.

Basing on the above result, we should expect that the season of parturition of the fin whale in the northern Pacific will be winter, from November to January, and gestation period will be almost one year.

THE GROWTH OF CALF

The period of nursing and the body length at weaning are very difficult to determine owing to the size regulation upon the fin whale. We have no data available on them. According to Mackintosh & Wheeler (1929), the nursing period is estimated to last about six months and the body length at weaning is assumed to be 12 meters (39 feet 5 inches). Considering the difference of the length at sexual maturity between southern and northern fin whales as we discuss in the following chapter, it is assumed that the length at weaning of the fin whale in northern fin whale is about 37 feet.

The youngest fin whales of our materials employed have 5 laminations in the ear plug. These are a male which is 56 feet and two females which are 52 and 55 feet long. It has been suggested that two laminations are deposited every year (Purves, 1955; Laws & Purves, 1956). If so, these whales are estimated to be two and a half years old. From figures 18 and 19, the mean length at that time is about 51 feet in male and 52 feet in female. In this stage fin whales are completly immature.

Of the sexually immature whales, we defined the stage of prepuberty as follows. The prepuberal female has ovaries of which ovarian follicles grow approaching maturity. And in the testes of the adolescent male as may be described in the following chapter, the majority of seminiferous tubules are open while closed tubules are not uncommon.

The body length of prepuberal females are between 55 feet and 65 feet and the average is 58.8 feet, while immature whales are under 61 feet. The former has from 8 to 12 laminations in the ear plugs and the latter has under 8 laminations. Of the male prepubertal whale, the body length is 57.7 feet in an average and the age corresponds with from 8 to 12 laminations. Estimating from above result it takes the fin whale about four years after its birth to attain its prepuberty.

SEXUAL MATURITY

DETERMINATION OF SEXUAL MATURITY IN FEMALE

The sexual maturity of female whales is determined easier than that of male whales. That is to say, we can determine the sexual maturity of females by means of corpus luteum or corpus albicans in ovaries. It is regarded that corpus albicans in ovaries remains recognizable and countable throughout the life of the whales. And if corpora lutea or albicantia are present in the ovary, the whale must, of course, be mature. Mackintosh & Wheeler (1929) stated that it might be argued that a female need not be regarded as mature until it has actually ovulated.

Concerning the sexual maturity of females, following characters are investigated.

Varginal band. We cannot determine sexual maturity by means of varginal band. Mackintosh & Wheeler (1929) reported that the bands were present in 31 (21.4%) of the 145 immature females of the southern fin whales. As shown in table 4, of 34 whales which have never been pregnant, 19 individuals (55.9%) have varginal bands, but 15 whales which have been pregnant have no bands.

Mammary gland. We can determine the maturity of mammary glands by observing the colour of them, that is to say, the immature gland is whitish pink while the mature gland is brown. This distinction is very clear as stated by Mackintosh & Wheeler (1929) and in the macroscopic structure, the former is fine but the latter is coarse. Nishiwaki & Oye (1951) classified the colour of mammary glands into 7 tones, but those are pretty difficult to distinguish one another. Figure 5 shows the thickness and the maturity of mammary glands of the fin whales in various sexual phases. In the immature stage, mammary gland is of course immature type and the thickness does not exceed 3.0cm. (average thickness is 1.5cm). In prepuberty, the gland is almost similar with

TABLE 4. THE EXISTENCE OF VERGINAL BANDS

	Exist	None	Total	%
Sexually immature	7	6	13	53.8
Prepuberal	9	8	17	52.9
Sexually mature, but never pregnant	3	1	4	75.0
Sexually mature	15	0	15	0.0

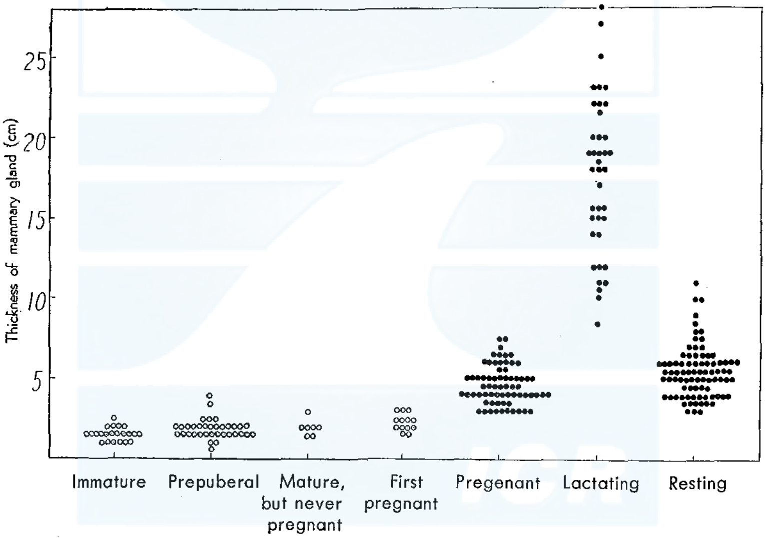

Fig. 5. Thickness of mammary gland in several sexual conditions for the female fin whale from the northern part of the North Pacific. Closed circle: mature type. Open circle: immature.

immature stage and average thickness is 1.8cm, but red gland of 4.0cm thick appears.

After attainment of sexual maturity, there are some whales whose mammary glands are still immature. These are supposed to be the whales which have never serected milk. Mackintosh & Wheeler supposed that it altered permanently after the first pregnancy. But we should correctly change their word "the first pregnancy" into "the first lactation", because in early pregnant period, mammary gland does not alter the condition as shown in figure 5. Then we can distinguish a mature whale which has never been pregnant and the first pregnant whale from other sexually mature whales by investigating the mammary gland and the ovaries.

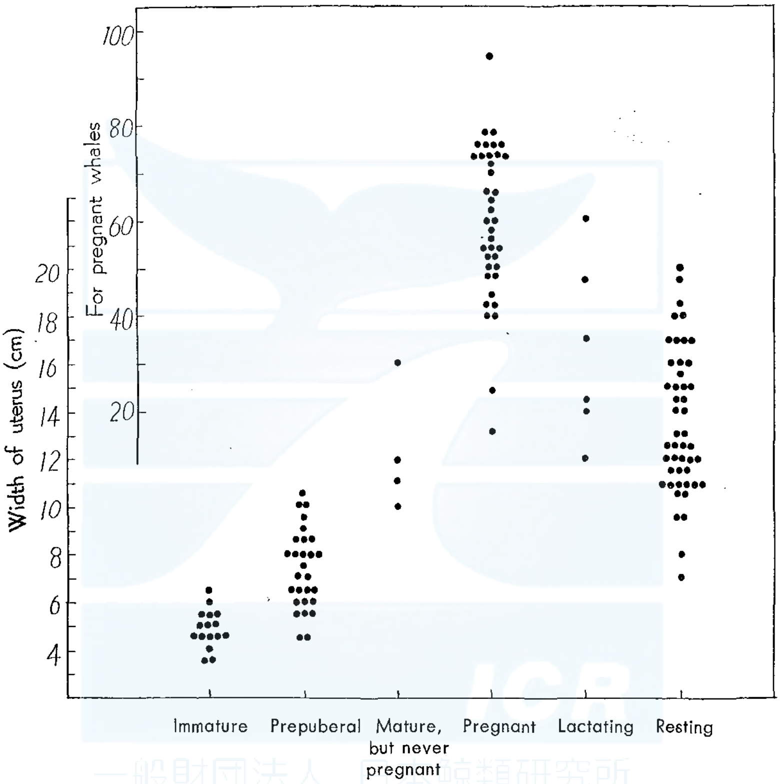

Fig. 6. Width of uterus cornu in several sexual conditions for the fin whale from the northern part of the North Pacific.

In sexually mature but mammary immature whales the thickness of mammary gland is not different from that of sexually immature ones. We have never found the whale whose mammary gland is mature but is not sexually immature.

Mature mammary gland usually exceeds 3.0m in thickness, and in a sexually resting whale, mammary gland which is 8.0cm or more over in thickness are very rare. Average thickness is 4.5cm. The thickness of the gland in pregnant whales of our material is not so different from that of the resting stage and between 3.0cm and 7.5cm. The gland during lactation varies between 8.5cm and 27.0cm.

As the conclusion of this section, in female whales we can easily distinguish sexual maturity by investigating the mammary gland but it is a rough method in sexually mature but never lactated whales, whose gland still remain in immature stage.

Size of uterus. Size of uterus across the cornu was measured when it lay in the collapsed condition.

Figure 6 shows the size of uterus in various sexual phases. In sexually immature stage, the size is between 3.5cm and 8.5cm (average size is 5.1cm). In prepuberal whales, uteri grow a little and the sizes are between 4.5cm and 10.5cm (average size is 3cm). We decided the size of uteri of sexually mature whales was over 10cm. This is a little shorter than the result by Mackintosh & Wheeler.

In sexually mature but never pregnant whale, the range was from 10cm to 16cm and the average was 12.3cm. In pregnancy the uterus grew to an enormous size. The smallest uterus of pregnant whale was 16cm in size. This whale was pregnant with small foetus (10cm). The largest uterus of our materials was 95cm. After parturition, involution may take place very rapidly. In lactating whales the largest size was 22cm and smallest was 12cm. Resting whales had uterus of 13.5cm in average size. But the range was between 7.0cm and 20cm.

DETERMINATION OF SEXUAL MATURITY IN MALE

It is difficult to determine sexual maturity of male whale with naked eyes. Mackintosh & Wheeler (1929) showed the maturity character of male as follows.

1. *Size of penis.*
2. *Size of testis.*
3. *Histology of testis.*

As Mackintosh & Wheeler stated, the size of the penis can be used only to distinguish definitely mature from definitely immature whales, although it is the readiest method to distinguish mature from immature males. Table 5 shows the length of the penis of ten males. A penis exceeding 1.3m usually indicate maturity for the fin whale in the northern Pacific.

Mackintosh & Wheeler used the size of the testis as a practical age character. The size was calculated in a manner to multiply together the length, breadth and depth in cm. And they said that if the size exceeded about 4*l* the fin whale was generally mature. Although Mackintosh & Wheeler considered that the size of testis was more convenient than the weight, recently many authors have employed the weight of testes for judging the sexual maturity.

TABLE 5. LENGTH OF PENIS OF FIN WHALES IN THE NORTHERN PACIFIC

Body length (feet)	Length of penis (cm)	Length of circumference at root of penis (cm)	Weight of testes (kg)		
58	84	52	2.3	2.5	Immature
59	105	—	1.4	1.5	〃
59	114	—	3.9	4.7	Mature
65	115	93	13.9	16.0	〃
63	135	—	5.9	6.2	〃
62	145	59	6.8	7.9	〃
63	145	—	9.5	8.9	〃
61	152	78	2.2	3.5	〃
63	155	88	4.9	5.3	〃
62	174	56	8.0	8.5	〃

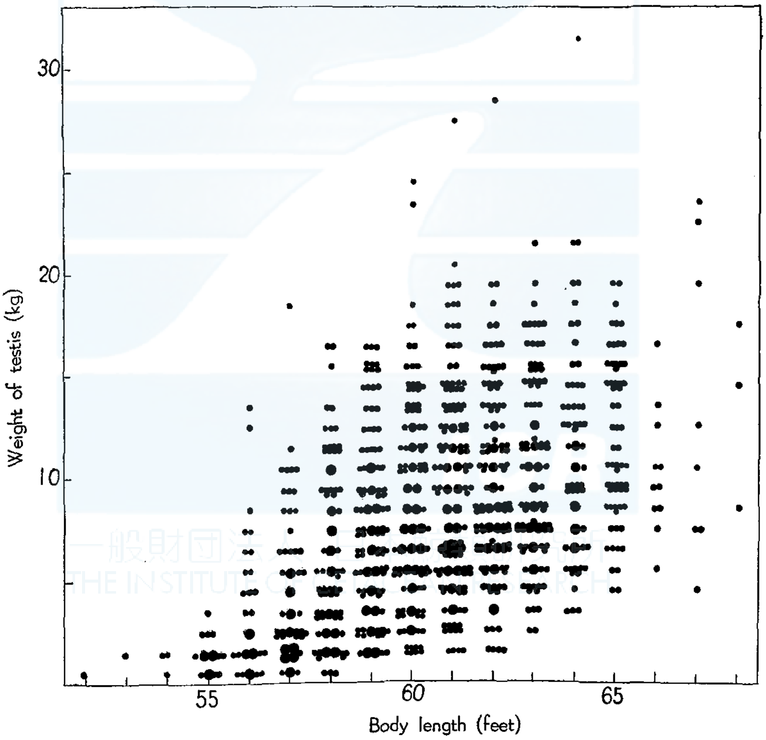

Fig. 7. Relation between body length and weight of larger testis for the fin whales in the northern Pacific.

Figure 7 shows the relation between the body length and the weight of the larger testis in each specimen. In our material the heaviest testis is 31.7kg, and the lightest is 0.3kg. Owing to size regulation, we have little data for the small whales under 54 feet.

From this figure it may be clear that the whale over 59 feet is sexually mature and the testis over 4kg is mature. But we cannot determine sexual maturity only by means of weight of testis. Therefore histological examination of testis should be employed to determine the sexual maturity of male whale as stated by Mackintosh (1942).

We examined histologically on 118 individuals and 227 testes, and classified as sexually immature, prepuberal and mature. The definition is owed to Chittleborough (1955); that is to say, in the immature testes all seminiferous tubules are closed, in the prepuberty testes the majority of tubules were open while closed tubules are not uncommon, and in the mature testes all tubules are open. Confirming the exitense of spermatozoa is not a suitable manner for determination of maturity, because in the times but the breedings season spermatozoa are very few in the tubules.

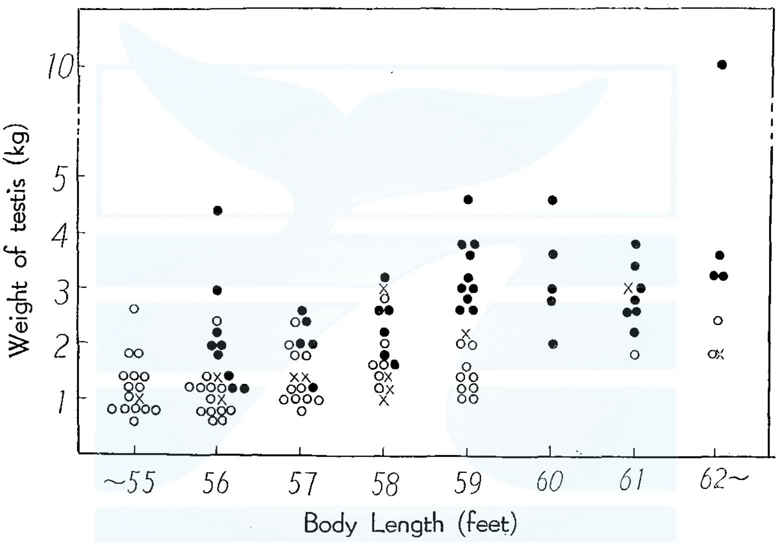

Fig. 8. Body length and maturity of testis in the fin whales from the northern Pacific. Solid circle: mature. Cross: prepuberal. open circle: immature.

Figure 8 shows the weight of testis (the larger one of the two) and body length of males whose testes were examined histologically. We could find from this figure, sexual maturity is concerned not with body length but with the weight of testis. So we should determine the sexual maturity by weighing testes which are examimed histologically simultaneously. Table 6 shows the weight frequency of immature, puberal and mature testes examined histologically. The heaviest immature testis is 3.0kg and the lightest mature testis is 1.0kg. And from figure 9, the weight of the testis of 75% in maturity is estimated to 2.6kg. In conclusion, the whale whose larger testis is 2.6kg or more over is regarded as sexually mature.

TABLE 6. NUMBER OF IMMATURE, PRE PUBERAL AND MATURE TESTIS EXAMINED HISTOLOGICALLY

Weight of testis in kg.	Immature	Prepuberal	Mature	Total
0.5-0.6	11	—	—	11
0.7-0.8	13	—	—	13
0.9-1.0	20	4	1	25
1.1-1.2	24	3	4	31
1.3-1.4	13	5	3	21
1.5-1.6	3	2	3	8
1.7-1.8	13	4	6	23
1.9-2.0	9	—	7	16
2.1-2.2	2	2	5	9
2.3-2.4	2	—	5	7
2.5-2.6	1	1	9	11
2-7-2.8	3	1	9	13
2.9-3.0	1	1	9	11
3.1-3.2	—	—	5	5
3.3-3.4	—	—	4	4
3.5-3.6	—	—	6	6
3.7-3.8	—	—	3	3
3.9-4.0	—	—	1	1
4.1-	—	—	9	9
Total	115	23	89	227

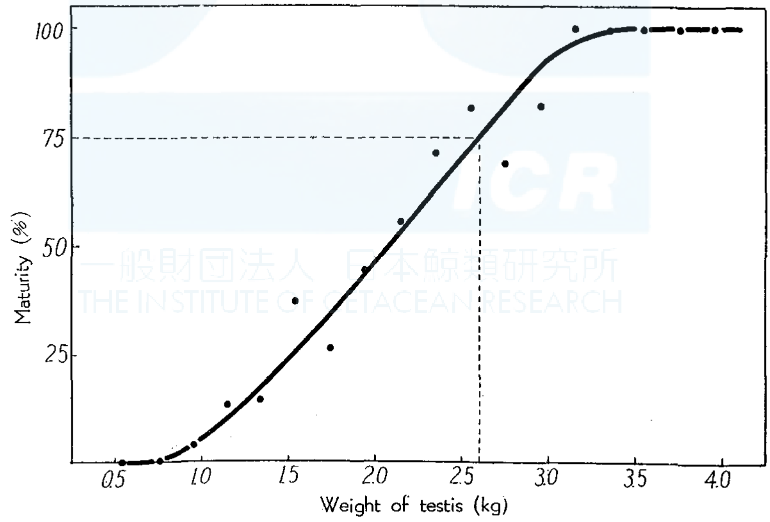

Fig. 9. Mature curve of testis based on the histological examination.

Matsuura & Maeda (1942) indicated that in the male fin whale from the northern Pacific combined testes over 7.5kg in weight is almost mature. Omura (1950) states that in the case of whales in the adjacent seas of Japan, the borderline between immature and mature is probably 3*l* in volume and 2.5kg. in weight. According to Ruud (1945), combined testes which are 6.7kg and less in weight are histologically immature for the fin whale from the North Atlantic. Nishiwaki & Hayashi (1950) states that if the combined weight of both testes is less than 5kg in the Antarctic fin whales, they are considered immature.

TABLE 7. SIZE DISTRIBUTION OF SEXUALLY MATURE AND IMMATURE FIN WHALES IN NORTHERN PACIFIC (1952–56)

Body length (feet)	Males			Females		
	Immature	Mature	Total	Immature	Mature	Total
50	1	—	1	—	—	—
51	—	—	—	—	—	—
52	2	—	2	4	—	4
53	3	—	3	2	—	2
54	5	—	5	2	—	2
55	71	5	76	47	1	48
56	75	28	103	62	2	64
57	89	87	176	73	1	74
58	54	181	235	96	21	117
59	48	272	320	108	43	151
60	22	347	369	55	71	126
61	10	372	382	39	153	192
62	10	310	320	32	184	216
63	1	241	242	22	194	216
64	—	132	132	7	253	260
65	—	75	75	3	244	247
66	—	20	20	3	225	228
67	—	10	10	1	163	164
68	—	3	3	1	88	89
69	—	—	—	—	50	50
70	—	—	—	—	18	18
71	—	—	—	—	4	4
72	—	—	—	—	5	5
73	—	—	—	—	2	2
74	—	—	—	—	1	1
Total	391	2,083	2,474	557	1,723	2,280
Average length	57.13	60.86	60.27	58.54	64.18	62.80

But above-mentioned results are not due to a histological examination exceping that by Ruud (1945). However. Ruud's value (3.3 ig in one testis) seems to be relatively heavier than our result.

BODY LENGTH AT SEXUAL MATURITY

By means of above method, we judged sexual maturity upon the fin whales investigated. Table 7 shows size frequencies of sexually mature and immature whales. Total whales examined are 2474 males and 2280 females. The largest sexually immature whales are 63 feet long in the males and 68 feet long in the females. The shortest sexually mature whales are 55 feet in both sexes. Size regulation is in force on the factory ship whaling in northern hemisphere and the size of limitation is fixed as 55 feet. So we have scanty data on short whales under 54 feet. Therefore we wonder whether the shortest sexually mature whales is under 54 feet long or not. According to Omura (1950) the shortest sexually mature fin whales in Japanese coastal whaling (size regulation is 50 feet) are 56 feet in both sexes.

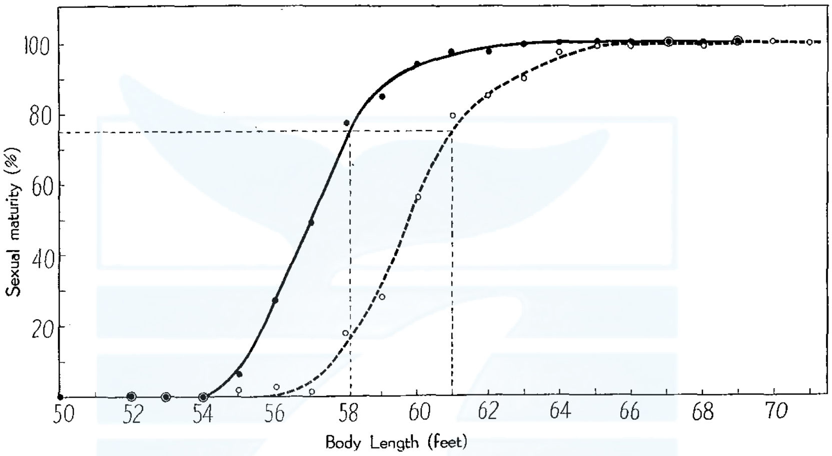

Fig. 10. Sexual mature curve of the fin whale from the northern part of the North Pacific. Solid circle and solid line: male. Open circle and broken line: female.

From our result it is known that the range of body length at sexual maturity is very wide. The range is 9 feet in the male and 14 feet in the female.

Figure 10 illustrates the percentages of sexually mature males and females in body length. The curve in this figure indicates that the body length in which the sexual maturity is 50 per cent is 57.1 feet in the male and 59.8 feet in the female and the same in which the maturity is 75 per cent is 57.9 feet in the male and 60.8 feet in the female. Therefore the mean body length of fin whales at sexual maturity in the northern Pacific will be 57 or 58 feet in the male and 60 or 61 feet in the female. And we conclude that the male attains sexual maturity at 58 feet and female does at 61 feet. Body lengths at sexual maturity of northern fin whales reported by previous authors are as follows.

Author	Body length		Locality
	male	female	
Matsuura (1935)	60′	64′	Coast of Japan
Omura (1950)	58′—59′	60′—61′	〃
Kasahara (1950)	58′—59′	60′—61′	〃
Sakiura & Others (1953)	58′—59′	61′	〃
Mizue & Fujino (1957)	56′	59′	Eastern China Sea
Matsuura & Maeda (1942)	58′—59′	61′	Northern Pacific
Omura (1955)	58′	61′	〃
Sleptsov (1955)	—	58′—62′	〃
Pike (1953)	57′—59′	60′	Coast of Canada
True (1904)	—	60′	Newfoundland
Ruud (1945)	17.5m(57′5″)	18m(59′1″)	North Atlantic
Jonsgård (1952)	58′	61′—62′	〃
Laws & Purves (1956)	58.5′	—	〃

Excepting the fin whale from the Eastern China Sea, the body length at sexual maturity of the northern fin whale is 57–59 feet in male and 58–62 feet in female.

Figure 11 shows the size distribution of the northern Pacific fin whale. Sexually mature whales distribute in nearly normal type. Average length of sexually mature whale is 60.86 feet in male and 64.18 feet in female. These are about 3 feet longer than the length at sexual maturity.

AGE AT SEXUAL MATURITY

Now, the number of laminations in the ear plug is regarded as the best age character of baleen whales. Since 1956 we have collected ear plug of whales in the northern Pacific. And the results are shown in table 8. In males, the eldest of sexually immature whales had 12 laminations, and the youngest mature whale had 8 laminations. In female, the eldest immature whale had also 12 laminations and youngest mature whale had 9 laminations. Furthermore the figure of 12 laminations and more is estimated as a mean age at sexual maturity. Purves (1955) and Laws & Purves (1956) estimated that 2 laminations are formed every year. If so, the fin whale in the northern Pacific will attain sexual maturity in early term of 7th year after birth. And the precocious will be mature sexually by 5th year. By 8th year all the fin whales will attain sexual maturity.

On the southern fin whale, Mackintosh & Wheeler (1929) assumed that the age at sexual maturity was three years old according to the size distribution. Kasahara (1950) got the same result by the same method about the fin whale in adjacent waters to Japan.

Mackintosh (1942) states, however, that it is not certain that this estimation was correct, but the recovery of a mark showed that a fin whale did not take more than three years to grow from birth to sexual maturity and could have down it into two years.

By means of baleen plates of the fin whale from the North Atlantic, Ruud (1945) considered the age at sexual maturity as 3–4 years. Nishiwaki (1952) stated that from the study of surface structure of baleen plates, the females reach sexual maturity in the pairing season following the fourth birthday and the males at the age of about three years and a half in the case of the southern fin whales. In the modified method of surveying baleen plates, Van Utrecht (1956) obtained a result that the age at which the female becomes sexually mature lies between 5 and 6 years.

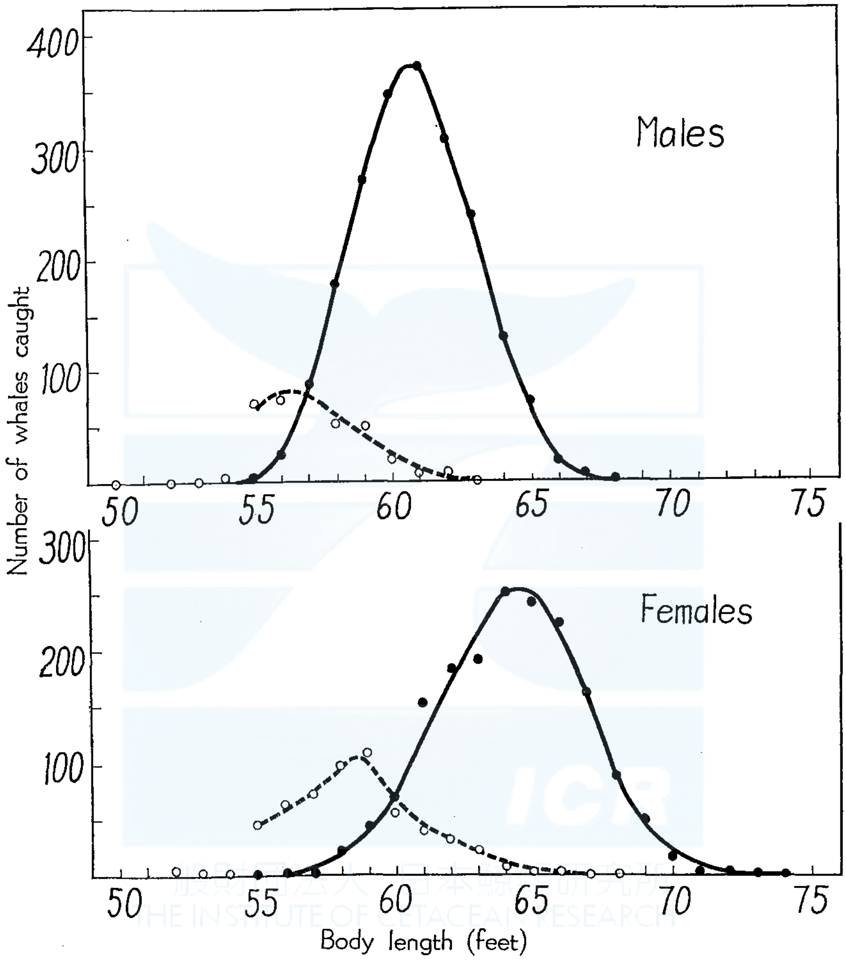

Fig. 11. Size distribution of sexually mature and immature fin whales from the northern Pacific (1952-56). Open circle and broken line: Immature, closed circle and solid line: mature.

Since the discovery of laminations in ear plug, Laws & Purves (1956) reported that sexual maturity was reaches at the age of from four to six years in the male in the North Atlantic. Nishiwaki (1957) learned in the same method the age of sexual maturity of the southern fin whale was four or five years.

Referring to these results, the age determination based on the frequency of body length is incomplete owing to the bias of samples in the selection of whales for profit by the whalers and the size regulation. The method with baleen plates is dangerous because of wearing of the tip of plate. Then laminations in ear plug will show the correct periods. But now we have never confirmed the number of laminations formed every year. And if 2 laminations do not be formed every year, the age assumed by us should be corrected. Further studies on this point are necessary.

TABLE 8. AGE OF SEXUAL MATURITY

No. of laminations	Estimated age (Year)	Males		Females	
		Immature	Mature	Immature	Mature
5	II	1	—	2	—
6	III	1	—	5	—
7		2	—	6	—
8	IV	5	1	12	—
9		10	—	12	1
10	V	3	1	13	2
11		4	4	6	2
12	VI	2	5	3	9
13		—	6	—	10
14	VII	—	6	—	7
15		—	4	—	12
16	VIII	—	6	—	6
17		—	10	—	16

PHYSICAL MATURITY

DETERMINATION OF PHYSICAL MATURITY

As an index of the physical maturity, the condition of cartilage layer between the epiphyses and centrum of the vertebral column has been employed. On the southern fin whales Wheeler (1930) studied the process of ossification of the vertebrae and he stated that an ankylosis commenced at both ends of the column and was completed among the anterior part of dorsal vertebrae. Of the northern Pacific fin whale there is no report on the process of ossification of the vertebrae. Only Pike (1953) investigated the physical maturity but he did not discussed on it.

So we studied the process of ossification in 1954. First we counted the number of vertebrae for the 19 whales. Table 9 shows the vertebral formula. Then we selected 20 points as follows; i.e., C2, C5, D1, D4, D7, D10, D13, L1, L4, L7, L10, L13, Ca1, Ca4, Ca7, Ca10, Ca13, Ca16, Ca20 and Ca24. Namely, the vertebrae was examined at intervals of three on each individual in the present study, while only

TABLE 9. NUMBER OF VERTEBRAE OF THE NORTHERN PACIFIC FIN WHALES (EXAMINED 19 WHALES)

	Cervical	Thorathic	Lumbar	Caudal	Total
Range	7	14—15	14—16	24—27	60—64
Average	7.0	14.7	15.0	25.3	62.0

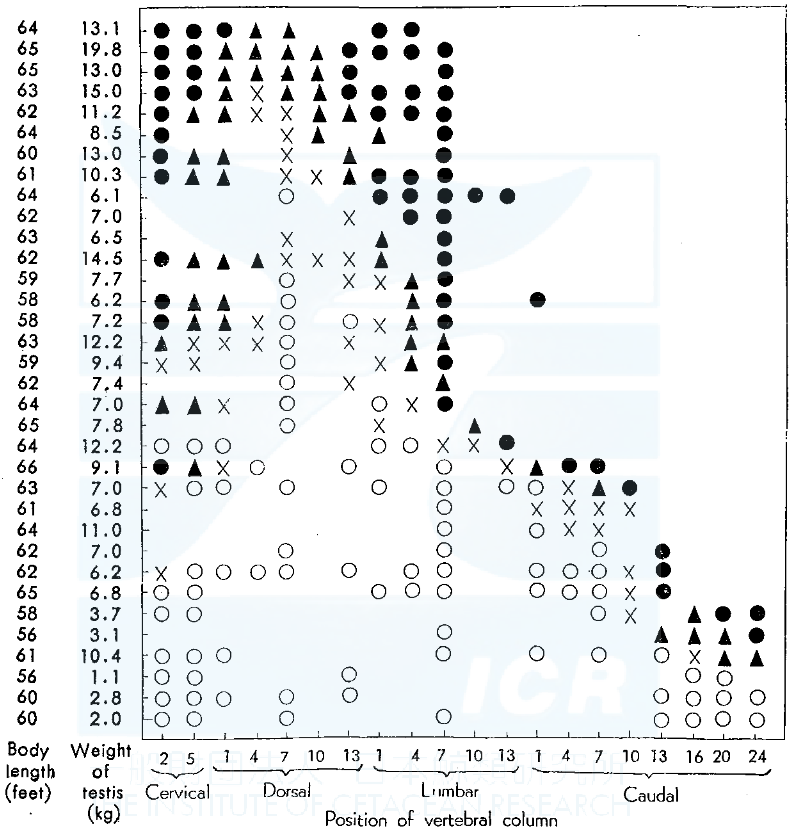

Fig. 12. Condition of cartilage layer between epiphyses and vertebral column in the male fin whales from the northern Pacific. Open circle: not fused, thick cartilage. Cross: not fused thin cartilage, Solid triangle: fused, but join visible. Solid circle: fused, no sign of join.

two or three vertebrae was examined in each individual by Wheeler (1930) and Laws & Purves (1957). Therefore the present method will be better for investigating the process of ossification of vertebrae.

The results are shown in figures 12 and 13. We arranged the data in order from that of the physically youngest whales in these figures.

And the data of body length, the weight of bigger testis and the number of ovulations were shown on the left side of each figure. Total whales examined were 34 males and 45 females.

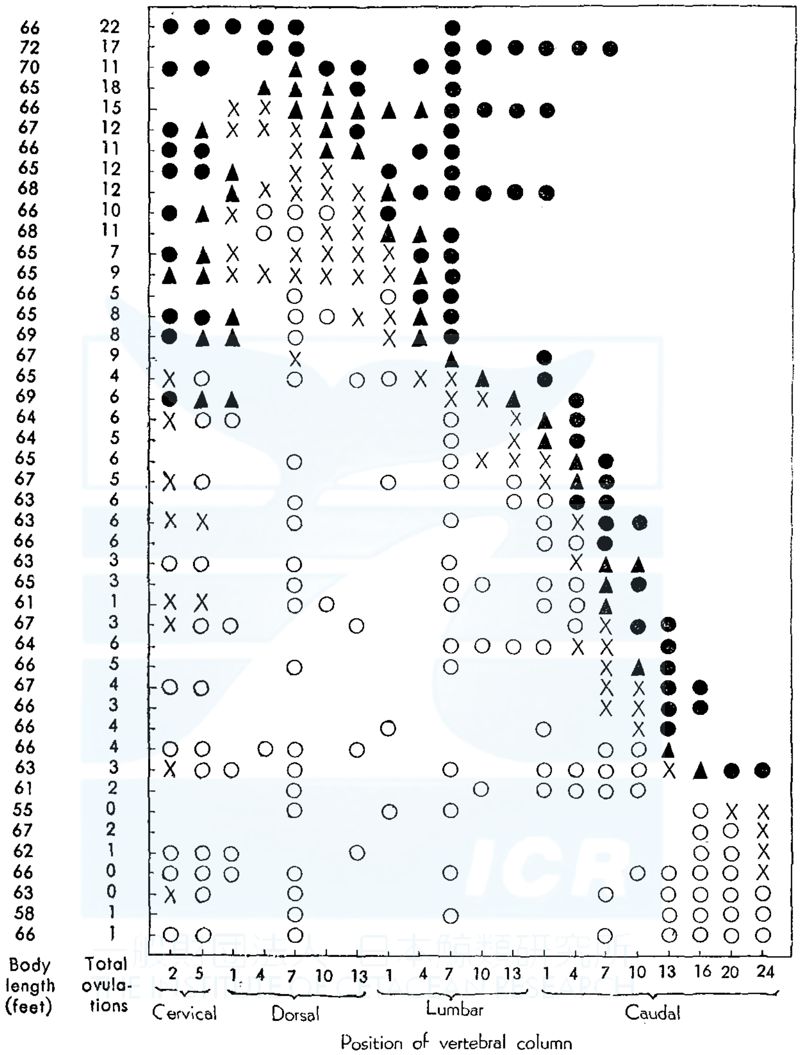

Fig. 13. Condition of cartilage layer between epiphyses and vertebral column in the female fin weales from the northern Pacific. Mark is the same as in figure 12.

The points seen from figures 12 and 13 will be as follows. The difference in the process of fusion of the vertebrae does not seen between the male and the female. In sexually immature stage no ossification of epiphyses occurs. The fusion of epiphyses begins from both ends of vertebral column, but the process of fusion from the anterior end progresses more slowly than that from the posterior end. The fusion of cartilage layer at the anterior end appears in the stage that fusion from posterior end attains at posterior parts of lumbar.

The end point of ossification throughout vertebral column is estimated to be from the 3rd to 6th dorsal vertebrae. This agrees with the result by Wheeler for southern fin whales.

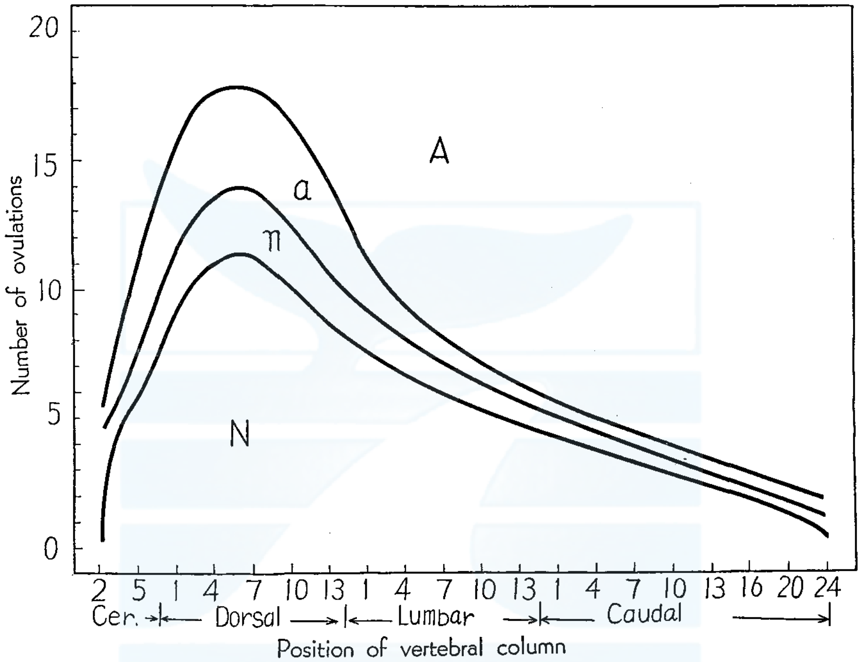

Fig. 14. Process of the fusion of the epiphyses cartilage layer for the female fin whales from the northern Pacific. N: not fused, thick cartilage. n: not fused, thin cortilage. a: fused, but join visible. A: fused, no sign of join.

Therefore, for the purpose of investigation of physical maturity, condition of epiphyses cartilage in 3rd to 6th dorsal vertebrae should be examined. In figure 14 the process of fusion of the epiphyses cartilage layer for female whales is shown based on the number of ovulations. When we investigated the process of ossification of vertebrae, we did not sampled their ear plugs. So we use the number of ovulations as the age character. It has been regarded as a good age character for whales. Therefore this may show the periodical process of ossification of vertebrae.

Above-mentioned phenomena are clearly shown with this figure. And the age at complete ankylosis, that is to say, physical maturity will be 14 to 16 ovulations. Laws & Purves (1956) gave similar figure for the female fin whale in the North Atlantic based on the number of laminations in ear plug.

Number of ovulation at physical maturity was calculated by Wheeler (1930), Peters (1939) and Nishiwaki & Oye (1948) for southern fin whale. Their value are 14~15 ovulations. This accords with our result. But Brinkmann (1948) calculated that it was 13. Furthermore, Pike (1953) states that those whose number of ovulations is under 19 are physically immature.

BODY LENGTH AT PHYSICAL MATURITY

Individual variation of body length becomes vast in progression of age. Figure 15 shows the variation of body length on the condition of ossification in verteblae. Although our data are scanty, the complete ankylosis will bear little relation to length as stated Wheeler (1930).

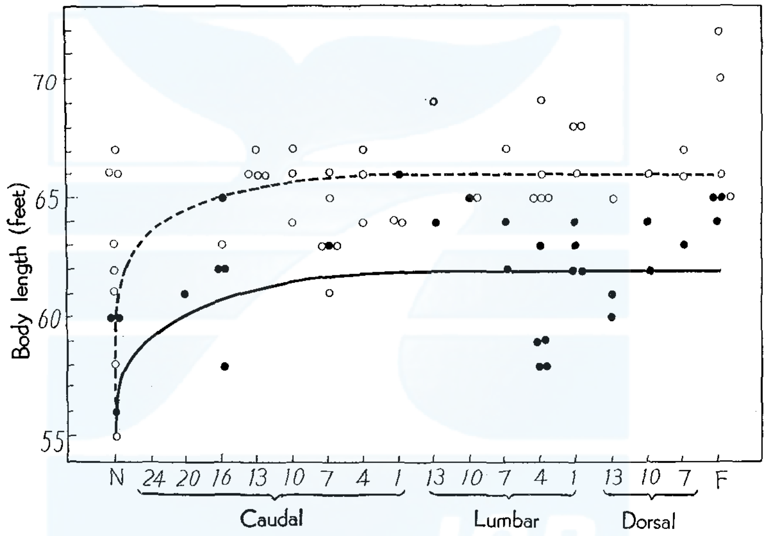

Fig. 15. Variation of the body length on the condition of ossification in vertebrae. Open circle and broken line: females. Closed circle and solid line: males.

Table 10 gives size distribution of sexually mature but physically immature and physically mature female whales judging with the number of ovulations. According to our result, those which are 15 ovulations and over are judged as physical mature. From this table, the largest physically immature whales is 74 feet long and the shortest physically mature whale is 59 feet long. The largest physically mature whale is 72 feet. Mean length of physically mature whale is 65 feet 5 inches. But by means of this table, the range of physically mature length cannot be given. Therefore, we used the number of laminations in ear plug as the standard to determine the physical maturity. According to figures 18 and 19, as we will mention latter, number of laminations at physical maturity are estimated to 40 to 45. So, we adopt 45 laminations and over

TABLE 10. SIZE DISTRIBUTION OF PHYSICALLY MATURE AND IMMATURE FEMALE FIN WHALES BASED ON NUMBER OF OVULATIONS

Body length (feet)	Physical		Total whales
	Immature*	Mature	
55	1	—	1
56	2	—	2
57	1	—	1
58	21	—	21
59	42	1	43
60	69	2	71
61	148	5	153
62	179	5	184
63	186	8	194
64	241	12	253
65	226	18	244
66	203	22	225
67	146	17	163
68	81	7	88
69	42	8	50
70	16	2	18
71	4	—	4
72	4	1	5
73	2	—	2
74	1	—	1
Total	1615	108	1723
Average length	64.10	65.43	64.18

* But Sexually mature.

TABLE 11. SIZE DISTRIBUTION OF PHYSICALLY MATURE AND IMMATURE FIN WHALE (OVER 45 LAMINATIONS)

Body length (feet)	Males		Females	
	Immature*	Mature	Immature*	Mature
55	2	—	1	—
56	5	—	—	—
57	9	1	—	—
58	22	4	1	1
59	23	4	5	1
60	29	3	9	1
61	23	3	16	3
62	38	5	20	
63	14	2	20	2
64	7	3	29	5
65	6	4	31	4
66	1	—	29	8
67	2	—	20	2
68	1	—	14	3
69	—	—	9	3
70	—	—	3	4
71	—	—	1	1
Total	182	29	208	38
Mean length	60.57	61.24	64.44	65.52

* But sexually mature.

as physical maturity. Table 11 shows that the size distribution of physically mature and immature but sexually mature whales based on the number of laminations. The largest physically immature male is 68 feet and shortest physically mature male is 57 feet. For the female, the largest physically immature whale is 71 feet and the shortest physically mature whale is 58 feet. And mean length of physically mature whales is 61 feet 3 inches in the male and 65 feet 6 inches in the female from this table.

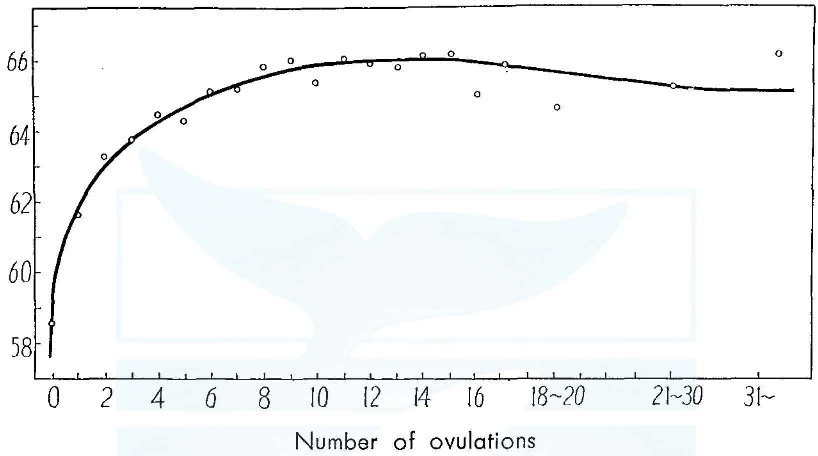

Fig. 16. Growth curve of the female fin whale from the northern part of the North Pacific, based on the total ovulation.

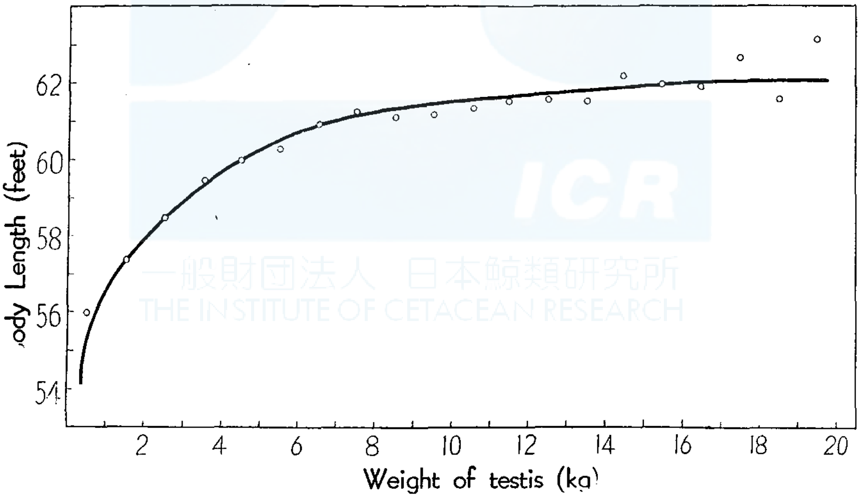

Fig. 17. Variation of the average size of fin whales in 1 kg groups of weight of testis.

Figure 16 shows mean length against number of ovulations. This figure may show growth curve of the female fin whale. But the growth in sexually immature stage cannot be drawn in this figure.

Now, from figure 16 it will be seen that maximum length is 66 feet long and number of ovulations at maximum length is 14–15. The length will be meant length of female fin whale at physical maturity. And the mumber of ovulations at that point corresponds to the result in figure 14. After that time body length seems to shrink a little about one foot.

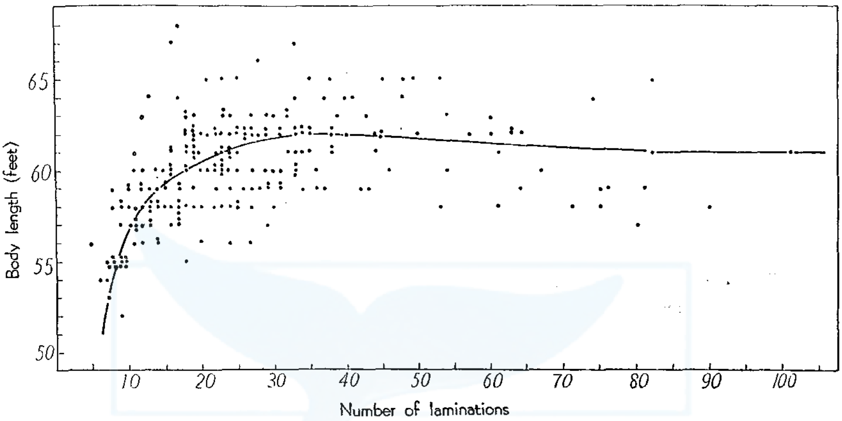

Fig. 18. Growth curve of the northern male fin whales based on the number of laminations in ear plug.

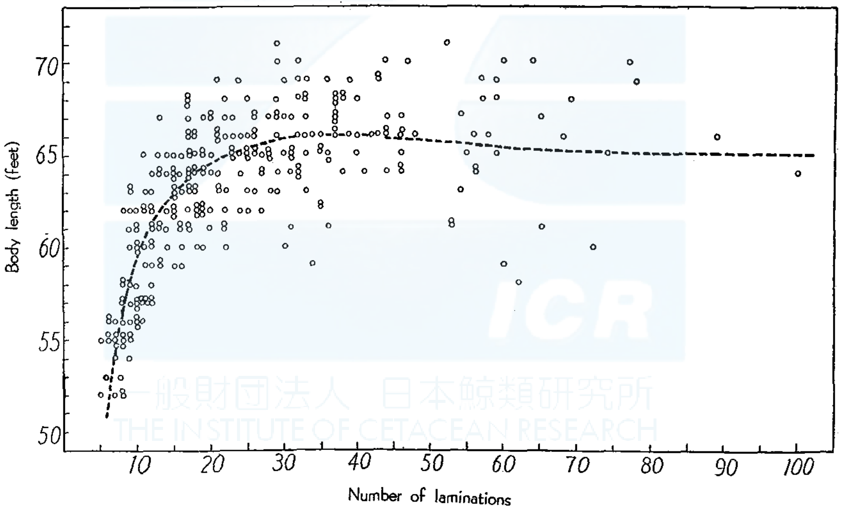

Fig. 19. Growth curve of the northern female fin whales based on the number of laminations in ear plug.

According to similar figure by Pike (1953) the body length at physical maturity is 68 feet.

Weight of testis is not a good age character as shown by Nishiwaki, Ichihara & Ohsumi (1958). Although it is dangerous to use weight of testis as an age character, we show the mean length against weight of testis in figure 17. This does not show the growth curve of male whale, but from this figure we can suggest the mean maximum length of male. It is 62 feet long.

Figures 18 and 19 shows relation between number of laminations and body length of males and females respectively. With the discovery of lamination in ear plug by Purves (1955), we could obtain the best age character for baleen whales. And then we can show the growth curve of fin whale based on number of lamination. On the growth curve we shall mention in the following chapter.

Even if vast individaul variation is seen, the mean maximum length is estimated to be 62 feet in males and 66 feet in females. Number of laminations at maximum length is from 40 to 45.

Furthermore after attainment of maximum length the shrinkage is seen in both male and female like as figure 16. Average length of shrinkage is seems to be about one foot. We have never known the paper on the shrinkage of whales after physical maturity.

From these series of our results, although there is vastly individual variation, the mean length at physical maturity is estimated to be 62 feet in male and 66 feet in female.

On the northern Pacific fin whale, the largest male is 68 feet long and the largest female is 74 feet in our material. According to the International Whaling Statistics from 1936 to 1956, the largest male is 77 feet and the largest female is 74 feet for the fin whale in the North Pacific. For the fin whale from the adjacent water to Japan, from 1910 to 1945 (during these periods Japan had not join the International Whaling Convention) these values are 75 shaku in male and 76 shaku (one shaku is almost one foot) in female. Therefore the largest fin whale in the North Pacific is 77 feet in male and 76 feet in female. But we wonder male fin whales which are over 70 feet are exsist realy. They may be mistaked the determination of the sex. Tago (1922) reported that the largest fin whale in adjacent waters to Japan was 82 shaku. And Cocks (1886) reported 24.6m (81 feet) long fin whale in the North Atlantic.

AGE AT PHYSICAL MATURITY

Nishiwaki, Ichihara & Ohsumi (1958) calculate number of ovulation in an year by means of the figure between number of laminations and number of ovulations. According to their study fin whale ovulates 0.8–0.9 times an year. We estimate number of ovulation at physical maturity is 15, and the age at sexual maturity is 5–6 years old. By means of these data, the age at physical maturity is calculated. It is 22 to 25 years old. Two laminations are estimated to deposit every year (Purves, 1955 ; Laws & Purves, 1956). If so, 40–45 laminations which we estimate as physical matulity are counted for 20–22½ years of age.

Table 12 shows estimated the age distribution of physically immature and mature female whale based on number of ovulations. We consider those who accumulate 15 and over corpora lutea or albicantia in their ovaries are physically mature. The eldest physically immature female is estimated to 30 years old (60 laminations) and youngest physically mature female is estimated 15 years old (30 laminations). And 25 years old whale (50 laminations) is recongnized to the age at physical maturity.

Age at physical maturity for male will be same as female, for figures 18 and 19 shows the almost simmilar growth curve in male and female. As the conclusion, if the northern fin whales deposits 2 laminations in ear plugs every year, they will attain at physical maturity by 22 to 25 years after birth.

TABLE 12. AGE AT PHYSICAL MATURITY OF FEMALE FIN WHELES IN THE NORTHERN PACIFIC

Number of laminations	Estimated age (Year)	Physical'y Immature	Physical'y Mature
26—29	XIII-XIV	24	—
30—33	XV-XVI	23	2
34—37	XVII-XVIII	17	—
38—41	XIX-XX	7	2
42—45	XXI-XXII	7	2
46—49	XXIII-XXIV	6	2
50—53	XXV-XXVI	—	3
54—57	XXVII-XXVIII	1	8
58—61	XXIX-XXX	1	4
62—65	XXXI-II	—	3

On the age at physical maturity, Wheeler (1930) states that the female fin whale attains physical maturity at 6-8 years of age. He considers that after attainment of sexual maturity at 2 years, of age 4 or 5 ovulations take place in every 2 years and it attains physical maturity after 14 or 15 ovulations. Nishiwaki (1952) states that southern fin whales attain physical maturity at about 11 years after birth, for he supposed female fin whale attains physical maturity at about 6 years after attainment of sexual maturity which is 5 years of age. According to the figure in the paper by Laws & Purves (1956), they seem to suppose that female fin whale attains physical maturity at 12-14 years of age.

Our result is significantly different from above papers. We consider that it dues to the difference of number of ovulations in every breeding season. The values of the authors are as follows.

Wheeler (1930)	4—5
Ruud (1940, '45)	6—7
Nishiwaki (1952)	2 in first year, 3.04 in succeeding period
Laws & Purves (1956)	2.8
Our result	1.6—1.8

Peters (1939) supports our result. He calculates 1.8 ovulations in every breeding season. Chittleborough (1954) suggested that the rate of number of ovulation in the humpback whale a little more than on per breading season.

Ruud, Jonsgård & Ottestad (1950) suggested that in the blue whale corpora albicantia accumulate at a rate of a little more than one a year.

GROWTH CURVE OF THE NORTHERN FIN WHALE

LONGEVITY

The oldest whale has 101 laminations in the ear plugs for male and 100 laminations in female. These whales are estimated to be 50½ years old and 50 years old respectively. On the other hand, the number of ovulations which we had observed in the Northern Pacific is 49. If 0.8 or 0.9 corpora albicantia accumulate in one year (Nishiwaki, Ichihara & Ohsumi, 1958) and the age at sexual maturity is six years after birth, the whale is estimated to be from 60 to 67 years old. However, number of laminations of this whale was 100. So, this is estimated to be 50 years old.

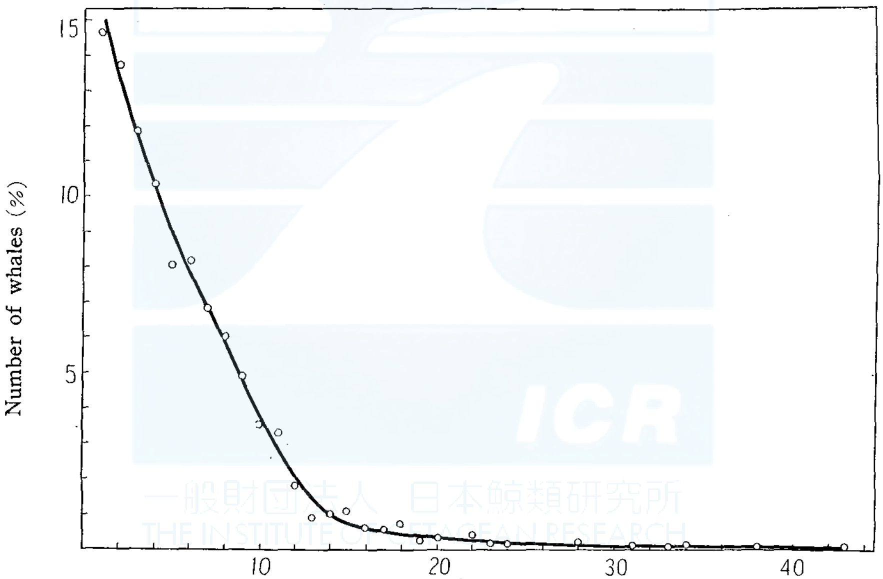

Fig. 20. Frequency of total ovulations for the female fin whale from the northern part of the North Pacific from 1952 to 1955.

Figure 20 shows the frequency of number of ovulations for the fin whale in the northern Pacific from 1952 to 1955. The number of female whales which has more than 15 corpora lutea and albicantia in the ovaries are only 4.93 per cent of all sexually mature whales. Thus, the physically mature female whales (more than 24 years old) are very rare in the northern Pacific.

Wheeler (1930) states that no signs of a climacteric have been observed in whales up to 20 years of age. Nishiwaki (1952) indicates that the average life of fin whale would be 25 to 30 years under natural conditions. And according to Brown (1957), the oldest marked fin whale had been recovered in the Antarctic is 22 years after marking. As the first year when the marking for whales took place in the Antarctic was 1934, we have not yet confirmed the whole life of the whales is whether older or not.

GROWTH CURVE

From the above results concerning birth, sexual maturity and physical maturity, we drew the mean growth curve of fin whale in the northern Pacific as shown in figure 21. This is nearly sygmoidal curve. In the first 2 years after birth, fin whale grows very rapidly and it is not seen the difference of growth rate between male and female. But after then it grows more slowly by degree and females exceeds males.

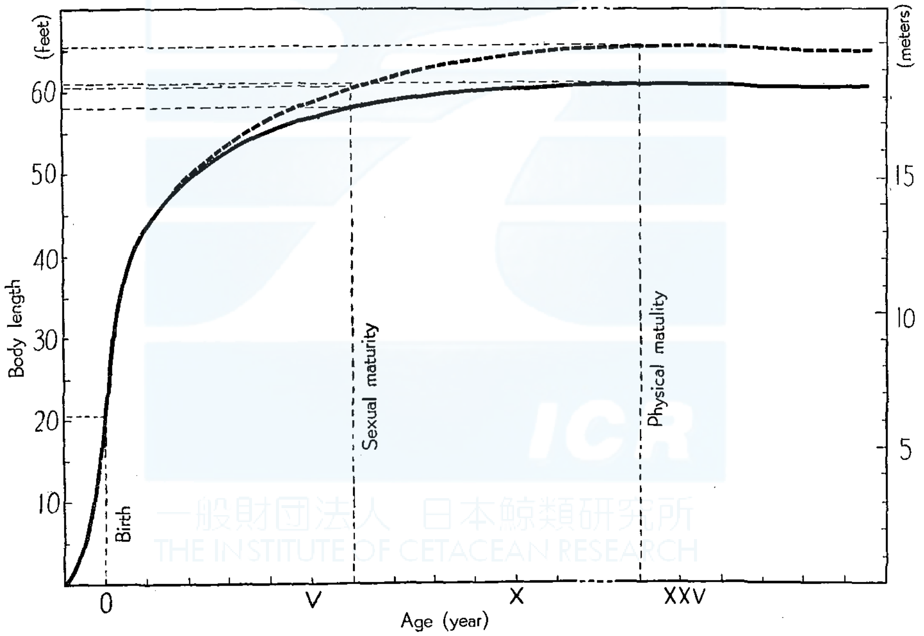

Fig. 21. Growth curve for the fin whale from the northern part of the North Pacific. Solid line: male. Broken line: female.

After attainment of physical maturity, the fin whale seems to shrink a little. This figure is different from the previous growth curves drawn by Mackintosh & Wheeler (1929), Kasahara (1950), Laws & Purves (1956). The individual variation of the body length at birth has been estimated to be two feet according to Kimura (1957). Furthermore as shown figures 18 and 19, it becomes very wide in adult whales. Therefore, we must perceive it on considering the growth curve of the whales.

DISCUSSION

We must discuss first in this chapter on the age of the fin whale. We used the number of laminations in ear plug as the age character. Now, it has been considered that two laminations deposit every year in the core of ear plug. Purves (1955) assumes that each interlamellar space represents the period of migration north or south. Laws & Purves (1956), comparing with the estimated age from the baleen plates, describes that if two laminations deposit in ear plug, these is fair agreement up to the fourth year after which the age as determined by the ear plugs differs from that obtained from the baleen plates analyses. According to Nishiwaki, Ichihara & Ohsumi (1958), the mean number of ovulation in one year is calculated to be 0.8 or 0.9 if 2 laminations deposit in one year. This result agrees with that by Peters (1939). Mackintosh (1942) describes that the rate of accumulation of corpora albicantia cannot have been much more than about one a year for marked fin whale caught in the waters off South Georgia.

TABLE 13. THE GROWTH OF MARKED FIN WHALES

Mark number	Sex	Estimated body length	Actual body length	Lapse of time	No. of lutea	Foetus	Weight of Testis in kg.	Number of laminations in ear plug
4658	Female	61 ft	58 ft	0—11	0-0, 0-0	None		—
4543	〃	62	66	0—11	0-5, 1-3	F. 8-3		—
3243	〃	70	55	3—0	0-1, 0 0	None		13
4267	〃	45	63	2—0	1-0, 0-2	F. 7-0		—
3213	〃	60	63	3—2	1-7, 0-8	F. 4-11		—
4552	〃	60	62	1—10	0-1, 0-0	None		11
6062	〃	55	64	1—8	0-3, 0-6	None		—
5995	〃	57	65	1—11	0-13, 0-2	None		—
6939	〃	62	64	1—11	1-5, 0-8	M. 11-6		41
6923	〃	62	64	2—0	1-4, 0-3	M. 3-11		32
4516	Male	65	61	0—10			14.5, 15.0	—
4451	〃	?	56	0—11			1.0, 1.0	—
4604	〃	55	61	0—11			1.8, 2.0	—
4641	〃	63	60	1—1			11.0, 11.5	—
7002	〃	60	58	0—10			4.7, —	—
4461	〃	57	59	1—11			7.2, —	—
6987	〃	50	62	1—10			5.1, 5.0	—
4558	〃	65	62	2—10			5.8, 5.7	21
5979	〃	60	58	2—0			1.1, 1.0	9

These results support our estimations, but for the certification of the theory, further studies should be needed. Marking investigation will be the most useful method for this purpose.

By the way, in the northern Pacific Japanese Government has continued marking investigation since 1953. Table 13 indicates the marked fin whales which recovered after the term of more than next whaling season since marking. It is difficult to estimate the body length of swimming whales. The estimated length of the whales which recovered within two weeks after marking are 2 or 6 feet (average 4 feet) longer than the actual length. Considering this result, growth rate of fin whale will be little. No. 3243 whale which was recovered in lapse of three years is accumulated one corpus albicans in ovaries. Considering to existence of verginal band and immaturity of mammary gland, this whale was assumed to had attained just sexual maturity. This means that it needs at least three years after birth to attainment of sexual maturity. This whale has 13 laminations in the ear plug.

TABLE 14. BODY LENGTH OF FIN WHALES IN SEVERAL REGIONS AT BIRTH, WEANING, SEXUAL MATURITY, PHYSICAL MATURITY AND MAXIMUM

	Northern Pacific		Coast of Japan		British Columhia		North Atlantic		Antarctic	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
At birth	21′		21′~23′a)		—	—	—	—	21′3″e)	
Weaning	—	—	—	—	—	—	—	—	39/4″e)	
Sexual maturity	58′	61′	58′~ 59 b)	60′~ 61′b)	57′~ 59′c)	60′c)	58′d)	61′~ 62′d)	63′0″f)	65′3″f)
Physical maturity	62′	66′	—	—	—	68′c)	—	70′d)	69′g)	73′g)
Largest length	68′	74′	66′b)	72′b)	66h)	71h)	68′d)	73′d)	82′h) 74′2″f)	88′h) 80′5″f)

Remarks a) Mizue (1951) b) Omura (1950) c) Pike (1953) d) Jonsgård (1952) e) Mackintosh & Wheeler (1929) f) Mackintosh (1942) g) Nishiwaki (1953) h) I.W.S.

A male fin whale (No. 5979) is sexually immature after 2 years since it was marked. As the estimated length is 60 feet, it might not be so short at marking. Number of laminations of this whale is 9.

From the biological data of No. 3443, 4552 and 5979 whales, fin whale is estimated to deposit at most 5 laminations in ear plug every year.

Laws (1956) reports on the growth and sexual maturity in aquatic mammals. He describes that if we convert the length of the female at puberty to a percentage of the size attained when growth ceases it is seen to be remarkably constant, averaging in cetaceans 85.1 per cent (range 80.0–85.5). Now we obtained the result that body length at sexual and physical maturity for the female fin whale in the northern Pacific are 61 feet and 66 feet respectively. Therefore, length at sexual maturity as percent of final length is 92.4. This differs from the value by Laws.

Although Laws (1956) states in the same paper that male whale attaines sexual maturity at a later age than the female, our result on this subject differs from it. Both sexes of fin whale attain sexual maturity at about six years of age. Furthermore, the age at physical maturity of male seems also to be the same as the female.

Table 14 shows the body length at several stage of growth in several regions. Length at birth will be the same in all stocks of fin whales. However, after birth the stocks in the northern hemisphere will grow more slowly than the other. The length at weaing has not been reported yet. On the length at sexual maturity of northern fin whale all reporters obtain almost at the mean length of 57–59 feet and female does at 59–62 feet. These are about 5 feet shorter than the stocks of southern hemisphere.

The investigation of physical maturity for the stocks of northern fin whales have been imcomplete. Comparing the size distribution of female fin whale northern Pacific with British Columbia and the North Atlantic, 68 feet and 70 feet for the length of physical maturity seems too longer than the theoretical value. The length of northern hemisphere fin whale at physical maturity is considered about 7 feet shorter than the southern stocks.

SUMMARY

The growth of the fin whale in the northern Pacific is studied by means of some biological data investigated on board of factory ships from 1952 to 1957. The essential points are concluded as follows.

1. Although we have no data on the breeding in October to April, the pairing season is estimated to include almost all seasons. But majority take place between November and January, the maximum falling at the middle of December.

Growth rate of foetuses for the northern Pacific fin whale is closely similar to that of other regions – coast of Japan, the North Pacific and the Antarctic.

Gestation period is estimated to continue till about 12 months. Then the body length at birth is supposed to be average 21 feet long in both sexes growth curve of foetuses is parabolic and growth equation is

$$L = 0.329M^{1.61}.$$

2. The youngest fin whale caught in the northern Pacific is two and a half years old (5 laminations) and in this stage whales are completly immature. After four years old fin whale approach to sexual maturity.

3. By means of histological examinations male fin whale which has its heavier testis of more than 2.6kg is regarded as sexually mature. The largest sexually immature whale is 63 feet long in the male and 68 feet long in the female. The shortest sexually mature whales is 55 feet in both sexes. Furthermore the average lengths of sexual maturity is estimated to be 58 feet in male and 61 feet in female.

Fin whale attains sexual maturity from four years of age till six years of age. The average age at sexual maturity is eariler part of six years of age for both the male and female.

4. After attainment of sexual maturity, ossification of vertebral epiphises begins from both ends of vertebral column and ends at 3rd to 6th dorsal vertebrae.

5. Female attains physical maturity from 22 years of age till 25 years of age. The average age at physical maturity is estimated to be 24 years old. The largest physically immature whale is 68 feet in male and 71 feet in female. On the other hand the shortest physically mature whale is 57 feet in male and 58 feet in female. The average length at physical maturity is 62 feet in male and 66 feet in female.

6. Shrinkage of body occurs after attainment of physical maturity. Average length of shrinkage is about one foot.

7. The maximum life of fin whale is estimated to be 50 years old. However, the physically mature fin whales (more than 24 years old) are very rare in the northern Pacific.

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AGE STUDY OF SPERM WHALE BASED ON READING OF TOOTH LAMINATIONS

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INTRODUCTION

The size limit for the sperm whales to catch is prescribed as 35 feet in the case of coastal whaling and 38 feet in the case of factory ship whaling by the International Regulation of Whaling. Referring to the body length at the sexual maturity, we suspect that the size limit for the sperm whale might be too severe when compared with that for the other species of whales. There is no doubt about that the keeping the size limit to catch in high level is the best way for the conservation of the whale resources. However, as the whaling operation becomes more intensive and the average body length of the whales to be caught diminish markedly, the whalers must wish to know plainly the indispensable minimum size limit for the conservation of the resources.

So we should obtain at first the exact knowledge on the sexual maturity and revise the size limit basing on them if necessary, then determine the number of catch on each stock of the sperm whales.

From this point of view, we enumerate here the previous studies on the sexual maturity of sperm whales. Matthews (1938) states that the female matures sexually at the former term of the second year after the birth and the male matures at the latter term of the same. Kasahara (1950) claimes that the sperm whale matures sexually at the middle of the third year after the birth. These were brought out not from the age determination of the whale but from only the size constitution. On the other hand, Clarke (1956) discussed in detail on the body length at sexual maturity (see table 20 of his paper). Nishiwaki & Hibiya (1951, 1953) and Nishiwaki, Hibiya & Kimura (1956) have investigated also on this problem, but as the data on the small whales are insufficient, the satisfactory result has not been conclusive.

Now, using the materials of the present series of whales collected during the last several years, we carried out again a deeper investigation on the above-mentioned subject. It has been thought that the teeth are the best age characters for the sperm whale, but the studies on them have never been published. We have studied here on the maxillary and

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mandibular teeth and have got the new information on the age of sperm whale.

Our sincere thanks are due to Dr. Ikusaku Amemiya, who kindly read our draft and critisized it. We are indebted to the several whaling stations, the fisheries experiment stations and the fisheries co-operative associations in Japan for the collection of our material. This study is supported in part by a Grant in Aid for Fundamental Scientific Research from the Ministry of Education. We wish to express our thanks to them all. And our grateful thanks are due to Professor Kotaro Fujita, of the University of Tokyo, for the guidance of our study.

MATERIAL

It has been noticed that in teeth of the sperm whale some year marks appear similarly in some other mammals. So we have collected the mandibular teeth of the whale, and cut longitudinally or transversely in

TABLE 1. SIZE DISTRIBUTION OF SEXUALLY IMMATURE AND MATURE SPERM WHALES USED IN THIS STUDY

Body length (feet)	Males		Females	
	Immature	Mature	Immature	Mature
21	1	—	—	—
22	1	—	1	—
24	1	—	—	—
27	—	1	3	—
28	—	—	1	1
29	—	—	1	2
30	2	—	—	5
31	1	3	—	6
32	—	3	—	12
33	—	4	—	10
34	—	4	—	9
35	—	6	—	13
36	—	2	—	8
37	—	3	—	3
38	—	2	—	1
39	—	4	—	—
40	—	3	—	—
43	—	1	—	—
44	—	1	—	—
45	—	1	—	—
46	—	1	—	—
48	—	1	—	—
50	—	2	—	—
51	—	4	—	—
52	—	1	—	—
53	—	1	—	—
Total	6	48	6	70

order to count the laminations on the cut surface of the tooth. We used teeth from the seventh through the tenth counted from the front in each individual, because they are the biggest of the dental series. But they are not satisfactory for our purpose, for the tips of the teeth began to be defaced following the growth of teeth, and their sections did not show the whole process of their growth, moreover the individual variations of attrition were considerable.

At this juncture, several years ago, we got a chance to get all teeth of a calf whose size was 22 feet long. All teeth were still in gum and not in defacing. Observing the maxillary teeth of this specimen, we found that the number of laminations in them was similar to that of

TABLE 2. COMPOSITION OF NUMBER OF LAMINATIONS IN THE TEETH OF EXAMINED SPERM WHALES

Number of laminations	Males		Females	
	Sexually Immature	Sexually mature	Sexually Immature	Sexually mature
2	1	—	—	—
3	—	—	1	—
4	1	—	—	—
5	1	—	—	—
7	—	—	1	—
8	—	1	4	—
9	1	—	—	1
10	1	3	—	1
11	1	3	—	4
12	—	4	—	6
13	—	3	—	2
14	—	4	—	2
15	—	2	—	2
16	—	2	—	1
17	—	2	—	1
18	—	1	—	5
19	—	—	—	1
21	—	—	—	2
22	—	—	—	3
23	—	—	—	1
24	—	—	—	1
26	—	1	—	1
28	—	1	1	1
29	—	—	—	2
31	—	2	—	3
32	—	—	—	1
33	—	—	—	2
37	—	—	—	1
44	—	1	—	—
49	—	—	—	1
65	—	1	—	—
Total	6	31	6	45

the mandibular teeth. Since then we have collected the maxillary teeth of the sperm whales whose mandibular teeth were defaced. At the same time, we have endeavoured to collect the teeth of small individuals as many as possible.

Tables 1 and 2 show the number of whales which we investigated and from which we collected the teeth. They are composed of the many whales which were netted with the fixed nets or stranded themselves. The biological data of them are shown in the appendix.

METHOD OF LAMINATION READING AND CHARACTERISTIC OF THE TEETH

For the purpose of determining the age of the sperm whale, the transversed section of the teeth is of no practical use. It may be understood by figure 1. Therefore we employed the teeth cut longitudinally through the axis. The tiny teeth were worn down with grinder and then filed and polished with iron rasps, and then polished with rough and fine whetstones. For the big teeth, after cutting off with metallic saw carefully never to cross the axis, we grinded it by the above-mentioned method.

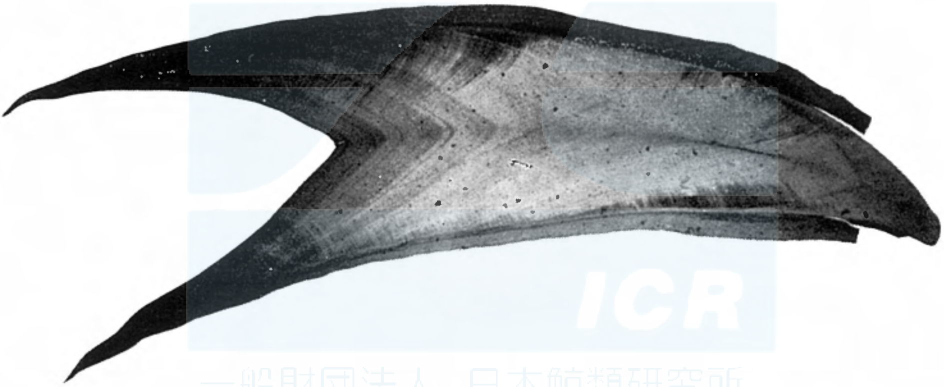

Fig. 1. Longitudinally section of a mandibular tooth of a sperm whale. (No. F 9). $7^1/_4$ laminations ($\times 2^2/_3$).

On counting the number of laminations we used the magnifying-glass ($\times 7$) or binocular dissecting microscope ($\times 20$). High magnification by the microscope was not only needless, but sometimes it made nuisance for counting, because the lamination which we counted consisted of from two to five fine lamellae in which more fine lamellae were found under the high-powered microscope. The aspect described here are shown obviously in figure 1.

Laminations will be also seen in the cement covering of the dentine. Although this lamination coincides with the same in the dentine, there are many cases of cement with obscure laminations. Outside of the teeth, jagged rings are appeared, as may be seen in the teeth of seals, but they are also rather obscure. So, both of them are not available as age character.

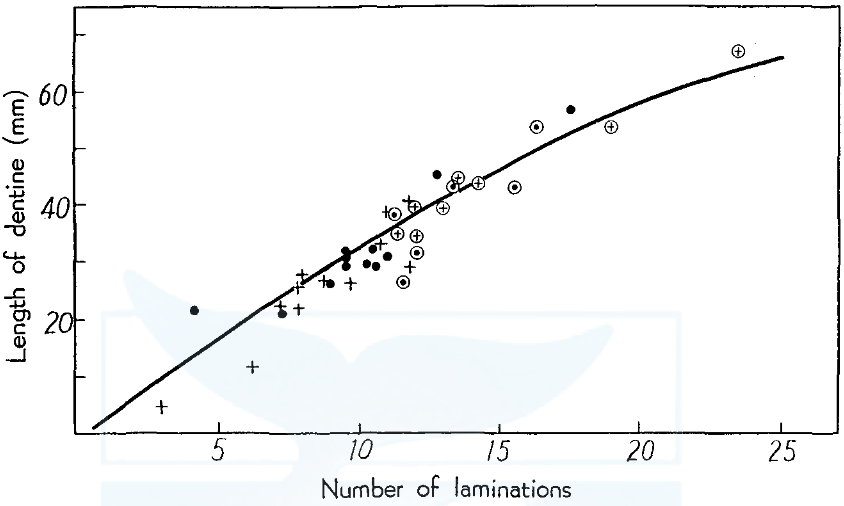

Fig. 2. Growth curve of mandibular teeth in the sperm whales.
Cross: female, closed circle: male, open circle: defaced:

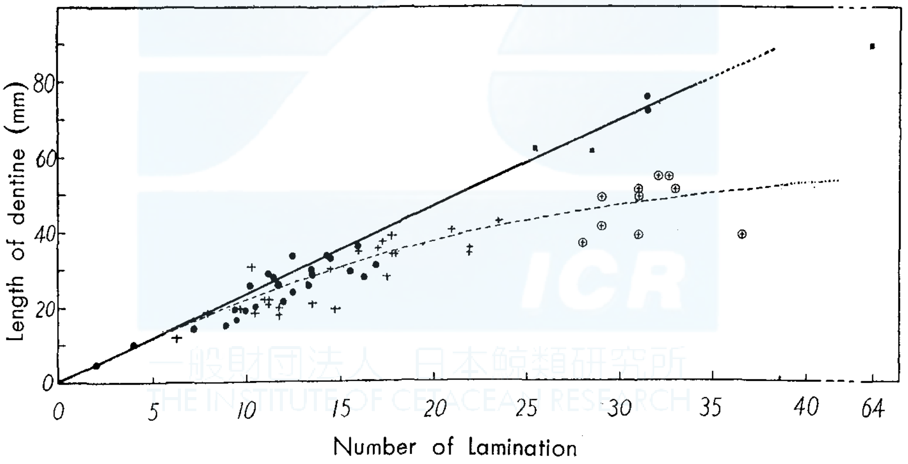

Fig. 3. Growth curve of maxillary teeth in the sperm whales.
Cross: female, closed cirde: male, square: northern male, open circle: radices dentes formed.

Using the teeth of six foetuses, we observed the developmental process of teeth and confirmed the presence of neonatal line in them. Moreover, on seven examples of which the teeth have never been defaced, we found that the number of laminations in each tooth of an similar throughout the dental series. But with the growth of animals mandibular teeth were defaced from their tops. The attrition begines at the stage of 12 laminations as is shown in figure 2. In the sperm whale, it is considered that the eruption of teeth have some relation with sexual maturity. And after the eruption attrition of teeth will begin. On the other hand, some of maxillary teeth are often buried in gum throughout the life. Figure 2 shows the relation between the number of laminations (in the case of the attrition in mandibular teeth we used number of laminations in the maxillary teeth) and the length of dentine. The lengths were measured along the axes. From this figure it is clear that the growth of teeth is faster than the attrition. At almost same age, both the teeth of males and females begin to be defaced.

Fig. 4a. A series of right mandibular teeth of a sperm whale foetus. Male, 400 cm in body length. ($\times {}^{4}/_{5}$)

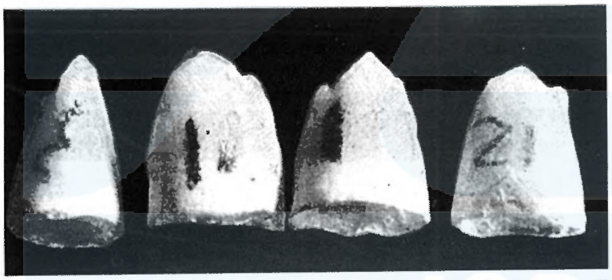

Fig. 4b. Four left mandibular teeth of a sperm whale foetus. Female, 365 cm in body length. (×3)

In old sperm whales, radices dentes are formed and the the teeth stop growing. The formation of radix dentis progresses both from anterior and posterior ends of the dental series. In maxillary teeth, radices dentes are formed at the stage of about 30 laminations for female whale, but not yet formed at the age of 65 laminations in the male maxillary teeth. As shown in figure 3, this phenomenon may have some relation with the physical maturity of the whale.

Examining the dental series of foetuses, it was found that the teeth other than the anterior four and the posterior four were conical and tridentate. After the birth the head of dentine is covered with cement, but it appears when the latter are uncovered. Figure 4 indicated a set of mandibular teeth of two foetuses. Osteodentines often bury within the dentine in maxillary teeth of females. The first formation of osteodentine may concern with the sexual maturity of female as shown in Plate II.

RELATION AMONG BODY LENGTH, WEIGHT OF TESTIS AND NUMBER OF LAMINATIONS IN THE TEETH

Figure 5 shows the relation between the body length of male whales and the weight of testes. In other species especially in baleen whales, the rapid increase of weight of testis appeared at the period of sexual maturity. Therefore, we can determine with relative ease the relation between the weight of testis and the body length at that stage. In the sperm whale, however, testis increases slowly in weight and it is difficult to determine the point of sexual maturity with the weight of testis only. In Figure 5 is also shown the mean curve of the relation between the body length and the weight of testis of the sperm whales caught in adjacent waters to Japan (Nishiwaki & Hibiya, 1951). The present data are shown with signs of circles. White circle represent an immature testis all of which were determined with histological investigation, and the black one is a mature testis.

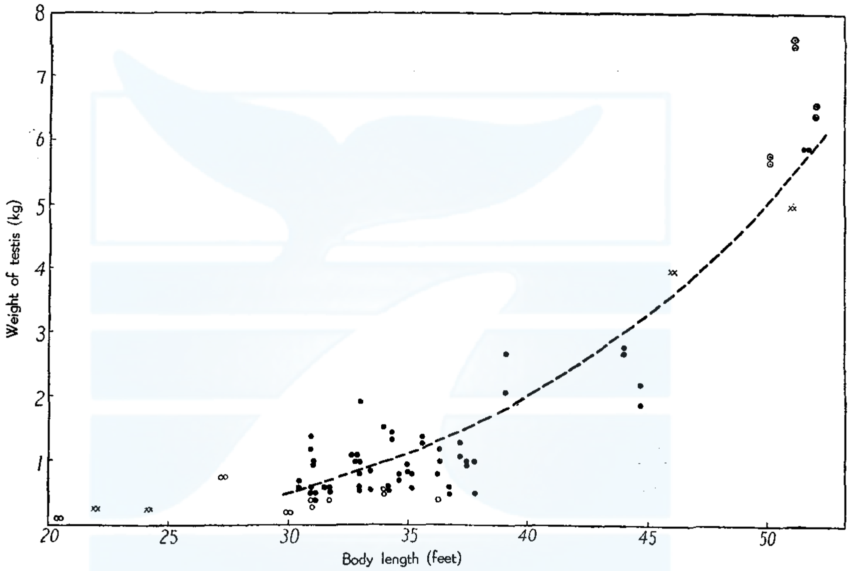

Fig. 5. Relation between the body length and the weight of testis in the sperm whales. Open circle: sexually immature, closed circle: sexually mature, cross: not examined histologically, point in the open circle: mature from the northern Pacific, broken line: mean curve by Nishiwaki, Hibiya & Kimura (1955).

Figure 6 shows the relation between the number of laminations in the teeth and the weight of testis in same manner.

In the previous papers (Nishiwaki & Hibiya, 1951, 1952; Nishiwaki, Hibiya & Kimura, 1956), we could not use enough data determining the sexually mature length in the male. So we did not get the conclusion on the problem and showed the presumptive length at sexual maturity for the male (less than 38 feet). We determined the sexual maturity of the male by the presence of spermatozoa in the seminiferous tubules. Clarke (1956) interposed some objections to our method. He states that since there is evidence that male sperm whales have a sexual cycle, it is doubtful whether the presence or absence of spermatozoa is a very reliable means of discriminating between mature and immature animals. He says that the whale whose seminiferous tubules are large and open should be regarded to be sexually mature. And he pointed out that the sexually mature length estimated by us in the previous papers would be bigger than that by him.

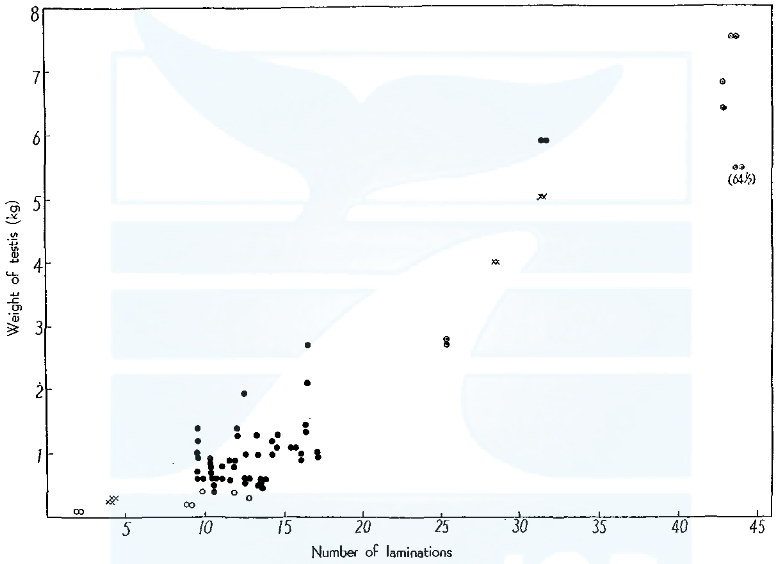

Fig. 6. Relation between the number of laminations and the weight of testis in the sperm whales. Marks are the same as figure 5.

In the present study, we classify the degree of the maturity of testes in following three stages, that is to say, these are the testes in which spermatozoa exist (+), those in which seminiferous tubules are open but spermatozoa do not exist (±), and those whose tubules are closed and decided as immature (−). And then we regard ± as mature.

Owing to the scanty of samples of the testes under 1.0 kg in weight, we suggested in our previous papers that the male sperm whale attained sexual maturity at 1.1 kg in testis weight. But from figure 4, the weight of testis at maturity is about 0.5 kg. According to Clarke (1956), the combined volume of both testes at maturity is 1.5 *l*. As the density of testes is about 1.0 g/cm^3, the figure of the weight in gram corresponds almost to that of the volumal in cubic centimeter. From our data, the combined weight of testes is calculated to be 1.0 kg. Therefore the value by Clarke is bigger than that by us.

Table 1 shows the body length of sexually mature and immature whales determined by the histological examination of testes in the male. Although number of samples are relatively few, the body length at sexual maturity is supposed to be 31 feet in the male.

Table 2 is a record of the number of laminations for sexually mature and immature whales. The number of laminations at sexual maturity estimated from this datum is about 10.

RELATION BETWEEN NUMBER OF OVULATIONS, BODY LENGTH AND ALSO NUMBER OF LAMINATIONS

Figure 7 shows the relation between the body length and the number of ovulations in the sperm whale. The deviation of the latter at each body length is remarkable. On the other view, the deviation of body length at each number of ovulations is also conspicuously vest. On the contrary, it is found that the frequency of ovulations correspond relatively close to the number of laminations (fig. 8).

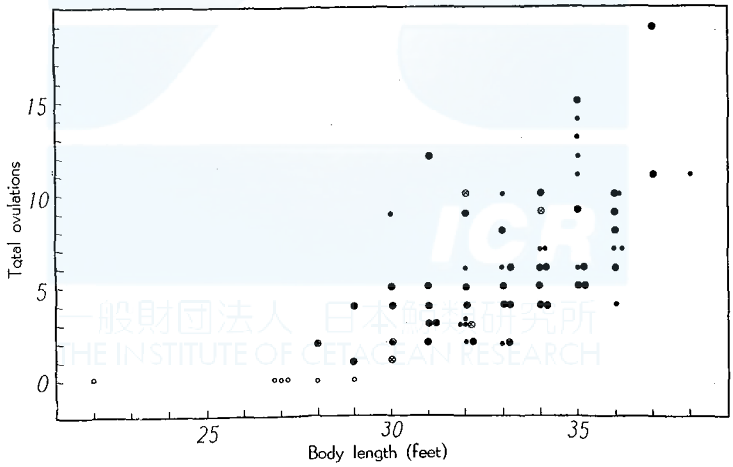

Fig. 7. Relation between the body length and the total ovulations in sperm whales. Open circles: sexually immature, cross in the open circle: ovulating, point in the open circle: resting, closed circles: pregnant.

The same phenomenon was observed on the laminations in the ear plug of fin whales (Nishiwaki, 1957), and the numbers of those laminations are regarded as the most reliable age characters for the baleen whales.

Similarly, the number of laminations in the teeth can be appreciated as the most reliable age character for the sperm whale. The lamination may be formed periodically in the teeth.

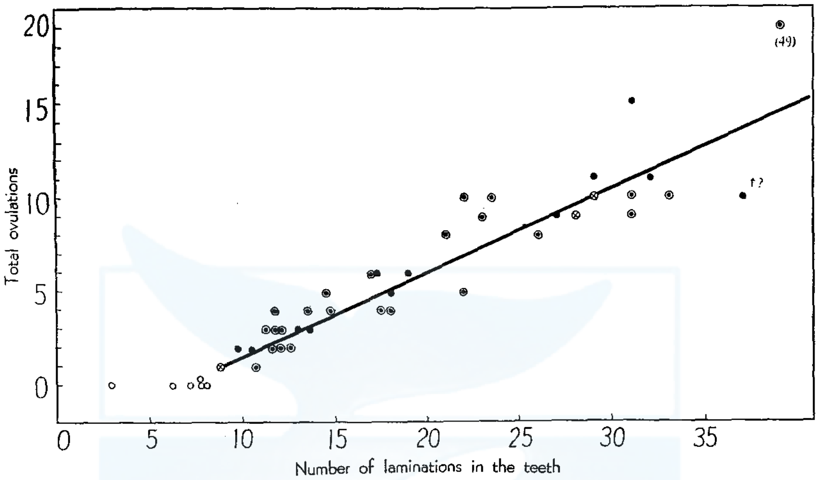

Fig. 8. Relation between the number of laminations and the total ovulations. Marks are the same as figure 7.

The experimental formula derived from our present data is as follows.

$Y=0.44X-3.00$ Y: Number of ovulations

X: Number of laminations in the tooth

From table 1, it is decided that the sexually mature length of the female sperm whale is about 29 feet. And the number of laminations at sexual maturity is about 9 according to table 2.

RELATION BETWEEN NUMBER OF LAMINATIONS IN THE TEETH AND BODY LENGTH

The frequency of ovulations has been regarded as a good age character for the whales. Figure 9 shows the relation between body length and the frequency of ovulations, and the curve will show the growth of the animal. But the growth during immature stage cannot be shown by this method. Furthermore, the number of ovulations in a breeding season varies with the individual and the year.

From this figure it will bee seen that the body length at sexual maturity (namely at the point of the first ovulation) is 29 feet long, and the length at physical maturity is 35-36 feet long as for the female sperm whale.

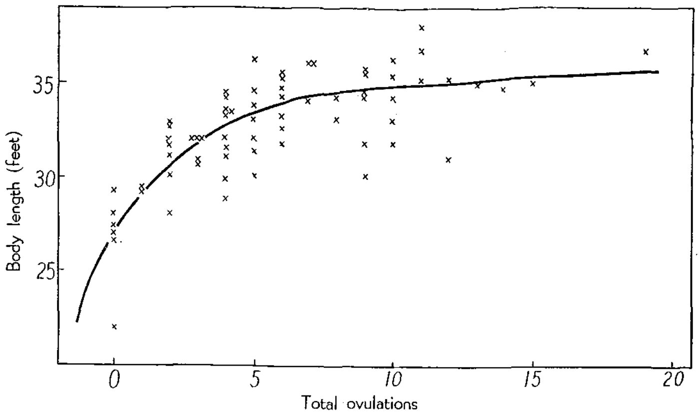

Fig. 9. Growth curve of the female sperm whales based on the total ovulations.

Figure 10 shows the relation between the number of laminations in the teeth and the body length. In this manner can be indicated the growth in both sexes, and also in foetus. Using the data by Matthews (1938), Matsuura (1936), and Mizue (1950) we adopted 16 months as the pregnant period and 13 feet as the body length at birth.

The mark × in figure 10 is the length and time at weaning by Clarke (1956). On our smallest male specimen which was 20 feet 6 inches in body length and with two laminations in its teeth, we had no chance examining its stomach content. Therefore it is not certain whether it was nursing or not. It was observed, however, that a male individual which is 22 feet long in body length and has three laminations in its

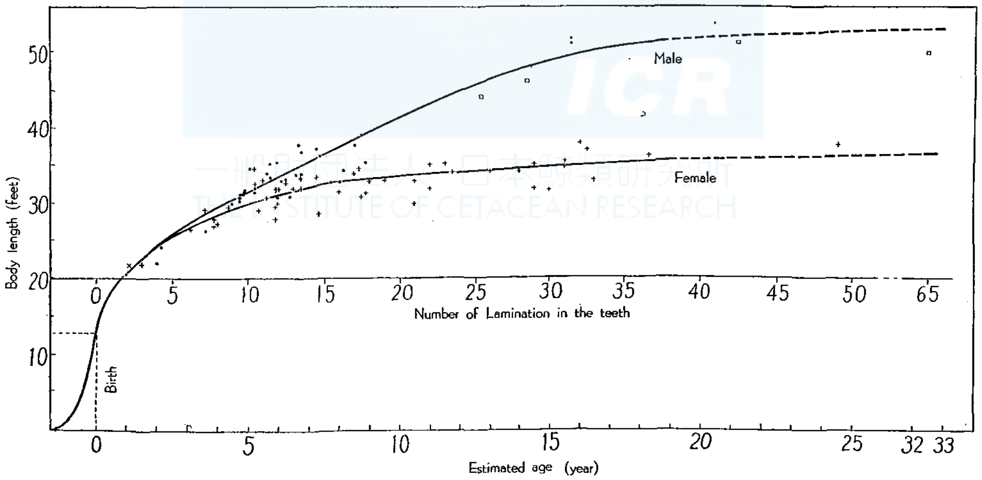

Fig. 10. Growth curve of the sperm whale according to number of laminations. Point: male, cross: female, square: male from the northern Pacific.

teeth and a female which was 22 feet long with four laminations had eaten squids. It was supposed that these had been already weaned. The lactating period is about 13 months by Clarke (1956). We consider that it is from 8 to 12 months, though continuance of lactation for 13 months are rather seldom case. From this point of view we consider that the whale which is 20 feet 6 inches in body length and with two laminations in teeth is one year old. According to the information about the teeth of the blue-white dolphin (Nishiwaki & Yagi, 1953) and the ear plugs of the fin whale (Laws & Purves, 1957), it is estimated that two laminations are formed in the teeth of sperm whales every year. If two laminations in the teeth of the sperm whale correspond to one year, the age at sexual maturity is four and a half or five years old, as the numbers of laminations are nine or ten in both sexes at that time. From figure 10, the body length at physical matuaity is 36 feet for the female. On the other hand, male grows rapidly after sexual maturity and continues to grow over 50 feet long. It was observed that the whale which was 51 feet 6 inches long in body length and has 31½ laminations in the teeth was not physically mature (Plate 2). According to the investigation on the physical maturity of the male sperm whale in the northern Pacific by one of us (Kimura, 1957), the body length at physical maturity was over 52 feet.

INVOLUTION OF CORPUS LUTEUM

We have very scanty informations about the involution of corpus lateum in the ovaries of whales. And it is an important problem whether corpus luteum becomes to disappear or not. As we can estimate the age of the female sperm whale by the teeth, we arrange in order the corpora lutea and albicantia by means of their diameters. On the whale whose teeth were not sampled, we estimate its age from figure 8 by the number of ovulations.

Table 3 shows the diameter of corpora lutea and albicantia. By the classification of the diameter of the corpora albicantia we will estimate the number of ovulation in each breeding season. As for the relation between the number of laminations in the teeth and number of times of ovulations we obtained the empirical formula as shown above chapter. It means that two corpora albicantia formed every two years. We used this value as the standard of arrangement.

Figure 10 shows the relation between the diameters of corpora lutea or albicantia and the estimated duration after the ovulation corresponding respectively to them. The duration after the last ovulation were estimated basing on the sexual conditions of the whales. For instance, a

TABLE 3. DIAMETER OF CORPORA LUTEA AND ALBICANTIA OF SPERM WHALES

Serial number	Body length	Number of lamination in the teeth	Estimated age after Sexual maturity	Number of corpora lutea / albicantia		Diameter of corpora lutea or albicantia in mm.	Sexual condition
				left	right		
F— 6	28′— 0″	$11\frac{3}{4}$	$1\frac{7}{8}$	0/1	0/1	34, 14	lactating
F—11	29′—10″	$11\frac{3}{4}$	$1\frac{7}{8}$	0/2	0/2	37, 22, 17, 14	resting
F—13	30′— 0″	12+	2+	0/1	0/1	35, 20	lactating
F—17	31′— 8″	$9\frac{3}{4}$	$\frac{7}{8}$	1/0	0/1	105, 33	pregnant, foetus: M, 5′—4″
F—18	31′— 9″	31+	$11\frac{1}{2}$+	0/5	0/4	30, 20, 19, 17, 14, 14, 13, 12	lactating
F—24	32′— 0″	$11\frac{2}{3}$	$1\frac{5}{6}$	1/1	0/1	95, 40, 28	pregnant, foetus: M, 84 cm
F—25	32′— 0″	22	7	0/3	0/2	28, 20, 13, 10, 6	just finished lactation
F—28	33′— 0″	18	5	0/2	0/5	32, 29, 27, 24, 18	lactating, thickness of mammary gland: 17 cm
F—39	34′— 3″	29	$10\frac{1}{2}$	2/5	0/4	100, 70, hereafter unknown	pregnant, foetus: 17 cm
F—42	34′— 9″	31+	$11\frac{1}{2}$+	1/5	0/8	100, 30, 24, 22, 20, 17, 17, 16, 15, 14, 14, 12, 11, 11	pregnant, foetus: 3′—2″
F—52	31′— 0″	—	$11\frac{1}{4}$	0/6	0/6	25, 22, 20, 18, 18, 15, 12, 12, 10, 10, 8, 7	lactating, thickness of mammary gland: 20 cm
F—53	31′— 1″	—	$1\frac{3}{4}$	0/1	0/1	37, 25	lactating
F—54	31′— 4″	—	$4\frac{1}{3}$	0/2	0/3	32, 15, 15, 11, 8	lactating
F—55	32′— 6″	—	$5\frac{1}{3}$	0/4	0/2	30, 25, 18, 15, 15, 8	lactating
F—56	33′— 6″	—	3	0/1	0/3	28, 25, 18, 11	lactating, slightly
F—57	34′— 6″	—	$4\frac{3}{8}$	0/3	0/2	26, 17, 16, 15, 12	lactating
F—58	34′— 6″	—	$8\frac{1}{4}$	0/6	0/3	20, 14, 12, 12, 10, 10, 10, 9, 8	lactating, slightly
F—59	35′— 6″	—	$5\frac{1}{3}$	0/2	0/4	50, 20, 20, 15, 15, 12	lactating, uterus was not involuted yet

whale which had one corpus luteum and was pregnant with 17 cm. long foetus was estimated to had ovulated three months ago. And about the lactating corpus albicans the time of the last ovulation is estimated by the thickness of mammary gland, the width of uterus, or density and quantity of the milk.

It is known from figure 11 that diameter of the corpus lateum graviditatis is about 100 mm., but it involutes rapidly after parturition, in the lactation its diameter is 30–50 mm. and in the end of the period it decreases to about 25 mm. then after 3 or 4 years it involutes to about 10 mm. After that time the corpus albicans continues to involute but does not disappear throughout the life. The most numerous number of ovulation was 19 in our samples, and its number of laminations in the teeth was 49, whereupon the estimated age was 24½ years old. We could not decide whether the corpora albicantia disappear or not in the older age than that of this specimen.

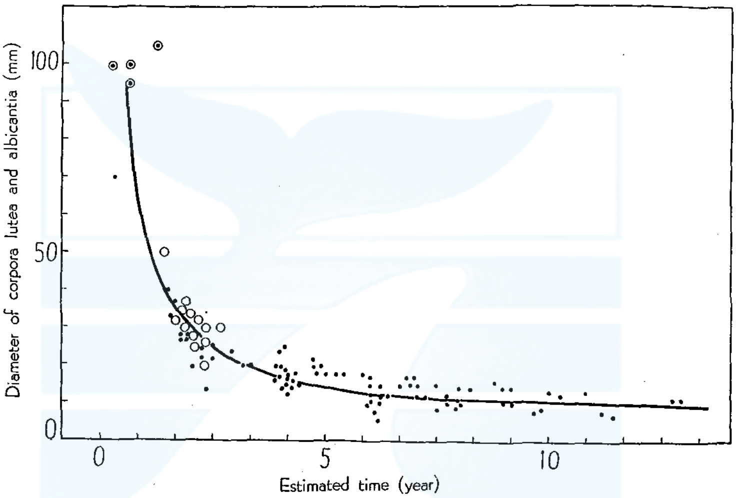

Fig. 11. Involuting course of corpora lutea of the sperm whales. Point in the open circle: corpus luteum, open circle: corpus albicans in lactating, point: corpus albicans.

DISCUSSION

The body length of male sperm whale at sexual maturity in our present study agrees well with the result by Clarke (1956). The fact is one of the reasons why this paper we adopted the condition of seminiferous tubule as the standard of sexual maturity according to Clarke. At the same time, it must be the most probable reason that we obtained the specimens of small whales. In our previous investigation, the whales under 34 feet long was very scanty because of the size regulation on the whaling. The most point becoming an issue in the present study was the finding of the practical method of estimating age by counting the laminations in the teeth in other words, the making clear whether two laminations correspond to the duration of one year or not.

On the aetiology of the laminated structure, there are many explanations (for instance Purves (1955) on the ear plug of the fin whale, and Laws (1953) on the teeth of the elephant seal), although there is some need for further studies. On the other hand we could get the result that two laminations in the teeth were formed annually by the experiment upon the blue-white dolphins, actually kept alive under observation. (loc. cit.)

This problem should be solved by further investigations. Marking expedition will be one of the methods of it. Omura & Kawakami (1956) reported basing on the marking investigation in the North Pacific, and stated that the growth in the sperm whales may be much slower than that is generally believed. One male, killed in the 4th year after the marking measured only 35 feet. Of the other three males, killed in 4th year and after the two are both 37 feet and another 39 feet. The length of two females, killed in the 5th and 6th year, were both 36 feet. And it will be better if possible that the method injecting lead-compound with the marking harpoon to deposit lead in teeth are employed.

SUMMARY

1. In the present study were available the sperm whales which had been caught in the northern Pacific or stranded in Japanese coasts in the last several years.
2. The number of laminations in the teeth is available as the criteria for the age estimation. Buried maxillary teeth are suitable for this purpose.
3. The top of dentine of the sperm whale are tridentate in the very young stage.
4. Mandibular teeth begin to be defaced several years after birth, and the pulp cavity of the maxillary teeth is closed at over ten years old. The phenomena may be related to the sexual and physical maturity respectively.
5. The weaning period is estimated to be one year after birth. The body length at this stage is about 21 feet.
6. The male sperm whale attains sexual maturity at the age of four or five (nine or ten laminations) and the body length at that stage is about 31 feet long and its heavier testis is 0.5 kg in weight.
7. The female sperm whale attains sexual maturity at the next breeding season of the age of four, and the body length at that stage

is about 29 feet long.

8. The eruption of teeth have some relation with sexual maturity.

9. Over the age of eighteen the whale attains physical maturity, and the body length is 52 feet long in male and 36 feet in female.

10. The number of ovulation in one breeding season is two in an average. That corpus luteum involutes repidly after parturition but it may not disappear throughout the life.

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EXPLANATION OF APPENDIX

Biological measurement of sperm whales of which teeth are sampled.

Remarks.

1) + : Buried teeth are exist but they are not counted.
2) ? : It is not clear whether teeth are exist or not.
3) ( ): Number of teeth buried.
    Left: anterior
    Right: posterior
4) U : Upper (Maxillary) teeth examined.
5) L : Lower Mandibular tooth examined.

EXPLANATION OF PLATES

PLATE I

Fig. 1. Maxillary and mandibular teeth of three female specimens. (×$^{2}/_{3}$)
Upper: maxillary teeth. Lower: mandibular teeth.
a: 26′6″, $6^{1}/_{4}$ laminations (F—2)
b: 29′4″, $7^{1}/_{4}$ laminations (F—9)
c: 28′0″, $11^{3}/_{4}$ laminations (F-6)

Fig. 2. Mandibular teeth of four specimens. (×$^{2}/_{3}$)
a: Female, 22′, 3 laminations (F—1)
b: Female, 27′10″, $7^{3}/_{4}$ laminations (F—3)
c: Male, 30′5″, $9^{1}/_{2}$ laminations (M—6)
d: Male, 34′, $13^{1}/_{4}$ laminations Defacing begins (M—18)

Fig. 3. Mandibular tooth of a male which is 49 feet long. (MN—3). (×$^{4}/_{7}$)
Tip of tooth has been relatively defaced.
Number of lamination is over 39.

PLATE II

Fig. 1. Maxillary teeth of four specimens. (×1)
a: Male, 20′6″, 2 laminations (M—1)
b: Female, 32′0″, $11^{2}/_{3}$ laminations (F—24)
c: Female, 33′0″, 22 lamination (F—25)
d: Female, 33′0″, over 33 laminations, roof formed (F—30)

Fig. 2. Maxillary teeth of two male specimens. (×$^{5}/_{8}$)
Upper: 51′0″, $43^{1}/_{2}$ laminations (MN—5).
Lower: 51′6″, $31^{1}/_{2}$ laminations (M—34).

Fig. 3. Maxillary tooth of the oldest specimen.
Male, 50′0″, $64^{1}/_{2}$ laminations (MN—4)

Fig. 4. Defaced Maxillary tooth of a male 52 feet over 42 laminations. (MN—6) (×$^{6}/_{7}$)
Laminations in cement are seen clearly.

APPENDIX

Number of samples	Body length (feet / inch)	Dental formula				Teeth examined	Length of dentine	Number of lamination in the teeth	Testis			
		Left upper	Left lower	Right lower	Right upper				Left weight	Maturity	Right weight	Maturity
M— 1	20— 6	+	(22)	(22)	+	U	5.0	2	0.1 kg	—	0.1 kg	—
M— 2	22	?	?	?	?	L	10.4	4				
M— 3	24— 3	?	?	?	?	L	21.7	$4\frac{1}{4}$				
M— 4	27— 4	+	(24)	(24)	+	L, U	21.5, 15.3	$7\frac{1}{4}$	0.75		0.75	
M— 5	30— 0	+	(23)	(24)	+	L, U	26.4, 15.7	9	0.2	—	0.2	—
M— 6	30— 5	+	(25)	(24)	+	L	30.8	$9\frac{1}{2}$	0.7	+	0.6	+
M— 7	30—10	+	21	25	+	L, U	31.4, 17.3	$9\frac{1}{2}$	1.4	+	1.2	+
M— 8	30—11	+	(1) 24 (6)	(1) 25 (7)	+	L, U	32.6, 20.0	$10\frac{1}{2}$	0.5	+	0.4	+
M— 9	31— 0	+	(1) 25 (8)	(1) 26 (9)	+	L	45.6	$12\frac{3}{4}$	0.3	—	0.6	+
M—10	31— 2	+	(2) 22 (6)	(3) 23 (7)	+	L, U	29.5, 19.7	$9\frac{1}{2}$	1.0	+	0.95	+
M—11	31— 8	+	(2) 23 (9)	(3) 24	+	L, U	33.6, 19.4	$9\frac{3}{4}$	0.4	—	0.6	+
M—12	31— 9		(9) 21 (6)	(8) 22 (7)		L	29.6	$10\frac{1}{2}$+	0.55	+	0.6	+
M—13	32—10	+	(1) 22 (4)	(3) 24 (6)	+	L, U	43.5+, 30.2	$15\frac{1}{2}$	1.1	+	1.1	+
M—14	33— 0	+	(3) 26 (8)	(2) 25 (6)	+	U	33.6	$12\frac{1}{2}$	0.6	+	0.55	+
M—15	33— 0	+	(1) 24 (6)	(1) 25 (4)	+	U	24.2	$12\frac{1}{2}$	1.95	+	1.0	+
M—16	33— 0	+	23 (1)	21	+	U	35.8	16	0.8	+	1.0	+
M—17	33— 5	+	(1) 25	(1) 24	+	L, U	26.4+, 27.4	$11\frac{1}{2}$	0.55	+	0.9	+
M—18	34		23	23		L	43.5+	$13\frac{1}{4}$+	1.3	+	Lost	
M—19	34— 0	2	(1) 22 (3)	(1) 21 (4)	+	L, U	38.7+, 28.8	$11\frac{1}{4}$	0.5		0.55	
M—20	34— 0	+	(1) 22 (4)	(1) 23 (3)	+	U	29.8	$13\frac{1}{2}$	0.55	+	0.6	+
M—21	34— 5	+	(1) 23	22	+	L, U	53.8+, 27.7	$16\frac{1}{3}$	1.45	+	0.35	+
M—22	34— 8	+	(2) 24 (7)	(3) 24 (6)	+	L, U	30.1, 25.6	$10\frac{1}{3}$	0.7	+	0.8	+
M—23	35		25 (8)	25 (8)		L	30.3	$10\frac{1}{3}$	0.85	+	0.90	+
M—24	35— 2	+	(2) 24 (5)	(2) 24 (5)	+	L	31.0+	11+	0.6	+	0.8	+
M—25	35— 7	+	(1) 24 (5)	(1) 25 (3)	+	L, U	32.0+, 21.7	12	1.3	+	1.4	+
M—26	36— 4	+	(2) 25	(1) 25	+	U	26.0	$11\frac{3}{4}$	0.4	—	0.8	+
M—27	36— 5	+	(1) 23 (5)	(1) 24 (4)	+	U	33.6	$14\frac{1}{3}$	1.2	+	1.0	+
M—28	36— 8	+	(1) 23 (1)	(1) 23 (1)	+	U	29.0	$13\frac{1}{2}$	0.6	+	0.5	+
M—29	37— 3	+	25 (7)	24 (7)	+	U	32.8	$14\frac{1}{2}$	1.1	+	1.3	+
M—30	37— 6	+	(1) 27 (3)	(1) 25 (3)	+	U	30.8	17	1.0	+	0.95	+
M—31	37—10	+	(1) 23 (2)	(1) 22 (2)	+	U	27.4	$13\frac{1}{3}$	0.5	+	1.0	+
M—32	39	+	?	?	?	L	57.0	$17\frac{1}{2}$	2.7	+	2.1	+
M—33	51	?	?	?	?	U	72.5	$31\frac{1}{2}$				
M—34	51— 6	+	(1) 22 (1)	21	+	U	76.0	$31\frac{1}{2}$	5.9	+	5.9	+
MN— 1	44	+	?	?	+	U	62.6	$25\frac{1}{3}$	2.7		2.8	
MN— 2	46	5	27 (1)	28 (1)	+	U	61.8	$28\frac{1}{2}$	—		—	
MN —3	49	?	?	?	?	L	82+	39+	—		—	
MN —4	50	+	21	20	6	U	105.2	$64\frac{1}{2}$	5.4		5.8	
MN —5	51	7	21	22	6	U	89.8	$43\frac{1}{2}$	7.5		7.6	
MN —6	52	5	22	22	6	U	74.6+	43+	6.4		6.8	

APPENDIX (Cont.)

Number of samples	Body length (feet inch)	Dental formula				Teeth examined	Length of dentine	Number of lamination in the teeth	Number of corpora		Remarks
		Left upper	Left lower	Right lower	Right upper				Lutea /	albicantia	
F— 1	22	?	(22)	(22)	?	L	4.8 mm	3	0/0	0/0	
F— 2	26— 6	+	(22)	(23)	+	L, U	11.7, 12.0	$6^{1}/_{4}$	0/0	0/0	
F— 3	27— 0	+	(23)	(23)	+	L	25.8	$7^{3}/_{4}$	0/0	0/0	
F— 4	27— 5	+	(25)	(24)	+	L, U	28.0, 18.5	8	0/0	0/0	
F— 5	28— 0	+	(21)	(22)	+	L	22.0	$7^{3}/_{4}$	0/0	0/0	
F— 6	28— 0	+	(2) 20 (13)	(1) 22 (11)	+	L, U	35.0, 20.7	$11^{3}/_{4}$	0/1	0/1	
F— 7	28—10	+?	(2) 22 (5)	(2) 22 (4)	+?	L, U	41.0, 19.2	$11^{2}/_{3}$	0/2	—	
F— 8	29— 3	+	(3) 21 (9)	(3) 22 (11)	+	L	33.4	$10^{2}/_{3}$	1/0	0/0	Lactating
F— 9	29— 4	+	(22)	(22)	+	L, U	22.4, 16.0	$7^{1}/_{4}$	0/0	0/0	
F—10	29— 6	+	(23)	(23)	+	L	27.0	$8^{3}/_{3}$	1/0	0/0	
F—11	29—10	+	(5) 23 (7)	(7) 23 (1)	+	L, U	29.5, 18.2	$11^{3}/_{4}$	0/2	0/2	
F—12	30— 0	+	(1) 22	(1) 22	+	L	40.0+	12+	0/1	0/1	Lactating
F—13	30— 0	+	25	25	+	U	48.9	21	1/4	0/4	pregnant
F—14	30—10	1	(2) 22 (7)	(2) 21 (5)	+	L, U	35.5+, 21.8	$11^{1}/_{3}$	0/1	0/2	
F—15	31	+	25 (2)	23 (2)	+	U	28.0	$17^{1}/_{2}$	0/3	0/1	Lactating
F—16	31— 6	+	(1) 26 (3)	(1) 25 (6)	+	U	38.9	$17^{2}/_{3}$	1/2	0/1	pregnant M 5—4
F—17	31— 8	+	(2) 24 (5)	(2) 23 (3)	+	L, U	26.6, 29.8	$9^{3}/_{4}$	1/0	0/1	pregnant F 11—5
F—18	21— 9	3	25 (1)	25 (1)	4	U	39.3 almost close	31+	0/5	0/4	Lactating
F—19	31—10	+	(1) 26 (2)	(1) 25 (1)	+	U	35.4	16	—	—	
F—20	31—10	+	26	25	+	U	49.4 almost close	29	1/3	0/6	
F—21	32	?	27	26	?	L	35.2+	12+	1/1		
F—22	32	?	22	22	?	L	40.1+	13+	1/0	0/2	pregnant
F—23	32	?	21 (6)	23 (5)	?	L	45.0+	$13^{1}/_{2}$	1/1	0/1	pregnant
F—24	32— 0	+	24	22	+	U	19.7	$11^{2}/_{3}$	1/1	0/1	pregnant M 256 cm
F—25	32— 0	+	(1) 23	22	+	U	34.5	22	0/3	0/2	
F—26	32— 7	+	(1) 26 (1)	(1) 26	+	U	18.6	$10^{1}/_{2}$	1/0	—	pregnant F 1—5
F—27	32- 10.	+	(5) 27 (10)	(10) 26 (10)	+	U	26.0	$12^{1}/_{2}$	0/1	—	
F—28	33— 0	4	21	21	4	U	33.9	18	0/2	0/3	Lactating
F—29	33— 0	+	24	23	+	U	40.5	21	0/6	0/2	
F—30	33— 0	3	26	27	4	U closed	51.5	33+	0/6	0/4	
F—31	33— 2	+	(1) 24	(1) 23	+	U	21.3	$13^{1}/_{2}$	0/3	0/1	
F—32	33— 3	+	(3) 23 (5)	(2) 21 (5)	+	L, U	39.0, 21.8	11	—	—	
F—33	33— 3	+	(1) 23 (3)	(1) 22 (2)	+	L	54.0+	19	1/2	0/3	pregnant (foetus, large, lost)
F—34	33— 9	+	(1) 22	(1) 23	+	L, U	44.0+, 30.0	14	0/8	0/1+	
F—35	34— 2	+	21	21	+	U	35.7	17	0/3	0/3	
F—36	34— 2	6	27	26	6	U	36.6	28	1/4	0/4	
F—37	34— 3	+		21+	+	L, U	67.0+, 43.0	$23^{1}/_{2}$	0/5	—	
F—38	34— 3	+	24	24	+	U	24.4 almost close	26	0/6	0/0	
F—39	34— 8	+	(7) 23 (10)	(8) 24 (11)	+	U	31.3	$10^{1}/_{2}$	—	—	
F—40	34— 8	2+	24	24 (1)	+	U	37.5	$17^{1}/_{3}$	1/1	0/4	pregnant 17 cm
F—41	34— 9	3	23	26	1	U closed	50.0	31+	1/5	0/8	pregnant 3—2″
F—42	35— 2	+	24	23	+	U closed	41.3	29	2/5	0/4	pregnant M—0—9
F—43	35— 5	2	24	23	3	U	36.0	22	0/8	0/2	
F—44	35— 6	1	21	25	2	U	33.8	$17^{3}/_{4}$	—	—	
F—45	35— 6	+	(1) 24 (2)	(1) 23 (1)	+	U	41.4	23	0/3	0/6	
F—46	35— 8	1	25	23	+	U	50.8 close	31	0/4	—	Lactating
F—47	36	+	25 (1)	25	1	L	47.4+	$21^{1}/_{3}$+	1/2	0/4	pregnant M 252 cm
F—48	36— 3	+	(2) 23 (6)	(1) 21 (6)	+	L, U	39.3$_{4}$, 40.7	$36^{1}/_{2}$	1/4		pregnant
F—49	36—10	4	23	22	1	U	64.6	49	0/9	0/10	
F—50	37— 7	5	25	22 (5)	3	U	55.3 almost close	$32^{1}/_{2}$	—	—	pregnant
F—51	38— 0	16	21	22	3	U	55.2 almost close	32	0/5	1/5	pregnant


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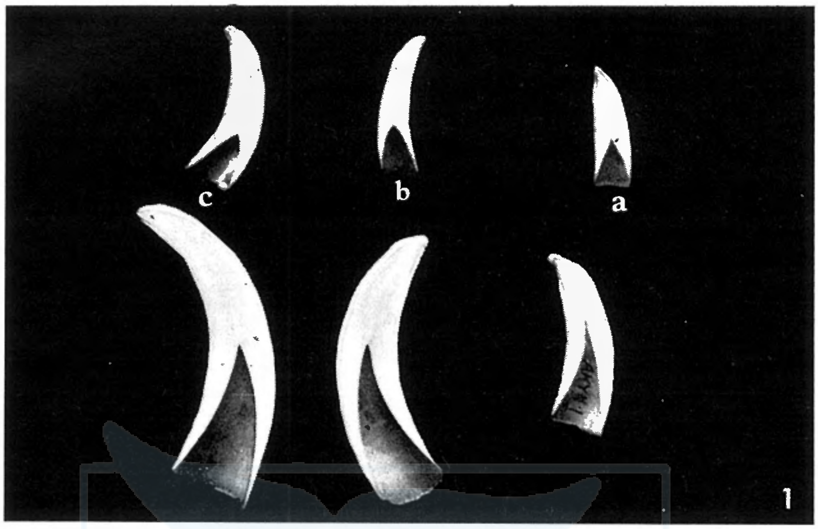

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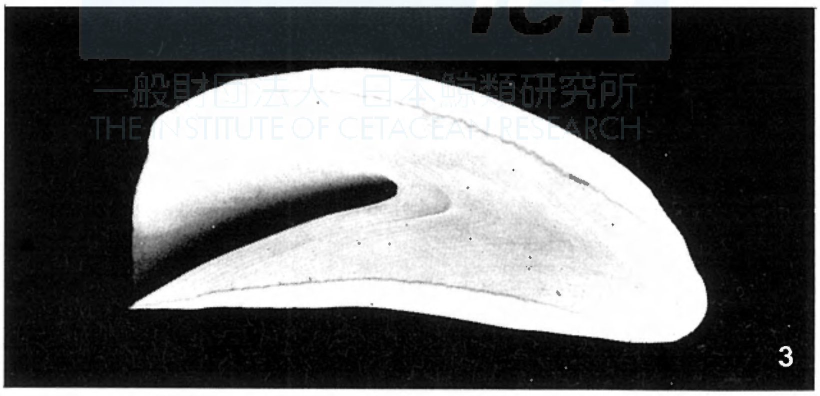

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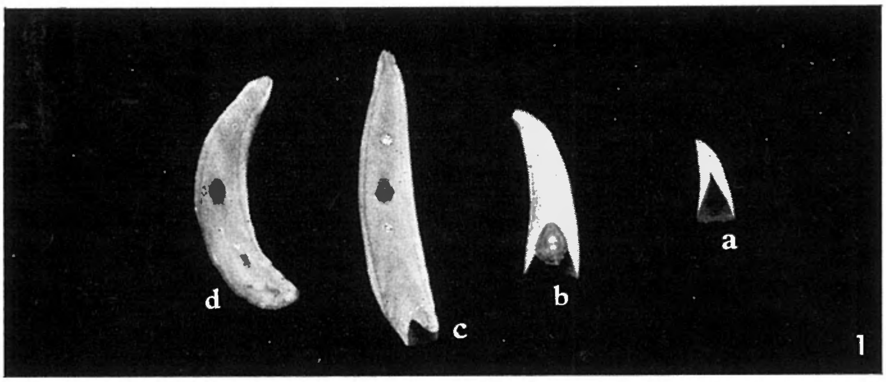

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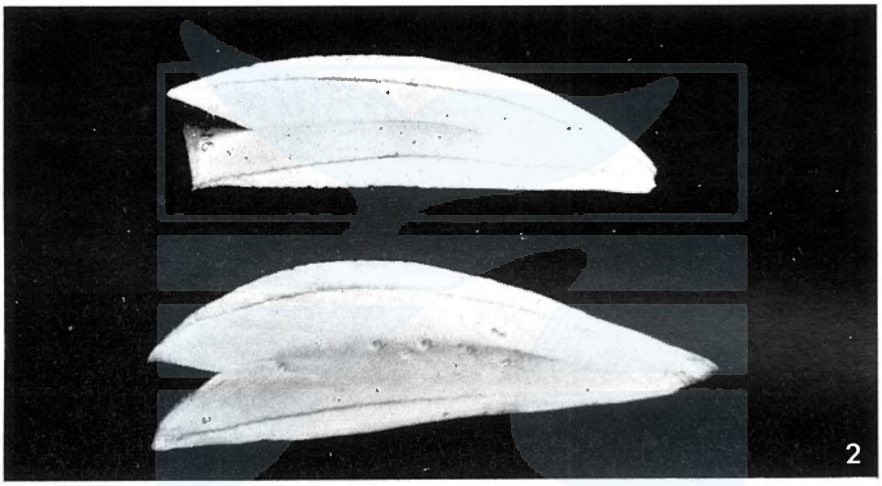

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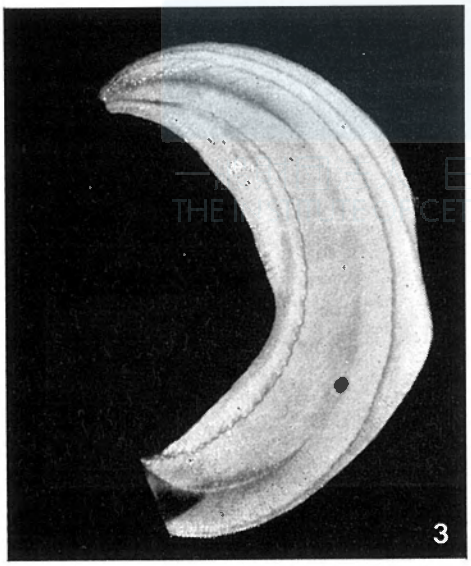

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4

AGE STUDIES OF FIN WHALE BASED ON EAR PLUG

MASAHARU NISHIWAKI, TADAYOSHI ICHIHARA
AND SEIJI (KIMURA) OSUMI

INTRODUCTION

An article examining ear plug as the determination of age of baleen whale, mainly concerning fin whale in the Antarctic, was given in the Scientific Reports of the Whales Research Institute No. 12. By that time, ear plugs had been already collected from the northern part of the North Pacific and reached to our Institute intact. The present paper examines ear plugs collected in the Antarctic season 1956–57, and in the northern Pacific season 1956 and 1957.

In preceding paper (Nishiwaki, 1957), the validity of ear plug as the age characteristic of the fin whale was explained in details. The present paper supplies the scanty data in preceding work, examining the laminations essential to the age determination except for baleen plate reading. Besides, it compares southern fin whales with northern fin whales, in their growths. It is considered in our studies that 2 laminations are deposited in one year in the ear plug.

As ear plugs were collected in large numbers as shown in the northern Pacific expedition of 1957, the study on age character may be extended to a clue to researches for whale stocks remaining undecided. However samples are supposed to have necessary but not yet sufficiant numbers for the latter study. When age compositions are considered as a clue to whale stocks, it is remarkable that the ear plug is worth analysing males and females together, but the hard effort and skillfulness are needed in the sampling of ear plug. On the other hand, even if the number of ovulations is related only to the age of female, it is easily counted through training after overies are picked up from the flensed whale. In the Japanese expeditions, the researches for ovaries have been carried out for most of whales killed, by inspectors and biologists on board the floating factory ships. In the present problem therefore the laminations of ear plug are considered chiefly against the numbers of total ovulations and interesting informations are obtained.

Acknowledgements are due to the Japanese government whaling inspectors and the staff of whaling companies who cooperated in the collection of ear plugs. We are also indebted to Mr. K. Nasu of our Institute for his helpful work on board.

MATERIAL AND METHOD

The numbers of ear plugs used in the present work were 288, 149 and 403 for the Antarctic expedition season 1956–57, the northern Pacific expeditions of 1956 and 1957 respectively, as shown in the appendixes.

In the northern Pacific expedition of 1956, the sampling of ear plugs was not carried out mainly for male but for female fin whales to compare the number of laminations with that of total ovulations. In the nothern Pacific expedition of 1957, the sampling of ear plugs was carried out at random for male as well as for female fin whales, so the samples collected may represent the whale stock to a considerable degree. In the Antarctic expendition season 1956–57, ear plugs were collected at random in 5 Japanese fleets but their numbers were not enough to represent the whale stock.

The ear plugs were preserved in 10% formalin solution soon after collections. Cutting down the convex side of ear plug with knife, we smoothed its surface to nearly longitudinal axis with iron rasp, since then we smoothed further its surface with rough and fine whetstones to read apparently the laminations. Then, the number of laminations of core was counted by authors alternately, by their naked eyes and with magnifying glasses or dissecting-microscopes.

COLOUR OF CORE

According to Symons (1956), the colour of ear plug varies from a dull ochre to black and this observation coincides with us. During our counting of laminations, we found the core of ear plug of the younger whale are easily discriminated from that of the older whale through its colour. In the younger stage of whale, especially from the birth to the sexual maturity, the colour of core is whitish yellow and the structure of core is fragile and coarse. When the whale becomes older, the colour of core changes from a dull ochre to blackish brown and the structure of core changes more hardly and densely. Each lamination before the sexual maturity is remarkably thick for male as well as for female fin whales. In this regard three samples of females are shown in Fig. 1.

VARIATION OF CORE LENGTH

It was already shown in the preceding paper (Nishiwaki, 1957) that the wide individual variations were found in the increases of thickness of laminations in the core of ear plugs. We now measure the lengths of cores on the samples caught in the northern Pacific in 1956 to confirm the above fact and compare with the samples from the Antarctic.

In order to explain the difference of length between the left and right core, five samples are shown in Table 1.

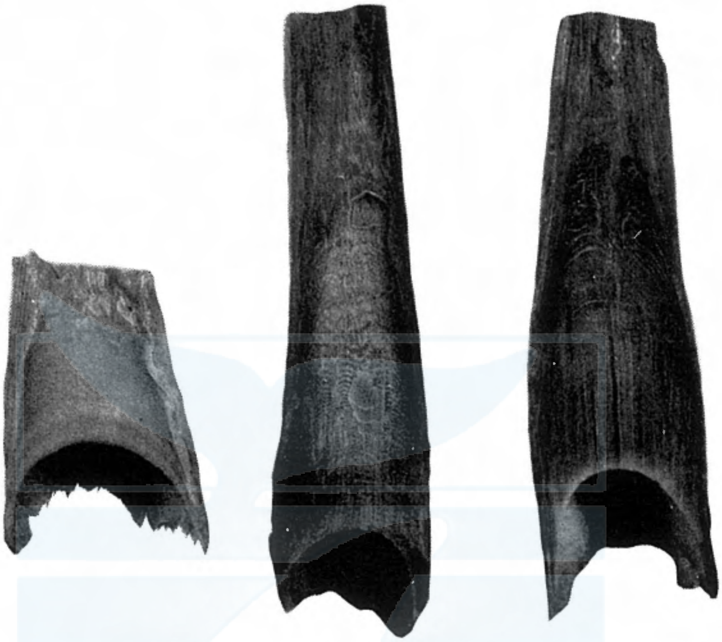

Fig. 1. Bisected specimens of ear plugs from fin whales. (×2/3)
Left specimen: from the Antarctic, sexually immature female, body length 58 feet, 7 laminations.
Middle specimen: from the Antarctic, sexually mature female, body length 70 feet, 36 laminations.
Right specimen: from the northern Pacific, sexually mature female, body length 64 feet, 100 laminations.

TABLE 1. THE DIFFERENCE OF THE CORE LENGTH AND THE NUMBER OF LAMINATIONS BETWEEN THE LEFT AND RIGHT EAR PLUG OF THE SAME FIN WHALE. THE SPECIMENS ARE CAUGHT IN THE NORTHERN PACIFIC IN 1956.

		Left core		Right core	
Body length in feet	Sex	Length in mm	No. of laminations	Length in mm	No. of laminations
56	Female	19	6	16	6
58	Female	27	9	26	9
63	Female	48	14	48	15
64	Female	67	100	51	100

The length between the two cores of an individaul differs to some extent but the lamination is the same in numbers. A little difference may depend upon the cutting technique of the core. The difference of 16 mm. shown in a female of 64 feet in length in Table 1 may come from the growing process of each ear plug. In Fig. 2, the lengths of cores of individuals are plotted against the number of laminations.

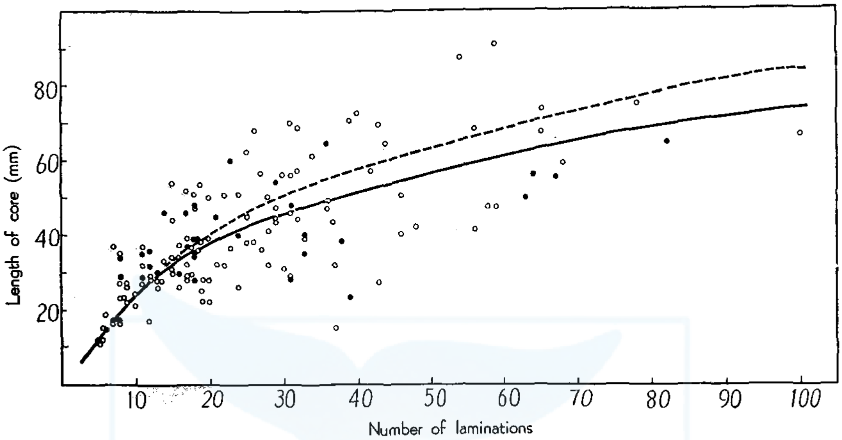

Fig. 2. Variation of core length in different ear plug of the fin whales caught in 1956 in the Northen Pacific.
Sold line: Northern Pacific. Broken line: Antarctic (Nishiwaki 1957).
Open circles: Females. Solid circles: Males.

There are also wide individual variations in the ear plugs of fin whales in the northern Pacific. It may be concluded that the length of core is useless for an age character of the fin whale. There is seen no variation of core length between males and females in Fig. 2. This fact supports that the sex of whale can not be discriminated with the morphological character of the ear plug. Moreover, the mean length of core of fin whale seems to be shorter in the northern Pacific than in the Antarctic; the core lengths of older whales are shorter in the former than in the latter by about 10 mm. This finding maybe depends upon the difference of skull width between two whale populations.

LAMINATION AND WEIGHT OF TESTIS

In Fig. 3, the weight of testis is plotted against number of laminations, indicating the heavier one of two testes. As shown in this figure, the weights of testis scatter wider in the older whales. In the northern Pacific, as all testes of whales killed were weighed, numbers of samples are much in the figure more than those in the Antarctic. In the Antarctic expeditions, the testes were not weighed usually, if they seem to be sexually mature from their volumes. Therefore, though actual numbers of ear plugs in the Antarctic are fairly much as shown in the appendix, all of them are not used for the present purpose and testes of rather younger individuals are plotted in Fig. 3.

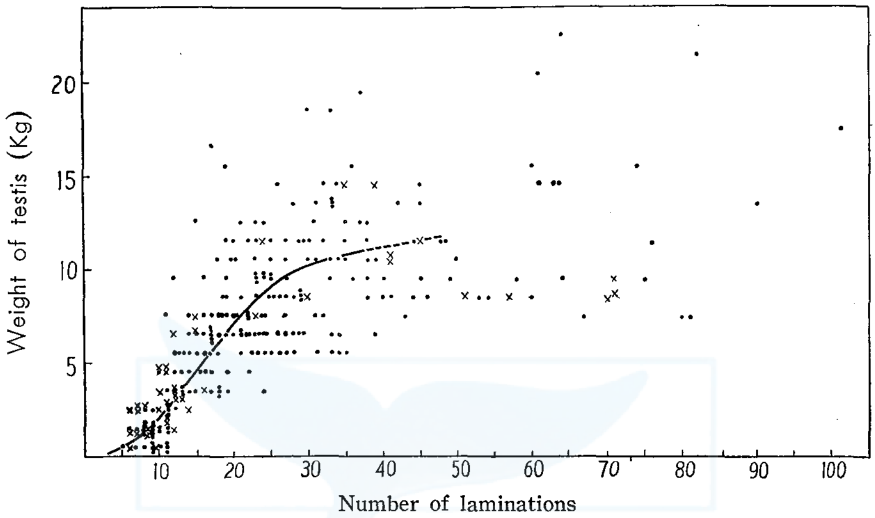

Fig. 3. Growth curve of weight of testis based on the number of laminations. The heavier testis in each individual is used as the symbol of the weight of the testis. black circle: Northern Pacific fin whales cross: Antarctic fin whales

With regard to the growth of testis, the difference between the southern and the northern fin whale is negligible and so the average growth is presumed in a curve as given in Fig. 3. The weight of 5.0 kg. in the sum of both testes has been used for the determination of mature male whale until now but recent histological studies testify this weight is rather heavier. For the present purpose, the male fin whale is considered to mature over 2.5 kg. in the weight of heavier testis. According to the growth curve, the weight of 2.5 kg. in the testis corresponds to the lamination of 11, that is, in the southern and northern hemispheres, male fin whales mature at the breeding season following 5 years after birth. It is interesting that the same fact is obtained for female fin whales. In the appendix, male fin whales, whose ear plugs have been collected, are divided into two groups; one group includes sexually immature whales and the other group involves sexually mature whales.

LAMINATION AND TOTAL OVULATIONS

For the present purpose, number of samples are 128, 108 and 201 in the Antarctic season 1956–57, in the northern Pacific seasons 1956 and 1957 respectively. In the northern Pacific, as the ear plugs in 1956 were collected with some schemes the frequency distribution of laminations for the saxually immature whale does not resemble that in 1957. However, the laminations of immature whales killed ranges similarly in both years; 11 from 5 laminations in 1956 and 12 from 6 laminations in 1957, that is, the ages of immature whales killed cover 6 from 2.5 years after birth. As tabulated in the appendix, it seems that some female whales mature early at 4.5 years and all females mature by 6 years after birth. When all samples of mature females are considered, an average number of laminations at the sexual maturity is about 11

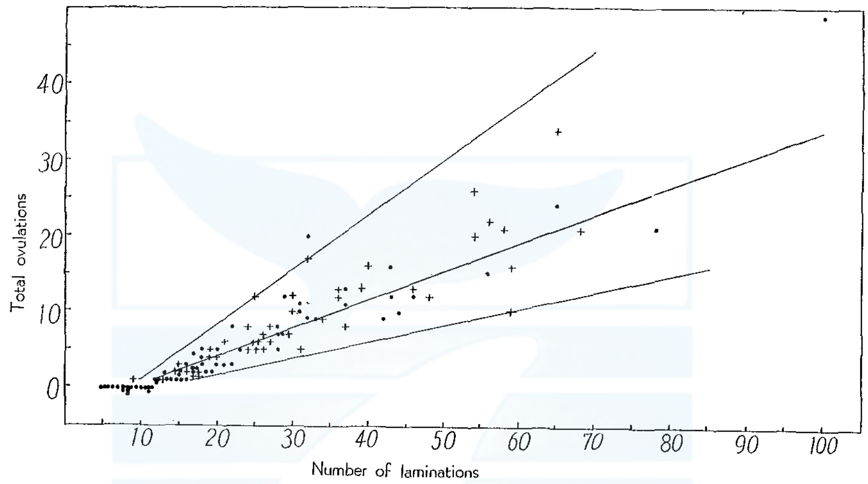

Fig. 4. Relation between the number of laminations and the total ovulations for the northern Pacific fin whale in 1956. cross: Pregnant.

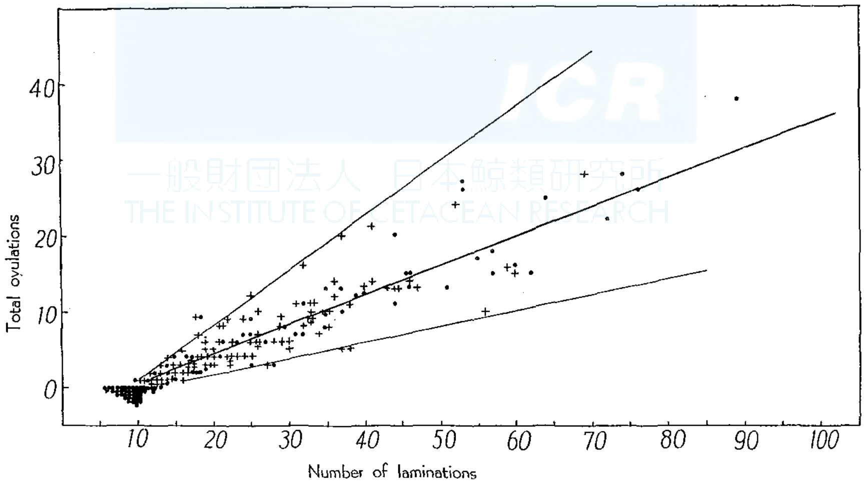

Fig. 5. Relation between the number of laminations and the total ovulations for the northern Pacific fin whale in 1957. cross: Pregnant.

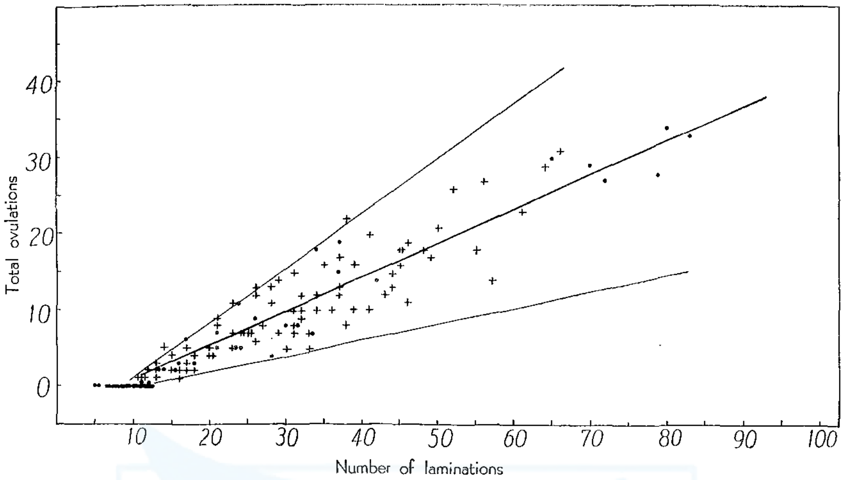

Fig. 6. Relations between the number of laminations and the total ovulations for the Antarctic fin whale in 1956～57. cross: Pregnant.

showing about 5.5 years after birth and this finding is shown in Figs. 4, 5 and 6.

From Figs. 4, 5 and 6 valuable suggestions are obtained on the relation between age of whales and number of ovulations. After the sexual maturity, individuals repeat ovulations, pregnancies and lactations in their breeding cycles but each ovulation does not always bring forth pregnancy. When ages increase more and more, total ovulations of individuals scatter in numbers wider and wider. In Fig. 3 of the previous paper (Nishiwaki, 1957), the variations of number of ovulations were in the same range both for younger and for older whales. This is a wrong assumption coming from scanty data and this must be rectified in the present paper. The differences between pregnant whale and resting whale are negligible in the range of such dispersion. For the present purpose, females maturing at the same age will be divided into two groups. Granted that one group has frequently pregnant chances following ovulations and the other has not frequently pregnant chances following ovulations, number of ovulations are more in the former group than in the latter group with increasing of ages.

It is assumable that there is a linear relation between number of laminations and number of ovulations. Using the samples in the northern Pacific season 1957 an equation is given by drawing a line among the upper dots as shown in Fig. 5. It is

$$Y=0.70X-5.67$$

Where Y is the number of ovulations and X is the number of laminations. In the same manner, a lower linear equation is

$$Y=0.21X-2.30$$

These both linear equations are applied to the samples in the northern Pacific season 1956 and in the Antarctic season 1956–57 being shown in Figs. 4 and 6. This important fact includes that, in the southern and northern hemispheres, the female fin whale matures at the same ages after birth and it accumulates about the same number of corpora lutea in its ovaries during a breeding season.

In the female fin whale, the numbers of ovulations and laminations are supposed to indicate its age, even if these show relative and absolute ages. Generally speaking, the frequency distributions of female whales based on the numbers of ovulations and laminations after the sexual maturity are expressed as exponential types in the catch of the Japanese expeditions. In such case, a regression line presumed to obtain the average number of ovulations for a year is not always effective. However, for the present purpose, the regression line of total ovulations to total laminations is given for each season, although our samples are small in numbers of the high age groups.

These linear equations are as follows.

Northern Pacific season 1956: $Y=0.42X-4.10$
Northern Pacific season 1957: $Y=0.38X-2.84$
Antarctic season 1956–57: $Y=0.45X-3.48$

Those lines are drawn in Figs. 4, 5 and 6. From these results, the average number of ovulations for a year ranges between 0.8 and 0.9, varing a little in each season. From a recovered female fin whale bearing a mark for 6 years, Mackintosh (1942) estimated the rate of accumulation of corpora lutea could not be much more than about one a year (or two every two years), although one could not draw any final conclusions from the particulars of a single whale. Peters (1939) estimated also that in the fin whale there was an average of 1.8 ovulations in two years. Our study is compatible with these estimations. The whale marking has been conducted every year since 1949 in the North Pacific by the Japanese whaling boats. However no biological information available for the number of accumulation of corpora lutea has been given from the fin whale recaptured until now. The variation among three seasons may depend upon the sampling errors as well as the localities of whales. As shown in the fact that the average number of ovulations for a year is in rather smaller figures in the northern Pacific than in the Antarctic, pregnancies following ovulations may appear more frequently in the former than in the latter, chiefly because the stock of whale is smaller in the former than in the latter.

From the upper line above mentioned, the number of ovulations for a year is obtained as about 1.4, corresponding to Laws' estimation in his provisional report (1956). Judged from this assumption, when the oestrus cycle without fertilization is repeated, ovulation of 2.8 and over occurs sometimes for a breeding season which is supposed to be 2 years for the fin whale. On the other hand, from the lower line, the number of ovulation for a year is given as about 0.4. When each ovulation always bring forth pregnancy, the fin whale sometimes ovulates in the ratio of 0.8 for a breeding season. This assumption supports that a breeding season for fin whale generally covers 2 years but it sometimes covers 3 from 2 years.

LAMINATION AND BODY LENGTH

In previous papers (Purves, 1955; Laws & Purves, 1956; Nishiwaki, 1957), the growth curve of fin whales based on the number of laminations is not enough, owing to the scanty samples.

Figs. 7 and 8 show the relation between the number of laminations and the body length for the southern and norther fin whales with our data. Since the young whales below 4 laminations are not caught, the earlier part of growth curve is not completed. But the body length at the birth is about 21 feet for fin whales, therefore the growth of early ages is presumed from these points of view. As shown in these figures, the individual variations of the body length are very large. For instance, the body lengths in the northern females at 30 laminations vary from 60 to 67 feet.

However it will be seen that the type of growth curves of the southern and northern fin whales are very similar each other. At the earlier age, males and females grow similarly and their growth rates are very large. From about 5 to 11 laminations the female grows more rapidly than the male. The body lengths at sexual maturity are as follows.

	Male	Female
Northern fin whale	58 feet	61 feet
Southern fin whale	63 ,,	67 ,,

The age at the maximum lengths is estimated to correspond about 40–45 laminations, according to these figures. That is to say, if the 2 laminations are deposited in one year, the age will be about 20-23 years at the maximum length. The number of ovulations at the physical maturity is about 15 for the fin whale. According to our studies on the fin whale there is the ovulation of 0.8–0.9 for a year and the age at sexual maturity is 5.5 years after birth. Then the age at physical maturity

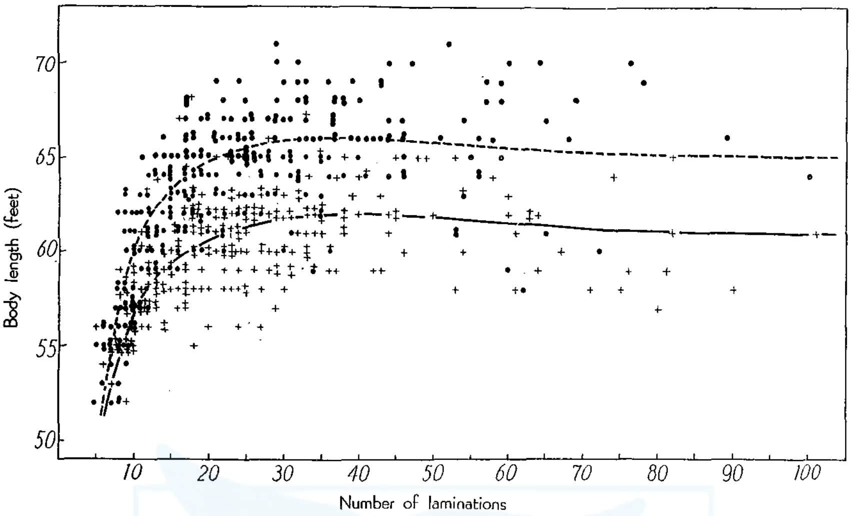

Fig. 7. Relation between body length and number of laminations for the northern Pacific fin whale. Black circle: Female, cross: Male.

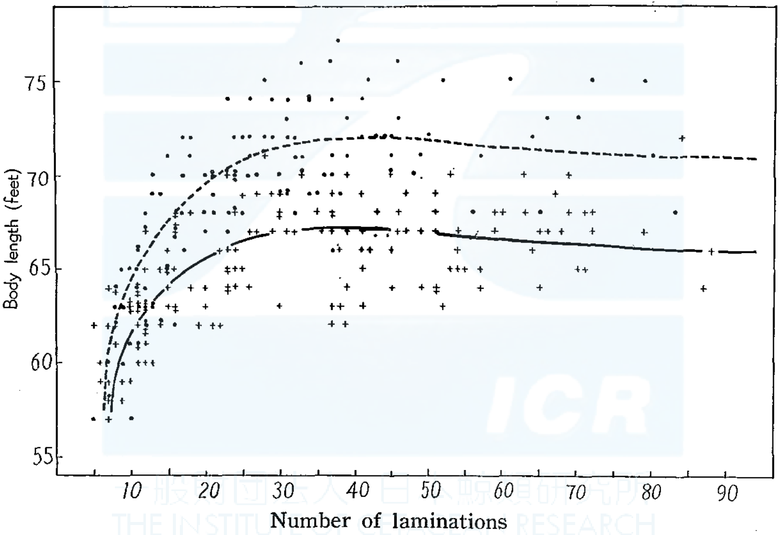

Fig. 8. Relation between body length and number of laminations for the Antarctic fin whale. Marks are the same as figure 8.

is between 21 and 24 years after birth. Therefore, the age at the maximum length is the same age at the physical maturity. The lengths at this age are as follows.

	Male	Femle
Northern fin whale	62 feet	66 feet
Southern fin whale	67 ,,	72 ,,

After the attainment of physical maturity, the body lengths seem to shrink in both sexes. This shrinking tendencies are shown in Figs. 7 and 8.

SUMMARY

1. With regard to the fin whales of the same ages, the length of core is generally shorter in the northern Pacific than in the Antarctic. Since the core length has wide individual variations, the measuring of them is not effective method for determining of age.
2. The growth of testis based on the number of laminations does not differ between fin whale in the Antarctic and that in the northern Pacific. In the female fin whale, the number of ovulations distributes with the same range against the number of laminations both in the Antarctic and in the northern Pacific.
3. In the Antarctic the body lengths at sexual maturity are 63 and 67 feet, and besides the body lengths at physical maturity are 67 and 72 feet, in males and females respectively. In the northern Pacific the body lengths at sexual maturity are 58 and 61 feet, and the body lengths at physical maturity are 62 and 66 feet, in males and females respectively.
4. Male and female fin whales mature at about 11 laminations. Judged from the relation between the number of laminations and the number of ovulations, female fin whales ovulate in the average between 1.5 and 2.0 per one breeding season. However, it is supposed that there is slight difference between the Antarctic and the northern Pacific fin whales. In the present work the Antarctic fin whale ovulates in 1.8, whereas, the northern Pacific fin whale ovulate 1.6 per one breeding season in average.

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APPENDIX. DISTRIBUTION OF THE NUMBER OF LAMINATIONS IN THE EAR PLUG OF FIN WHALES.

I. NORTHERN PACIFIC FIN WHALES (1956)

Number of lamination	Females					Total	Males		Total
	Immature	Ovulating	Pregnant	Lactating	Resting		*Immature	Mature	
5	2					2	1		1
6	2					2	1		1
7	1					1	2		2
8	5					5	3		3
9	2		1			3			
10	2					2			
11	3					3	1	1	2
12					3	3	1	1	2
13			1		2	3		1	1
14					1	1		1	1
15			2		4	6			
16			1	1	1	3		1	1
17			3	1	3	7		2	2
18				1	2	3		6	6
19			2		2	4			
20			1		2	3		1	1
21			1		1	2		1	1
22					2	2			
23					1	1		2	2
24			2			2		1	1
25			4			4			
26			2			2			
27			2			2			
28					3	3			
29			1		2	3		1	1
30			2			2			
31			1		2	4×		2	2
32			1		2	3			
33					1	1		2	2
34			1			1			
36			2			2		1	1
37			1	1	1	3		1	1
38								1	1
39			1			1		1	1
40			1			1			
42					1	1			
43					2	2			
44					1	1			
46			1		1	2			
48			1			1			
54			2			2			
56			1		1	2			
58			1			1			
59			2			2			
63								1	1
64								1	1
65			1		1	2			
67								1	1
68			1			1			
78					1	1			
82								1	1
100				1		1			
Total	17		43	5	43	109×	9	31	40
							Grand Total		149

* Whose heavier testes are under 2.5 kg.

× The mark includes a whale whose ovaries are not observed

II. NORTHERN PACIFIC FIN WHALES (1957)

Number of lamination	Females					Total	Males		Total
	Immature	Ovulating	Pregnant	Lactating	Resting		*Immature	Mature	
6	3					3			
7	5					5			
8	7					7	2	1d)	3
9	10					10	10		10
10	11	1	1			14×	3	1	4
11	3		1		1	5	3	3	7×
12	3		3		3	9	1	4	5
13		1	5①a)	①a)		7		5	5
14		①b)	3	①b)	2	6		5	5
15			5		1	6		4	6×
16			3			3		5	5
17			6		3	9		8	8
18			4		3	7		3	4×
19			5		1	6		9	9
20			3			3		5	5
21			3		2	5		4	4
22			6			7×		7	7
23			3		1	5×		9	9
24			3		1	5×		8	8
25			3		3	6		7	7
26			5			5		4	4
27			1	1		2		7	7
28			1		1	2		4	4
29			3	1	1	5		6	6
30			2			2		3	3
31			1		1	2		3	3
32			2		2	4		3	3
33			6			6		6	6
34			1			1		4	4
35			3	1	2	6		4	4
36			2			2		1	1
37			2		2	4		1	1
38			3			4×		5	5
39					1	1			
40			1		1	2		2	2
41			2			2		1	1
42								1	1
43			1			1		1	2×
44			2		2	4		2	2
45								3	3
46			1		3	4		1	1
47			1			1			
48								2	2
49								1	1
50								1	1
51					1	1			
52			1			1			
53					2	2		2	2
54								1	2×
55				1		1			
56			1			1			
57					2	2			
58								1	1
59			1			1			
60			1		1	2		2	2
61								2	2
62					1	1			
63								1	1

Number of lamination	Females					Total	Males		Total
	Immature	Ovulating	Pregnant	Lactating	Resting		*Immature	Mature	
64		1				1		1	1
69			1			1			
71								1	1
72					1	1			
74		①c)		①c)		1		1	1
75								1	1
76				1		1		1	1
80								1	1
81								1	1
89					1	1			
80								1	1
101								1	1
Total	42	5	103	8	46	206 ×	19	172	197 ×
							Grand Total		403

* Whose heavier testes are under 2.5 kg.
a) The pregnant and lactating whales
b, c) The ovulating and lactating whales
d) Its testes are 2.6 kg. and 2.0 kg.
× Marks includes whales whose ovaries and testes are not observed

III. ANTARCTIC FIN WHALES (1956-57)

Number of lamination	Females					Total	Males		Total
	Immature	Ovulating	Pregnant	Lactating	Resting		*Immature	Mature	
5	2					2	1		1
6							3		3
7	2					2	5		5
8	3					3	4		4
9	3					3	2		2
10	2				1	3	1	3	4
11	4		3			7	2	6	8
12	4	1	1		1	7	2	5	7
13			3		1	4	1	1	2
14			1		1	2		3	3
15			2		1	3		4	4
16			2		1	3		8	8
17		1	3			4			
18			2		1	3		2	2
19								2	2
20			3			3		3	3
21			2		2	4		2	2
22								2	2
23			3		1	4		7	7
24			2		3	5		3	3
25			2			2		2	2
26			3		1	4		3	3
27			1			1		2	2
28			2		1	3		1	1
29			2			2		2	2
30		1	1			2		4	4
31			4		1	5		1	1
32			3			3		1	1
33		1	2			3		2	2

Number of lamination	Females					Total	Males		Total
	Immature	Ovulating	Pregnant	Lactating	Resting		*Immature	Mature	
34			2		1	3			
35			1			1		1	1
36			1			1		1	1
37			3		2	5		6	6
38			2			2		3	3
39			2			2		3	3
41			2			2		5	5
42					1	1		1	1
43			1			1		1	1
44			2			2			
45			3			3		3	3
46			2			2		3	3
47								2	2
48			1			1			
49			1			1		2	2
50			1			1			
51								6	6
52			1			1		1	1
53								2	2
54								3	3
55			1			1		1	1
56			1			1			
57			1			1		2	2
59								3	3
60								1	1
61			1			1			
63								2	2
64			1			1		1	1
65					1	1		2	2
66			1			1		1	1
67								2	2
68								1	1
69								2	2
70				1		1		1	1
71								2	2
72					1	1		2	2
79					1	1		1	1
80		1				1			
83					1	1			
84								1	1
87								1	1
88								1	1
Total	20	5	78	1	24	128	21	139	160
							Grand Total		288

* Whose heavier testes are under 2.5 kg.

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ON THE SEROLOGICAL CONSTITUTION OF FIN WHALE

III. HUMAN B BLOOD GROUP SUBSTANCES IN ERYTHROCYTES AND SOME NOTES ON ANTI-FIN Ju SPECIFIC ANTIBODIES

KAZUO FUJINO

Many comparative studies have been undertaken on cell-antigens common to human and various kinds of animals. Especially, reports on distribution of the human A, B, O blood group substances and Forssman's antigen in animal kingdom, seem to be important and interesting from the standpoint of systematic serology. Terashima (1942) reports that human A blood group substance can be analyzed immunochemically into four partial antigens, i. e., AI, AII, AIII and AIV, and shows that A type human cells possess all of these, A type dog cells AII AIII AIV, A type pig cells AIII AIV and sheep cells AIV respectively. Friedenreich and With (1933) states that human B blood group substance may be divided serologically into three components, i. e., B_1, B_2 and B_3 and then the erythrocytes of B type human, rabbit and guinea pig contain $B_1B_2B_3$, B_2B_3 and B_3 respectively. As regards O antigen system Inoue (1943) describes that the erythrocytes of O type human, rat and rabbit possess OIOIIOIII, OIIOIII and OIII of the components of O blood group substances respectively. Basing upon these results many analysis have been worked out on partial antigens being contained in erythrocytes, saliva and other secretions or organ tissues of animals.

Symbols of Friedenreich and With have been used by some workers ever since. But in the present paper, to avoiding the confusion with those of B_1 and B_2 of human blood B subgroups, abovestated three groups are replaced with the symbols of BI, BII and BIII respectively in accordance with the proposal of Furuhata (1957). Summarizing the reports on B partial antigens in animal erythrocytes it is known that BIBIIBIII exist in the cells of human (Friedenreich and With, 1933), orang-utan (Dahr, 1937), monkey and ape (Noda, 1949) (Ishii et al, 1954), tortoise and frog (Sakuma, 1942), BIIBIII in the cells of rabbit (Friedenreich and With, 1933), Kangaroo, tapir, weasel, cat (Dahr, 1937) (Ogura, 1953a) and giraffe (Nakano, 1949) (Furuhata, Mori and Ro, 1949), BIII in the cells of guinea pig (Friedenreich and With, 1933), capuchin monkey, elephant, dog, badger, bison (Dahr, 1937), Japanese racoon-dog (Furuhata and Ro, 1948), camel and whales (AZAMI, 1949). Furthermore, Ogura (1953b) reports that the B substance in the horse and sheep erythrocytes has a simpler structure than BIII of guinea pig cells. Accordingly to the classification of

Friendenreich and With (1933) the author detects the B substances in the erythrocytes of whales, and confirmed the existence of some components of B antigen by adsorbing and immunizing experiments. The author reports here on a new B partial antigen in fin whale cells which has simpler structure than the already-known BIII in guinea pig cells, and simultaneously notes some observations on the anti-fin Ju normal antibodies in the sera of immune animals and the appearance of immune antibody into egg-white of a fowl.

HUMAN B BLOOD GROUP SUBSTANCES IN FIN WHALE ERYTHROCYTES

MATERIALS AND METHODS

Anti-BI, anti-BII and anti-BIII sera were prepared by the method of Yamaguchi (1943). Details of those and other items on materials and methods are as follows.

Anti-B_{I} agglutinin. When a rabbit is immunized with human B (BIBIIBIII) blood group erythrocytes, anti-BI antibody is produced alone in relation to B antigen, because the cells of rabbit possess BII and BIII components. This phenomenon is termed as the intravital filtration (Furuhata, 1957, p. 156). Then species-specific and anti-C agglutinins which are produced simultaneously should be adsorbed away from this serum by the A type human erythrocytes. These A type cells are taken from five or more individuals and are mixed together for use of adsorption. After these procedures may be obtained the anti-BI agglutinin available for the experiments.

Anti-B_{II} agglutinin. Being adsorbed the anti-C and the anti-O (Eisler's or Kagaya's anti-human cell heterogeneous antibody, (Eisler, 1930; Kagaya, 1940) agglutinins with A and O types human cells and anti-BIII agglutinin with guinea pig cells from the serum of fowl immunized with rabbit erythrocytes (BIIBIII), available anti-BII agglutinin can be obtained alone. A type cells which are used for adsorption are taken from several individuals similary to the previous case.

Anti-B_{III} agglutinin. If the anti-C and the anti-O agglutinins are adsorbed away from serum of a fowl immunized with the erythrocytes of guinea pig (BIII), the anti-BIII agglutinin will be taken out alone.

Erythrocytes of human and fin whales. Collecting, preserving and other treatments of these erythrocytes are just the same as those in previous report (Fujino, 1953).

Erythrocytes of rabbits and guinea pigs. Bloods were taken from ear vein in rabbit and from heart with syringe in guinea pig. After separation and washing with salt solution, these erythrocytes were used to various experiments.

Immune animal. Mature rabbits and fowls, weighing more than 2.0 kg in the former and 1.5 kg in the latter, were used as immune animal. Prior to immunization, anti-human A and anti-human B normal antibodies, that is the "Serum type", were detected on the sera of these animals.

Immune sera. Each immune animal was given intravenously on alternate days a series of (seven times') injections of 10% erythrocytes suspensions. A dose of injection of these immune antigens is 5 ml. in a rabbit and 3 ml. in a fowl. Seven days after last injection, animals were sacrificed for bleeding by puncture of cervical artery. After separation and inactivation these immune sera (1) were added with 1/10 volume of 5% carbolic acid and preserved in refrigerator at the temperature of 0° to 5°C, or (2) were kept in freezer at the temperature of −5° to −10°C after mixing with 1/10 volume of 1% sodium azide (NaN_3).

Adsorption tests and immunizing experiments. For the purpose of detection of B antigen in the fin whale erythrocytes, adsorption tests and immunizing experiments must be made on their cells. Firstly the stated three partial antibodies were used in such adsorption tests. After thorough adsorption with fin whale cells, descendings of their titers against human B cells were examined. If the descent occurs, it is assumed that the fin whale cells used for adsorption possess the corresponding or simpler B antigen. When no descent occurs, existence of corresponding B antigen will be denied. Secondarily the existence of B antigen should be confirmed with immunizing experiments. Prior to immunization normal anti-human B antibody of immune animal (fowl) was examined. If acendings of titers of anti-human B agglutinins take place after immunization with fin cells, B antigen exists in their cells. In this case immunizing and post-immunizing procedures are just the same as those in preparation of anti-BIII agglutinin.

In case of fowls' immune sera, the cells of antigen show a tendency to cling on bottom wall of hole-glass before formation of agglutinating lumps, and therefore the more frequent shaking or mixing seem to be necessary during reacting period than in the case of rabbit sera.

EXPERIMENTS AND RESULTS

Preparation of anti-B_I, anti-B_{II} and anti-B_{III} sera. These partial antibodies were prepared with the method used by Yamaguchi (1943). Their titers did not generally reach up to so high, and are showed in table 1, i. e., 1 : 256 in anti-BI, 1 : 16 in anti-BII, and 1 : 256, 1 : 64 and 1 : 32 in anti-BIII agglutinins respectively. But these sera were useful enough to analysis of partial antigens.

TABLE 1. AGGLUTININ TITERS OF IMMUNE ANTI-BI, ANTI-BII AND ANTI-BIII SERA PREPARED FOR ADSORPTION TESTS

Name of serum	Immune animal	Normal sera of imm. animal										Immune antigen	Immune sera											
		Treatment	Human cell	Dilution									Treatment	Human cell	Dilution									
				1	2	4	8	16	32	64	128				1	2	4	8	16	32	64	128	256	512
Anti-BI no. 13 serum	No. 10 rabbit male (o')4)	No ads.	A	—	—	—	—	—	—	—	—	Human B type cells	No1) ads.	A	⧻	⧻	⧻	⧻	⧻	⧻	╫	╫	+	—
			B	—	—	—	—	—	—	—	—			B	⧻	⧻	⧻	⧻	⧻	⧻	╫	╫	+	—
			O	—	—	—	—	—	—	—	—			O	⧻	⧻	⧻	⧻	⧻	╫	╫	+	—	—
													Ads.3) by human A cells.	A	—	—	—	—	—	—	—	—	—	—
														B	⧻	⧻	⧻	⧻	⧻	⧻	╫	+	+	—
														O	—	—	—	—	—	—	—	—	—	—
Anti-BII no. 45 serum	No. 18 fowl female (α'β')	No ads.	A	⧻	╫	╫	+	—	—	—	—	Rabbit cells	No 2) ads.	A	╫	╫	+	—	—	—	—			
			B	╫	+	—	—	—	—	—	—			B	+	+	⧻	⧻	╫	+	—			
			O	—	—	—	—	—	—	—	—			O	⧻	⧻	╫	+	—	—	—			
		Ads. by human A cells	A	—	—	—	—	—	—	—	—		Ads. by human A cells	A	—	—	—	—	—	—	—			
			B	+	±	—	—	—	—	—	—			B	+	⧻	⧻	╫	+	—	—			
			O	—	—	—	—	—	—	—	—			O	—	—	—	—	—	—	—			
		Ads. by human B cells	A	⧻	╫	+	—	—	—	—	—		Further3) ads. by guinea pig cells	A	—	—	—	—	—	—	—			
			B	—	—	—	—	—	—	—	—			B	╫	⧻	╫	+	+	—	—			
			O	—	—	—	—	—	—	—	—			O	—	—	—	—	—	—	—			

TABLE 1. AGGLUTININ TITERS OF IMMUNE ANTI-BI, ANTI-BII AND ANTI-BIII SERA PREPARED FOR ADSORPTION TESTS (cont.)

Name of serum	Immune animal	Normal sera of imm. animal										Immune antigen	Immune sera											
		Treatment	Human cell	Dilution									Treatment	Human cell	Dilution									
				1	2	4	8	16	32	64	128				1	2	4	8	16	32	64	128	256	512
Anti-BIII no. 17 serum	No. 4 fowl male (o')	No ads.	A	—	—	—	—	—	—	—	—	Guinea pig cell	No ads.	A	+++	+++	+++	+++	++	++	+	—	—	—
			B	—	—	—	—	—	—	—	—			B	+++	+++	+++	+++	+++	+++	+++	++	+	—
			O	—	—	—	—	—	—	—	—			O	+++	+++	+++	++	++	+	—	—	—	—
													Ads. by[3] human A cells	A	—	—	—	—	—	—	—	—	—	—
														B	+++	+++	+++	+++	+++	+++	++	++	+	—
														O	—	—	—	—	—	—	—	—	—	—
〃 〃 no. 20 serum	No. 8 fowl male (o')	No ads.	A	—	—	—	—	—	—	—	—	〃	No ads.	A	+++	+++	+++	+++	++++	++	+	—	—	—
			B	—	—	—	—	—	—	—	—			B	++	++	+++	+++	+++	++	++	+	—	—
			O	—	—	—	—	—	—	—	—			O	+++	+++	+++	+++	++	+	—	—	—	—
													Ads. by[3] human A cells	A	—	—	—	—	—	—	—	—	—	—
														B	++	++	+++	+++	++	+	+	—	—	—
														O	—	—	—	—	—	—	—	—	—	—
〃 〃 no. 44 serum	No. 17 fowl female (α')	No ads.	A	+++	++	—	—	—	—	—	—	〃	No ads.	A	+++	++	++	±	—	—	—	—		
			B	—	—	—	—	—	—	—	—			B	+	++	+++	+++	++	+	—	—		
			O	—	—	—	—	—	—	—	—			O	+	+	++	+	—	—	—	—		
		Ads. by human A cells	A	—	—	—	—	—	—	—	—		Ads. by[3] human A cells	A	—	—	—	—	—	—	—	—		
			B	—	—	—	—	—	—	—	—			B	+	++	+++	+++	++	+	—	—		
			O	—	—	—	—	—	—	—	—			O	—	—	—	—	—	—	—	—		

Remark: 1) Even before adsorption, no anti-B$_{11}$ or anti-B$_{111}$ antibody is not involved in this serum. (see Material 1))
2) This serum contains anti-B$_{111}$ antibody besides anti-B$_{11}$ one.
3) These sera are used for adsorption test with fin whale erythrocytes later on. 4) Serum type.

Adsorption tests of partial antibodies with fin whale erythrocytes. After purifying procedures each partial antibody was used for adsorption test with fin whale erythrocytes. Comparisons of their titers against human B cells between before and after adsorption are shown in table 2. Fin whale cells used for adsorption were examined previously on their blood groups (Ju-system only), but in cases of Nos. 17 and 20 sera these examinations were not made because of the lack of available reagent for blood grouping.

TABLE 2. ADSORPTION TESTS OF ANTI-BI, ANTI-BII AND ANTI-BIII AGGLUTININS WITH THE ERYTHROCYTES OF FIN WHALES

Name of serum	Treatment		Dilution of serum[3)]										Remark
			1	2	4	8	16	32	64	128	256	512	
Anti-BI no. 13 serum	Control		⧻	⧻	⧻	⧻	⧻	⧻	⧺	+	+	—	No descent of titer
	After ads. by	no. A29 Ju$_1$ cell	⧻	⧻	⧻	⧻	⧻	⧻	⧺	+	+	—	
		no. A31 Ju$_2$ 〃	⧻	⧻	⧻	⧻	⧻	⧻	⧺	+	+	—	
		no. A45 Ju$_1$ Ju$_2$ 〃	⧻	⧻	⧻	⧻	⧻	⧻	⧺	+	+	—	
Anti-BII no. 45 serum	Control		⧺	⧻	⧺	+	+	—	—	—	—	—	No descent of titer
	After ads. by	no. A29 Ju$_1$ cell	⧺	⧻	⧺	+	+	—	—	—	—	—	
		no. A31 Ju$_2$ 〃	⧺	⧻	⧺	+	+	—	—	—	—	—	
		no. A45 Ju$_1$ Ju$_2$ 〃	⧺	⧻	⧺	+	+	—	—	—	—	—	
Anti-BIII no. 17 serum	Control		⧻	⧻	⧻	⧻	⧻	⧻	⧺	⧺	+	—	Titer descend
	After ads. by[1)]	no. 285 cell	⧻	⧻	⧻	⧻	⧺	⧺	+	+	—	—	
		no. 286 〃	⧻	⧻	⧻	⧻	⧺	⧺	+	+	—	—	
		no. 287 〃	⧻	⧻	⧻	⧻	⧻	⧺	+	+	—	—	
		no. 288 〃	⧻	⧻	⧻	⧺	⧺	+	+	—	—	—	
		no. 289 〃	⧻	⧻	⧻	⧻	⧺	⧺	+	+	—	—	
		no. 293 〃	⧻	⧻	⧻	⧻	⧺	⧺	+	+	—	—	
〃 〃 no. 20 serum	Control		⧺	⧺	⧻	⧻	⧺	+	+	—	—	—	Titer descend
	After ads. by[2)]	no. 2 cell	⧺	⧺	+	+	—	—	—	—	—	—	
		no. 3 〃	⧺	⧺	+	+	—	—	—	—	—	—	
		no. 4 〃	⧻	⧺	+	+	—	—	—	—	—	—	
〃 〃 no. 44 serum	Control		+	⧺	⧻	⧻	⧺	+	—	—	—	—	Titer descend
	After ads. by	no. A29 Ju$_1$ cell	⧻	⧻	⧺	⧺	+	—	—	—	—	—	
		no. A31 Ju$_2$ 〃	⧻	⧻	⧺	⧺	+	—	—	—	—	—	
		no. A45 Ju$_1$ Ju$_2$ 〃	⧻	⧻	⧺	⧺	+	—	—	—	—	—	

Remark: 1) and 2), Blood types of fin whale cells were not examined in these case.
3) Agglutinin titers against human B type erythrocytes.

In this table agglutinin titers in the column of "control" show the pre-adsorbing titers against human B cells and the others show the the post-adsorbing those. As no descent of the titers is seen in the anti-BI and anti-BII sera, it may be assumed that the corresponding B antigens, i. e. BI and BII, are not contained in the fin whale cells. While in the case of anti-BIII agglutinin descents of titers can be seen independently to blood groups of adsorbing cells at the degrees of 1/2 to 1/4 in no. 17 serum, 1/8 in no. 20 serum and 1/2 in no. 4 serum respectively. However, the anti-BIII agglutinin is not adsorbed thoroughly away in any case. From these facts it can be thought that the fin whale cells possess a portion of BIII antigen independently to their blood types, at least to Ju system. To confirm the existence of B antigen which seems to have simpler structure than BIII was worked out the following immunizing experiment.

Immunization of fowl with fin whale cells. In this experiment, prior to immunization the serum type and its titers of fowl's serum was examined, and after immunization the ascent of titer against human B cells was examined. As shown in table 3, such ascent of this titer was recognized at the degrees from 0 up to 8 times in no. 38 serum, from 0 up to 16 times in no. 47 serum and from 2 up to 16 times in no. 46 serum respectively. According to these results the existence of B partial antigen was immunologically confirmed.

All these anti-B agglutinins produced by the immunization was able to be completely adsorbed with both guinea pig cells and any other fin whale cells than immune antigens belonging to Ju1 type (nos. 47 and 48), Ju2 type (no. 59) and Ju1Ju2 type (nos. 45 and 48).

According to the results of adsorbing and immunizing tests in previous items 2) and 3), it was established that the B antigen in fin whale cells had the simpler structure than BIII in guinea pig cells. Though the comparative survey between this antigen and BIV in sheep and horse cells which was described by Ogura (1953b) has not been worked out, the author should like to use "BIV′" provisionally as the symbols of this substance. By using of this symbols the erythrocytes of B type human, rabbit, guinea pig and fin whale are shown to have following antigenic structures in relation to B antigen system.

B type human : BI BII BIII BIV′
rabbit : BII BIII BIV′
guinea pig : BIII BIV′
fin whale : BIV′

DISCUSSION

As already stated BIV′ antigen is contained in fin whale (*Balaenoptera physalus*) cells independently to Ju blood group system. And so far as author's survey reaches it can be assumed that this BIV′ partial antigen

TABLE 3. ANTI-B AGGLUTININS PRODUCED BY FOWLS-IMMUNIZED WITH FIN WHALE ERYTHROCYTES

Serum No.	Fowl, immunized	Normal sera of fowl								Immune antigen	Immune sera															Remarks
		Treatment	Cells for agglutinogen	Dilution							Treatment	Cells for agglutinogen	Dilution													
				1	2	4	8	16	32				1	2	4	8	16	32	64	128	256	512	1024	2048	4096	
38	No. 16 male (α')[2]	No ads.	Human A	⧺	+	—	—	—	—	No. 144 Ju_1 type cells	No ads.	Human A	⧻	⧻	⧺	+	—	—	—	—	—	—	—	—	—	Titer ascend
			〃 B	—	—	—	—	—	—			〃 B	⧻	⧻	⧻	⧺	+	—	—	—	—	—	—	—	—	
			〃 O	—	—	—	—	—	—			〃 O	⧻	⧺	+	—	—	—	—	—	—	—	—	—	—	
			No. 144 fin Ju_1	—	—	—	—	—	—			No. 144 fin Ju_1	+	⧺	⧻	⧻	⧻	⧻	⧻	⧻	⧻	⧺	+	—	—	
											Ads. by human A cells	Human A	—	—	—	—	—									
												〃 B	⧻	⧻	⧺	+	—									
												〃 O	—	—	—	—	—									
47	No. 20 female (α')	No ads.	Human A	⧺	+	+	±	—	—	No. 40 Ju_1 type cells	No ads.	Human A	⧻	⧻	⧻	⧻	⧺	⧺	⧺	+	—	—	—	—	—	Titer ascend
			〃 B	+	—	—	—	—	—			〃 B	⧻	⧻	⧺	⧺	⧺	+	—	—	—	—	—	—	—	
			〃 O	+	—	—	—	—	—			〃 O	⧻	⧻	⧻	⧺	+	+	—	—	—	—	—	—	—	
			No. 40 fin Ju_1	—	—	—	—	—	—			No. 40 fin Ju_1	⧻	⧻	⧻	⧻	⧻	⧻	⧻	⧻	⧻	⧻	⧺	+	—	
		Ads. by human O cells	Human A	⧺	+	—	—	—	—		Ads by human A cells	Human A	—	—	—	—	—	—								
			〃 B	—	—	—	—	—	—			〃 B	⧻	⧻	⧺	⧺	+	—								
			〃 O	—	—	—	—	—	—			〃 O	—	—	—	—	—	—								
46	No. 19 male (α'β')	No ads.	Human A	⧻	⧻	⧺	+	±	—	No. 49 Ju_2 type cells	No. adsorp.	Human A	⧻	⧻	⧻	⧺	+	—	—	—	—	—	—	—		Titer ascend
			〃 B	⧻	⧺	+	—	—	—			〃 B	⧻	⧻	⧻	⧻	⧻	⧺	+	—	—	—	—	—		
			〃 O	+	±	—	—	—	—			〃 O	⧻	⧻	⧻	⧻	⧺	+	—	—	—	—	—	—		
			No. 49 fin Ju_2	—	—	—	—	—	—			No. 49 fin Ju_2	⧻	⧻	⧻	⧻	⧻	⧻	⧻	⧻	⧻	⧺	+	—		
		Ads. by human O cells	Human A	⧻	⧺	+	—	—	—		Ads. by human A cells	Human A	—	—	—	—	—	—								
			〃 B[1]	⧺	+	—	—	—	—			〃 B	⧻	⧻	⧻	⧺	+	—								
			〃 O	—	—	—	—	—	—			〃 O	—	—	—	—	—	—								

Remark: 1) This normal agglutinin was not adsorbed completely by human A type cells, but was adsorbed by guinea pig (B_{III}) cells. Therefore this agglutinin may be assumed to be one corresponding to B III or simpler structural B antigen than B III.

2) Serum type.

occurs in the cells of all fin whale individual independently to any other blood group systems of this species and constitutes a component of species-specific antigen of their erythrocytes. At present it has been immunochemically ascertained that the erythrocytes of sperm whale (*Physeter catodon*) and dolphin (*Prodelphinus caeruleoalbus*) possess some kind of more complicated structural B antigen than Biv′, likely to be Biii (Fujino, unpublished data). In past days such analysis on B substance in whale cells has been reported by Azami (1949) alone. After investigating on two whales, he recognized the existence of Biii, still the specification on these whale species was not noted. However, such structural differences of B substance by whale species seem to offer to the author a prospect of discussion upon the evolutional relationship among various whale species, particularly between whalebone and toothed-whales. But any discussions on such problem should be taken up after obtaining the comprehensive data on the distribution of A, B and O blood group substances among cetaceans.

As previously cited, Ogura (1953b) reports that the erythrocytes of sheep and horse have a simpler structural B substance than Biii, and are to be named as Biv. Comparative survey between Biv and Biv′ will be discussed in future issue.

NORMAL AGGLUTININ IN IMMUNE ANIMAL AND THEIR PRODUCING ABILITY OF IMMUNE AGGLUTININ

The author is working at immunogenetical researches on identification of breeding populations of whales in concerning to fishery problems (Fujino, 1956). To carrying out such extensive investigations it is very important to obtain immune antibodies, which have high specificities and high titers, for blood grouping.

After examining the normal agglutinins of animals specific to human A and B blood group antigens, Hibino (1935) introduces a term of " Serum type of animals ", and classifies the animal sera into four groups, i. e. $\alpha'\beta'$, α',β' and o', accordingly as the existence of anti-A or anti-B hetero-hemagglutinins. And then he illustrates that serum type of animal is a serological constitution, which is closely related to the producing ability of corresponding immune antibodies. While basing upon the quantity of human A-like substance in the saliva, Koshino (1938, 1939) divides rabbits serologically into two groups of secretor and nonsecretor, and confirmes that the nonsecretor is more excellent producer of anti-human A immune antibody than the secretor. Then he concludes that serum type and secretor-nonsecretor type of rabbit are important serological characters to be previously tested in case of preparation of immune anti-A antibody.

Same idea as abovestated points must be considered in preparation of the reagent for blood grouping on fin whales. The author notes here some data on the anti-Ju normal agglutinin in animal sera and the results of production of anti-Ju immune agglutinins by these animals. These data are not obtained under the intentional survey, but may serve to some extent for future work. As showing in table 4, the heterohemagglutinin specific to Ju1 antigen occurs in the normal serum of a fowl among three and the heterohemagglutinin specific to Ju2 antigen occurs in the normal sera of the three rabbits among five and a fowl among three. It can be seen from table 4 that the titers of anti-Ju2 immune agglutinins reach up to higher in rabbits (nos. 34, 35 and 36 sera) than in fowl (no. 46 serum), but in contrary to this tendency the titers of anti-Ju1 immune agglutinins reach up to higher in fowls (nos. 38 and 47 sera) than in rabbits (nos. 33 and 37 sera). In table 5 are shown some examples of agglutinin titers to explain the degree of specificity of these immune sera.

TABLE 4. AGGLUTININ TITERS OF NORMAL AND IMMUNE SERA PRODUCED BY RABBITS AND FOWLS IMMUNIZED WITH THE FIN WHALE ERYTHROCYTES

Immune animal				Normal agglutinin				After immuniz.		Immune[1)] antigen		Serum No.
Species	No.	Sex	Serum type & A^+ or A^-	anti-Ju_1		anti-Ju_2				No.	Blood group	
				Exist.	Titer	Exist.	Titer	Anti-Ju_1	Anti-Ju_2			
Rabbit	33	male	$o'-A^+$	–	....	+	1: 8	1: 160	1: 8	111	Ju_1	33
〃	37	〃	$\alpha'-A^+$	–	....	–	....	1: 40	....	155	〃	37
Fowl	16	〃	α'	–	....	–	....	$\underline{1:\ 800}$	....	144	〃	38
〃	20	female	α'	–	....	–	....	$\underline{1:\ 640}$	....	40	〃	47
Rabbit	35	male	$\alpha'-A^+$	–	....	–	....	1: 20	$\underline{1:\ 320}$	107	Ju_1Ju_2	35
〃	34	〃	$o'-A^+$	–	....	+	1: 64	....	$\underline{1:\ 12800}$	113	Ju_2	34
〃	36	〃	$o'-A^-$	–	....	+	1: 64	....	$\underline{1:\ 640}$	139	〃	36
Fowl	19	〃	$\alpha'\beta'$	+	1: 2	+	1: 4	1: 2	1: 160	49	〃	46

Remark: 1) Erythrocytes of fin whale.

According to this table it may be assumed that the degree of specificity of anti-Ju1 is rather low both in fowls and rabbits, and that the degree of anti-Ju2 specificity is low in fowl but rather high in rabbits, especially higher in those with normal anti-Ju2 agglitinin. After summarizing the abovestated points, followings seem to be concluded on preparation of anti-Ju1 and anti-Ju2 reagents.

1) To use rabbit that has corresponding normal agglutinin as the anti-Ju2 immune agglutinin producer.
2) To use fowl as the anti-Ju1 agglutinin producer.

By accomplishing the more extensive detection of normal anti-Ju1 agglutinin in fowl serum and of Ju blood group substances in various or-

TABLE 5. SOME EXAMPLES OF AGGLUTINATION REACTIONS OF ANTI-Ju1 AND ANTI-Ju2 IMMUNE (UNADSORBED) SERA AGAINST FIN WHALE ERYTHROCYTES

Serum no.	Cell antigen		Dilution of antiserum														Titers of blood group specific aggl.	Immune animal
	No.	Blood group	10	20	40	80	160	320	640	1280	2560	5120	10240	20480	40960	81920		
38	111	Ju_1	⧻	⧻	⧻	⧻	⧻	⧻	⧺	+	—	—	—	—	—	—	Anti-Ju_1=800	fowl
	139	Ju_2	⧻	⧻	⧻	⧻	⧻	⧻	⧺	+	—	—	—	—	—	—		
33	159	Ju_1	⧻	⧻	⧻	⧻	⧺	⧺	+	—	—	—	—	—	—	—	Anti-Ju_1=160	rabbit
	158	Ju_2	⧺	⧻	⧻	⧻	⧺	⧺	+	—	—	—	—	—	—	—		
34	165	Ju_1	⧻	⧺	⧺	+	—	—	—	—	—	—	—	—	—	—	Anti-Ju_2=12,800	〃
	139	Ju_2	⧻	⧻	⧻	⧻	⧻	⧻	⧻	⧻	⧻	⧺	⧺	+	+	—		
35	168	Ju_1	⧻	⧻	⧻	⧺	+	—	—	—	—	—	—	—	—	—	Anti-Ju_1= 20	〃
	139	Ju_2	⧻	⧻	⧻	⧻	⧻	⧻	⧻	⧻	⧺	+	—	—	—	—	Anti-Ju_2=320	
46	40	Ju_1	⧻	⧻	⧻	⧻	⧻	⧻	⧺	⧺	+	—	—	—	—	—	Anti-Ju_2=160	fowl
	49	Ju_2	⧻	⧻	⧻	⧻	⧻	⧻	⧺	⧺	+	—	—	—	—	—		

gans or glands of immune animals, however, more excellent reagents must be obtained.

APPEARANCE OF IMMUNE ANTIBODIES INTO EGG-WHITE OF A FOWL INJECTED WITH FIN WHALE ERYTHROCYTES

No. 20 female fowl in table 3 (producer of no. 47 serum) was in a state of egg laying during the period of immunizing experiment. So the author tried to trace the appearance of immune antibody into egg-white. In the following are reported some notes on such observation. As already stated the no. 20 female fowl was given intravenously on alternate days a series of (seven-times') injections of 10% suspension of Jul type fin whale erythrocytes, and sacrified for bleeding 7 days after last injection. During the period of experiment this fowl laid a egg respectively in each 4th, 7th, 12th, 14th and 20th day from the start of injection, be-

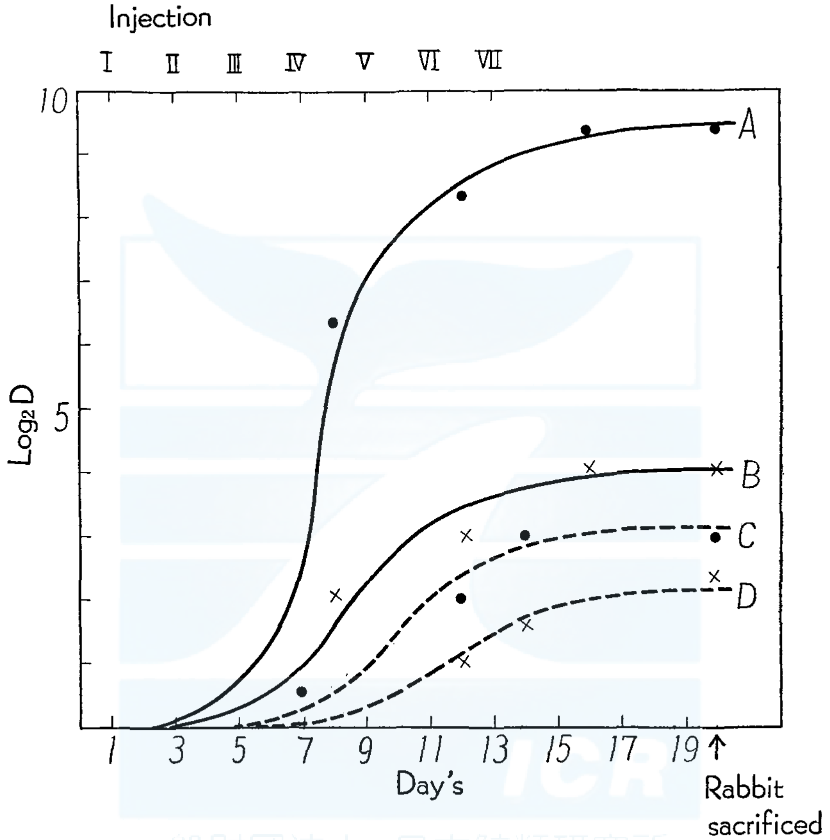

Fig. 1. Production of anti-Ju_1 and anti-B agglutinins in serum and egg-white of no. 20 fowl (D in $Log_2 D$=limiting dilution titers) A: anti-Ju_1 in serum, B: anti-B in serum C: anti-Ju_1 in egg white, D: anti-B in egg white.

ing up to 5 eggs in all. The author traced ascendings of anti-Ju1 and anti-human B agglutinin titers in these egg-whites and sera obtained by test bleedings. After centrifuging and inactivating, these agglutinins were titrated with hole-glass (slide glass) method. Limiting dilution titers of these agglutinins are plotted in figure 1.

It may be assumed from this figure that both anti-Ju1 and anti-B agglutinins in the egg-white begin to appear few days later than those in the serum and don't reach up to so high titers as those of the latter. As this observation was performed at the base of coastal whaling, no quantitative analysis have been carried out on globulins in egg-white and serum.

SUMMARY

1. Basing upon the classification of Friedenreich and With (1933) the author carried out the analysis of the human B blood group substance in the erythrocytes of cetaceans from the view points of systematic serology. A new partial antigen which has simpler structure than BIII in the guinea pig cells were detected immunologically in the fin whale erythrocytes independently to their blood groups. This antigen was named provisionally as BIV′. By this symbol the B blood group substances in the erythrocytes of human, rabbit, guinea pig and fin whale may be expressed as BIBIIBIIIBIV′, BIIBIIIBIV′, BIIIBIV′, and BIV′ respectively. Comparative survey between BIV′ and BIV in the erythrocytes of sheep or horse (Ogura, 1953b) will be discussed in the future issue.
2. Normal agglutinins specific to Ju antigens of fin whale erythrocytes were detected in the sera of rabbits and fowls which were used as immune animal. In case of preparation of reagents for blood grouping on Ju system of fin whales, it is desirable that fowl is used as the immune animal for anti-Ju1 agglutinin producer and rabbit which has normal anti-Ju2 agglutinin is used as the anti-Ju2 agglitinin producer.
3. Appearance of immune antibodies into egg-white of a fowl was observed on the way of preparation of the anti-Ju1 agglutinin. It may be assumed from the results of this observation that both anti-Ju1 and anti-human B agglutinins begin to appear into egg-white few days later than into serum and don't reach up to so high titers as those of the latter.

ACKNOWLEDGEMENT

The author should express his hearty thanks to Prof. Tanemoto Furuhata and the late Dr. Katsumi Yamaguchi for suggestion on this study.

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COCCONEIS DIATOMS INFECTED ON WHALES IN THE ANTARCTIC

TAKAHISA NEMOTO

Diatoms infected on the whales have been studied by Hart (1935), Kalcher (1940), Hustedt (1952) and Nemoto (1956), and many interesting diatom specimens are found on the skin films of whales by their works. Among them, *Cocconeis ceticola*, which is first described by Nelson in Bennett's paper (1920) is the most dominant species on whales, but it has never been found as the plankton or on any other host than whales. The next real parasitic *Cocconeis*, *C. Wheeleri* is described by Hart (1935), but Okuno (1954) considers it may be a variety of *C. ceticola*. Above two-mentional forms and a new variety of *C. ceticola*, *C. ceticola* f. *constrica* described in the previous report (Nemoto, 1956) from sperm whales in the North Pacific are also observed among the collections from the Antarctic whales.

The study on the samples collected by the Japanese Antarctic whaling expeditions reveals that some characteristic forms of *Cocconeis* are found besides three above forms. Some of new *Cocconeis* forms seem to transform their types according to their host species or parasitic positions of whales. Diatom samples treated here are collected by the Japanese whaling expeditions from various species of whales and preserved in formalin sea water.

The preparations and the method of this examination are the same as those in the previous report (Nemoto, 1956), but Hyrax is mainly used in this study as a mounting medium. The phase-microscope is mainly used for the preexamination of species before electron-micrograph studies.

NOTE ON SPECIES

Cocconeis ceticola Nelson

C. ceticola is the most dominant diatom on whales as it has been considered up to this time. The typical form is mostly found on fin whales, sei whales and blue whales, while I have never found any typical specimens of *C. ceticola* on sperm whales as in the case of northern sperm whales. *Cocconeis* specimens found on sperm whales are all constricted forms except some vague ones.

Cocconeis ceticola form. *constricta* Nemoto

This variety form of *C. ceticola* is mainly found on sperm whales as in the North Pacific. But some specimens found on humpback whales bear such constricted valves as those of *C. ceticola* f. *constricta.* These constricted forms, however, have wider girdles than typical *C. ceticola* f. *constricta.*

Cocconeis ceticola form. *subconstricta* **form. nov.**

Cells are solitary, forming patches on the skins of blue whales. Valves are rather broadly oval and constricted at only one side of the valve where the stauros of rache valve reaches. The surface structures and sizes of valves are the same as the original form of *C. ceticola.*

This form is found only on blue whales caught in the Antarctic waters among *C. ceticola,* and is considered one of the intermediate forms between *C. ceticola* form *constricta* and the original form of *C. ceticola.*

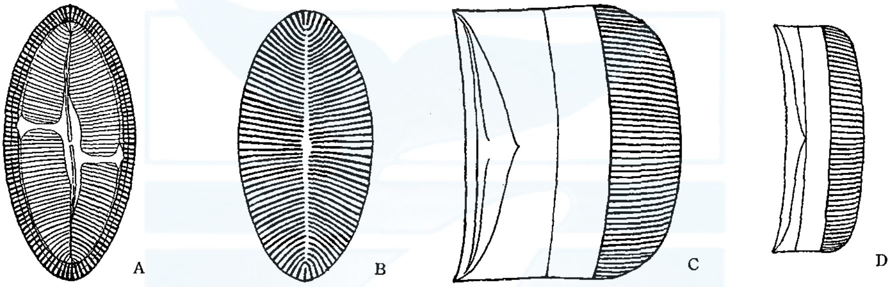

Fig. 1. *Cocconeis Wheeleri* Hart, ×1000. A, rache valve. B, racheless valve. C, D, girdle views of *C. Wheeleri.*

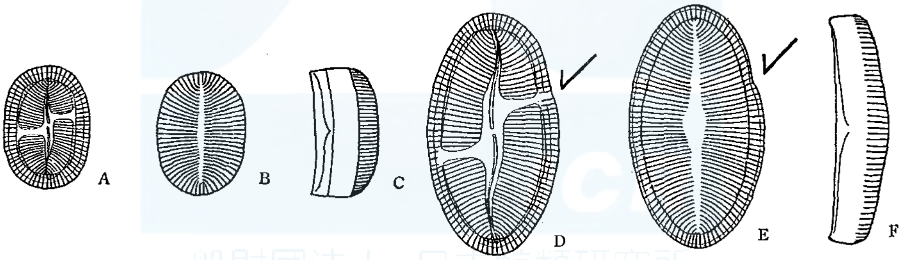

Fig. 2. A, B, C, *Cocconeis ceticola* collected from humpback whales. ×1000. D, E, F, *Cocconeis ceticola* fo. *subconstricta* n. fo. ×1000. Notice the broader girdles of valves illustrated in C figure. Arrowes show the constricted position of the valves.

Cocconeis Wheeleri Hart

Hart (1935) describes this characteristic diatom only from Antarctic humpback whales, and I also observe it mainly on humpback whales. Many specimens collected from tail flukes of humpback whales are almost all *Wheeleri* type, and on the other hand *ceticola* type specimens are very small in number on humpback whales. (Fig. 2. A. B. C.)

The most characteristic distinctions between two above forms may be the curvature of valves and width of girdles' portion. Other distinction, such as the size of valves is not clear enough to divide two forms as described in Okuno's report. The sizes of valves of *Wheeleri* are rather larger than *C. ceticola* as described by Hart (1935). But the largest *C. ceticola* is also as large as *C. Wheeleri* (Okuno, 1954).

In the previous paper (Nemoto, 1956) I considered *C. Wheeleri* might be one variation of *C. ceticola* as described in Okuno's report, because no specimens of *C. Wheeleri* was found on other baleen whales than humpback whales, and popular *C. ceticola* was also not observed on humpback whales. It suggests that *C. ceticola* transformed its shapes when it attached to humpback whales. However, I have not been able to derive any valid reason for above transformation of *Cocconeis* specimens after such consideration, and samples collected from a blue whale in the Antarctic are also all *Wheeleri* types. So I describe here *C. Wheeleri* again as a form different from *C. ceticola* after the description by Hart. Some discussion on this point is stated in the following chapter.

DISCUSSION

The original type of *Cocconeis ceticola* is reported by Nelson in Bennett's paper (1920). After their descriptions and successive investigations by Hart (1935), Hendey (1937), Okuno (1954) and Nemoto (1956), all typical forms of *C. ceticola* are elliptic-lanceolate in the outlines. This typical form of *C. ceticola* is mostly collected from fin whales. *Cocconeis* diatoms collected from fin whales are all this *ceticola* type. On the contrary, the constricted form *C. ceticola* f. *constricta* is only found on sperm whales as in the northern Pacific (Nemoto, 1956). The outline of the constricted form is broadly oval and constricted at the median margin of the valve and it is considered that the constricted form is one of the transformations of *C. ceticola* on sperm whales, and the constricted form has never been found on fin whales.

Ceticola form is also found on sei and blue whales, but *ceticola* form is rarely found on humpback whales, while, *C. Wheeleri* is only found on humpback whales. *Cocconeis Wheeleri*, reported by Hart from the Antarctic humpback whales, has never been found on the species of whales but a blue whale. *C. Wheeleri* resembles closely *C. ceticola* but has much greater width of the girdle and stronger curvature of the valves as described by Hart (1935). The sizes of valves are also larger than those of *C. ceticola*. But in opposition to Hart's description, Okuno (1954) considers *C. Wheeleri* may be a synonym of *C. ceticola,* because sizes and structures of valves of *C. Wheeleri* do not differ so markedly as *C. Wheeleri* is separated from *C. ceticola.*

I also considered that *C. Wheeleri* might be a fixed variety form of

C. ceticola in my previous report, because *C. Wheeleri* is found only on humpback whales and few *ceticola* type is found on humpback. It suggests that *C. ceticola,* which is very common on other whales, is transformed by any causes of humpback whales' skins when it attached to the whales. But the further observations after above suggestion, reveals that, though *C. ceticola* has many variety forms, it is best to consider *C. Wheeleri* is the fixed species on humpback whales though it is possible that further information on structures, etc., may cause me to revise my present opinion. These variety forms and *Cocconeis Wheeleri* are listed in figure 3. As shown in figures, various forms of *Cocconeis ceticola* are found on each whale. Especially, it is an interesting fact that the outlines of valves differ in each whale species as partly described in above descriptions. The types A, B and C are collected from fin and sei whales in the North Pacific and the Antarctic. They are all typical *ceticola* forms, and these host whales are mostly related to each other.

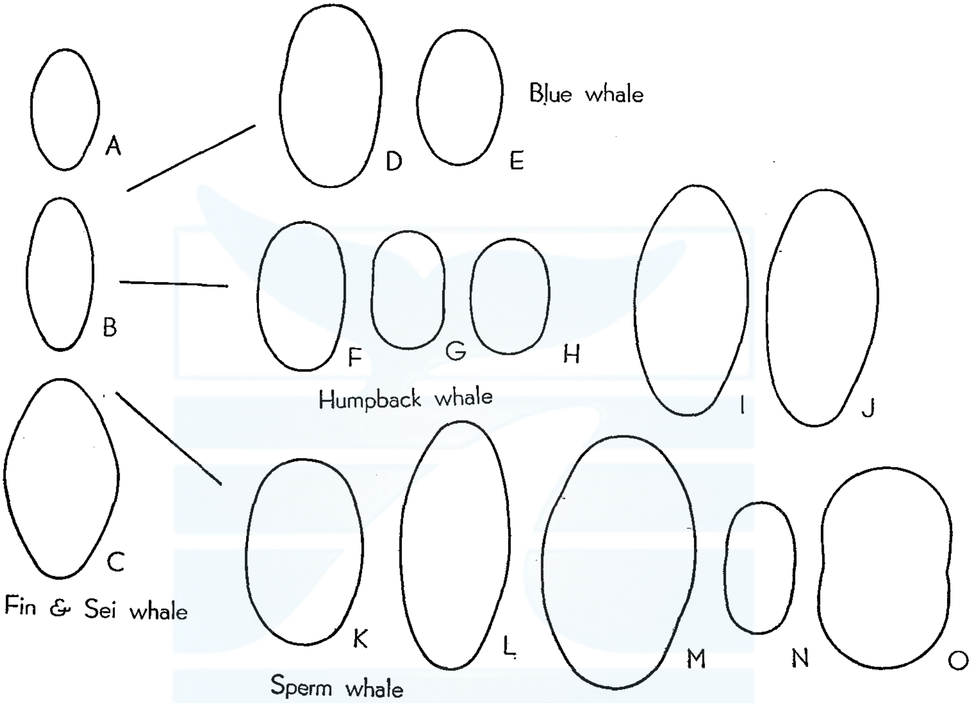

Fig. 3. A, B, C, *Cocconeis ceticola* Hart collected from fin and sei whales. D, *C. ceticola* f. *subconstricta* collected from a blue whale. E, *C. ceticola* collected from the same blue whale. F, G, H, *C. ceticola* & *ceticola* f *constricta* collected from humpback whales. I, J, *C. Wheeleri* collected from humpback whales. K, L. Ambiguous *C. ceticola* collected from sperm whales. M, N, O, *C. ceticola* f. *constricta* collected from sperm whales.

The next figures D and E are found on a blue whale caught in the Antarctic waters. The characteristic point of the former specimens is a constriction on only one side of the valves. This constriction is usually found on the marginal position where the stauros of rache valves reaches alike *constricta* form which has two constrictions on both sides. The latter oval form is found on the same blue whale and it closely resembles some specimens collected on humpback whales. This oval form is not the typical elliptic lanceolate *ceticola* form, and this type is also observed on sperm whales as shown in K illustration. The oval form is considered as the first transformation of *C. ceticola* on other whales than fin whales.

F illustration is collected among the ventral grooves of humpback whales in the Antarctic. The next G illustration is collected from the same whales. The following figures, H, I and J illustrations are obtained also from humpback whales. But, these specimens are collected from the tail flukes of humpback whales. The latter two specimens are apparently *Wheeleri* types. *Cocconeis Wheeleri* has been found only on humpback whales by Hart (1935) and also by my examinations on Japanese collections in 1954 and 1957, but in 1958 I found *C. wheeleri* on a blue whale in the Antarctic. The typical *Wheeleri* specimens are mostly collected from the tail flukes of humpback whales. On the contrary to this fact, there is no dominant patch of typical *Wheeleri* among the ventral groove specimens in 1957. And the ventral groove specimens are almost all rather small oval forms or sometimes constricted form like *C. ceticola* f. *constricta.* This phenomenon suggests that, though the materials are few in number, the parasitic positions on whales may have some effect to the transformation of the form of *C. ceticola* or the related forms.

From the girdle view of above *Cocconeis* specimens, some interesting features are also observed. The subconstricted form, D and E illustrations have narrow girdles as *ceticola* form shown in figure 2. But oval and constricted form collected from humpback whales among ventral grooves have the wider girdles like *Wheeleri,* though they never bear the stronger curvature of valves such as *Wheeleri.* So from the girdle view, it resembles *C. Wheeleri* more than *C. ceticola.* The microstructure of the girdles of the specimens is now under close examination and it will be discussed in the next report.

The deformation of *C. ceticola* on sperm whales is also very characteristic. In the lower series, these typical variety forms on sperm whales are illustrated. K illustration shows the first deformation, which is mostly related to the original type and mostly related to Karcher's photographs in 1940. L illustration is as large as *C. Wheeleri,* but this specimen bears slight curvature of valves like that of *ceticola* form. M, N and O illustrations are all constricted forms, though some differences are observed among these forms. M specimen is large and the constricted positions are not situated at the median portions of outlines. N specimen is generally of moderate size, and rather slender than other *constricta* forms. This type is also shown in figures 11 and 12 in plate II. The constriction of the type is not sometimes so distinct as oval *constricta* form. O illustration is the most typical *constricta* forms, and no typical difference is observed in surface structures, from the constricted forms of *C. ceticola* f. *constricta* from humpback whales but the sizes of valves.

SUMMARY

Cocconeis diatoms infected on the Antarctic whales are examined. *Cocconeis ceticola* is mostly common on fin, sei and blue whales, but it is found on humpback and sperm whales in rare cases. *Cocconeis Wheeleri* Hart is the dominant species on humpback whales and *Cocconeis ceticola* f. *constricta* Nemoto is the dominant species on sperm whales.

One new form, a variety form of *C. ceticola*, *Cocconeis ceticola* f. *subconstricta* is described from blue whales in the Antarctic.

Some specific differences among host whales, and transformations of *Cocconeis* diatoms are suggested.

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EXPLANATION OF PLATES

All photomicrographs have been taken by electronmicroscope. The materials are boiled with hydro-chloric acid to remove the organic contents before the photographing.

PLATE I

Fig. 1. Rache valve of *Cocconeis ceticola* f. *constricta* Nemoto collected from a sperm whale in the Antarctic. × 4000.

Fig. 2. Rache valve of *Cocconeis ceticola* collected from a humpback whale in the Antarctic. ×4000.
Fig. 3. Racheless valve of *Cocconeis ceticola* f. *subconstricta* n. fo. collected from a blue whale in the Antarctic. × 4000.

PLATE II

Figs. 1 & 2. *Cocconeis ceticola* f. *subconstricta* n. fo. collected from a blue whale in the Antartic.
Figs. 3 & 4. *Cocconeis ceticola* f. *constricta* collected from a humpback whale in the Antarctic.
Figs. 5. & 6. *Cocconeis ceticola* collected from a humpback whale in the Antarctic.
Figs. 7–9. *Cocconeis Wheeleri* Hart collected from humpback whales in the Antarctic.
Fig. 10. Ambiguous *Cocconeis ceticola* Nelson collected from a sperm whale in the Antarctic.
Figs. 11–15. Various forms of *Cocconeis ceticola* f. *constricta* Nemoto collected from sperm whales in the Antarctic.

All photographes show 1,000 magnifications.

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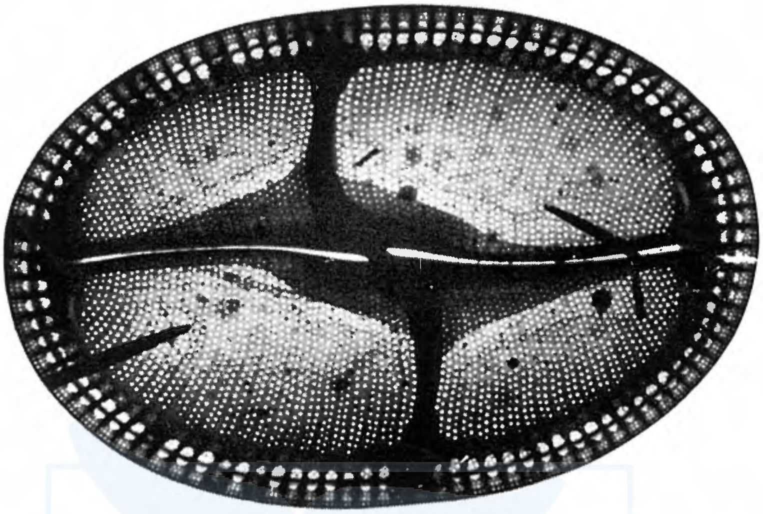

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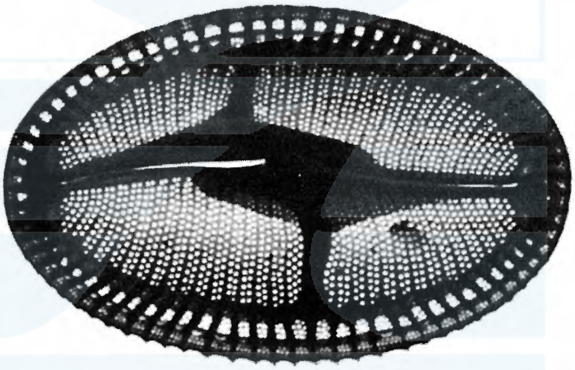

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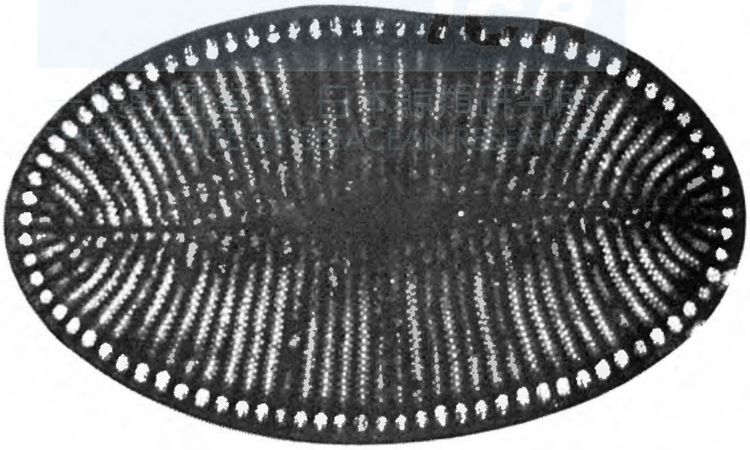

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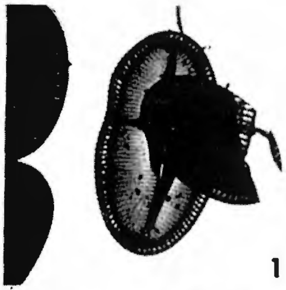

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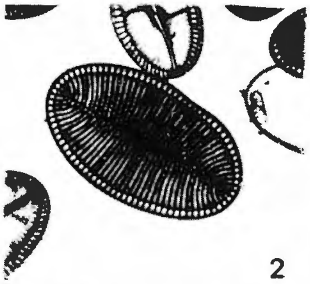

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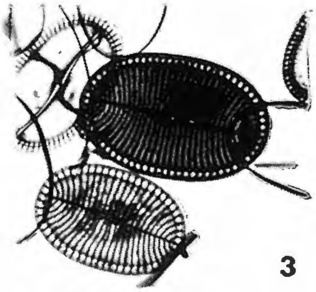

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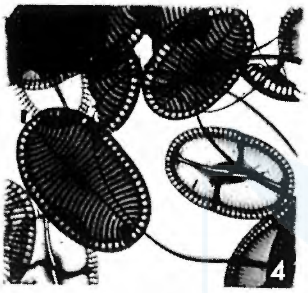

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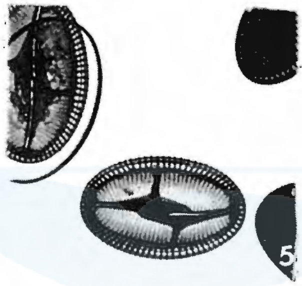

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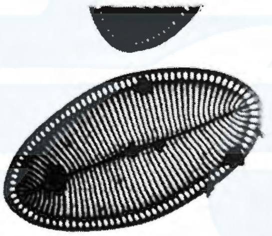

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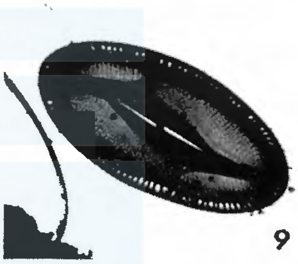

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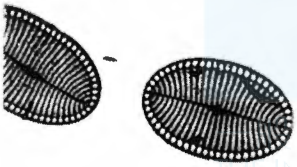

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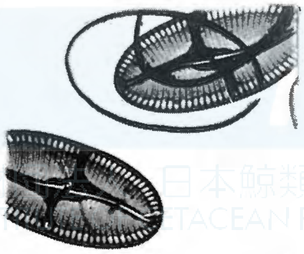

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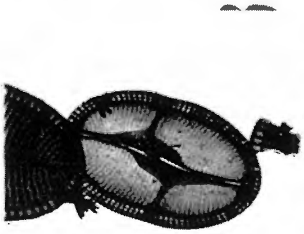

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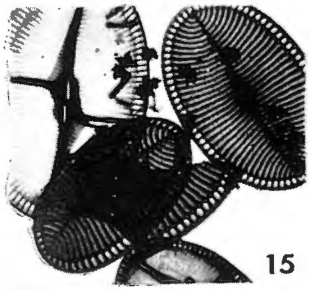

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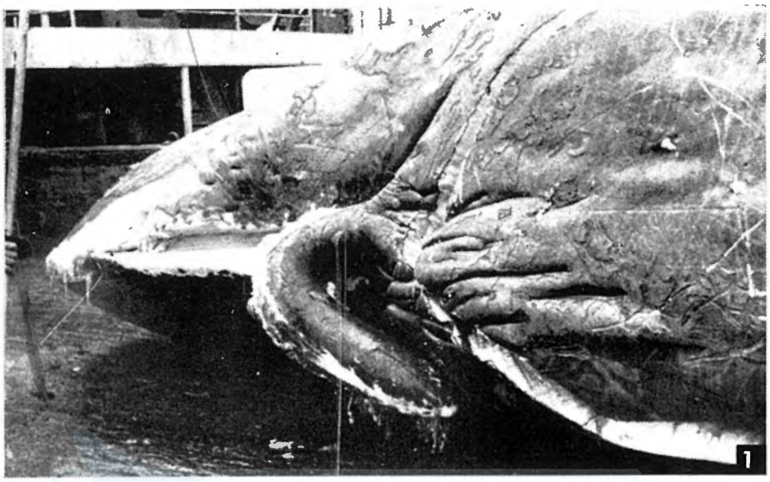

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THYSANOËSSA MACRURA AS A FOOD OF BALEEN WHALES IN THE ANTARCTIC

TAKAHISA NEMOTO AND KEIJI NASU

A giant euphausiid, *Euphausia superba* has been only considered as the staple food of baleen whales in the Antarctic waters, because almost all baleen whales in the Antarctic feed exclusively on the swarms of *Euphausia superba*. Some other euphausiids, such as *Euphausia crystallorophias*, *E. frigida*, *E. triacantha* also widely distribute from the sub Antarctic to high Antarctic zone. But few of above species have been noted as the food of Antarctic baleen whales. The Antarctic neritic species, *Euphausia crystallorophias* is considered to bear some value as a food of little piked whales, some blue and fin whales in the high latitude of Ross Sea (Marr, 1956), however, it has never been observed in waters out of the pack ice.

An Antarctic *Thysanoëssa*, *Thysanoëssa macrura* G. O. Sars distributes largely in the Antarctic waters and it is a very common euphausiid next to *E. superba* (Rustad, 1930; Ruud, 1932), though it has never been observed in the stomachs of whales in previous studies except three cases by Peters (1956). Rustad (1930) describes on this point that *E. superba* and *Thysanoëssa macrura* play the predominant part as food for larger animals, e.g. whales seals, and birds. Of the two species *E. superba* seems to play the greater part, this species alone being recorded from almost all stomach contents containing euphausiids. And *T. macrura* has never been found as a staple diet of baleen whales.

In 1956, Japanese whaling expeditions operated in the so called whaling area I and VI where the whaling operation had been forbidden until that year. In some euphausiids samples collected through above operations, dominant appearances of *Thysanoëssa macrura* are observed. These Japanese collections covered wide areas from 50° east to 100° east longitudes, from 170° west to 80° west longitude. And so many numbers of samples have been collected in the following season of 1957. *T. macrura* is found again in considerable number of samples. Thus, *T. macrura* is considered to play some part as the staple food of Antarctic baleen whales, though in has never been noticed by any investigations before this report.

The result that *Thysänoessa macrura* was not observed in collections in 1955, might be due to the fact that the samples of 1955 were restricted to the waters from 80° east to 130° east longitude in the so-called whaling area IV. The numbers of whales examined and samples collected in the successive years are listed in tables from 1 and 2.

TABLE 1. NUMBER OF WHALES EXAMINED AND SAMPLES COLLECTED IN THE WATERS WEST OF 100° E IN 1956 AND NUMBER OF WHALES EXAMINED AND SAMPLES COLLECTED IN THE WATERS EAST OF 170° W IN 1956

West	Whale species				East	Whale species			
Number of whales	Fin	Blue	Humk-back	Sei	Number of whales	Fin	Blue	Humk-back	Sei
Whales examined	978	97	95	1	Whales examined	3535	278	145	6
Whales fed	496	52	55	1	Whale fed	2477	148	92	5
Collected samples	25	4	1	—	Collected samples	69	3	3	—
Unknown	8	1	—	—	Unknown	—	7	—	—

TABLE 2. NUMBER OF WHALES EXAMINED AND SAMPLES COLLECTED IN THE WATERS EAST OF 170° E IN 1957

	Whale species			
Number of whale	Fin	Blue	Humk-back	Sei
Whales examined	5832	611	71	133
Whales fed	2478	311	47	55
Collected samples	301	37	4	5
Unknown	1	—	—	—

Description of *T. macrura* G. O. Sars

The rostrum is narrow and lanceolate, reaching to a little back to the end of the first antenuular segment. Lateral margin of carapace bear a denticle on its two-third from the tip of the margin. Eyes are large with a transverse constriction above the middle. Antennulae with the upper flagellum is somewhat shorter than the sum of the two distal peduncular joints. Second thoracic legs are very elongate, with the merus reaching beyond the end of the antennular peduncle. Oschium and merus are very strong and heavy. Carpus somewhat is curved distally bearing about 6 or more setae. The propodus is about one-fourth as long as carpus, bearing about 7 to 14 setae on both margins. The dactylus is broad and bears 4 to 5 strong setae and 3 to 5 slender setae. Abdomen without any keel or spine, telson bears two pairs of dorsal spines. Six abdomnal segment is fully as long as the sum of the two preceeding segments. Preanal spine of females is indented, but rather smooth in males. This sexual distinction is well developed in young specimens. Terminal process of the copulatory organ distally expanded in both sides and especially outwards. Proximal process and lateral process are rather slender and terminal parts curved. Spine-shaped process is curved through about 90° angle. Females attain to about 29 mm from the tip of the rostrum to the last of telson, on the other hand the adult males are far smaller, only 20 mm in the largest specimens as described by Hansen (1911). Females are always dominant in number among the patches of *T. macrura* like northern Pacific euphausiids.

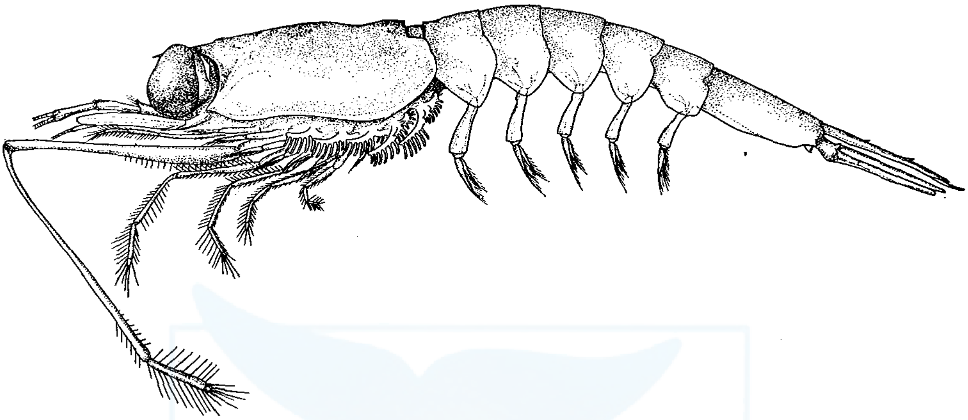

Fig. 1. Adult female of *Thysanoëssa macrura* G. O. Sars.

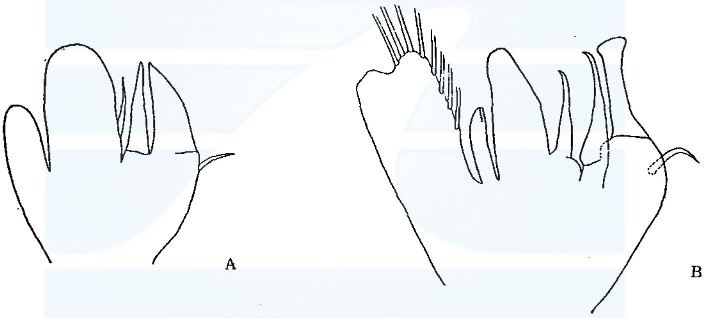

Fig. 2. Male copulatry organs of *T. macrura* A. inmature male B mature male.

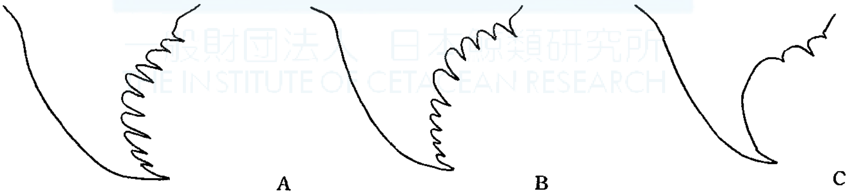

Fig. 3. Preanal spines of *T. macrura*. A. inmature female. B. mature female C. mature male

OCCURRENCE

Thysanoëssa macrura is found in our collections as shown in tables 3 and 4. In 1956, 5 samples are found containing *T. macrura* in 105 ones. No other euphausiid is observed in these 5 samples, and observations by biologists on board confirm that the stomachs were satiated only with this *T. macrura* in above 5 samples. The further collections in 1957, show also such ratio of occurrences as in the previous year. Of course other collected samples consist of only *Euphausia superba* in various stages. The mingled collections with *E. superba* and *T. macrura* are also observed in less number in both years. In these mingled collections, specimens of *E. superba* are rather young ones and full grown euphausiid have never been observed. So the sizes of *E. superba* is not so large as adult specimens in these mingled samples.

The eyes of *T. macrura* is fragil like the North Pacific *Thysanoëssa T. longipes* (Nemoto, 1957). When *T. macrura* is found among *Euphausia superba*, the eyes of *T. macrura* are nearly digested. On the other hand, those of *E. superba* remain undigested.

As shown in table 5, the occurrences of *T. macrura* differ in each month of the whaling season. The most dominant appearance is observed in the late decade of January and the first decade of February. In other decades, comparatively few samples of *T. macrura* are observed, and we see none of them in many samples in March. From above facts, some seasonal or distributional pecuriarity of *T. macrura* is suggested.

In 1956, a Japanese fleet operated in the waters from 40° east to 90° east longitudes so called whaling area III. From these 30 samples, *T. macrura* is found in two samples collected in the waters near 40° east line, and none of *T. macrura* is found in other collection from 50° 90° east longitude as shown in figure 4. And 5 samples of *T. macrura* are found in the waters near 130° east longitudes

In 1957, many samples of *T. macrura* are collected in the area from 135° west to 100° west longitudes. Except the waters near the pack ice in this area, *T. macrura* is considered to be important as a food of whales as shown in figure 5. In the waters from 170° west to 140° west, many collections of stomachs of whales are all *E. superba* but one *T. macrura*. In this area we have also none of *T. macrura* in the previous year. It may be considered from above facts that *E. superba* does not distribute so uniformly, and perhaps *E. superba* is scarce or *T. macrura* is very common in this area. Thus many whales that fed on *T. macrura* may be found in our researches.

During the Antarctic whaling season in 1957, oceanographical data were collected on the board of the factory ship "Nisshin-maru" at interval of 4 hours, the discussion of which will be published after the examination and we may state simply its quatation here for our study. Oceanographic conditions of January and February show, generally, water masses of the lower temperature and salinity are formed by melting ice towards the north. On the other hand, water masses of the higher temperature and salinity run towards the south.

TABLE 3. OCCURRENCE OF *THYSANOËSSA MACRURA* IN THE JAPANESE COLLECTION OF STOMACH CONTENTS OF BALEEN WHALES IN 1956

Euphansiid species	East of 170° W Whale species			Euphansiid species	West of 100° E Whale species		
	Fin	Blue	Hunpback		Fin	Blue	Hunpback
E. superba	65	3	3	*E. superba*	23	4	1
T. macrura	4	—	—	*T. macrura*	1	—	—
				E. superba *T. macrura*	1	—	—

TABLE 4. OCCURRENCE OF *THYSANOËSSA MACRURA* IN THE JAPANESE COLLECTION OF STOMACH CONTENTS OF BALEEN WHALES IN 1957

Euphansiid species	Whale species			
	Fin	Blue	Hunpback	Sei
E. superba	274	36	1	5
T. macrura	21	—	3	—
S. superba & *T. macrura*	6	1	—	—

TABLE 5. OCCURRENCE OF *THYSANOËSSA MACRURA* IN 1957

	January			February			March	
Species	1	2	3	1	2	3	1	2
E. superba	8	27	20	52	55	87	41	26
S. superba & *T. macrura*	—	—	4	2	—	—	—	—
T. macrura	1	2	9	8	3	1	—	—

Between the currents towards the north and the south the cyclonic eddies are formed, therefore, the isotherms and the isohalines bend far laterally, and the whaling grounds in the Antarctic waters is located near the cyclonic eddies, that is, whaling grounds are formed in the center of the water boundary forming cyclonic eddies as Ruud (1929) and Uda (1954) describe. It seems that the krill *T. macrura* is concentrated by the water current on such areas.

As above mentioned, in 1957 the area where *T. macrura* occurred was covered on the waters from 135°W to 100°W longitude, and the greatest concentration was observed at the adjacent waters of 110°W longitude. Generally speaking in the area were *T. macrura* had been dominaratly appeared the temperature and salinity were approximately 0°C and $33.60^{0}/_{00}$ respectively in our observations. So *T. macrura* may distribute relatively high temperature and salinity and may be the food of baleen whales of which are distributed off comparatively warmer waters in the Antarctic.

SUMMARY

An Antarctic *Thysanoëssa*, *T. macrura* is found as a stable food of baleen whales. Considering dominant appearances of *T. macrura* in stomachs of whales, it must bear significance for the Antarctic whales in the certain Antarctic area.

T. macrura is considered to distribute relatively higher temperature and salinity than *Euphausia superba*.

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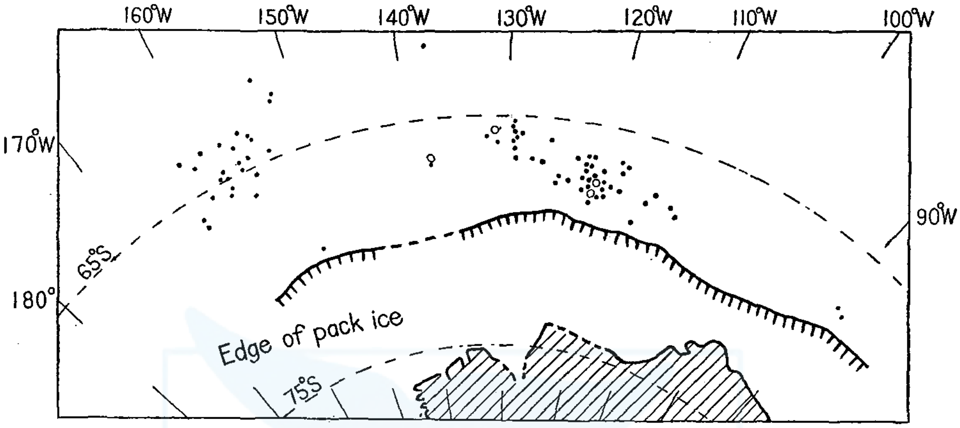

Fig. 4. Occurrences uf *T. macrura* in the collected samples in the Antarctic waters in 1956.

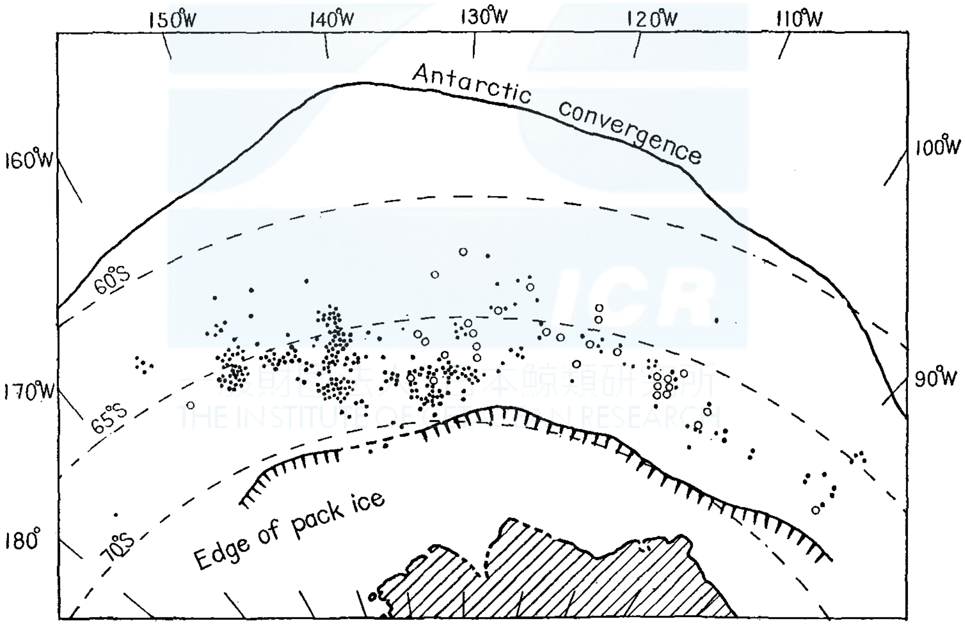

Fig. 5. Occurrences of *T. macrura* in the collected samples in the Antarctic waters in 1957.


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GRAY WHALE OBSERVED IN THE BERING SEA

TADAYOSHI ICHIHARA

The gray whale is a moderate-sized whalebone whale about 40 feet long and now survives from its extermination only in the Pacific Ocean. There is not any information available on the gray whale alive elsewhere. The stock of the gray whale was protected from whaler by the international law in 1946, since then it has increased by and by. Gilmore (1955) stated "The California gray whale is back by the thousands again, twice almost exterminated by man". Sleptsov (1955) also described the number of the gray whale apparently increasing since 1946.

The gray whale has characteristics to enter inlets and lagoons in the breeding warm waters and even in the feeding cold waters. This peculiar behavior makes the observation easy. Many valuable informations on the life history of the gray whale have been given through the observation from the shore and from the air by plane and helicopter, especially in California.

The migration of the gray whale seems to be more regular in its course than other rorqual. One route of its migration is the west side and the other route is the east side in the Pacific Ocean. The west side whale, Korea gray whale, stays in the waters adjacent to Korea in winter and lives in the Okhotsk Sea in summer. It crosses the Japan Sea in transit of its journey. On the other hand, the east side whale, California gray whale, breeds calves in the waters near California in winter and feeds in the Bering Sea and the Polar Sea in summer. It crosses the North Pacific Ocean and the Bering Sea in transit of its migration. The migration of the Korea gray whale seems to be more simple in its course than that of the California gray whale, because the areas in transit are more narrow for the former than for the latter. In 1955, the migration routes of the gray whale were outlined in the Gilmore's map, in which the author separated the west population from the east one. Sleptsov also stated that two populations of gray whales might have mingled with each other long before the depletion of their stocks, but the sharp decrease in numbers of whale led each stock to isolation. Whereas, gray whales sometimes lived near the Kurile Islands and off the East Japan far from their normal migration routes, he stated. We have now no knowledge on the gray whale off the shore of Japan ourselves. According to Gilmore's map, the distribution of the gray whale in the Bering Sea is restricted within the waters near Siberia. In the same year when Gilmore drew the map, Sleptsov showed the distribution of the gray whale near Siberia. According to Sleptsov, the gray whale lives farther northward in Olyutorskiy Gulf in the Bering Sea and it usually does not appear off Kamtchatka and near the Commander Islands. It arrives in the Russian waters in the Bering Sea late in May and early in June, usually staying in the Bering strait and along the coast of the Chukchi Sea in summer, however, in a very few cases it enters Olyutorskiy Gulf. The California gray whale sets forth the northward migration from the warm waters in the interval between March and April. After two or three months, the gray whale appears again in the summer feeding areas. Where does it live in transit of its journey? Here I would like to quote Zenkovich's description (Kleinenberg & Makarov 1955), in which Grebnitskii states that no gray whale is found near the Commander Islands, although we had chances to see it in the past. Inhabitants familiar with creatures near the Commander Islands have now nothing to tell about the gray whale themselves, but they remember their forefathers' memories that they saw gray whales in the waters near the Aleutian Islands in the past.

In the past six years, the Japanese boats began the scouting works from the middle of May soon before the whaling seasons were open. In the northern part of the North Pacific and in the Bering Sea, they took records on whales which contained not only the important species for the whaling industry, but also the rare species; the gray and black right whale under protection from whalers. We have little actual knowledge, in regard to the remainder of the gray whale south in the Bering Sea during the seasons above mentioned, except two evidences. One evidence is uncertain, that is, an animal something like a gray whale was discovered from the boat at the position of 55°01′N, 162° 28′E on August 17 in 1956. This whale was moving to SE in its course and did not give whalers the chance to approach it. In May every year, we could find other whales containing the blue, fin, humpback and sperm, off Kamtchatka and in the west side waters near the Aleutian Islands, where we had no chance to discover the gray whale early in summer. The gray whale may cross there earlier than other whales on its northward migration.

On the other hand, there was another evidence of the gray whale in the south of the Bering Sea on May 29 in 1957. When I was charged in the whale marking on board a catching boat, I found a gray whale north in the Unimak Pass. This whale was moving northwards, and I had never expected that the gray whale lived there, and so I set myself to observe it in details. It was about 35 feet long and was swimming alone without fright at the noisy tons of engine of our boat. I could see many barnacles and cyamids on its body, but find no difference from the descriptions by other workers on its swimming behavior. It was wounded in the right back and bled from there whenever it came to the surface of water. Because of such injury, this whale might have remained south in the Bering Sea on its northward migration and appeared in the waters far from the Gilmore's route.

In the northern parts of the Bering Sea, Japan has several informations on the gray whale. West of St. Lawrence Island on August 2 in 1955, a Japanese catching boat discovered three herds of gray whales. Mr. Nasu, a member of the Whales Research Institute, took pictures of these herds, one of which is shown in figure 1 by his courtesy. The first herd consisted of two whales, 37 and 41 feet long, swimming at the position of 63°34′N, 172°48′W. The second was composed of about 20 whales from 36 to 41 feet long, feeding at the position of 63°35′N, 172°44′W. The third consisted of about 150 whales ranging from 35 to 40 feet long. The position discovered ranged from 63°59′N, 171°24′W to 63°54′N, 170°50′W. In the second and third cases, the herd was divided further into smaller groups including only one, two or three whales. Such compositions of herds were generally found in the humpback whale. These gray whales were swimming very gently to WSW or to SW in their courses. Moreover, another catching boat discovered a gray whale at the position of 63°25′N, 172°33′W west of St. Lawrence Island on July 28 in 1957. Its migration course was not constant. As mentioned above, there are a few data available on the distribution of gray whale in the

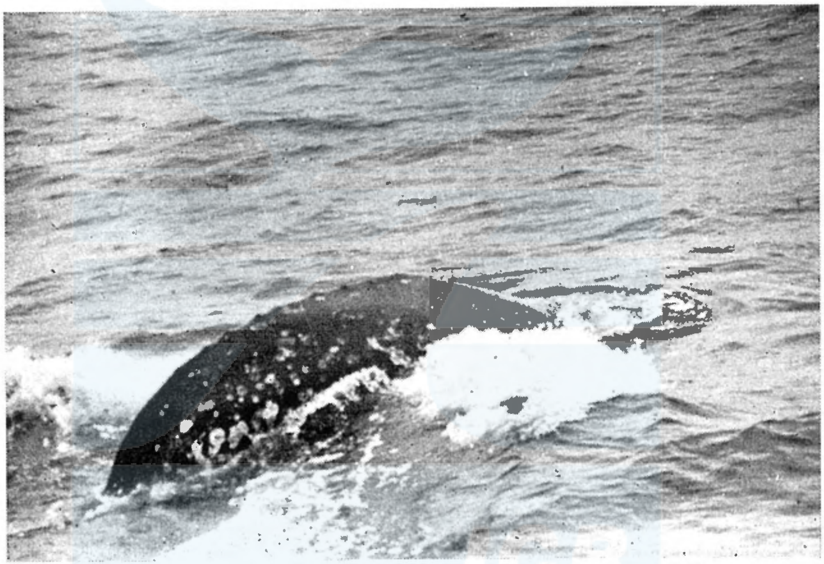
Fig. 1. Swimming gray whale (Photograph by Mr. Keiji Nasu.)

Bering Sea, so it is not easy to draw its migration routes on the map.

Here, let us cast a glance over the distributions of other whales. Fin whales marked in 1957 bore two evidences on their northward migrations. According to Kawakami & Ichihara (1958) two fin whales marked in the Bering Sea early in July moved northwards along the contour line of 200 meters, ranging from the Unimak Pass to Cape Navarin in Siberia. With regard to the humpback whales marked, we have no evidence of their movements in the Bering Sea. Our knowledges on the distribution of this species are as follows : A great number of humpback whales usually fed south of the east part of the Aleutian Islands in the interval between May and September. And in the past years they often appeared north of the Aleutian Islands. In the Bering Sea, 3 humpback whales were recorded to live near the contour line mentioned above, that is, 1 humpback whale swam at the position of 54°40′N, 171°31′W, on July 27 in 1955, 2 whales at the position of 55°40′N, 174°10′W and 1 whale at the position of 56°50′N, 175°20′W on June 22 in 1957. Besides, we have the information that 12 humpback whales lived in Anadyr Gulf late in

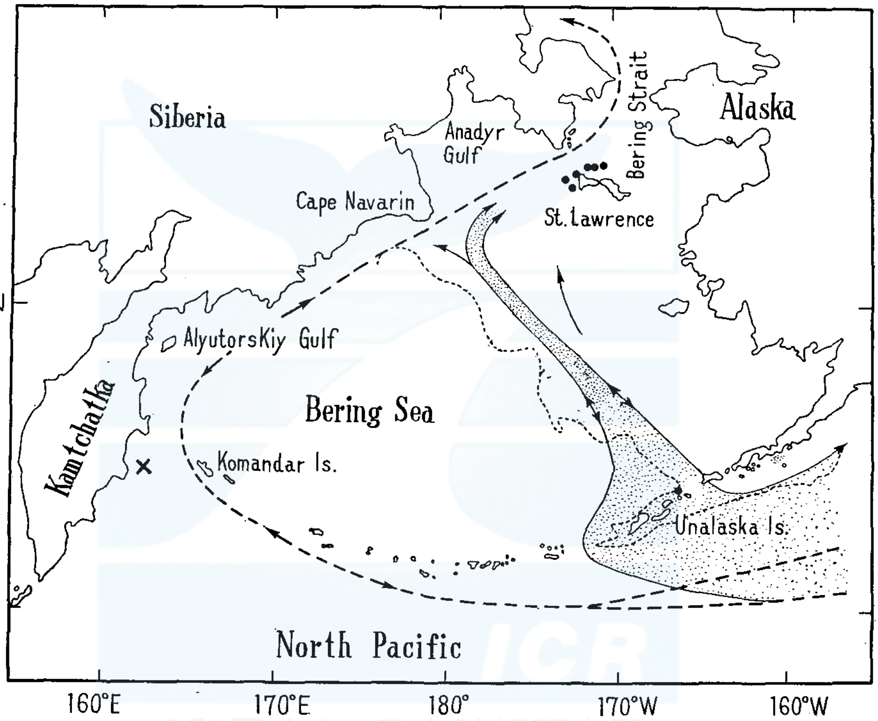

Fig. 2. Magration route of the gray whale in the Bering Sea

.... Contour line of 200 meters ● Position discovered
←-→ Gilmore's route × Uncertain record
<═> My proposed route

August 1957. Sleptsov (1955) stated humpback whales often appeared in herds of hundreds in Anadyr Gulf, whereas they seldom appeared off Kamtchatka every season. Certainly, our records indicate humpback whales live in less numbers off Kamtchatka than in the east waters of the Aleutian Islands in summer. As regards the sei whale in the northern part of the Bering Sea, it is reported that an animal was swimming at the position 59°19′N, 177°56′W on July 30 in 1955. Even if the season of northward migration differs a little among whale species, can we not draw the migration route of the gray whale in the same manner as that of the fin or humpback whale? I here examine the migration route of the gray whale in the Bering Sea and show it with Gilmore's route in figure 2. My proposed route was already assumed by Kellogg in 1929.

With regard to the food of the gray whale, there are many descriptions reported in the past. Kellogg states 'In the Bering Sea, gray whales feed on several kinds of amphipods resembling sand fleas'. According to Gilmore, gray whale fattens on abundant large plankton, especially euphausiid shrimps in the polar waters off Kamtchatka and in the Bering Strait. Arseniev and Zenkovich (Kleinenberg & Makarov 1955) showed the food of the gray whale compaing with those of other whales, and according to their observations gray whales feed on bottom living amphipods in the Bering Strait and the Chukchi Sea. It is appreciated from their paper that in the northern part of the Bering Sea humpback whales resemble gray whale in their foods.

As far as we continue to protect gray whales from whalers in the future, we shall have many chances to observe them enjoy their lives, and we shall be able to draw their accurate migration routes on the map.

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A DESCENDANT OF MOBY DICK, OR A WHITE SPERM WHALE

SEIJI (KIMURA) OHSUMI

"Moby Dick, or the white whale" which was written by a great novelist Herman Melville in 19th century, is commended as the highest ocean literature in the world, and a crazy devotion of the tiny man who stands opposite to the vast and mystically apprehended force, is depicted with the dignified and grandeur style in the novel.

Although, of course, Moby Dick was not a real animal but a symbol of the evil principle of the universe, it was a white sperm whale. The sperm whale is a grotesquely formed animal, but if Moby Dick were merely a huge sperm whale and not covered with the snow-white skin, it would not be so terrible. Melville explained the whiteness of the whale spending one chapter, and he emphasized the mystery of the white animal. Various nations have in some way recognized a certain royal pre-eminence in this hue, for instance, the white elephant in Siam and the white horse in Japanese shrines are the mere examples of it.

Well, does the white sperm whale really exist in the world? Sperm whales are usually black or of iron slate, although they are more or less white ventrally, or have some light streaks or mottling (Plate I. figure 1). Matthews (1938), Omura (1942) and Ohno & Fujino (1952) reported on the body colour of southern sperm whales from the Antarctic, and Omura (1950), Fujino & Others (1955) and Kimura (1957) reported on that of the sperm whales from the North Pacific. On the whales from the Atlantic, Clarke (1956) described in detail. In these five scientific reports, there is no record on the sperm whale as white as Moby Dick. Tomilin (1957) says that it is well known that Moby Dick is perhaps an albino of the sperm whale, but he does not show the specimen. A well-defined head whorl was regarded as a sign of comparative age in the sperm whale by the old time whalers (Beale, 1839). Although Matthews (1938) doubts this assumption, according to my experiences, the body colour of sperm whales gradually becomes lighter as they grow older, especially in the head. It is supposed that the whiteness of Moby Dick is due to its old age, but Melville wrote that the whale was clearly an albino.

They say that one of the materials to create the Monster Moby Dick is the Reynolds's report (1839) on the white whale in the Pacific named Mocha Dick. I am sorry I have never read the report, so I wonder whether it is scientifically true or not. At any rate, Moby Dick has been a traditional and imaginary existence.

In the time of American whaling, Captain Ahab searched for Moby Dick throughout all the oceans in the world, frantically burning with the revengeful thought, and after he found the whale at last and a terrible scene was enacted, wound with the rope he himself threw, he was driven into the water by the whale and drowned to death.

However, in the modern whaling, a decendant of Moby Dick appeared really, and was very easily caught by a Japanese catcher boat ultinately. Captain Ahab would pay old scores hearing this news.

It was caught by the Seki-maru No. 3 in April 19th, 1957. Mr. Hiroshi Ume was the gunner in this operation. The position caught was the adjacent water to Japan, Lat. 42°24.5′N, Long. 148°52.5′E. This whale was flensed at once at Akkeshi land-station of Taiyo Fishery Co. Ltd. I regret that I did not see the whale there. But fortunately, thanks to Mr. Hironosuke Soh, a member of the company, some fine photographs were taken on the whale. I have an honour of showing the whale with the photographs.

As shown in figures from 2 to 6, the descendant of Moby Dick was completely white. Unfortunately a pink iris and a red pupil which are the second characters of the albino were not observed, but it may be apropriate that the whale should be determined as an albino.

The whale is male and 35 feet long. Therefore it is not so gigantic or grotesque like Moby Dick. If it had not been killed in young generation, it would have reigned over the sea in future like the ancestor Moby Dick.

In connection with this white whale, once a gray sperm whale was caught by a Japanese whaling fleet in the Antarctic in December 1950. Mr. Fujino took its photographs shown in figures 7 and 8. This whale is male, and is over 50 feet long. The whale is supposed to be fairly old. Head, jaw and ventral portion is very white, but dorsal side is gray and the penis is black, so this whale is not so white as the above-shown white whale. Nevertheless, this gray coloured sperm whale is a very rare one.

I am much indebted to Mr. Hironosuke Soh of Taiyo Fishery Co. Ltd. and Mr. Kazuo Fujino of our Institute, who willingly offered me very valuable photographs shown in figures from 2 to 8.

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EXPLANATION OF PLATES

PLATE I

Fig. 1. A normal sperm whale from the northern Pacific in 1954.

Fig. 2. One white and two normal sperm whales caught in adjacent waters to Japan. (Soh photo.)

Fig. 3. The white sperm whale. Dorsal view. Anterior portion of the body is worn thinly. (Soh photo.).

PLATE II

Fig. 4. The white sperm whale. Posterior view. (Soh photo.).

Fig. 5. The white sperm whale. Head and lower jaw. The gray portion is abrasion. (Soh photo.).

Fig. 6. The white sperm whale. Ventral view. (Soh photo.).

PLATE III

Fig. 7. A gray sperm whale caught in the Antarctic. Posterior view. Ventral portion is lighter, but penis is black. Blackness of the right upper jaw is blood. (Fujino photo.).

Fig. 8. The gray sperm whale. Anterior view. Head is very white. (Fujino photo.).

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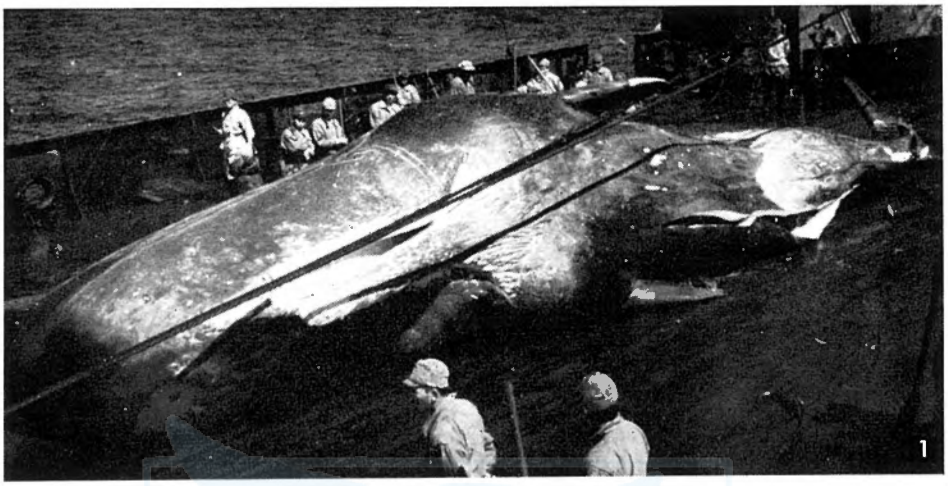

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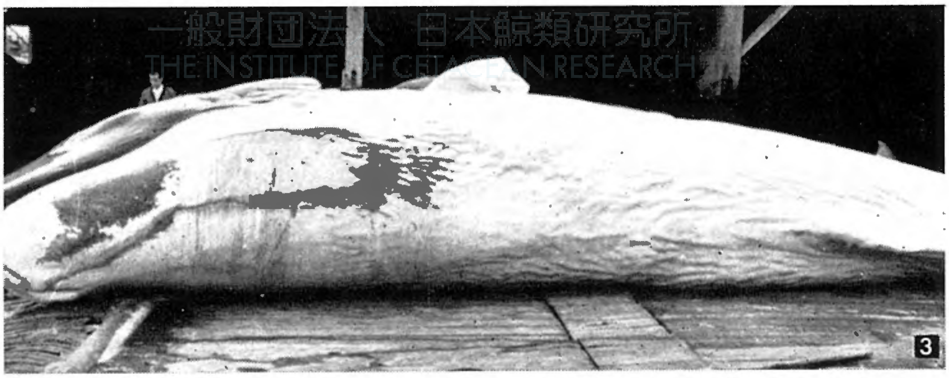

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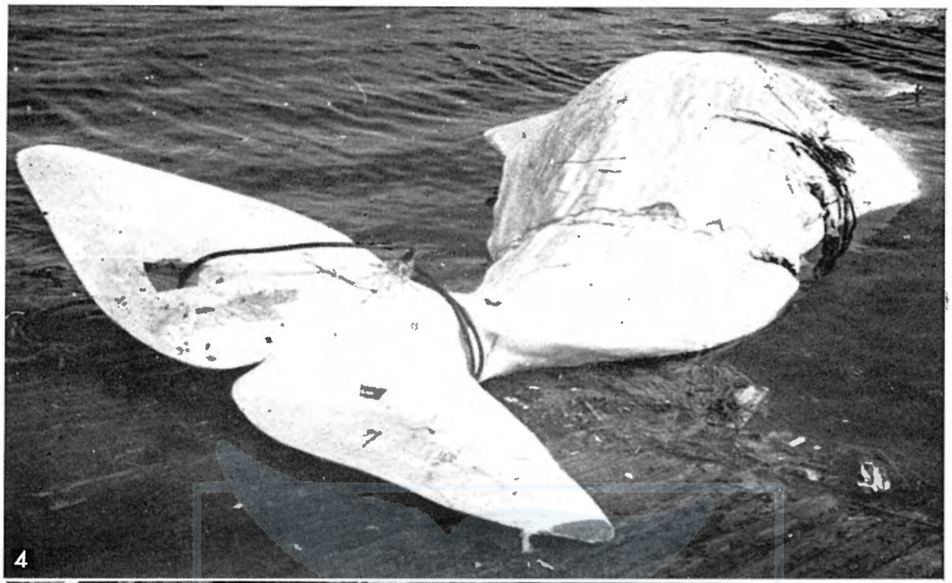

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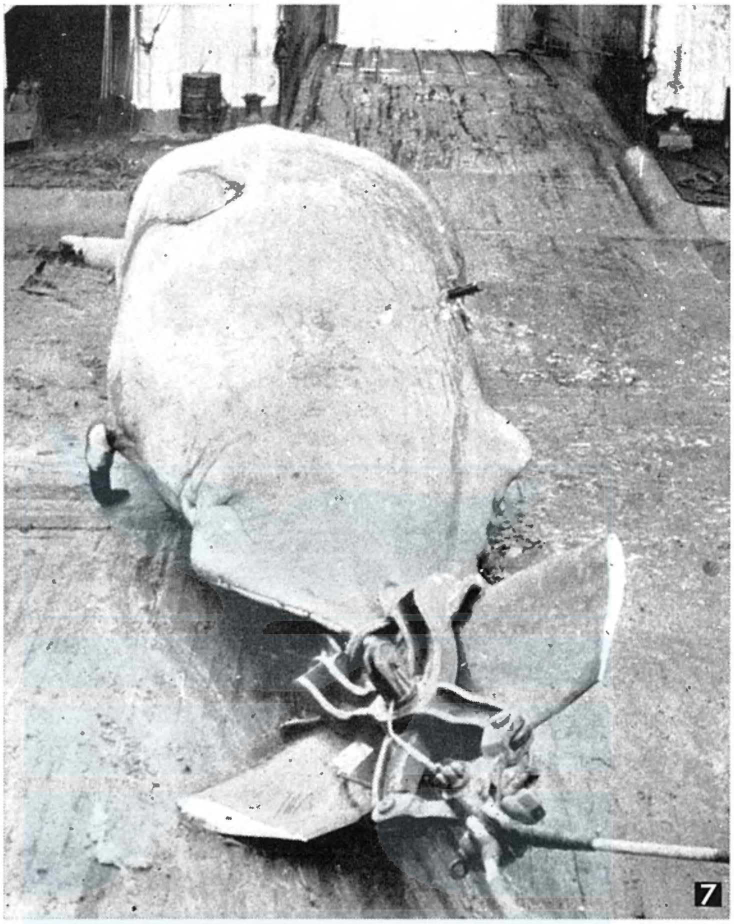

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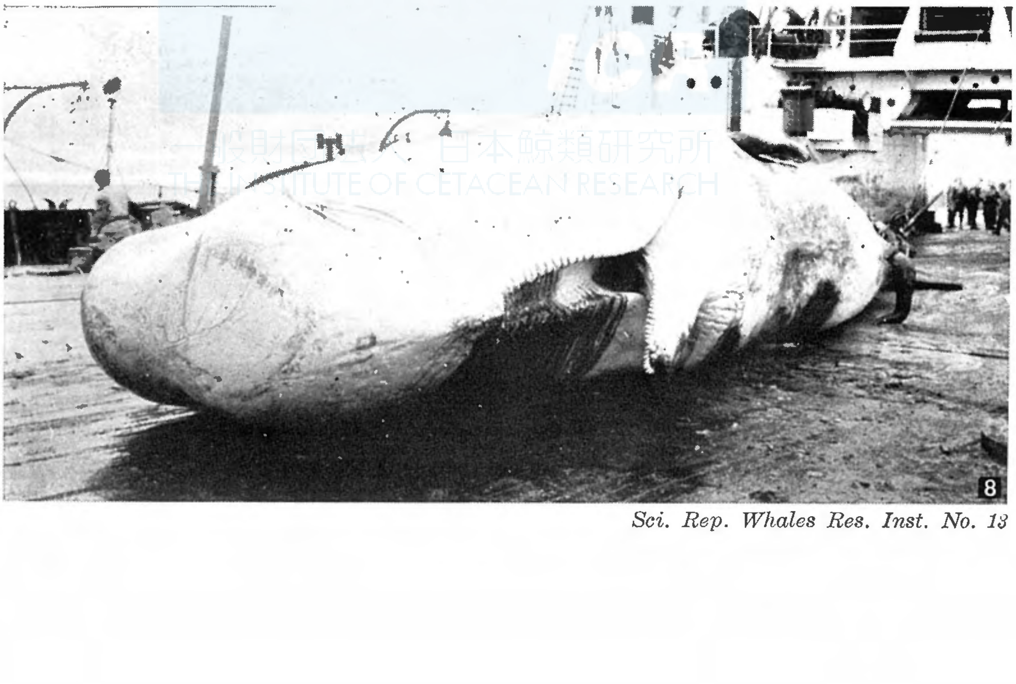

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DEFORMED LOWER JAW OF SPERM WHALE

KEIJI NASU

There are some reports on a deformed lower jaw of the sperm whale (Clarke, 1957 ; Tomilin, 1957). The writer of this note intend to report two whales which have these deformed lower jaws observed in the land whaling station and the pelagic whaling.

1. On the 22nd of March, 1956, a whale of which the lower jaw heavily bent was found on the board of the factory ship "Kyokuyo-maru" in 52°08′N, 176°47′W. This whale was a male and 48 feet in body length, which was natural on the external form of the body and the internal organs except the lower jaw (see the fig. 1).

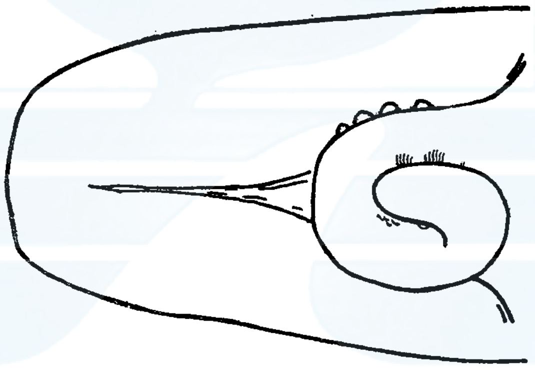

Fig. 1. Bent lower jaw like a swirl. Sperm female 36 feet, at Kushiro in Hokkaido, 16 September 1957. (Drawn by Mr. Heihachiro Kawamura)

2. On the 16th of September, 1957, a sperm whale captured in 42°48′5″N, 147°10′E was treated at the Kyokuyo Hogei Co. Ltd. at Kushiro in Hokkaido. The whale was a female and 36 feet in body length. It was intensely bent like a swirl as shown in plate I. The whale was deformed only the lower jaw as the foregoing.

3. On the 10th of November, 1957, a whale - a male and 37 feet in body length - bent to the left, captured in the whaling ground off Kinkazan was treated at the Kinkai Hogei Co. Ltd. at Ayukawa in Miyagi Prefecture. In the deformed lower jaw, *Conchoderma* sp. heavily grew (see the fig. 2 in plate I).

4. On the 10th of December, 1956, a whale whose lower jaw bent was captured by the "Nisshin-maru" expedition in 60°06′S, 126°14′W (see the fig. 3 in plate I).

It was a male and 44 feet in body length. The whale's lower jaw bent to the right and it also was natural except the lower jaw. Teeth developed completely in external observation, but the extreme point of teeth of the bent part was sharper than of the unbent part.

On the exposed teeth, the interval of the left line was longer than the right one. As for the form of alveolus of the bent part, in general, that of the left line was nearly an ellipse and that of the right line was nearly a circle. Especially, the form of alveolus in the vicinity of the extreme point of the bent part was a longer ellipse.

Then, at the below side of the bent part, the bone of the left side was covered by the right side one, and the left and right bones suited at each other.

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EXPLANATION OF PLATE

Fig. 1. Deformed lower jaw. Sperm male 48 feet, in the northern Pacific, 22 March 1956. (Photo. by Mr. Heihachiro Kawamura)

Fig. 2. Deformed lower jaw. Sperm male 37 feet, at Ayukawa in Miyagi Pref. 10 November 1957. (Photo. by Nobunori Kimura)

Fig. 3. Deformed lower jaw. Sperm male 44 feet, in the Antarctic waters, 10 December 1956. (Photo by Mr. Yukio Abe)

NOTE ON EMBRYO OF BAIRD'S BEAKED WHALE

HIDEO OMURA

On 5th August 1957 a Baird's Beaked Whale, *Berardius bairdii*, was treated at Otohama landstation in Chiba Prefecture, attached to the Tokai Gyogyo K.K. I had fortunately been there on a few days visit. This whale was a female of 1,076 cm long. It contained a functional corpus luteum in one of the ovaries, though each of the uterine cornua showed no enlargement. I cut open the cornu longitudinally and obtained a embryo shown in figure 1. The length of this embryo is 12mm from head to caudal flexure, and measured in straight. The tail flukes are not developed, the tail being tapered. The hind limb protrusion is not observed.

According to Omura, Fujino & Kimura (1955) the pairing of the Baird's beaked whale is taken place in winter, and the majority in February. This embryo, therefore, shows an exceptional pairing taken place in summer.

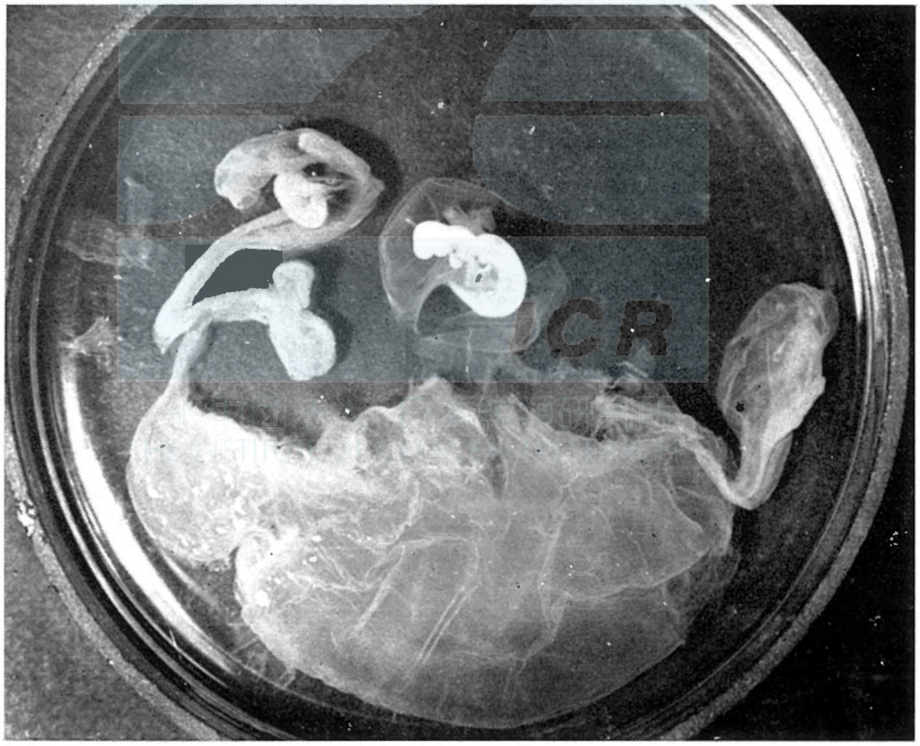

Fig. 1. Embryo of Baird's beaked whale. 12 mm long.
(Photo by K. Fujino)

Recently a photograph shown in figure 2 was kindly forwarded me from Prof. I. Kubo of the Tokyo University of Fisheries. According to the discription attached to this picture, this is a fetus of Baird's beaked whale, taken on 21st August 1927 at Tateyama-machi, a nearby town of the Otohama landstation. Body length of this fetus is recorded as 8 shaku (242 cm), and it concides well with the growth curve given by the above cited authors.

Fig. 2. Fetus of Baird's beaked whale. 242 cm long.

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STUDIES OF THE RELATION BETWEEN THE WHALING GROUNDS AND THE HYDROGRAPHIC CONDITIONS

III. THE AVERAGED CONDITIONS OF THE WHALING GROUNDS AND THEIR TRENDS OF VARIATION DURING 1946∼55

MICHITAKA UDA AND NOBORU SUZUKI*

1. *Maps of Whaling Grounds.*

Recently we have plotted the maps of yearly whaling grounds in the adjacent waters of Japan during the late ten years (1946∼'55) and its accumulated or averaged map of whale catch for each rectangle of 1° of longitude and latitude as shown in Figs. 2 and 3.

They indicate us the whaling grounds in the Tohoku Sea-region (North-Eastern Sea-region off Japan) lying along the *polar frontal-zone* in the north pacific, and particularly having two favourable core-grounds α, β in coincidence with the tops of the coastal Oyasiwo cold current and of the off-shore Oyasiwo cold current, respectively.

2. *Zonal and Meridional Trends of Distribution of Whale Catch.*

Over the area (35°–45°*N.*, 140°–150°*E.*) we have plotted the yearly curves of zonally summed (for each latitude φ) whale catch (N_φ) and meridionally summed (for each longitude λ) whale catch (N_λ) for each species (Sperm-Whale, Sei-Whale and Fin-Whale) during the above 10 years, as shown in Figs. 4, 5, 6 and 7.

From them we can easily find the trends of northerly shift and easterly offing extension of whaling grounds during the years, especially the remarkable variations of the distributions in the years of 1950∼'55 compared to those of 1946∼'49.

(1) In the case of Sperm-Whale, (Fig. 4) N_φ during 1946∼'49 showing double max. of I. 37°–38°*N.* and II. 42°–43°*N* changed to N_φ during 1950∼'55 showing almost single max. of II. i.e. the northern shift of whaling grounds corresponding probably to the prosperity of the offing north-going warm current.

Moreover N_λ during 1946∼'49 limited to 141°∼148°*E.* extended 142°∼150°*E*, in the years 1950∼'55, having its offing principal max. on 147°∼148°*E* and coastal sub-max. of 142°∼144°*E.*

The rate of easterly extension is about 2° longitude during 5–8 years i.e. from 145°–146°*E* in 1947∼'48 to 147°∼'148°*E* in 1952∼'55.

(2) In the case of Sei-Whale (Fig. 5, 6), N_φ-curve during 1946∼'49 showing double max. I. 37°–39°*N.*, II. 42°–43°*N* gradually changed to the

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* Tokyo University of Fisheries.

single max. pattern during 1950~'55, showing the principal II. max, which indicates clearly the trend of northern shift of Sei-Whale grounds as before (1). Similarly N_λ-curve represents the tendency of easterly offing extension of grounds from the max. of 141°–147*E*. during 1946~'49 to the max of 145°–149°*E* during 1950~'55.

(3) In the case of Fin-Whale (Fig. 7) N_φ-curve showing the principal max. I (40°–43°*N*.) and secondary southern max. II (37°–39*N*.) during 1946~'49 changed to the pattern of I max. and new northern max. III (44°–45°*N*.) instead of the vanished max. II, which shows the northern shift of the whaling grounds.

N_λ-curve having the coastal max. of 141°–144°*E* and offshore max. of 145°–149°*E*, except the general offing tendency, indicate the concentrated Fin-Whale grounds near the frontal zone of the prevailing Tugaru Warm Current lying at *NE* off Hatinoe during the period of 1951~'55.

Inspecting those curves of $N(\lambda, \varphi)$, we can remark the seasonal trends of the whaling grounds (of Sperm-Whale and Fin-Whale) i.e. in the beginning (Apr., May) and end (Nov., Dec.) periods lying comparatively near the coast and during prosperous whaling season (from June to October) proceeding to the easterly offing and moreover during June-Sept. the center of gravity of whaling grounds proceeding to north and from Oct. coming down to south generally.

3. *The Variation Pattern of the Whaling Ground during the Former and Latter 5 Years of 1946~'55,*

After the World War II we have obtained 10 years data for whaling grounds now dividing them into the former-half sum (1946~'50)N_A and latter-half sum (1951~'55)N_B, we compared to each other and studied the variation during the periods.

(1) First as shown in Figs. 8, 9, 10 and 11, the time variation curves of each whale catch (sperm, fin-blue, and sei-whales) indicate generally the earlier coming of whaling catch N_B compared to N_A, in particular in spring season (about May).

Figs. 12, 13 and 14, show the distribution of whale catch for each whaling base station, which tell us the northern increase (such as off Kusiro in the waters of Hokkaido) compared to the remarkable southern decline (e.g. off Ayukawa, Kamaisi etc.). Those variations of whale catch are commonly remarkable after the year of 1950, which may correspond to the hydrographic change due to the prevailing north-going warm current.

(2) In order to clear up the circumstances we have constructed the difference maps of whale catch ($\Delta N = N_B - N_A$)

i.e. $\Delta N > 0_{(+)}$ means $N_B > N_A$·····the increase of catch
$\Delta N = 0$ 〃 $N_B = N_A$·····no change
$\Delta N < 0_{(-)}$ 〃 $N_B < N_A$·····the decline of catch

as shown in Figs. 15, 16, 17 and 18, which indicate commonly the northerly offing (*SE* far off Kusiro and east far off Sanriku) increase against to the coastal and southerly decline (*SE* off Kinkazan), except the peculiar increase of fin-whale catch along the frontal zone of the Tugaru Warm Current.

4. *Probable Causes of the Variation*

The whaling intensity in the neighbouring waters of Japan increased remarkably in recent years as shown in Fig. 19, i.e. the tendencies of increasing ship-tonnage, ship-speed and the summed operational days may take warning to the over-fishing, inspite of the maintained total yields (see Fig. 20). The index numbers shown in the fig. 21 are referred to the standard of 1947. The coastal intense whaling and its disturbance of whale migration may contribute to the coastal decline and the offing exploration of the new whaling grounds. However, we should note the influence of hydrographical fluctuation of the growing warm current during the years from 1950 to 1955 which reflected to the increase of bluefin tuna and skipjack fisheries etc.

Both factors are important to the consideration of future prediction and conservation in addition to the efficient exploration of the whaling industry in Japan.

5. *The Optimum Water Temperature of Whaling Grounds.*

We have collected the surface water temperature records in the whaling grounds and compiled statistically in Figs. 1 and 21 and Table 1. Shoals of whales are found in the oceanic frontal zone where they can feed themselves on the plenty of food-animals and not so much influenced by water temperature.

Accordingly they swim in the waters of wide range for water temperature i.e. eurytherm in general. However, we can note some favourable temperature or optimum temperature for each whale species, as for example frequently Sei-Whale fonds of warmer water of about 14°-24°C (18°-24°C), and Sperm-whale in intermediate water of 12°-24°C (frequently 16°-22°C) Fin-whale in colder water of 10°-20°C (frequently 14°-18°C) seen.

In general in the North-Eastern Sea off Japan in winter (Jan.-Mar.) 8°-16°C, in spring (Apr.-June) 8°-20°C, in summer (July-Sept.) 14°-25°C, and in autumn (Oct.-Dec.) 10°-20°C are the favourable temperature to search the whaling grounds along oceanic frontal zone.

Concluding this paper we wish to state our sincere thanks to the aids of Miss Yukiko Ohtsuka for the computation and map construction during our researches.

TABLE 1. OPTIMAMUM WATER TEMPERATURE OF TOHOKU SEA-REGION WHALING GROUNDS. (1946∼'55 AVERAGED)

Month, Decade	(Off Kusiro North)	Off Kinkazan (South)	Remarks
Jan. Early	—	Sp. 12°—16°C	Sp (8°—11°C)
〃 Middle	—	〃 8°—16°C	
〃 Late	—	〃 Ca 12°C	
Feb. Early	—	〃 10°—14°C	
〃 Middle	—	〃 12°—15°C	→ Off Kumano Nada Sp. 14°—15°C 〃 〃 17°—18° 〃 〃 15°—18°
〃 Late	—	〃 10°—15°C	
Mar. Early	—	〃 5°—13°C	
〃 Middle	—	〃 8°—12°C	
〃 Late	—	〃 12°—13°C	
Apr. Early	Sp. 2°—6°C	〃 7°—16°C	
〃 Middle	〃 2°—8°C	〃 8°—16°C	Whaling grounds moving to North. Off Kusiro (2°—16°C) Off Kiukazan (7°—22°C)
〃 Late	—	〃 4°—16°C	
May Early	〃 2°—8°C	〃 10°—18°C	
〃 Middle	〃 4°—12°C	〃 14°—20°C	
〃 Late	〃 6°—12°C	〃 16°—20°C	
June Early	〃 4°—10°C	〃 14°—20°C	
〃 Middle	〃 8°—16°C	〃 16°—22°C	
〃 Late	〃 8°—16°C	〃 16°—22°C	
July Early	〃 8°—18°C	〃 20°—22°C	Center of Gravity of Whaling grounds lying off Kusiro. (8°—22°C) off Kinkazan (18°—26°C)
〃 Middle	〃 12°—14°C	〃 18°—22°C	
〃 Late	〃 14°—22°C	〃 22°—26°C	
Aug. Early	〃 15°—22°C	〃 22°—26°C	
〃 Middle	〃 16°—22°C	〃 22°—26°C	
〃 Late	〃 13°—20°C	〃 22°—25°C	
Sept. Early	〃 15°—22°C	〃 22°—25°C	
〃 Middle	〃 12°—20°C	〃 22°—24°C	
〃 Late	〃 10°—18°C	〃 20°—25°C	
Oct. Early	〃 10°—16°C	〃 18°—22°C	
〃 Middle	〃 10°—16°C	〃 18°—22°C	Whaline grounds moving to South, its centre of gravity shifted to the offing of Kinkazan. off Kusiro (4°—16°C) off Kinkazan 12°—22°C
〃 Late	〃 10°—15°C	〃 18°—22°C	
Nov. Early	〃 8°—13°C	〃 18°—22°C	
〃 Middle	〃 6°—12°C	〃 14°—22°C	
〃 Late	〃 12°—14°C	〃 14°—20°C	
Dec. Early	〃 8°—12°C	〃 14°—19°C	
〃 Middle	Ca 4°C	〃 14°—20°C	
〃 Late	—	〃 12°—16°C	

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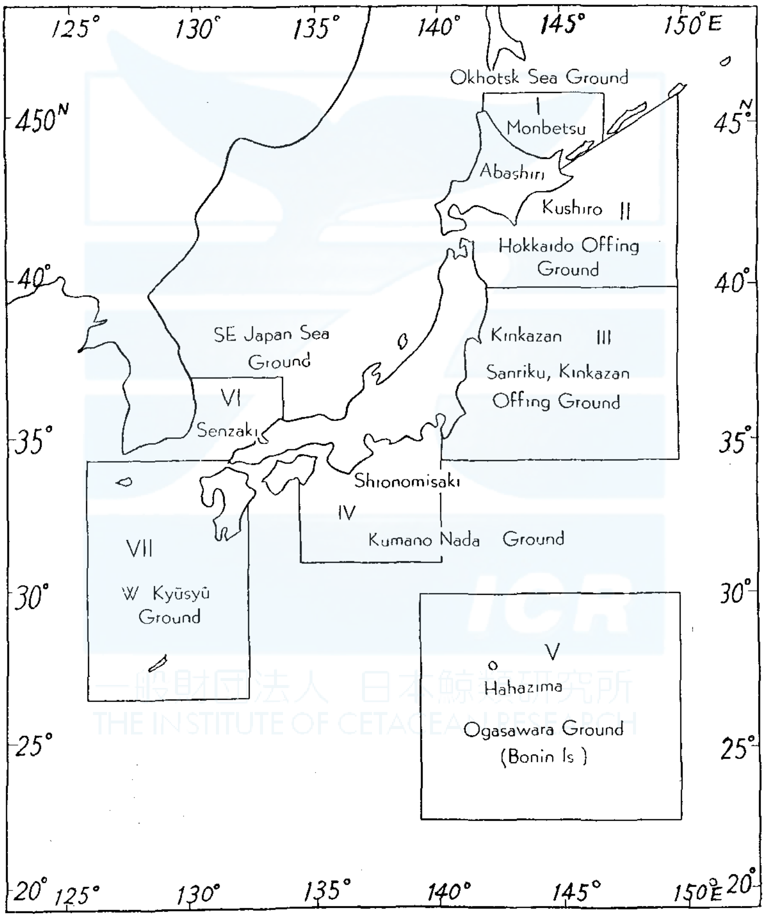


Fig- 1. Sea region of whaling grounds.

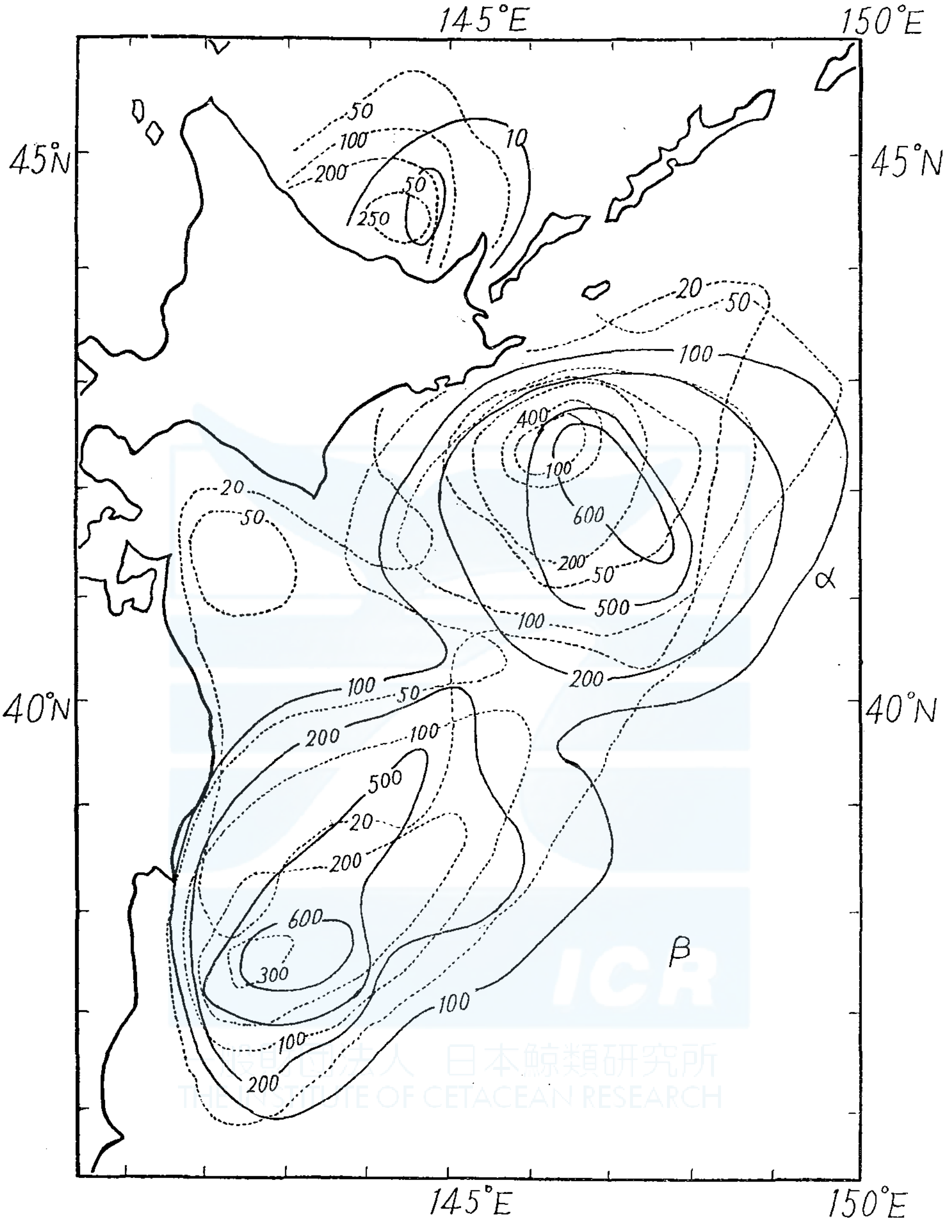


Fig. 2. Whaling grounds in the 10 years of 1946–55 Solid line: sperm whales. Broken line fine whales. Dotted line sei whales

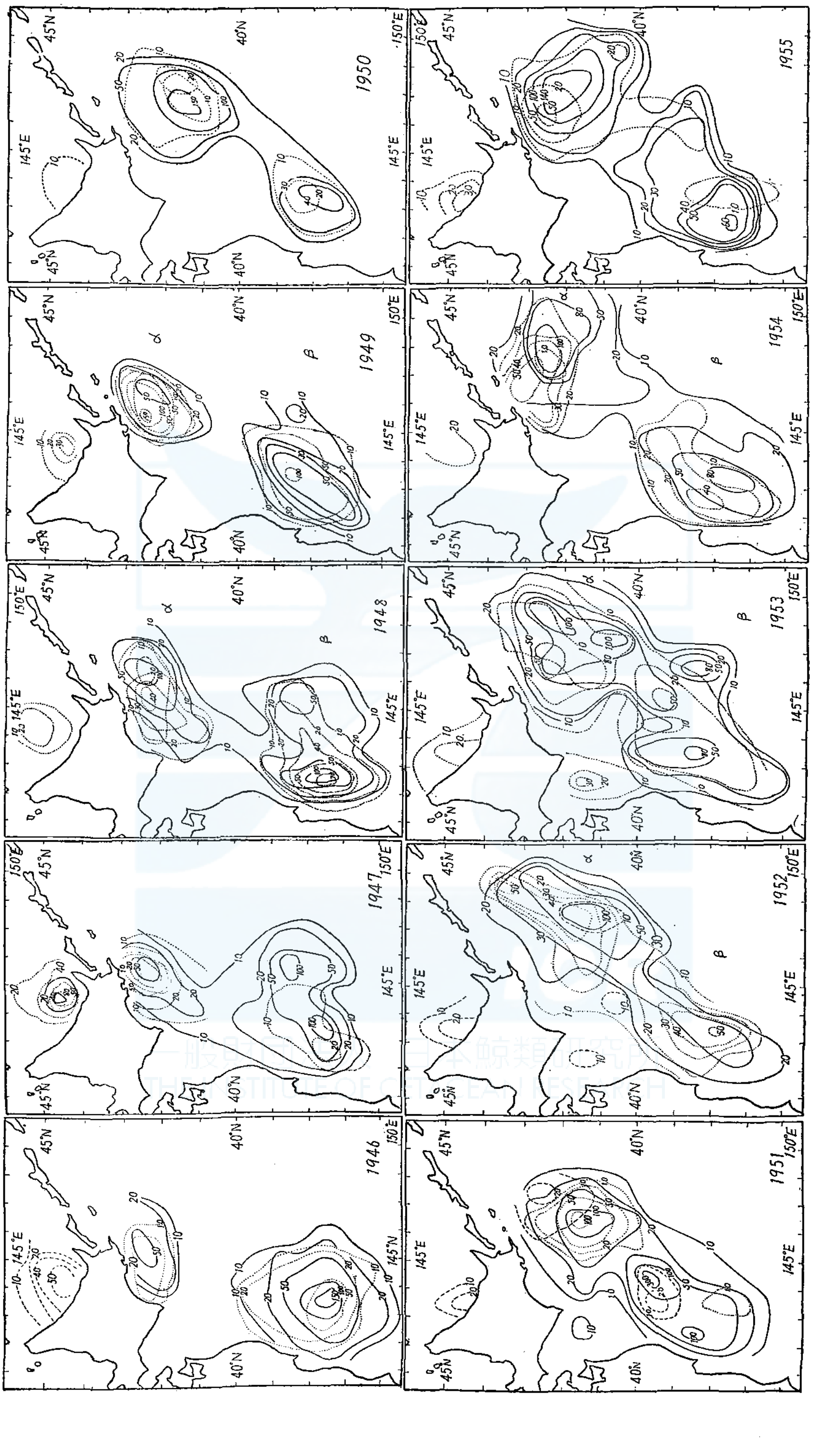


Fig. 3. Whaling grounds from 1946 to 1955. Solid line: sperm whales. Broken line: fin whales Dotted line: sei whales.

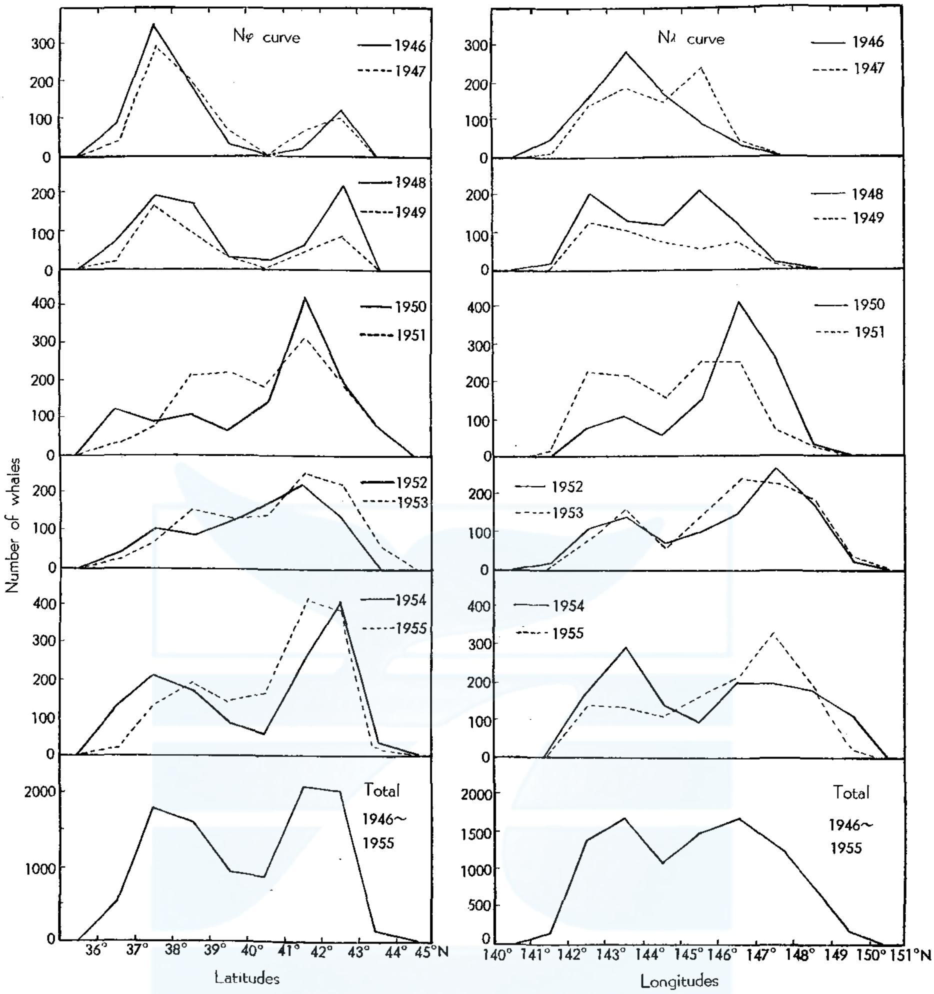


Fig. 4. *Nφ* and *Nλ* curves of sperm whales from 1946 to 55

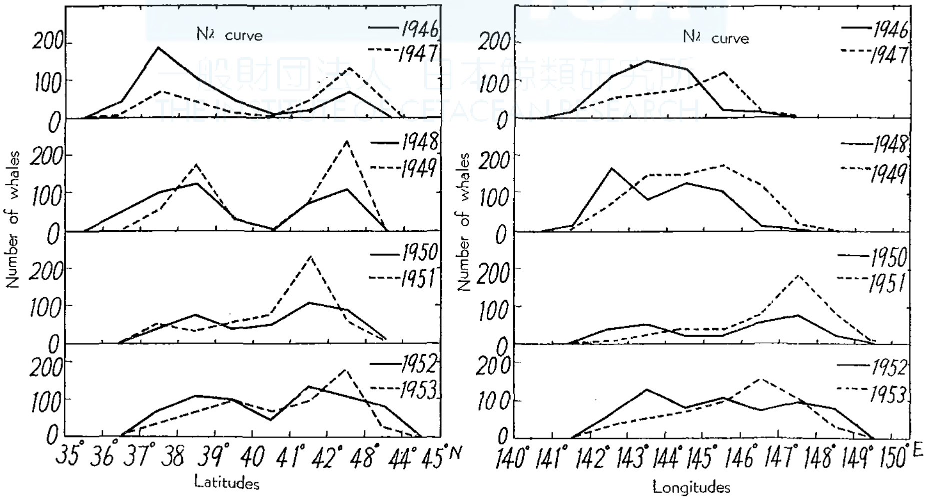


Fig. 5. *Nφ* and *Nλ* curves of sei whales from 1946~'53

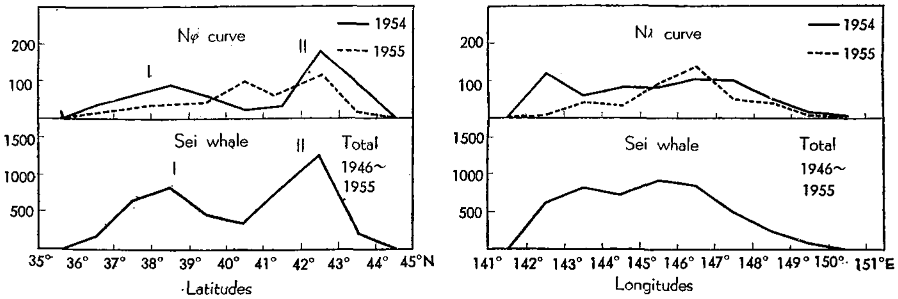


Fig. 6. *Nφ* curves and *Nλ* curves of sei whales from 1954 to '55.

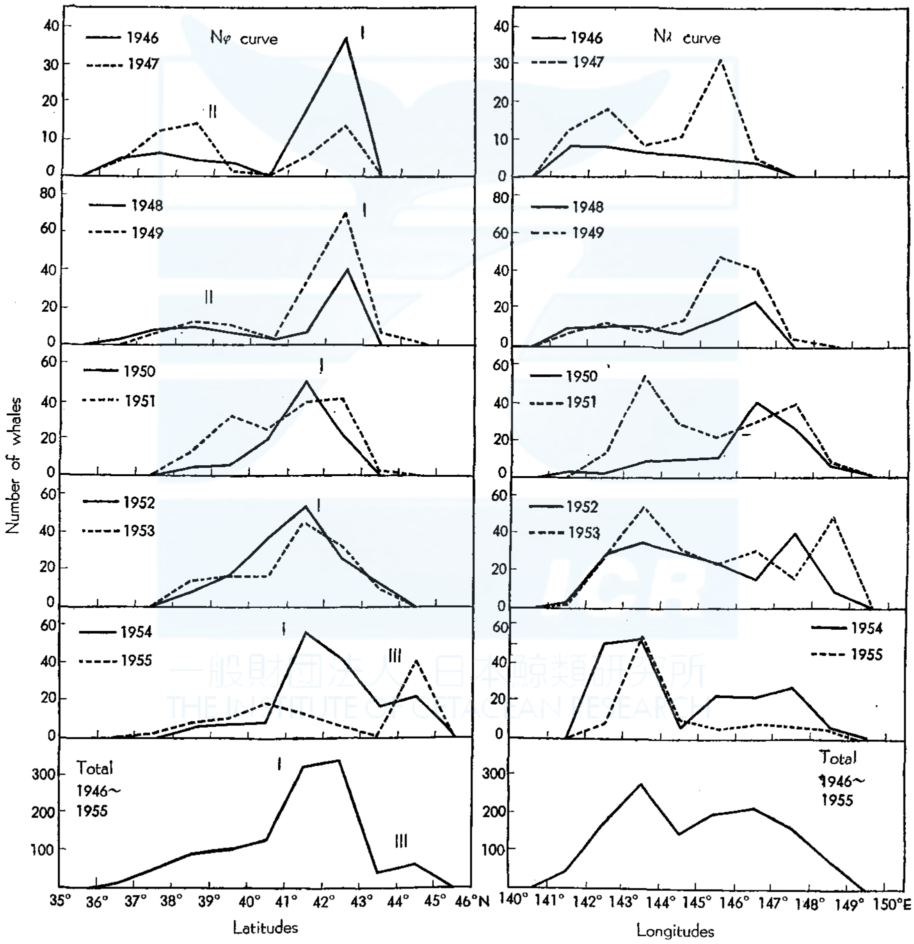


Fig. 7. *Nφ* curves and *Nλ* curves of fin whales from 1946 to '55.

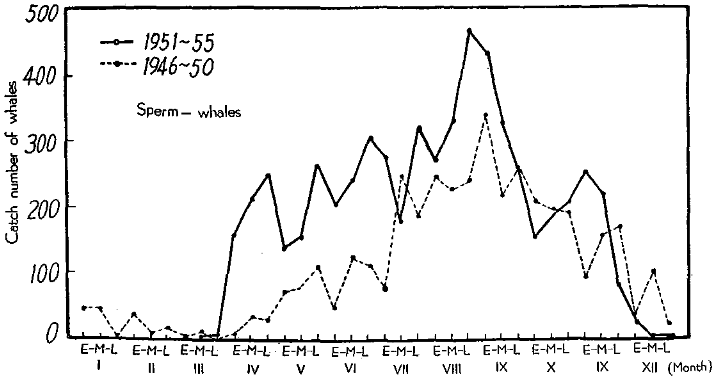


Fig. 8. Number of canght sperm whales in each month.

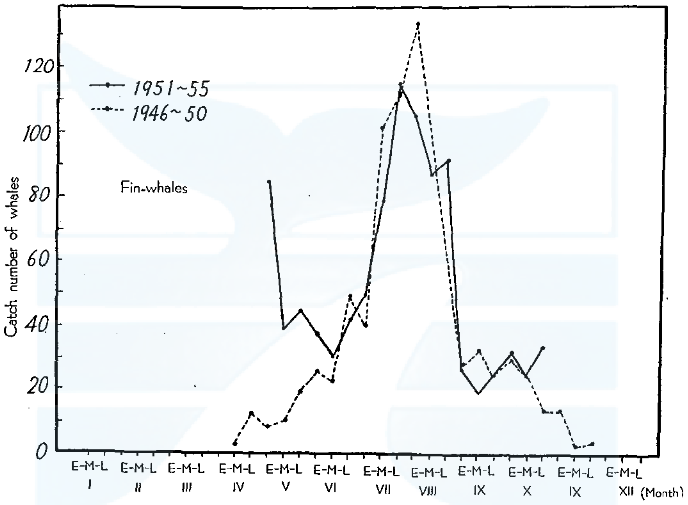


Fig. 9. Number of canght fin whales in each month.
E....Early M....Middle L....Late

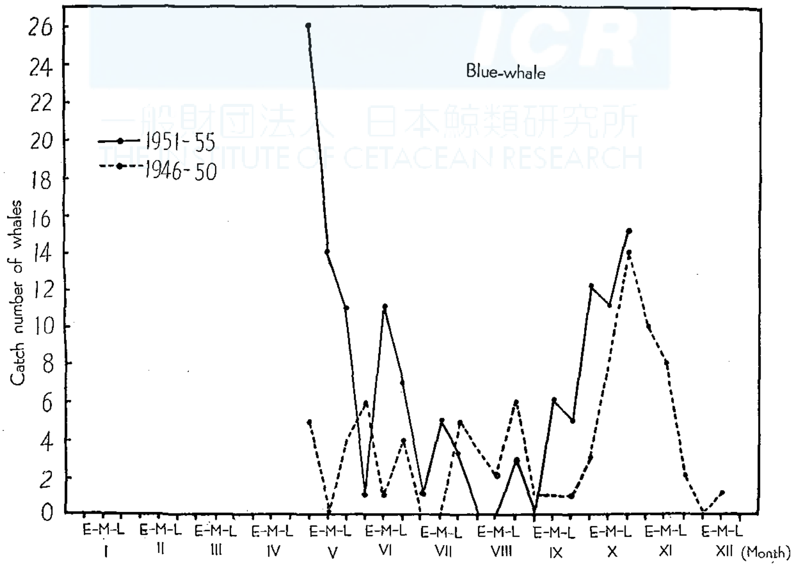


Fig. 10. Number of caught blue whales in each month.

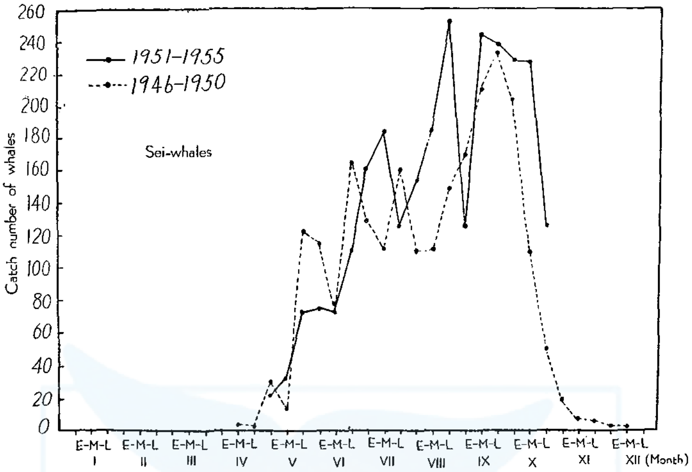


Fig. 11. Number of caught sei whales in each month.

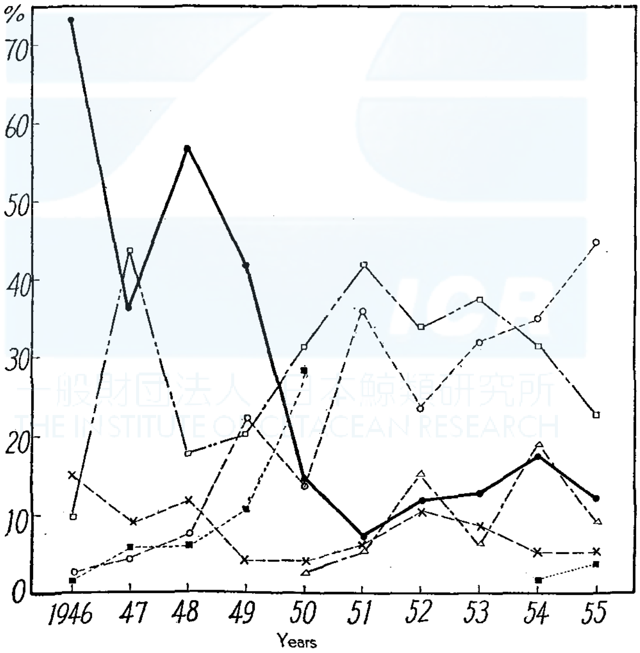


Fig. 12. Number of caught sei whales in each month.
E...Early M...Middle L...Late

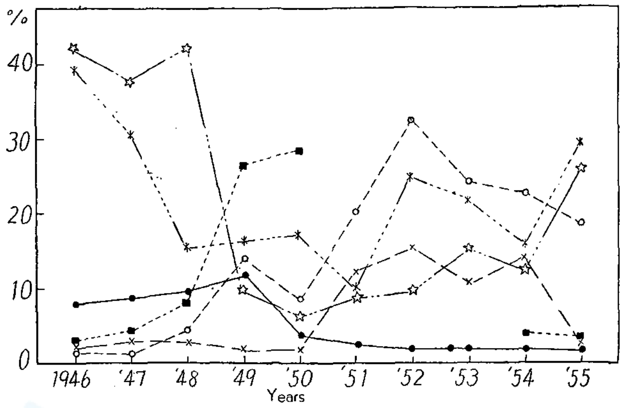


Fig. 13. Catch constitution of each land stations fin whales.

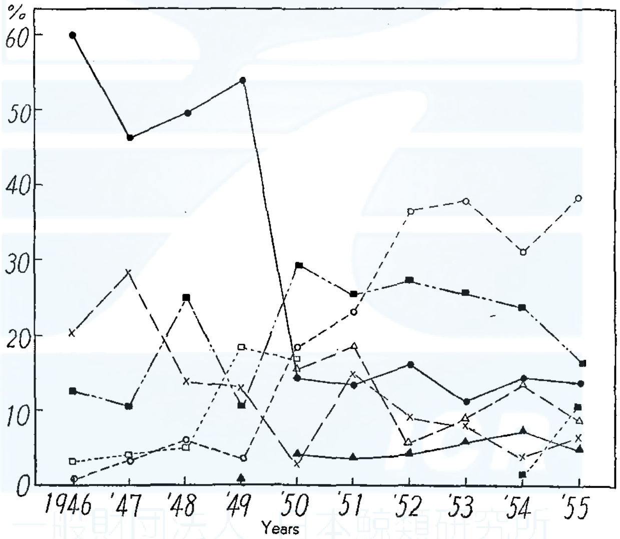


Fig. 14. Catch constitution of each land stations sperm whales.

A ----○---- ····Kushiro.
B ——●—— ····Ayukawa.
C —·—□—·— ····Atsukeshi.
D ·······■······· ····Kiritatsupu.
E ——×—— ····Kamaisi.
F ——△—— ····Onagawa.
G ——▲—— ····Oosawa.

} From the offing of sanriku to the offing of Hokkaido.

H —·—✳—·— ····Abashiri.
I —·—☆—·— ····Monbetsu.

} Okhotsk sea region.

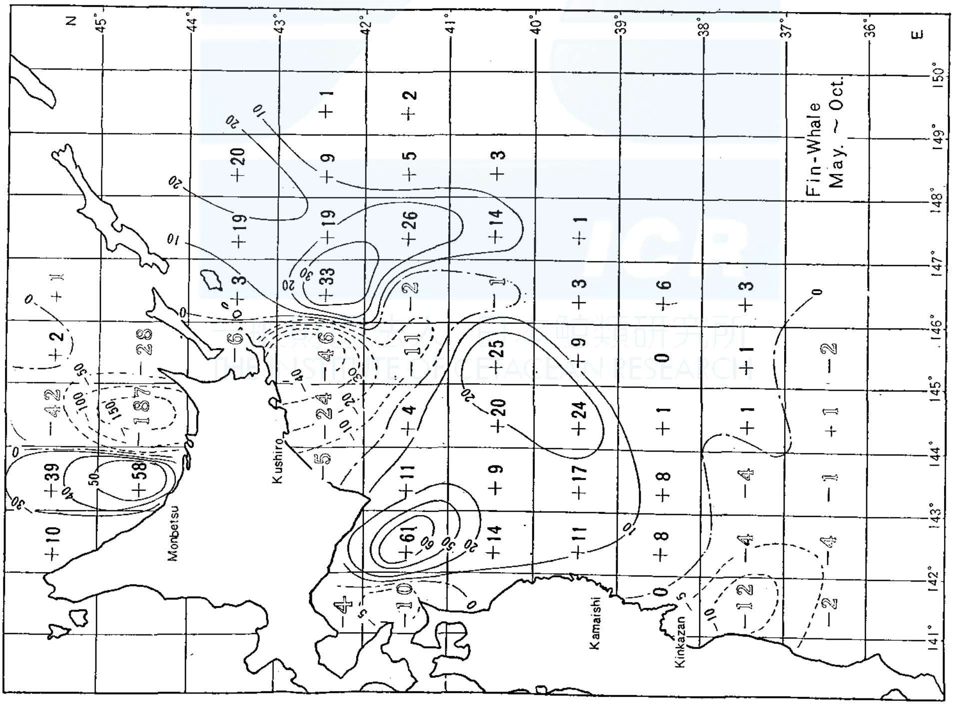
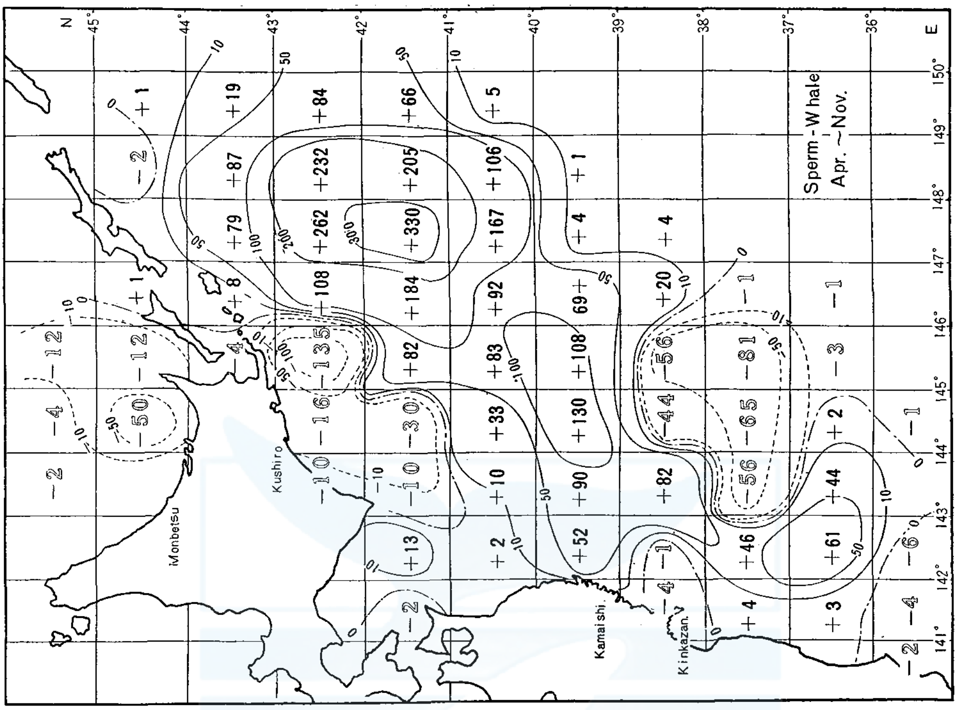


Fig. 15



Fg. 16

Figs. 15-16. The variation map of whale catch during the former and latter 5 years of 1946-45.

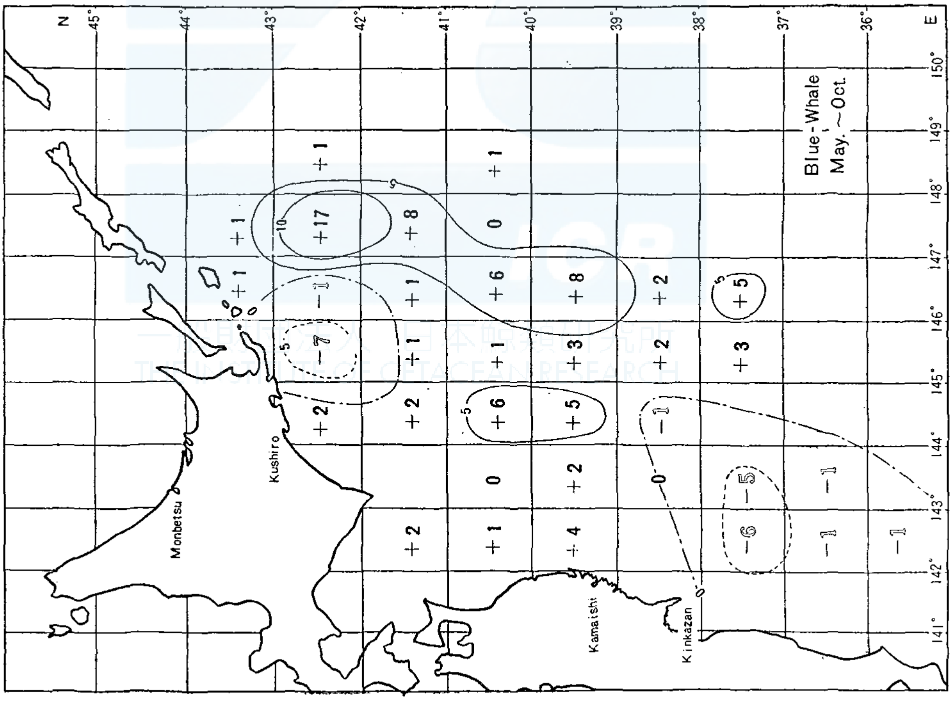


Fig. 17.

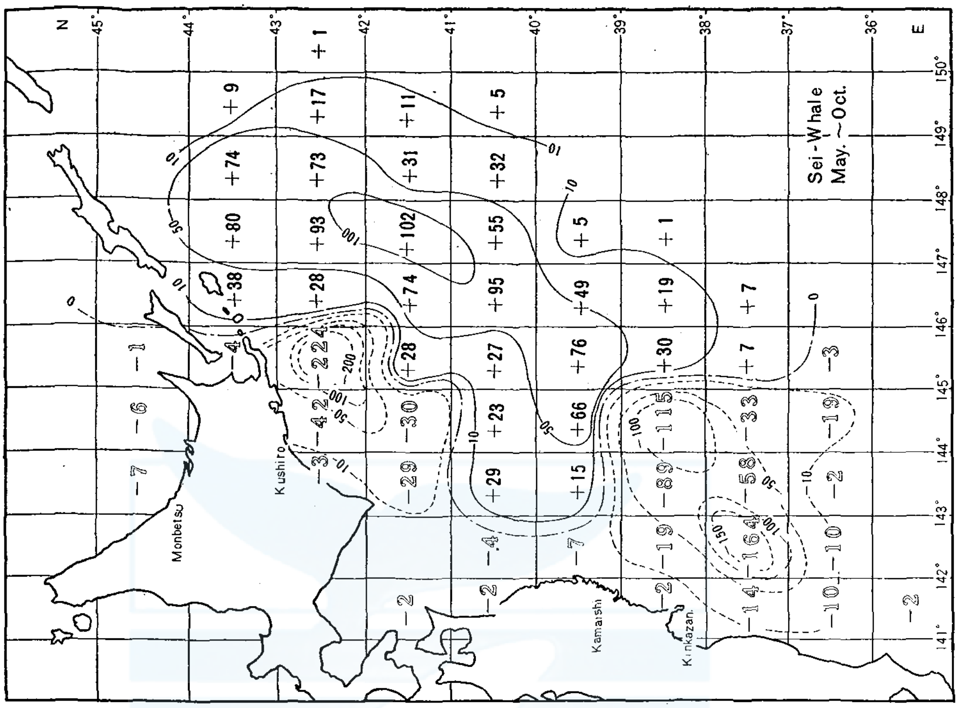


Fig. 18.

Figs. 17–18. The variation map of whale catch during the former and latter 5 years of 1946–45.

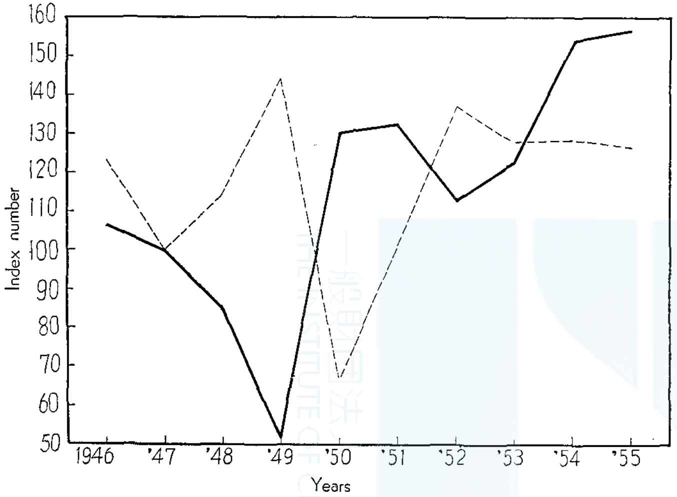


Fig. 19. The trends of waling effort referred to that in the year of 1947.

—— Sperm whale - - - - - Baleen whale

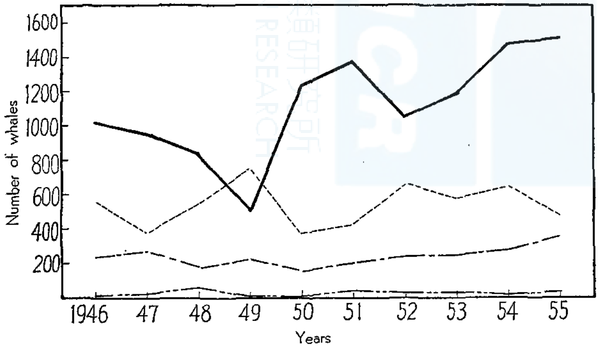


Fig. 20. Number of cautght whales in each year.

—— Sperm whale - - - - - Sei whale

—·—·— Fin whale —··—·· Blue whale

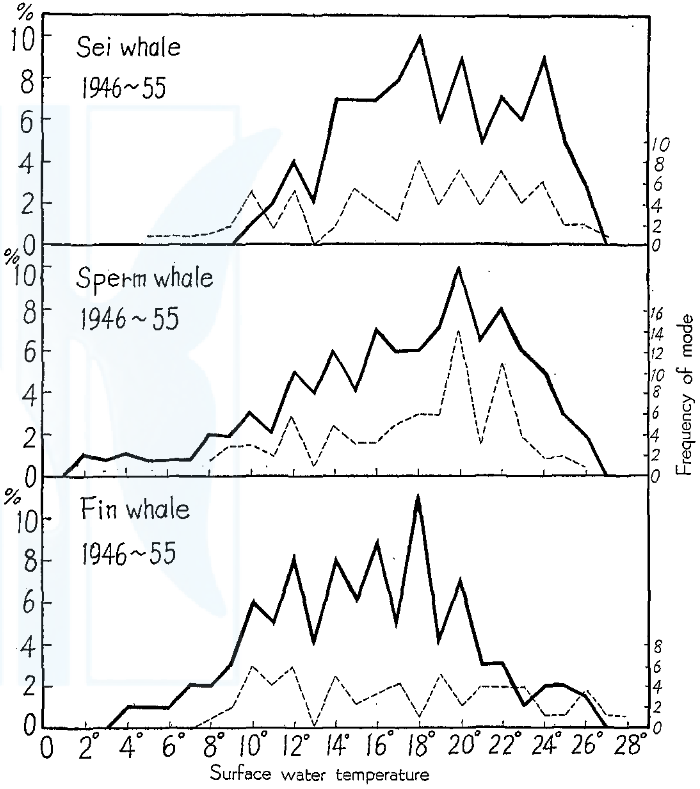


Fig. 21. Number of whales in each year.

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OBSERVATIONS ON THE SPINAL CORD OF THE RIGHT WHALE

YASUSHI SEKI*

The spinal cord of a female Eubalaena glacialis captured on May 23rd, 1956, off Kinkazan, was investigated morphologically. The body length measured 11.65 m (38 feet 4 inches). The spinal cord was removed two days after the capture (May 25th) and fixed in formalin. After measuring, photographing and macroscopical observations, it was cut in each segment corresponding to the spinal nerve roots. For microscopical studies they were refixed then in Müller's solution for 2 weeks in 37°C, imbedded into celloidin, sectioned transversely or longitudinally and stained with Pal-carmine method, hematoxylin-cell-staining method and Masson-Goldner's method**.

RESULTS

GROSS ANATOMY OF THE SPINAL CORD, THE SPINAL NERVE ROOTS AND THE MENINGES

Following measurements were done outside of the vertebral canal, so that the spinal cord might be somewhat contracted from the natural state of the cord. After Hosokawa, this contraction rate is 2 to 3 per cent of the total length of the spinal cord.

The total length of the spinal cord		ca. 174 cm,
Cervical cord	(consisting of 8 segments)	ca. 23 cm,
Thoracic cord	(,, 14 segments)	ca. 105 cm,
Lumbal cord	(,, 10 segments)	ca. 36 cm,
Coccygeal cord	(,, 8 segments)	ca. 10 cm.

It is remarkable that the spinal cord is very short (174 cm) for the body length (11.65 m). The cord length ratio for the body length is 14.9%, while that of the matured fin-whale is said 24.3% (Hosokawa). There are in all 40 segments in the spinal cord, though the total number of the vertebral bones of the Eubalaena amounts to 56 or 57. Of course, the spareness in number of the segments in the cord is caused by shortening of the coccygeal cord (8 segments in the coccygeal cord

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** Many thanks are due to Miss T. Koide, Miss T. Ogisaka and Miss M. Suda, technicians in the Institute for Brain Research, for their great efforts to manufact the microscopical preparates.

against 25 or 26 of the coccygeal vertebrae). None of the spinal nerve root is recognized below Co. 8. The caudal end of the conus medullaris is seen ca. 1 cm below the caudal border of the radix of Co. 8. The lower border of the dural sack is found at nearly the same level with the caudal end of the conus medullaris; thus the filum terminale internum is difficult to see. The filum terminale externum i.e. the portion of the filum mantled with the dura mater, runs farther caudalward.

At most levels of the spinal cord, the points where the dura mater is penetrated by the spinal nerve roots are not so far distant from the places where the fila of the roots are connected with the cord. The cauda equina can not be recognized inside the dura mater. The internal lamina of the dura is markedly thick (3 mm in the cervical roots portion, 2 to 3 mm in the thoraco-lumbal roots portion and 1.5 to 2 mm in the coccygeal roots portion), and outside this membrane, there is a very wide epidural space filled with extremely rich blood vessels and fatty tissue. After penetration of the dura, the radices descend side by side making *epidural* cauda equina, and reach the corresponding intervertebral foramina. There the radices of the lower thoracic, the lumbal and the coccygeal nerve roots have to run in the epidural space for very long distance (for several meters). In the subarachnoidal space i.e. between the arachnoid and the pia mater, many blood vessels are seen, too. They are chiefly made of arterial network, with fine and dense arachnoid trabeculae, surrounding the surface of the spinal cord. In Fig. 1, an

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EXPLANATION OF FIG. 1

1. Pons Varoli, Medulla oblongata, C. 1, 2 and 3.
2. from C. 4 to Th. 2.
3. Th. 3.
4. Th. 4.
5. a little part of Th. 4 and uppermost part of Th. 5.
6. a little part of Th. 5 and uppermost part of Th. 6.
7. a little part of Th. 6 and upper two thirds of Th. 7.
8. lower third of Th. 7 and uppermost part of Th. 8.
9. a little part of Th. 8 and upper two thirds of Th. 9.
10. lower third of Th. 9 and upper two thirds of Th. 10.
11. lower third of Th. 10 and Th. 11.
12. The 12 and upper half of Th. 13.
13. lower half of Th. 13 and Th. 14.
14. L. 1, 2 and upper two thirds of L. 3.
15. lower third of L. 3, from L. 4 to L. 6 and upper two thirds of L. 7.
16. lower third of L. 7, from L. 8 to Co. 5 and upper half of Co. 6.
17. lower half of Co. 6, Co. 7 and 8, lower end of conus medullaris and filum terminale.

C: Cervical cord Th: Thoracic cord
L: Lumbal cord Co: Coccygeal cord

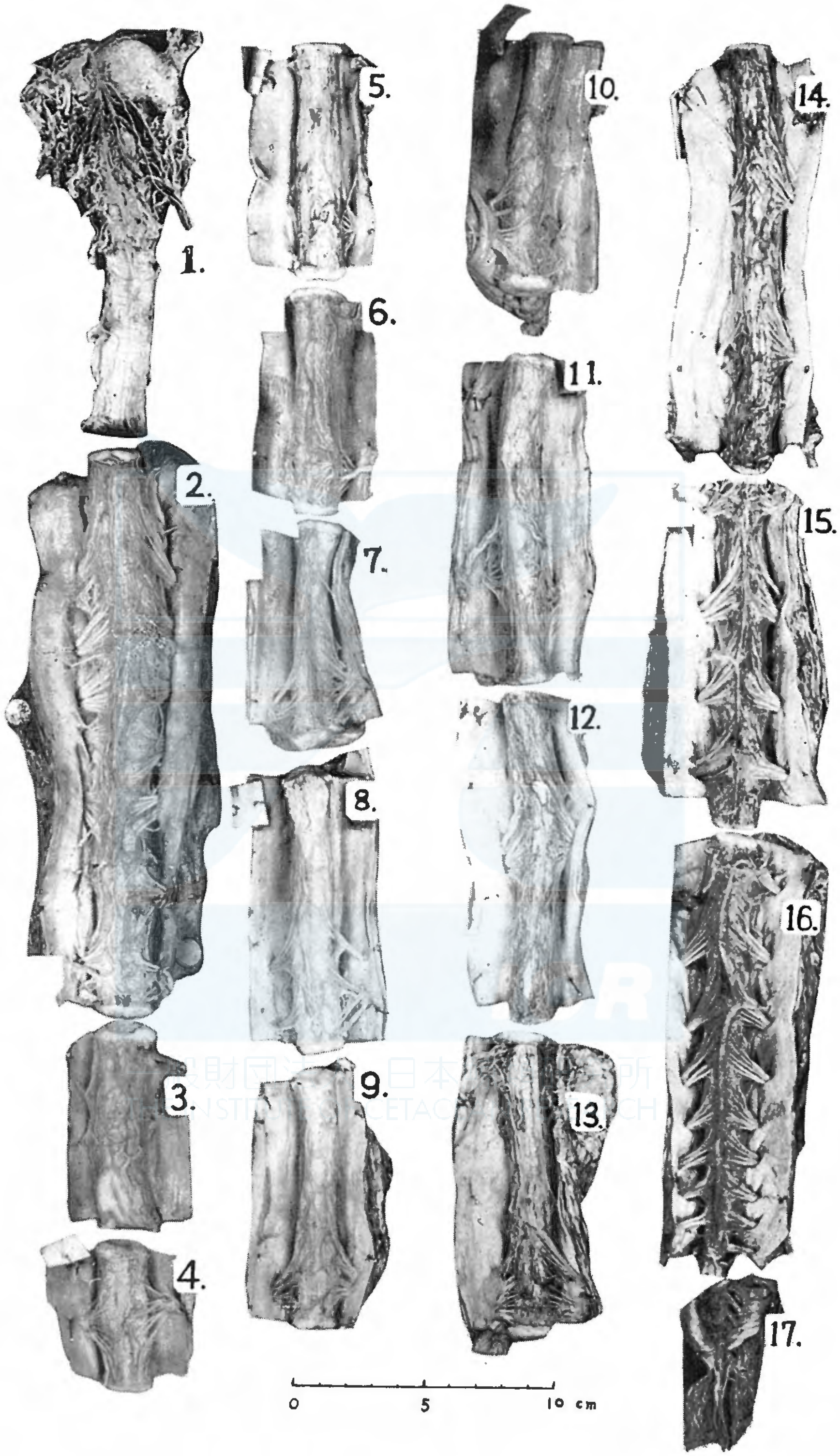

Fig. 1

external view, the cervical enlargement is clearly visible; however, the lumbal one is hardly to recognize. Table 1, showing the thickness of the spinal cord, indicates the same also.

TABLE 1. THICKNESS OF THE SPINAL CORD (diameter in mm)

	Transverse	Ventro-dorsal		Transverse	Ventro-dorsal
C 1	15.0	14 0	Th 10	13.0	13.5
4	15.0	14.0	14	12.5	12.5
6	17.0	16.0	L 3	13.5	12.0
8	17.5	14.0	7	13.0	11.0
Th 2	17.0	15.0	Co 1	12.5	10.0
5	13.0	13.0	5	8.0	7.0

DIMENSION OF THE CROSS SECTIONS OF EACH SEGMENT

In Fig. 2, our measurements on the extent of the cross section area of each segment are indicated by curves. They are acquired from the celloidin sections stained by Pal-carmine method. In the curves denoting the entire area and the white substance, the cervical enlargement is shown clearly, but the lumbal one not distinctly. In the curve presenting the gray substance, both the cervical and the lumbal enlargement are recognized moderately. It is significant that the maximum extent of the lumbal enlargement is found not in the lumbal, but in the coccygeal level, which results perhaps from the formation of the huge tail (not the flukes) of the cetacea. Guldberg (1885) described the lumbal enlargement in embryos of some Balaenopterae, Cunningham (1877) observed

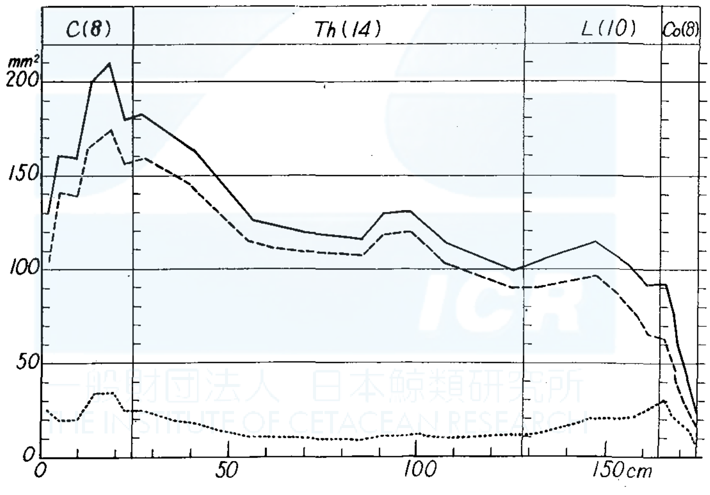

Fig. 2. Curves showing the variations in sectional area of the gray substance (····), the white substance (----) and the entire area (——) in each segment of the spinal cord.

it also in matured Phocaena, though, as a rule, the lumbal enlargement has not been definitely recognized in the cetacea. In our material an external view, the lumbal enlargement is not so clearly developed, but gray substance in the same levels are doubtless expanded.

ANTERIOR COLUMN

The anterior columns are developed well, even in the thoraic level, occupying nearly half of the total gray substance in the cross section. At the levels from cervical to upper thoracic (cervical enlargement) and from middle lumbal to upper coccygeal (lumbal enlargement) cord, the gray substance is occupied over half by the anterior column (Fig. 3—13). In the cervical enlargement the anterior columns are developed very much to the lateral direction ; on the contrary, in the lumbal enlargement the anterior columns are larger in the ventrodorsal extent than in the transverse one. It is said that the motor cells innervating the musculature of the extremities are situated in the lateral part of the anterior column, and so it seems quite natural, that they are poorly developed in the lumbal enlargement of the Eubalaena.

Most of the cells of the anterior column are deeply stained with carmine or hematoxylin, large sized and polygonal shaped ; among these large cells there are also small sized, triangle, spindle or polygonal shaped, scattered cells. Moreover, we find light coloured, somewhat roundish-polygonal or spindle shaped, large or medium sized (50 to 100 μ) cells, situating at the medial and lateral periphery and the dorsal part of the anterior column, sometimes as a few scattered cells among the deep coloured polygonal larger cells of this column. Majority of them are seen in the cervical, lower lumbal and coccygeal levels ; they are rather scanty in the thoracic and upper lumbal cord. Hatschek (1896) described chromophobe cells in the anterior column of the common dolphin (Delphinus delphis), but it is not clear that they correspond or not with the light coloured cells we found. He noted the chromophobe cells are in number over that of the chromophile cells in the lumbal cord ; but they are never so in our material. In the thoracic and upper lumbal levels, the light coloured cells are only of small amount ; on the other hand, as later mentioned, the lateral horn cells are very well developed in the same levels ; in addition, as most of these cells exist in the neighbourhood of the pars intermedia, we supposed that the cells might be associated with some autonomic function.

When we examine the cells of the anterior column in longitudinally sectioned preparates, most of their long axis are parallel with that of the spinal cord in the thoracic levels, but not always just so in the cervical or the lumbo-coccygeal levels mingling here with cells extended in oblique or transverse plane.

Is it true that the cells in such giant sized animals as the Eubalaena are larger than the cells in man? In Table 2, the sizes of the cells are indicated concerning the anterior columns of Eubalaena and man. The human cells seem somewhat smaller than the cetacean cells but not so distinctly in the cervical or thoracic level; however, in the lumbal enlargement, the cetacean cells are doubtless much larger than those of man. In man, the differences of the cell size between the cervical, the thoracic and the lumbal level are not so remarkable, while in the cetacea, the cell size in the coccygeal level is conspicuouly larger than those in the other levels. From the data as above mentioned we considered that the size of the nerve cells seems more related to the length of the nerve fibers originating from them than to the body size of the animals; in the Eubalaena the spinal nerves in the lower levels have to run for very long distance.

TABLE 2. CELL SIZE OF THE ANTERIOR COLUMN
(measurements of 100 cells in each level)

Eubalaena gracialis

	Average (μ)	Maximum (μ)	Minimum (μ)
C 6	56 × 21	69 × 46	17 × 6
Th 8	44 × 16	69 × 29	23 × 6
Co 1	94 × 36	171 × 69	40 × 11

Homo sapiens

	Average (μ)	Maximum (μ)	Minimum (μ)
C 6	46 × 16	93 × 37	17 × 11
Th 8	30 × 13	57 × 20	11 × 6
L 4	48 × 25	97 × 40	19 × 7

The anterior roots appear at a wide range of the anterior surface of the cord, extending from the anterior to the lateral funiculus. Some of them start even in the anterior median fissure (Fig 8).

POSTERIOR COLUMN

At almost all levels, the posterior columns are far less developed than the anterior columns on the same section, especially so in the middle cervical, the whole thoracic, the lower lumbal and the upper coccygeal cord. The poor development of the posterior column in the cetacea was previously described by many authors (Guldberg 1885, Hatschek 1896, Sano '09 usw.). In addition, the border of the gelatinous substance of Rolando looks not so distinct in most levels of the cord. The same results were mentioned by Hatschek (1896) in Delphinus delphis and by

Sano ('11) in Delphinus tursio (=Tursiops truncatus), and these were considered chiefly due to less developed cutaneous sensibility and lack of the hair in the whales (Kappers '36).

At C. 1, however, the posterior column is moderately large assuming nearly the same size as the anterior column at the same level. More rostrally, in the medulla oblongata, the spinal root and its nucleus of the trigeminal nerve are very well developed, and the lower extension of this nucleus reaches down to the level of C. 1 (Fig. 3, 14, 15). It is to consider that the Eubalaena has a great many sensory organs in the skin or the mucous membrane of the head portion. In fact, in our laboratory, Ogawa and Shida recently confirmed the existence of structures, which seem to be sensitive apparatuses having rich nerve endings, in the lips, tongue, palate and basis of the mouth cavity of the Eubalaena. The presence of these structures must be related to the marked development of the trigeminal sensory nuclei in the central nervous system.

The postero-marginal cells are developed well in the cervical or especially in the lumbo-coccygeal, but less in the thoracic levels in the zona spongiosa of the posterior column. Their size are 15 to 50 μ in the transverse, 15 to 120 μ in the longitudinal direction. Namely, most of their long axis are directed longitudinally.

The nucleus proprius of the posterior column is chiefly composed of small sized (5 to 20 μ) spindle shaped cells and medium sized (10 to 40 μ) polygonal or somewhat rounded cells, and the long axis of the former are directed longitudinally and measured up to 30 μ. In the lumbo-coccygeal levels they contain sometimes the typical cells of the Clarke's column.

It is peculiar that the posterior columns of both sides come to adhere on the midline in the lower half of the thoracic and the coccygeal cord. (Fig. 8, 13).

CLARKE'S COLUMN

The Clarke's columns of the Eubalaena are well developed in the thoraco-lumbal levels, but it is not easy to determine their upper and lower limits, as in the cord more cranial or caudal than the portion above mentioned, there are also a few cells at the same position. It is especially so in the upper cervical cord, where the cells in question represent possibly the cervical nucleus of Stilling ; on the other hand, some of quite the same type of Clarke's cells are seen not only in the lowest lumbal levels but also in the whole coccygeal cord. The caudal extension of the Clarke's column is well known in the spider monkey (Chang '51), and we meet here with the resembling structure in the Eubalaena ; it deserves attention, that both animals have very well developed tails.

At the levels from lowest thoracic to middle lumbal cord, the Clarke's column shows its maximum development, and it is composed of some cell groups, involving many large, roundish nerve cells (20 to 90 μ). Most of these cells are directed longitudinally and their long axis are measured up to 180 μ, but some cells appear round still in longitudinal sections. Our noteworthy finding is the fusion of the dorsal cell groups of both sides on the midline, but the ventral cell groups are separated from the contralateral ones at the same levels (Fig. 8, 9, 10). Dexler ('11) in Halicore dugong, Hatschek (1896) and Schacherl ('02) in Delphinus delphis, mentioned also the fusion of the Clarke's column on the midline.

PARS INTERMEDIA

In comparison with the spinal cord of other mammals, the territory occupied by the intermediate zone is moderately wide in the Eubalaena and there we see a great many nerve cells and a large amount of nerve fibers. Because of the well developed gray commissure, in most levels of the cord, the dorsal funiculus are far distant from the anterior funiculus. These findings upon the pars intermedia, suggest certain functional (especially of autonomic nature) differences of this part between the cetacea and the other animals.

On the transverse sections, the anterior white commissure in the thoracic levels are hardly recognized, but on the longitudinally sectioned preparates, many fibers are crossed in the thoracic cord making small angles (5° to 10°) to the median plane. On the other hand, in the cervical or lumbo-coccygeal levels, the anterior commissural fibers are clearly seen on the transverse sections. Hatschek (1896) noted also the characteristic anterior white commissure extended in the sagittal direction in the dolphin.

The nucleus of the lateral column is recognized in the levels from D. 1 to L. 8, showing the group of middle sized (20 to 60 μ), roundish or spindle shaped cells in the light coloured gray substance at the lateral border of the intermediate zone. In most heights, this column makes the lateral horn protruding into the lateral funiculus (Fig. 7, 8, 9, 10). Takahashi ('13) mentioned the gelatinuous substance in the lateral horn nucleus; and in our material, just the same findings are obtained.

The reticular formation is well developed in C. 1; it is represented by many scattered cells at the part adjacent to the lateral border of the intermediate zone and in the neighbouring white substance of the lateral funiculus. In C. 2, it is similarly found but a little less developed than in C. 1. At the other levels of the cord, the cells in question are far poorly developed than at C. 1 and 2; only a few cells are seen in the dorso-lateral border of the intermediate zone and sometimes also in the neighbouring white substance.

It is a peculiar finding that the central canal is completely obliterated at any level of the cord. Although the border of the central gelatinous substance is considerably distinct in the upper portion below the obex and also in the coccygeal levels, traces of the ependymal cells are nowhere to be recognized. Hatschek (1896) in Delphinus delphis, Biach ('06) in Phocaena communis, described also that the central canal was fully obliterated. In man, the central canal of the spinal cord is in the adults often closed and changed into a cord-like structure formed by the remaining ependymal cells. Biach ('06), however, noted an opened central canal in the lower portion of the spinal cord in Delphinus tursio.

ACCESSORY NERVE ROOTS

In the Eubalaena, the spinal roots of the accessory nerve are very poorly developed, and only in the 1st cervical level. They are recognized there as few fascicles consisting of a small number of thick fibers. This finding is contradictory to the description Hatschek's (1896) that the spinal root of the accessory nerve was observable as "Respirationsbündel" of Krause until the level of the cervical enlargement. On the other hand, the accessory nerve roots are developed well in the lower portion of the medulla oblongata of the Eubalaena.

At C. 1, the lateral part of the anterior column makes a somewhat reticular appearance protruding into the lateral funiculus, where groups of deeply stained, large sized polygonal cells are present. When we follow it up to the medulla oblongata, this structure separates gradually from the anterior column, and makes independent and *beaded* cell islands extending longitudinally. At the lower level of the rhomboid fossa, these islands become larger in the lateral funiculus and continue directly to the nucleus ambiguus (Fig. 3, 14, 15). Namely, in the Eubalaena, it is confirmed that the lower extension of the nucleus ambiguus is fused into the lateral part of the anterior column in the 1st cervical level. From this lower extension of the nucleus ambiguus, perhaps some parts of the bulbar roots of the accessory nerve take origin.

Ogawa and Chen ('47) remarked the lower extension of the dorsal vagal nucleus continuing to the medial border of the lateral funiculus of the 1st cervical level in some ungulates. The same facts were confirmed also by Mannen and Seki ('58) in some pinnipedia. However, in the Eubalaena, a similar finding is not obtained.

NUCLEUS CERVICALIS LATERALIS

Rexed and Brodal described the lateral cervical nucleus in the cat ('51); the corresponding cell groups are seen also in the 1st cervical cord of the Balaena (Fig. 3). They are found in the dorso-medial part of the lateral funiculus as a spindle, oval or irregularly reticular shaped gray substance, having middle sized (20 to 35 μ) roundish and somewhat deeply stained polygonal cells. It shows no sharp limit to the medial situating reticular formation. This nucleus changes its shape and largeness from section to section, and sometimes disappears on one side. The upper limit of this nucleus is in the lowest level of the medulla oblongata, while caudalward it is present, though less distinctly, until in the 2nd cervical level.

PYRAMIDAL TRACT

The pyramids are flat assembly of bundles of longitudinally running thin fibers, which lie on either side of the midline at the ventral border of the medulla oblongata (Fig. 15). At the lower levels of the medulla oblongata, the pyramidal tracts of both sides come to fuse together and make a wedge-shaped unpaired white substance area between the anterior funiculi of both sides (Fig. 14). More caudalward, the pyramid, decreasing the quantity of its fibers, changes into a spindle shaped tract and its location shifts slowly to dorsal and reaches then in the 1st cervical level (Fig. 3). During the course above noted almost all fibers of this tract remain seemingly in the longitudinal direction, so that the decussation of the pyramidal fibers is very hard to recognize.

However, in the upper levels of the hypoglossal nucleus, we see some fiber bundles, which are mediated between the medial parts of the pyramids of both sides (Fig. 15), but we can not yet ascertain the decussation i.e. the interchange of the fibers of the pyramidal tracts. In the lower level of the medulla oblongata, most fibers of the pyramids are stil uncrossed.

At the 1st cervical cord, the pyramidal tract appears on the midline as a spindle shaped longitudinal bundle, which decreases gradually its dimension, and then it disappears in the 2nd cervical level.

Neither in the medulla oblongata nor in the spinal cord, we can trace further course of the pyramidal fibers branching off from their main tract.

Rawitz ('09) and Gans ('16) in Phocaena, and Matsumoto ('53) in Cogia breviceps and Berardius bairdii, described the pyramidal decussation, but some previous authors could not confirm it (Hatschek and Schlesinger '02, Wilson '33, Jelgersma '34 usw.). We have to examine further the preparates sectioned parallel to the long axis of the medulla oblongata, in order to determine the problem whether the pyramidal decussation exists or not in the cetacea.

The pyramidal tracts of the Eubalaena are composed chiefly of very fine medullated nerve fibers, showing light coloured area in the myelin-stained preparates sharply contrasted to deep coloured neighbouring white substances.

POSTERIOR FUNICULUS AND ITS NUCLEI

Hatschek (1896) described in the dolphin the posterior funiculus as a bundle, in which the posterior median septum is dismissed. In the spinal cord of the Eubalaena, we see no definite posterior median septum on most sections of the thoracic and cervical levels except at C. 1, but in the lumbo-coccygeal levels the septum is clearly visible. The border between the Goll's and Burdach's funiculus is not definitely recognized even in the upper cervical levels.

At the levels beneath the obex, because of the disappearance of the posterior median septum and the neighbouring fibers in the posterior funiculi, the Goll's nuclei of both sides come to adhere on the midline (Fig. 14), and in the levels upper to the obex, of course, they are separated again.

The lower extensions of the Goll's nucleus of both sides are fused together in the Bischoff's nucleus in the lowest level of the medulla oblongata. The Bischoff's nucleus is situated on the midline of the posterior funiculus in this level and sometimes also in the 1st cervical cord (Fig. 3), and has been considered as remarkably present in the animals which have a well developed tail. In the Eubalaena, however, this nucleus is not so large developed.

FIBER TRACTS IN THE WHITE SUBSTANCE OF THE SPINAL CORD

In our preparates of the spinal cord of the Eubalaena, any long fiber tract is not certainly traceable in the ventro-lateral funiculi. But only the areas corresponding possibly to the dorsal spino-cerebellar tract of Flechsig are seen at the dorsal margin of the lateral funiculi of both sides. These areas are composed of many large nerve fibers (10 to 15 μ), begin at the lowest level of the cord, and show deeply stained zone in sections of the lower thoracic and the lumbo-coccygeal cord, but they are hardly to distinguish from neighbourhood in the upper thoracic and the cervical level. In the levels from C. 1 to the medulla oblongata, they appear clearly at the same position as deep coloured areas.

SUMMARY

The results of macroscopical and microscopical observations upon the spinal cord of female Eubalaena glacialis are summarized as follows:

1. The length of the spinal cord is very short (14.9% of the body length). The cauda equina is not present inside the dura mater, but exists only in the epidural space, where we see also extremely rich blood vessels and fatty tissue. Externally, the lumbal enlargement is not distinctly seen, but in the curve indicating the dimension of the gray substance of each level in the cross section, we can recognize clearly the lumbal enlargement, the maximum extent being in the coccygeal level.
2. The anterior column of the cervical enlargement is very well developed in the transverse direction, but in the lumbal enlargement, the anterior column is elongated rather in the ventro-dorsal direction. These results are due perhaps to the lack of the lateral part of the anterior column in the lumbal enlargement, which innervates the musculature of the lower extremities.
3. In addition to the commonly deep coloured motor cells, there are light coloured cells in the dorsal part and the lateral or medial periphery of the anterior column. We guess that the latter might be associated to the autonomic function.
4. Comparing the cell size of the anterior column between the Eubalaena and man there is little difference in the cervical or the thoracic level; but in the lumbal enlargement, the cells of the Eubalaena are doubtless much larger than those of man. We are of the opinion that the size of the nerve cells is more related to the length of the nerve fibers originating from them than to the body size of animals.
5. The posterior column is as a whole less developed; only in C. 1 it is moderately large. The largeness in C. 1 is caused probably by the lower extension of the spinal root and its nucleus of the trigeminal nerve, which are well developed in the medulla oblongata.
6. Fusion of the posterior columns of both sides is seen in the lower thoracic and the coccygeal levels.
7. The Clarke's column is well developed especially in the lower thoracic and the upper lumbal levels. Rostrally, the Clarke's column is continued to the cervical nucleus of Stilling in the upper cervical levels; also the caudal extension of the Clarke's column is clearly developed.
8. The pars intermedia occupies a wide territory. The fibers of the anterior white commissure are crossed in the thoracic levels, making small angles to the median plane.

9. The lateral horn cells exist in the levels from D. 1 to L. 8 in the light coloured gray substance at the lateral border of the intermediate zone.

10. The reticular formation is relatively well developed in the levels of C. 1 and 2, but far less in the other levels.

11. The central canal is fully obliterated for the whole length of the spinal cord.

12. The spinal roots of the accessory nerve are very poorly developed, and only in the 1st cervical level.

13. The lower extension of the nucleus ambiguus is directly continuous to the lateral part of the anterior column in the 1st cervical cord.

14. In the Eubalaena, cell groups corresponding to the lateral cervical nucleus are recognized in the 1st cervical level.

15. The pyramidal tract forms an unpaired bundle between the anterior funiculi of both sides in the lowest level of the medulla oblongata and in C. 1. The pyramidal decussation is not demonstrated in spite of careful pursuit down to its lower disppearance.

16. At the dorsal margin of the lateral funiculus, an area possibly corresponding to the dorsal spino-cerebellar tract is traceable.

ACKNOWLEDGEMENT

I am grateful to Prof. T. Ogawa for his constant direction and revision. My thanks are also due to Ass. Prof. H. Hosokawa and Mr. T. Shida for their kind advices and offering of the unpublished data.

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ABBREVIATIONS USED IN FIGS. 3—13.

ac,	anterior column	lf,	lateral funiculus
af,	anterior funiculus	nB,	nucleus of Bischoff
amf,	anterior median fissure	ncl,	lateral cervical nucleus
an,	arterial network in the subarachnoidal space	nppc,	nucleus proprius of the posterior column
ar,	anterior root fibers	pc,	posterior column
awco,	anterior white commissure	pf,	posterior funiculus
ccl,	lateral horn cells	pi,	pars intermedia
ceCl,	caudal extension of Clarke's column	pms,	posterior median septum
		pr,	posterior root fibers
cl,	lateral column	py,	pyramidal tract
cnSt,	cervical nucleus of Stilling	sgc,	Substantia gelatinosa centralis
cpm,	postero-marginal cells	sgd,	Substantia gelatinosa dorsalis
dlfL,	dorso-lateral fascicle of Lissauer	vcCl,	Clarke's column
fr,	reticular formation	zsp,	Zona spongiosa
gco,	gray commissure	★▲ •	deep coloured cells
ld,	denticulate ligament	○△	light coloured cells

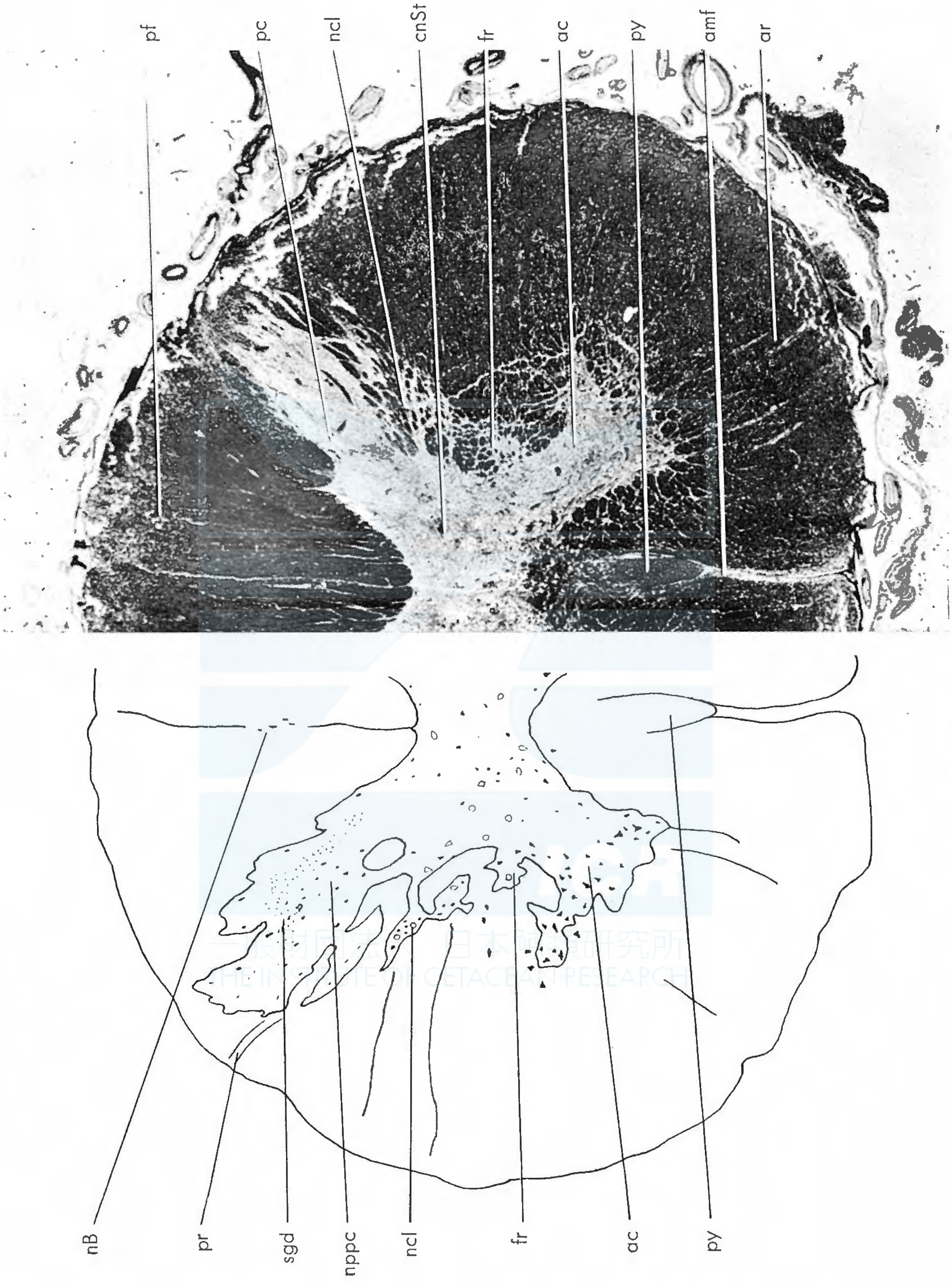

Fig. 3. 1st cervical cord (×10)

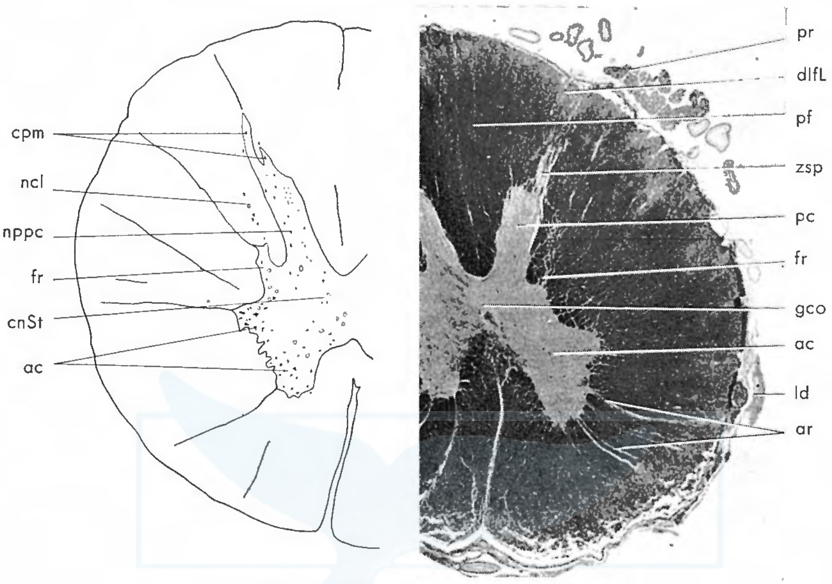

Fig. 4. 2nd cervical cord (×5)

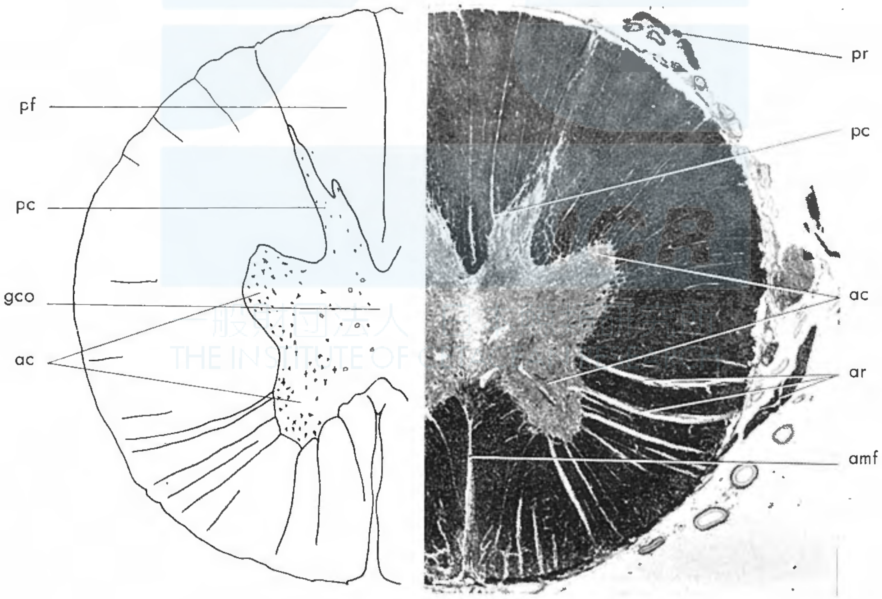

Fig. 5. 5th cervical cord (×5)

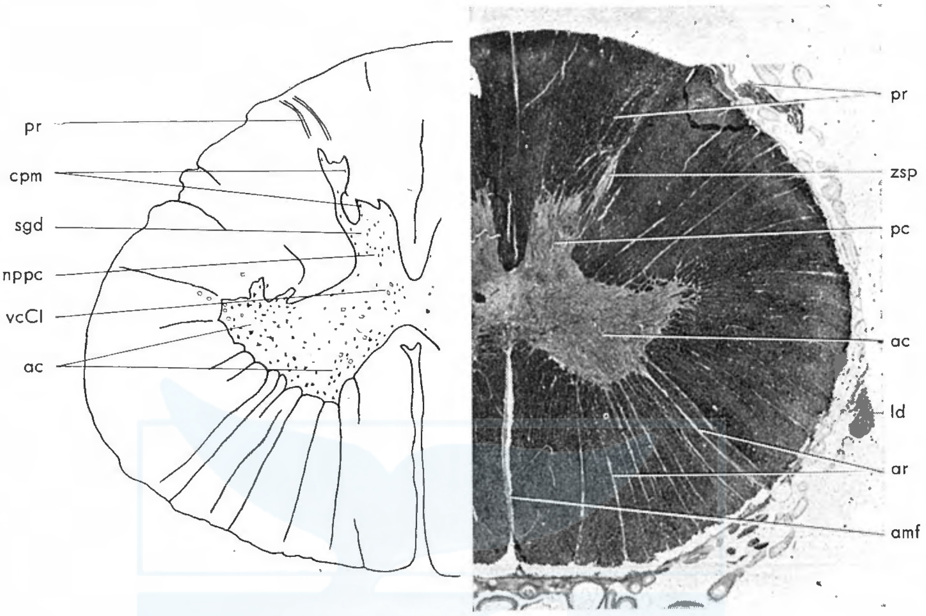

Fig. 6. 8th cervical cord (×5)

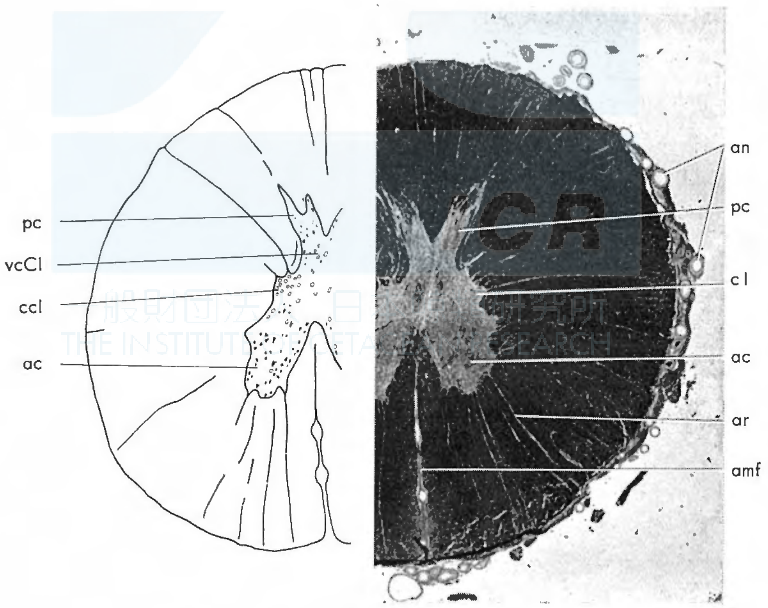

Fig. 7. 5th thoracic cord (×5)

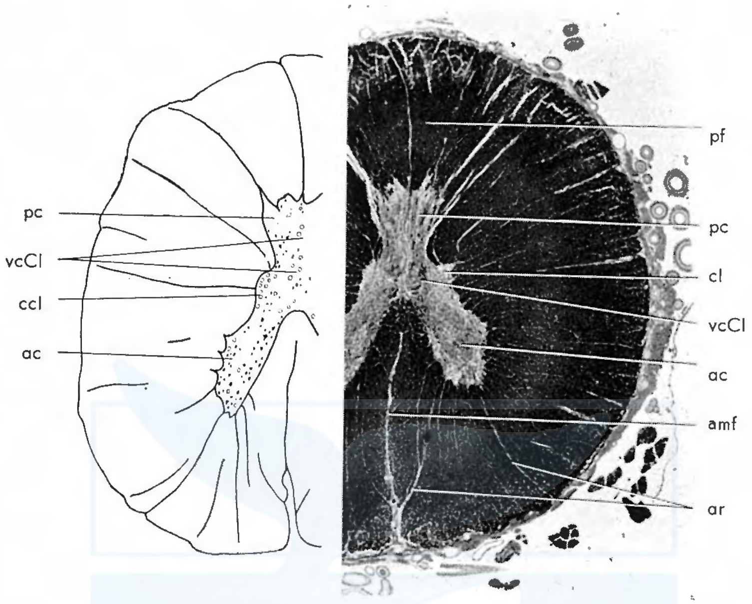

Fig. 8. 10th thoracic cord (×5)

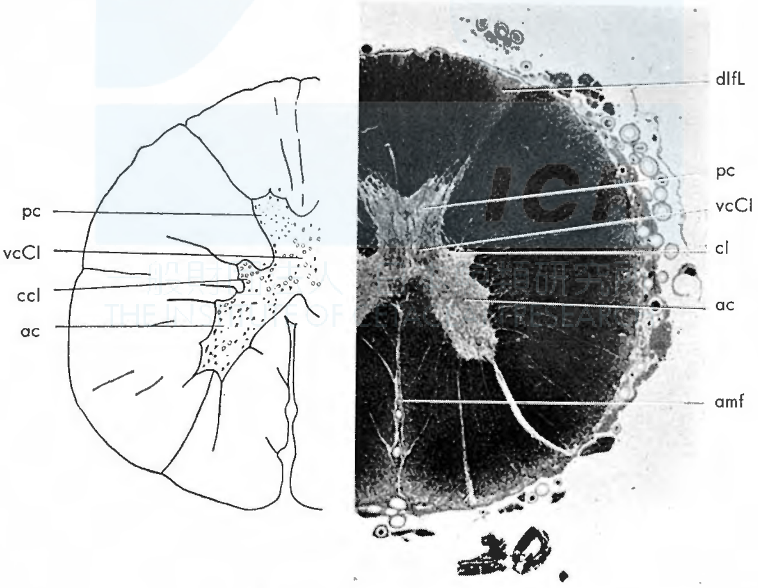

Fig. 9. 14th thoracic cord (×5)

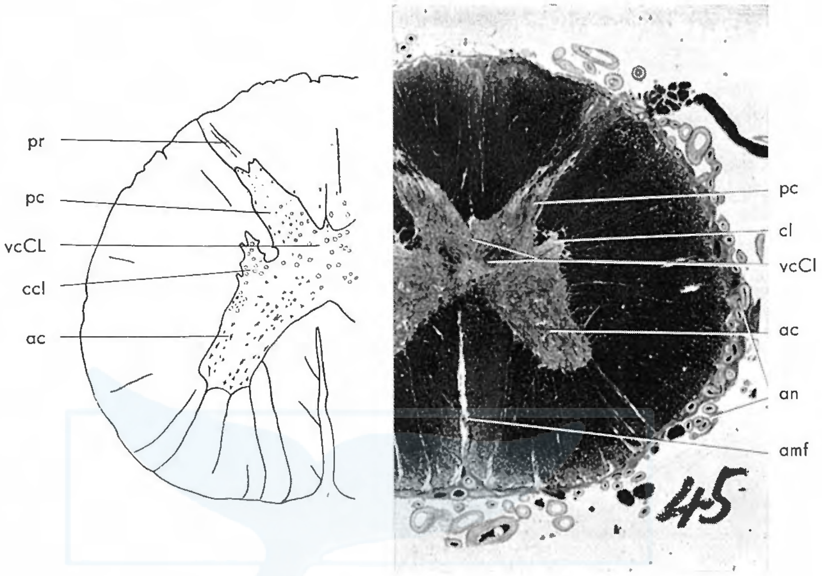

Fig. 10. 3rd lumbal cord (×5)

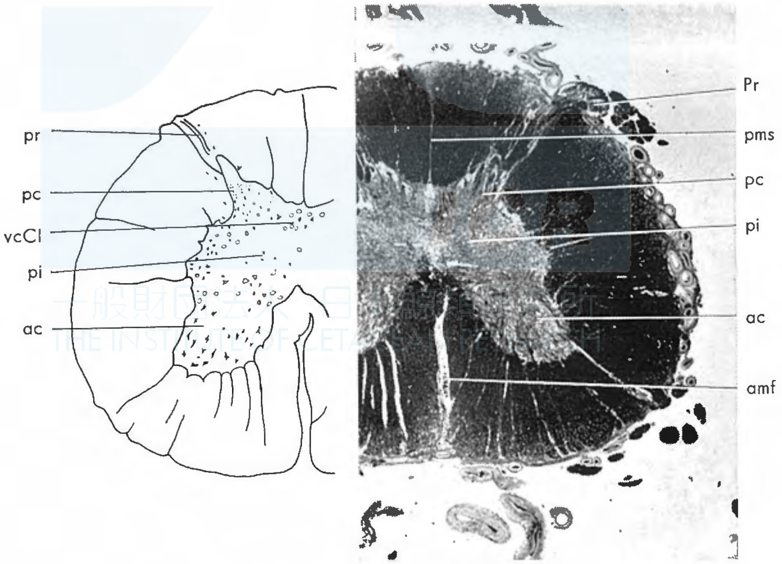

Fig. 11. 7th lumbal cord (×5)

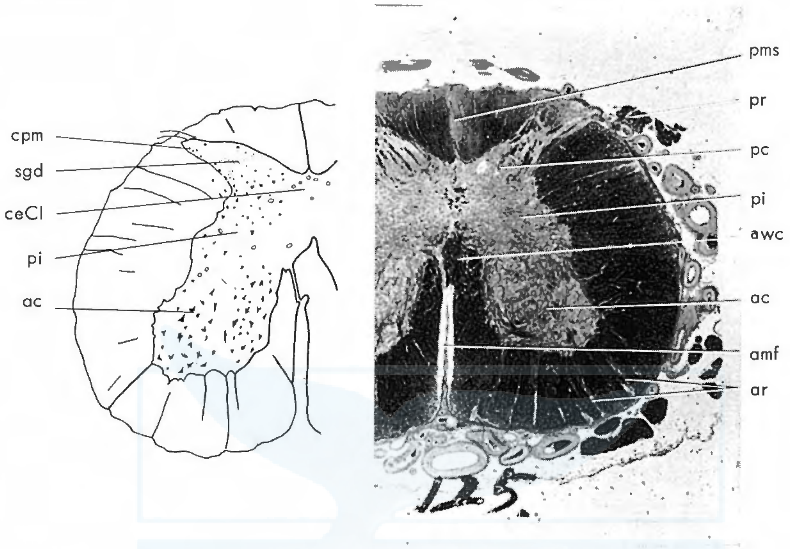

Fig. 12. 1st coccygeal cord (×5)

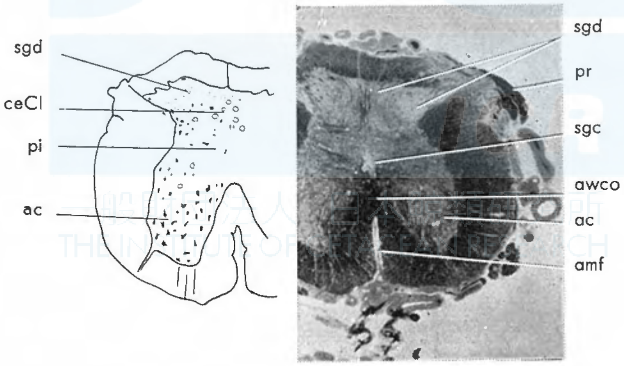

Fig. 13. 5th coccygeal cord (×5)

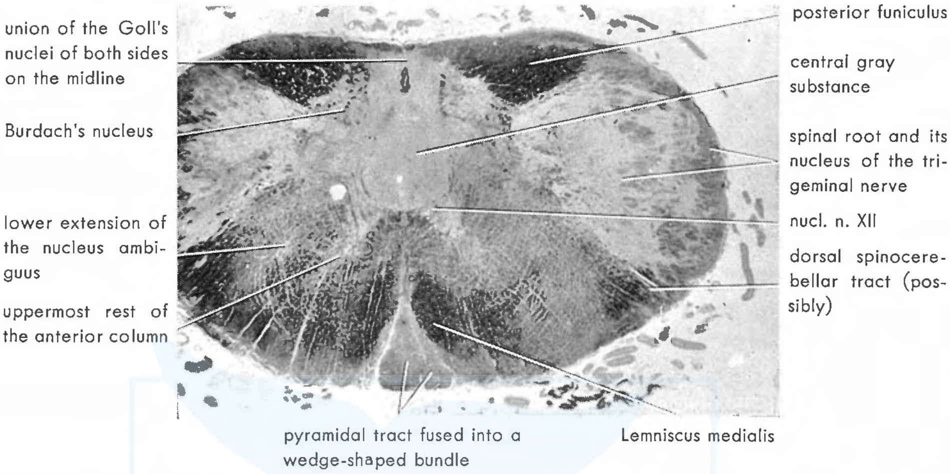

Fig. 14. Lower level of the medulla oblongata

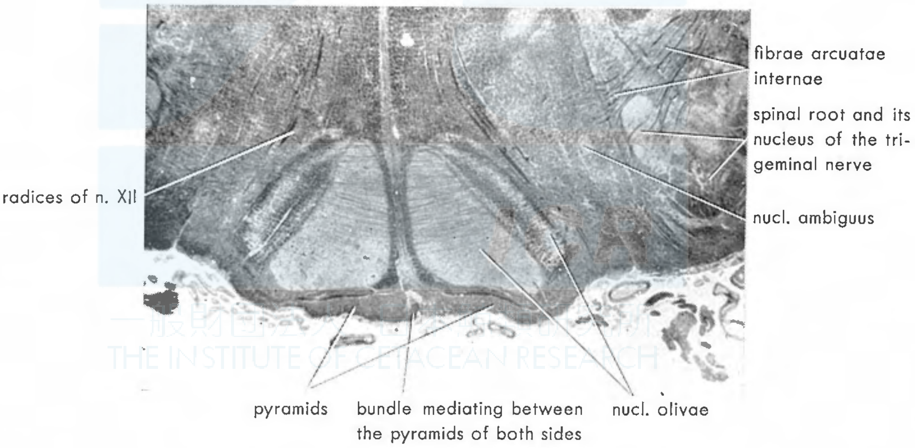

Fig. 15. Upper level of the medulla oblongata


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HOW TO COUNT THE RENCULI OF THE CETACEAN KIDNEYS, WITH SPECIAL REGARD TO THE KIDNEY OF THE RIGHT WHALE

TOSHIRO KAMIYA*

The highest degree of lobulation of the kidney is met with amongst all mammalia in the kidney of the cetacea. The cetacean kidney is separated into numerous renculi, looking as a whole like a bunch of grapes. Many authors have counted hitherto the renculi constituting a kidney in various kinds of the cetacea (Table 1). But in determining the number an important point to be considered is, that the lobulation of the cetacean kidney is always never so complete that all the renculi are individualized and there are many formations made of two or more renculi fused together or incompletely separated.

TABLE 1. NUMBER OF THE RENCULI OF THE CETACEA REPORTED HITHERTO

Name of the authors	Year	Species of the whale	Number of the renculi	Remarks
Hyrtl, J.	1872	*B. rostrata*	156	Embryo
Watson, M. and Young, A. H.	1879	*Delphinapterus*	400	*
Beauregard et Boulart.	1882	*B. musculus*	ca. 3000	
Daudt, W.	1898	*B. musculus*	ca. 3000	
Schulte, H. von W.	1916	*B. borealis*	ca. 1350	Embryo
Anthony, R.	1922	*Mesoplodon*	474	*
Anthony, R.	1926	*Delphinus delphis*	459	*
Ping, Chi.	1926	*Neomeris phocaenoides*	145–150	
Ommanney, F. D.	1932	*B. physalus*	5998–6372	
Hosokawa, H. and Ohe, T.	1947	*B. borealis*	3251	Unpublished
Matthews, L. H.	1950	*Stenella frontalis*	ca. 300	**
Matthews, L. H.	1950	*B. musculus*	ca. 3000	**

* cited from Daudt, W. 1898 and Ommanney, F. D. 1932.

** cited from Burne, R. H. 1952.

A great variance upon the number of renculi reported until today is caused not to a small extent very probably by the ways how the authors treated the aggregated renculi, though the calculation methods employed by them have not been always mentioned. Usually in cases of larger whales only a small portion of the kidney was really examined and the

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whole number was estimated roughly by arithmetical multiplication. As an example, Ommanney (1936) adopted the following method upon the kidney of one female Fin whale. The whole weight of the kidney was 65.5 kg. The number of renculi counted in a given area (20×20 cm) of a section surface was between 80 and 85. The weight of a given block of the kidney substance measuring 20 × 20 × 5 cm was 1.82 kg. The average diameter of the renculi (counting 40 renculi) was 2.4 cm. The number of renculi in the block was therefore : (80 or 85)×5.0/2.4. The result is nearly to double the number counted in the given area, since the block of kidney was about twice (5/2.4) the rencular diameter in depth. The total number of renculi in the whole mass of the kidney was thus given roughly by :

$$\frac{(80\text{ or }85)\times 5}{2.4}\times\frac{\text{Total weight of the kidney}}{\text{weight of the block}},\ \text{i. e.}\ \frac{(80\text{ or }85)\times 5}{2.4}\times\frac{65.5}{1.82}$$

i. e. 5998 or 6372. Ommanney estimated that the true number will lie somewhere between these two figures. He cut the block of the renal substance at random from the mass of a lobe of the organ, and he added also that the calculation took account of the spaces in the kidney occupied by connective tissue and blood vessels.

In such cases the connective tissue with blood-vessels and roots of the ureter deserve special attention. And it is noteworthy that the comparative volume of these non-proper tissues is quite different among the cetacea. The present author is interested to find rather few connective tissue in the kidney of the dolphins in comparison with those of mystacoceti and of some larger odontoceti. With the latter are meant here such toothed whales as *Ziphius cavirostris, Berardius bairdii* etc., in which the connective tissues are comparatively tough and pretty abundant.

In the present work an attempt was done for counting the renculi of a cetacean kidney as exactly as possible. For this purpose we settled at first the standard unit of a renculus and then counted the renculi separately one by one. When in the counting we adhere only to the external appearance of a renal mass, we find it often very difficult to determine the degree of fusion or separation. From this reason a new method was devised after we had observed comparatively the kidneys of some cetacean kinds ; that is the combination of external studies by macroscopic dissection with internal observations by cutting across the renculus with dissection knife on a horizontal or sagittal plane. By doing so, we tried to discern the structure of the cortex, medulla and papilla of a renculus, and were able to determine the standard unit (Fig. 1).

The method here employed is well applicable to systematic observation of the cetacean kidneys and any body can use it with ease.

I wish to thank Prof. Teizo Ogawa and Ass. Prof. Hiroshi Hosokawa for their kind help, guidance and encouragement.

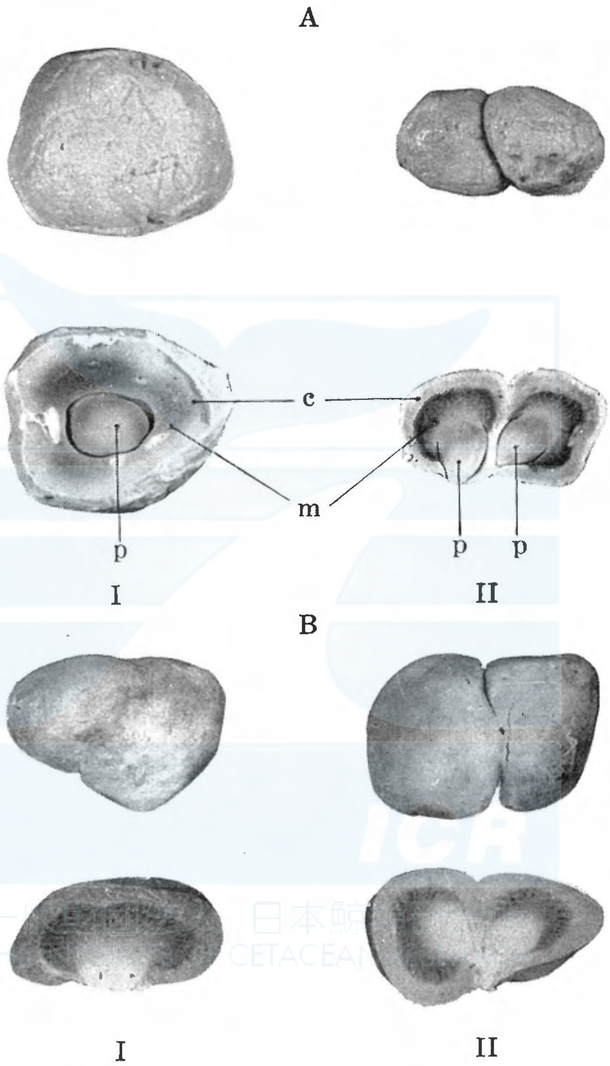

Fig. 1. Standard types of the renculus (natural size)
A-Sperm whale (*Physeter catodon*)
B-Sei whale (*Balaenoptera borealis*)
c-renal cortex (rencular cortex)
m-renal medulla (rencular medulla)
p-renal papilla (rencular papilla)
A-I is by horizontal section; A-II, B-I and B-II are by sagittal sections.

METHOD

All the materials are fixed in 10% formalin, and then the ureter, blood-vessels and the connective tissue are cut out and removed carefully. At first, all of the renculi are arranged in order by natural appearance, and classified as the following: apparently a single renculus---two renculi apparently fused---three renculi apparently fused---four renculi apparently fused---etc., in this way by external appearance each renculus-group is numbered (Group I, II, III, ---, 1st column in Appendix table I), the number of renculi belonging to each renculus-group is reckoned (2nd column in Appendix table I) and weights of each group are measured (7th column in Appendix table I). This way is termed **the classification by external appearance.**

Secondly, all of the renculi are cut in the horizontal or sagittal direction without dissolving the above mentioned grouping and in each group the renculi are arranged in order according to the number of papillae as the following: renculus with one papilla---renculus with two papillae---renculus with three papillae---renculus with four papillae---etc., in this was each renculus-group is divided according to the number of papillae (Group 1, 2, 3,---, 3rd column in Appendix table I), the number of renculi and papillae belonging to each papillae-group is reckoned (4th and 5th column in Appendix table I), and in the same way the number of papillae belonging to each renculus-group is calculated (6th column in Appendix table I). This way is termed **the classification by counting papillae of the renculus.**

On hand of the above procedures, the following calculations are done: 1) the number of renculi by their natural appearance (2nd column in Appendix table I), 2) proportion of the number of each group determined by external appearance to the total number of the renculi (2nd column in Appendix table I), 3) proportion of the number of papillae belonging to each renculus-group classified above to the total number of the papillae contained in all the renculi (6th column in Appendix table I).

MATERIALS

MYSTACOCETI;

1. Right whale (*Balaena glacialis* LINNÉ)*
2. Little Piked whale (*Balaenoptera acuto-rostrata* L.)

ODONTOCETI;

3. Goose-beaked whale (*Ziphius cavirostris* CUVIER)
4. Killer whale (*Orcinus orca* LINNÉ)
5. Risso's dolphin (*Grampus griseus* CUVIER)

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* This Right whale was legitimately caught in May 1956, for the scientific investigation with the special permission of the Japanese Government.

6. Pacific Pilot whale (*Globicephalus melas* TRAILL)
7. Bottle-nosed dolphin (*Trusiops truncatus* MONTAGU)
8. Common dolphin (*Delphinus delphis* LINNÉ)
9. Suji-iruka (*Prodelphinus caeruleo-albus* MEYEN)
10. Finless black porpoise (*Neomeris phocaenoides* CUVIER)
11. True's porpoise (*Phocaenoides truei* ANDREWS)

The following three species were used for comparison:

Sei whale (*Balaenoptera borealis* LESSON)
Sperm whale (*Physeter catodon* LINNÉ)
Pacific Beaked whale (*Berardius bairdii* STEJNEGER)

Those materials could be obtained through the kindness of many persons; I wish to say here sincere thanks especially to Dr. Munesato Yamada of the University of Okayama, Mr. Masayuki Nakajima at Enoshima Marineland and Messrs. Yoshinori Kimura and Katsuro Abe at Ayukawa-machi.

OBSERVATIONS

The number of the renculi in eleven species of the cetacea is shown in Appendix table I (in each species only the right kidney was examined).

We will treat here especially the kidney of the Right whale in details:

The total number of the renculi is 5377 in the Right whale; this value surpasses the total number of the renculi of the Blue whale, which amounts to 3000 (Beauregard et Boulart 1882, Daudt W. 1898 and Matthews L. H. 1950) and comes pretty near that of the Fin whale, which was said ca. 6000 (Ommanney F. D. 1932).

From my studies the following data are given;

1. Classification by external appearance

Group	I	2303	(42.8%, not aggregated renculus)
Group	II	2110	(39.4%, two renculi are aggregated together)
Group	III	740	(13.8%)
Group	IV	211	(3.9%)
Group	V	9	(0.2%)
Group	VI	4	(0.07%)

In comparison with other species of the cetacea it is remarkable in the Right whale that the difference between Group I and Group II is very small, being only 193 (3.4%), and the highest aggregation is seen in Group VI. Those two points may be influenced to some extent by immaturity of the individual (Fig. 2).

2. Classification by counting the papillae

Group	I	2748	(27.1%)
Group	II	4204	(41.4%)
Group	III	2268	(22.3%)
Group	IV	865	(8.5%)

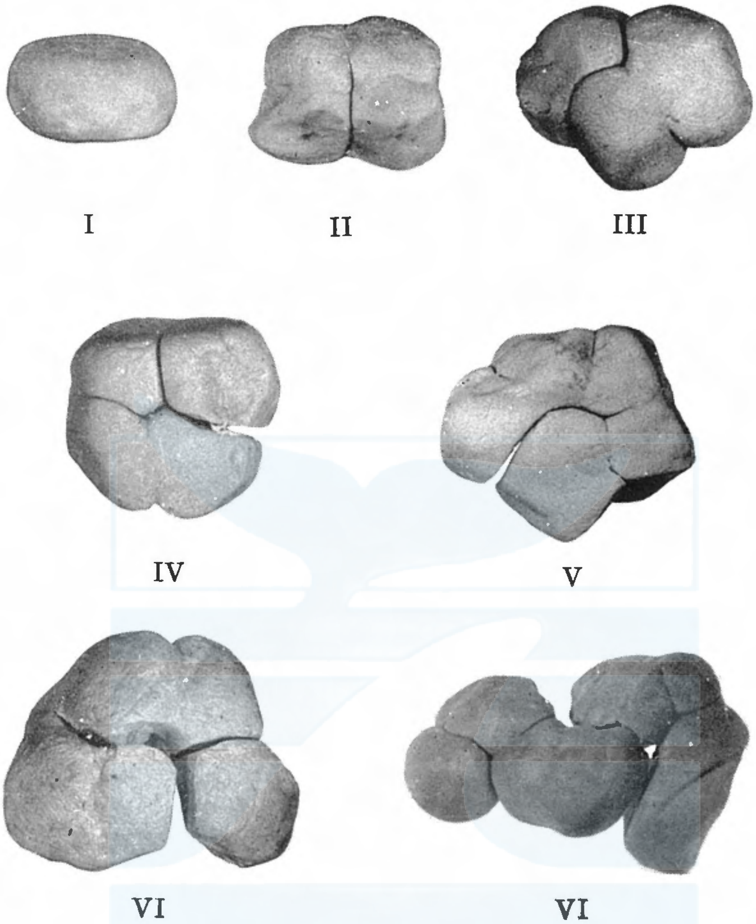

Fig. 2. Several types of the renculus of the Right whale; classification by the external appearance (natural size)

Group V	47	(0.5%)
Group VI	24	(0.2%)

The classification by external appearance is coincident with the classification by counting the papillae at 80.8% in Group I, at 94% in Group II, at 87.3% in Group III, at 88.2% in Group IV, at 88.8% in Group V and at 100% Group VI. These percentages mean the degree of coincidence between external lobulation and internal formation of papillae (3rd and 4th columns in Appendix table I).

Next, all of the renculi are classified again by the number of papillae (Appendix table II). In Appendix table II, each renculus is classified according to the papillae. Group I means that they have one papilla within one renculus, Group II means that they have two papillae within one renculus, and so forth. There are seven groups in all. By com-

TABLE 2. SUMMARY OF MEASUREMENTS AND CALCULATIONS ON THE CETACEAN KIDNEYS (IN EACH SPECIES ONLY THE RIGHT KIDNEY WAS EXAMINED)

Species of the whale	Body length (m)	Sex	Total weight of the kidney (kg)	Total weight of the renculi (kg)	Number of the renculi	Number of the papillae	Average weight of one renculus (g)	Average weight of one papilla (g)
Balaena glacialis	11.65	♀	32.40	13.813	5377	10156	2.57	1.36
Balaenoptera acuto-rostrata	6.80	♀	4.16	3.269	1250	1290	2.61	2.53
Ziphius cavirostris	6.40	♀	3.64	2.165	1912	2743	1.13	0.79
Orcinus orca	5.42	♀	3.04	1.801	1217	2024	1.47	0.89
Globicephalus melas	3.05	♀	1.15	0.693	641	906	1.08	0.76
Grampus griseus	3.00	♂	0.79	0.666	378	394	1.76	1.69
Trusiops truncatus	2.23	♂	0.31	0.242	375	542	0.65	0.45
Prodelphinus caeruleo-albus	2.07	♂	0.21	0.185	270	318	0.69	0.58
Delphinus delphis	1.77	♀	0.18	0.153	269	415	0.57	0.37
Neomeris phocaenoides	1.52	♀	0.23	0.212	138	152	1.53	1.38
Phocaenoides truei (embryo)	0.82	♀	0.03	0.027	389	492	0.07	0.05

TABLE 3. THE RELATION BETWEEN GROWTH AND LOBULATION *PRODELPHINUS CAERULEO-ALBUS* MEYEN (IN EACH STAGES ONLY THE RIGHT KIDNEY WAS EXAMINED)

Body length (cm)	Sex	Number of the renculi	Number of the papillae
85 (embryo)	♀	288	347
110	♀	271	394
150	♀	344	435
180	♀	274	299
200	♂	270	303
207	♂	270	318
220	♂	330	395

TABLE 4. THE DIFFERENCE OF THE NUMBER BETWEEN RIGHT AND LEFT

Species of the whale	Number of the renculi		Number of the papillae	
	r	l	r	l
Grampus griseus	378	381	394	402
Delphinus delphis	269	249	415	386
Phocaenoides truei (embryo)	389	409	492	495
Prodelphinus caeruleo-albus (embryo)	288	275	347	325
〃 〃 (young)	344	386	435	466
〃 〃 (adult)	270	318	257	304
Neomeris phocaenoides (adult)	185	240	154	205
〃 〃 (adult)	138	132	152	156

paring with the classification by external appearance there are some distinguishable traits, for example Group II is 2448 (45.5%) showing a higher percentage than Group I which is 1935 (36%).

The average weight of one renculus and papilla are 2.57 g and 1.36 g, while the highest and lowest weight of one renculus is 8.5 g and 0.9 g respectively. The heaviest renculus has seven papillae, while the lightest has only one papilla within the renculus. The total weight and the total renculi weight of the right kidney are in the Right whale 32.4 kg and 13.813 kg respectively. The principal results on the kidney of each species are shown in Table 2. The relation between growth and lobulation in one dolphin-species (*Prodelphinus caeruleo-albus* MEYEN) is shown in Table 3. Increase of the lobulization with age can not be clearly concluded from this table. The difference of the number between kidneys of both sides is shown in Table 4, but the sampling number is insufficient to say any definite difference, and there seem also to exist individual and sexual differences. In a species of dolphin (*Prodelphinus caeruleo-albus* MEYEN), a difference was observed by individuals, but perhaps no difference by the sex.

SUMMARY

The cetacean kidney shows the highest degree of the lobulation in all the mammals, but its lobulation can never be said as perfect and we see many renculi fused together or incompletely separated. Because of it, to determine the real number of the renculi, a great difficulty occurs if one proceeds without keen discrimination. For this reason a new method was devised and countings were performed by two following ways:

1. Classification by external appearance.
2. Classification by counting papillae of the renculi.

This method gives the results much more accurately than any method of previous authors, as to the number of the cetacean renculi.

By this method the number of the renculi was studied in eleven species of the cetacea and especially the right kidney of a 11.65 m long female Right whale was here treated. The total number of the renculi and papillae amounted in this whale to 5377 and 10156 respectively. In this species of the baleen whale the rencular aggregation occurs in higher degree than in any other cetacea comparatively studied in the present work. Remarkably high percentage of the renculi in fusion was confirmed in the Right whale not only by external appearance, but also by counting the papillae.

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APPENDIX TABLE I. THE CLASSIFICATION BY EXTERNAL APPEARANCE (IN EACH SPECIES ONLY THE RIGHT KIDNEY WAS EXAMINED)

Italic denotes percentage.

1) Ratio to the total number of the renculi.
2) Ratio to the number of the renculi of each groups of the classification by external appearance.
3), 4) Ratio to the total number of the papilla.
5) Ratio to the total weight of the renculi.

1. *Balaena glacialis* 11.65 m. ♀

Groups by natural appearance	Number of renculi of each group	Types by number of papillae in a renculus	Number of renculi of each type	Number of papillae	Total number of papillae of each group	Weight (g)
I	2303 *42.8*[1]	1	1860 *80.8*[2]	1860 *18.3*[3]	2748 *27.1*[4]	4157 *30.1*[5]
		2	441 *19.1*	882 *8.68*		
		3	2 *0.09*	6 *0.06*		
II	2110 *39.4*	1	75 *3.55*	75 *0.74*	4204 *41.4*	5857 *42.4*
		2	1984 *94.03*	3968 *39.07*		
		3	43 *2.04*	129 *1.27*		
		4	8 *0.28*	32 *0.32*		
III	740 *13.8*	2	23 *3.1*	46 *0.45*	2268 *22.3*	2700 *19.5*
		3	646 *87.3*	1938 *19.08*		
		4	71 *9.6*	284 *2.8*		
IV	211 *3.9*	3	3 *1.42*	9 *0.09*	865 *8.5*	1021 *7.4*
		4	186 *88.15*	744 *7.33*		
		5	21 *9.95*	105 *1.03*		
		7	1 *0.58*	7 *0.07*		
V	9 *0.2*	5	8 *88.8*	40 *0.39*	47 *0.5*	52 *0.4*
		7	1 *11.2*	7 *0.69*		
VI	4 *0.07*	6	4 *100*	24 *0.24*	24 *0.2*	26 *0.2*
Total	**5377**		**5377**	**10156**	**10156**	**13813**

2. *Balaenoptera acuto-rostrata* 6.8 m. ♀

Groups by natural appearance	Nnmber of renculi of each group	Types by number of papillae in a renculus	Number of renculi of each type	Number of papillae	Total number of papillae of each group	Weight (g)
I	1003 *80.24*	1	1003 *100*	1003 *77.75*	1003 *77.75*	2408 *73.65*
II	216 *17.28*	1	186 *86.1*	186 *14.42*	246 *19.07*	727 *22.24*
		2	30 *13.9*	60 *4.65*		
III	30 *2.4*	1	22 *73.3*	22 *1.71*	39 *3.02*	127.5 *3.90*
		2	7 *23.3*	14 *1.09*		
		3	1 *3.4*	3 *0.23*		
IV	1 *0.08*	2	1 *100*	2 *0.16*	2 *0.16*	7 *0.24*
Total	**1250**		**1250**	**1290**	**1290**	**3269.5**

3. *Ziphius cavirostris* 6.4 m. ♀

Groups by natural appearance	Number of renculi of each group	Types by number of papillae in a renculus	Number of renculi of each type	Number of papillae	Total number of papillae of each group	Weight (g)
I	1398 *73.1*	1	1121 *80.19*	1121 *40.87*	1679 *61.2*	1360 *62.8*
		2	273 *19.53*	546 *19.91*		
		3	4 *0.29*	12 *0.44*		
II	490 *25.6*	1	26 *5.31*	26 *0.95*	995 *36.3*	745 *34.4*
		2	426 *86.94*	852 *31.06*		
		3	35 *7.14*	105 *3.83*		
		4	3 *6.12*	12 *0.44*		
III	20 *1.0*	2	7 *35*	14 *0.51*	54 *2.0*	45 *2.1*
		3	12 *60*	36 *1.31*		
		4	1 *5.0*	4 *0.15*		
IV	4 *0.2*	3	1 *25.0*	3 *0.11*	15 *0.5*	15 *0.7*
		4	3 *75.0*	12 *0.44*		
Total	**1912**		**1912**	**2743**	**2743**	**2165**

4. *Orcinus orca* 5.42 m. ♀

Groups by natural appearance	Number of renculi of each group	Types by number of papillae in a renculus	Number of renculi of each type	Number of papillae	Total number of papillae of each group	Weight (g)
I	534 *43.9*	1	520 *97.4*	520 *25.7*	548 *27.1*	590 *32.8*
		2	14 *2.6*	28 *1.4*		
II	571 *46.9*	1	7 *1.2*	7 *0.3*	1137 *56.2*	960 *53.3*
		2	562 *98.4*	1124 *55.5*		
		3	2 *0.4*	6 *0.3*		
III	96 *7.9*	2	15 *15.6*	30 *1.5*	275 *13.4*	204 *11.3*
		3	79 *82.3*	237 *11.7*		
		4	2 *2.1*	8 *0.4*		
IV	16 *1.3*	4	16 *100*	64 *3.2*	64 *3.2*	47 *2.6*
Total	**1217**		**1217**	**2024**	**2024**	**1801**

5. *Globicephalus melas* 3.05 m. ♀

Groups by natural appearance	Number of renculi of each group	Types by number of papillae in a renculus	Number of renculi of each type	Number of papillae	Total number of papillae of each group	Weight (g)
I	420 *65.5*	1	416 *99.05*	416 *45.92*	424 *46.8*	373 *53.82*
		2	4 *0.95*	8 *0.88*		
II	183 *28.5*	1	2 *1.09*	2 *0.22*	364 *40.18*	247 *35.64*
		2	181 *98.91*	362 *39.96*		
III	35 *5.5*	3	35 *100*	105 *11.59*	105 *11.59*	65 *9.38*
IV	3 *0.5*	4	2 *66.67*	8 *0.88*	13 *1.43*	8 *1.15*
		5	1 *33.33*	5 *0.55*		
Total	**641**		**641**	**906**	**906**	**936**

6. *Grampus griseus* 3 m. ♂

Groups by natural appearance	Number of renculi of each group	Types by number of papillae in a renculus	Number of renculi of each type	Number of papillae	Total number of papillae of each group	Weight (g)
I	334 *88.4*	1	334 *100*	334 *84.77*	334 *84.77*	565 *84.83*
II	43 *11.4*	1	27 *62.79*	27 *6.85*	59 *14.97*	98 *14.71*
		2	16 *37.21*	32 *8.12*		
III	1 *0.26*	1	1 *100*	1 *0.25*	1 *0.25*	3 *0.45*
Total	**378**		**378**	**394**	**394**	**666**

7. *Trusiops truncatus* 2.23 m. ♂

Groups by natural appearance	Number of renculi of each group	Types by number of papillae in a renculus	Number of renculi of each type	Number of papillae	Total number of papillae of each group	Weight (g)
I	228 *60.8*	1	228 *100*	228 *42.07*	228 *42.07*	119 *49.17*
II	117 *31.2*	1	6 *5.13*	6 *1.11*	228 *42.07*	91 *37.60*
		2	111 *94.87*	222 *40.96*		
III	29 *7.73*	1	1 *3.45*	1 *0.81*	82 *15.13*	31 *12.81*
		2	3 *10.34*	6 *1.11*		
		3	25 *86.21*	75 *13.84*		
IV	1 *0.26*	4	1 *100*	4 *0.74*	4 *0.74*	1 *0.41*
Total	**375**		**375**	**542**	**542**	**242**

8. *Delphinus delphis* 1.77 m. ♀

Groups by natural appearance	Number of renculi of each group	Types by number of papillae in a renculus	Number of renculi of each type	Number of papillae	Total number of papillae of each group	Weight (g)
I	184 *68.4*	1	150 *81.52*	150 *36.14*	219 *52.77*	86.5 *56.35*
		2	33 *17.93*	66 *15.90*		
		3	1 *0.54*	3 *0.72*		
II	65 *24.2*	1	1 *1.54*	1 *0.24*	133 *32.05*	48 *31.27*
		2	60 *92.31*	120 *28.92*		
		3	4 *6.15*	12 *2.89*		
III	17 *6.3*	3	17 *100*	51 *12.29*	51 *12.29*	15 *9.77*
IV	3 *1.1*	4	3 *100*	12 *2.89*	12 *2.89*	4 *2.61*
Total	**269**		**269**	**415**	**415**	**1535**

9. *Neomeris phocaenoides* 1.5 m. ♀

Groups by natural appearance	Number of renculi of each group	Types by number of papillae in a renculus	Number of renculi of each type	Number of papillae	Total number of papillae of each group	Weight (g)
I	119 *86.2*	1	116 *97.48*	116 *76.32*	122 *80.26*	180.5 *85.75*
		2	3 *2.52*	6 *3.95*		
II	19 *13.8*	1	8 *42.11*	8 *5.26*	30 *19.74*	30 *14.25*
		2	11 *57.89*	22 *14.47*		
Total	**138**		**138**	**152**	**152**	**210.5**

10. *Prodelphinus caeruleo-albus* 2.07 m. ♂

Groups by natural appearance	Number of renculi of each group	Types by number of papillae in a renculus	Number of renculi of each type	Number of papillae	Total number of papillae of each group	Weight (g)
I	214 *79.3*	1	213 *99.53*	213 *66.98*	215 *67.61*	134 *72.24*
		2	1 *0.47*	2 *0.63*		
II	49 *18.1*	1	11 *22.45*	11 *3.46*	87 *27.36*	44 *23.72*
		2	38 *77.55*	76 *23.9*		
III	7 *2.6*	1	1 *14.29*	1 *0.31*	16 *5.03*	7.5 *4.04*
		2	3 *42.86*	6 *1.87*		
		3	3 *42.86*	9 *2.83*		
Total	**270**		**270**	**318**	**318**	**185.5**

11. *Phocaenoides truei* 0.82 m. (Embryo) ♀

Groups by natural appearance	Number of renculi of each group	Types by number of papillae in a renculus	Number of renculi of each type	Number of papillae	Total number of papillae of each group	Weight (g)
I	276 *70.95*	1	269 *97.46*	269 *54.7*	283 *57.5*	17.0 *61.2*
		2	7 *2.54*	14 *2.8*		
II	102 *26.22*	1	32 *31.37*	32 *6.5*	172 *35.0*	9.0 *32.4*
		2	70 *68.63*	140 *28.5*		
III	7 *1.8*	3	7 *100*	21 *4.3*	21 *4.3*	1.0 *3.6*
IV	4 *1.03*	4	4 *100*	16 *3.3*	16 *3.3*	0.8 *2.8*
Total	**389**		**389**	**492**	**492**	**27.8**

APPENDIX TABLE II. THE CLASSIFICATION BY COUNTING PAPILLAE OF THE RENCULUS (IN EACH SPECIES ONLY THE RIGHT KIDNEY WAS EXAMINED)

Species	Groups →	I	II	III	IV	V	VI	VII	Total
Balaena glacialis 11.65 m. ♀	1[1]	1935	2448	694	265	29	4	2	**5377**
	2[2]	*36*	*45.5*	*12.9*	*4.9*	*0.5*	*0.07*	*0.04*	
	3[3]	1935	4896	2082	1060	145	24	14	**10156**
	4[4]	*19.05*	*48.2*	*20.5*	*10.44*	*1.43*	*0.24*	*0.14*	
Balaenoptera acuto-rostrata 6.8 m. ♀	1	1211	38	1	—	—	—	—	**1250**
	2	*96.88*	*3.04*	*0.08*	—	—	—	—	
	3	1211	76	3	—	—	—	—	**1290**
	4	*93.88*	*5.89*	*0.23*	—	—	—	—	
Ziphius cavirostris 6.4 m. ♀	1	1147	706	52	7	—	—	—	**1912**
	2	*59.99*	*36.92*	*2.72*	*0.37*	—	—	—	
	3	1147	1412	156	28	—	—	—	**2743**
	4	*41.82*	*51.48*	*5.69*	*1.02*	—	—	—	
Orcinus orca 5.42 m. ♀	1	527	591	81	18	—	—	—	**1217**
	2	*43.3*	*48.56*	*6.66*	*1.48*	—	—	—	
	3	527	1182	243	72	—	—	—	**2024**
	4	*26.38*	*58.4*	*11.5*	*3.56*	—	—	—	
Globicephalus melas 3.05 m. ♀	1	418	185	35	2	1	—	—	**641**
	2	*65.21*	*28.86*	*5.46*	*0.31*	*0.15*	—	—	
	3	418	370	105	8	5	—	—	**906**
	4	*46.14*	*40.84*	*11.59*	*0.88*	*0.55*	—	—	
Grampus griseus 3 m. ♂	1	362	16	—	—	—	—	—	**378**
	2	*95.77*	*4.23*	—	—	—	—	—	
	3	362	32	—	—	—	—	—	**395**
	4	*91.88*	*8.12*	—	—	—	—	—	
Trusiops truncatus 2.23 m. ♂	1	235	114	25	1	—	—	—	**375**
	2	*62.67*	*30.4*	*6.67*	*0.27*	—	—	—	
	3	235	228	75	4	—	—	—	**542**
	4	*43.36*	*42.07*	*13.84*	*0.74*	—	—	—	
Prodelphnus caeruleo-albus 2.07 m. ♂	1	225	42	3	—	—	—	—	**270**
	2	*83.3*	*15.5*	*1.11*	—	—	—	—	
	3	225	84	9	—	—	—	—	**318**
	4	*70.75*	*26.42*	*2.83*	—	—	—	—	
Delphinus delphis 1.77 m. ♀	1	151	93	22	3	—	—	—	**269**
	2	*56.13*	*34.57*	*8.18*	*1.12*	—	—	—	
	3	151	186	66	12	—	—	—	**415**
	4	*36.39*	*44.82*	*15.9*	*2.89*	—	—	—	
Neomeris phocaenoides 1.52 m. ♀	1	124	14	—	—	—	—	—	**138**
	2	*89.9*	*10.1*	—	—	—	—	—	
	3	124	28	—	—	—	—	—	**152**
	4	*81.6*	*18.4*	—	—	—	—	—	
Phocaenoides truei (Embryo) 0.82 m. ♀	1	301	77	7	4	—	—	—	**389**
	2	*77.4*	*19.8*	*1.8*	*1.03*	—	—	—	
	3	301	154	21	16	—	—	—	**492**
	4	*61.2*	*31.3*	*4.3*	*3.3*	—	—	—	

[1] Number of the renculi.
[2] Ratio to the total number of the renculi.
[3] Number of the papillae.
[4] Ratio to the total number of the papillae.


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COMPARISON OF THE SIZE OF CELLS AND SOME HISTOLOGICAL FORMATIONS BETWEEN WHALES AND MAN

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INTRODUCTION, MATERIAL AND METHODS

Cells and histological formations constructing the huge bulk of the whale's body are not so large as one might suppose. They are of the similar size to those of other mammals including man. Probably the size of cells is determined by some biological factors which are, although unknown yet, rather common in the animal kingdom. The present writers, following the histological studies of whales, happened to be attracted to this notable similarity of cell size among whales and man and tried to examine this similarity precisely and statistically.

Several kinds of histological preparations of whales and man were used for this purpose. Whales used comprise the right whale (*Balaena gracialis* Bonnaterre)***, blue whale (*Balaenoptera musculus* L.), fin whale (*Balaenoptera physalus* L.), sei whale (*Balaenoptera borealis* Lesson), one kind of the beaked whale (*Berardius bairdii* Stejneger) and one kind of the dolphin (*Lagenorhynchus obliquidens* Gill), all of which were adult. Each of the specimens taken from these materials was embedded in celloidin, sectioned fifteen μ in thickness and stained with hematoxylin and eosin. Measurements of nerve cells and fibres were, however, made on the preparations stained by the Pal-carmin method.

In order to explain the method of statistical calculations, table 1 is to be referred to, in which the results of observations and calculations are shown. The first column gives the items of investigation, which includes several kinds of cells and histological units. For the measurements such cells were chosen at random that appeared to be cut through the center approximately. At the same time nearly round cells as possible were selected and two diameters of each cell, being at right angles to each other, were measured by the micrometer. Then the arithmetic average of these two values was got to represent the size of this cell. The same holds good for such structures as the lung alveoles, Langerhans islets, renal corpuscles, etc. As to the muscle and nerve fibres,

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*** With the special permission of the Japanese Government, this right whale was caught in May, 1956, for the scientific investigations. It was a female and 38 feet 4 inches in length.

the thickness of each fibre was measured to show its size.

Following the second and third columns which tell the species of whales and the axis of measurement respectively, the fourth column (N) gives the sample size or the number of cells examined. Column 5 ($\bar{x}$) shows the sample mean or the arithmetic average of the measurements, which is represented by $\sum_{i=1}^{N} x_i/N$. The unit of these figures is always "micron." While the sixth column (S) indicates the total variance given by $\sum_{i=1}^{N}(x_i-\bar{x})^2$, two following columns (s^2 and u^2) state the sample and standard variances respectively. These two variances are given by S/N and $S/(N-1)$.

Column 9 gives the confidence interval for 'm' or the mean of the mother population. The significance level α for the figures is 0.05. It means that the mean of the mother population lies within this interval with the probability of 95%. It is computed by the form

$$Pr.\{\bar{x}+u\sqrt{F/N}\geqq m\geqq\bar{x}-u\sqrt{F/N}\}=1-\alpha. \quad (\alpha=0.05)$$

'F' is to be got by checking the table of F-distribution ($n_1=1$, $n_2=N-1$).

Column 10 shows the critical regions for the samples, indicating that the measurements of all the sample must be, with the probability of 95%, within this region. It is computed by the form

$$Pr.\{\bar{x}+u\sqrt{(N+1)F/N}\geqq x_i\geqq\bar{x}-u\sqrt{(N+1)F/N}\}=1-\alpha. \quad (\alpha=0.05)$$

The last column gives the result of the statistical comparisons. Supposing that two samples are to be compared, of which the sizes and standard variances are M, N and u^2, v^2 respectively, the first step of the statistical test is to get 'F_0' given by u^2/v^2 ($u^2>v^2$) as well as the 'F' value from the F-distribution table, the degrees of freedom (n_1, n_2) being M-1 and N-1. If 'F_0' is larger than 'F' ($F_0>F$), it means that the comparison of these two samples is statistically impossible (X). For the null-hypothesis that these two belong to one and the same mother population can be abandoned with the danger of 5%. If 'F_0' is less than 'F' ($F_0<F$), the second step of the test is to be taken. After calculating the common standard variance w^2 which is given by $(n_1u^2+n_2v^2)/(n_1+n_2)$ or $(S_x+S_y)/(M+N-2)$, 'F_0' should be got by the following form.

$$F_0=(\bar{x}-\bar{y})^2MN/w^2(M+N)\ .$$

S_x, S_y and $\bar{x}$, $\bar{y}$ represent the total variances and sample means of the two samples to be tested. Then the 'F' value is to be got by

TABLE 1. SIZE OF CELLS AND CELL AGGREGATES OF WHALES AND MAN.

(1) Item	(2) Species	(3) Axis	(4) Sample size N	(5) Sample mean $\bar{x}(\mu)$	(6) $S(\mu^2)$	(7) $s^2(\mu^2)$	(8) $u^2(\mu^2)$	(9) Confidence interval of mother mean ($\alpha=0.05$) (μ)	(10) Critical region for sample ($\alpha=0.05$) (μ)	(11) Statistical comparison ($\alpha=0.05$)	
Liver cells	a. Right w.	length	50	18.6	195.5	3.9	4.0	19.2~18.0	22.7~14.5		
		width	50	13.9	144.0	2.9	2.9	14.4~13.4	17.3~10.5	a~b	−
		average	50	16.3	99.1	1.9	2.0	16.7~15.9	19.2~13.4		
	b. Blue w.	length	50	18.3	181.3	3.6	3.7	18.8~17.8	21.9~14.7		
		width	50	14.9	157.3	3.1	3.2	15.4~14.4	18.5~11.3	a~c	
		average	50	16.5	100.0	2.0	2.0	16.9~16.1	19.4~13.6		
	c. Man	length	50	18.0	182.2	3.6	3.7	18.5~17.5	21.6~14.4	b~c	
		width	50	14.4	199.1	4.0	4.1	14.9~13.9	18.0~10.8		
		average	50	16.3	138.7	2.8	2.8	16.8~15.8	19.7~12.9		
Heart muscle fibres	a. Sei whale		100	10.7	717.7	7.2	7.3	11.2~10.2	16.0−5.4	a~b	−
	b. Man		100	10.6	609.9	6.1	6.2	11.1~10.1	15.6~5.6		
Purkiuje fibres	a. Sei whale		20	37.1	3848.8	192.4	202.6	43.8~30.4	67.7~6.5	a~b	×
	b. Man		10	26.2	355.5	35.5	39.5	30.6~21.8	40.7~11.7		
Cortical cells of the adrenal gland	a. Right w.	length	30	13.3	74.7	2.5	2.6	13.9~12.7	16.7~9.9		
		width	30	10.0	57.7	1.9	2.0	10.5~9.5	12.8~7.2		
		average	30	11.7	31.6	1.1	1.1	12.1~11.3	13.8~9.6		
	b. Man	length	30	14.1	85.6	2.9	3.0	14.7~13.5	17.5~10.7	a~b	+
		width	30	11.7	69.0	2.3	2.4	12.3~11.1	15.1~8.3		
		average	30	12.9	59.7	2.0	2.0	13.4~12.4	15.9~9.9		
Fat cells	a. Right w.		50	92.6	13773.0	275.3	281.1	97.3~87.9	126.2~59.0	a~b	×
	b. Man		50	56.3	4605.3	91.2	94.0	59.1~53.5	76.3~36.3		

TABLE 1. (CONTINUED)

(1) Item	(2) Species	(3) Axis	(4) Sample size N	(5) Sampel mean $x(\mu)$	(6) $S(\mu^2)$	(7) $s^2(\mu^2)$	(8) $u^2(\mu^2)$	(9) Confidence interval of mother mean ($\alpha=0.05$) (μ)	(10) Critical region for sample ($\alpha=0.05$) (μ)	(11) Statistical comparison ($\alpha=0.05$)	
Parietal cells of the gastric mucosa	a. Sei w.	length	50	19.3	297.8	6.0	6.0	20.0~18.6	24.3~14.3	a~ b	−
		width	50	15.9	264.0	5.3	5.4	16.6~15.2	20.9~10.9		
		average	50	17.6	140.0	2.8	2.9	18.1~17.1	21.2~14.0	c	+
	b. Fin w.	length	50	19.1	351.1	7.0	7.2	19.9~18.3	24.8~13.4	d	+
		width	50	15.3	320.9	6.4	6.5	16.0~14.6	20.3~10.3	e	+
		average	50	17.2	154.6	3.1	3.2	17.7~16.7	20.8~13.6		
	c. Blue w.	length	50	20.8	202.7	4.1	4.1	21.4~20.2	25.1~16.5	b~ c	×
		width	50	15.7	112.0	2.2	2.3	16.1~15.3	18.6~12.8	d	+
		average	50	18.3	93.3	1.9	1.9	18.7~17.9	21.2~15.4	e	−
	d. Right w.	length	50	23.1	459.6	9.2	9.4	24.0~22.2	29.5~16.7		
		width	50	16.7	333.3	6.7	6.8	17.4~16.0	21.7~11.7	c~ d	×
		average	50	19.9	214.2	4.3	4.4	20.5~19.3	24.2~15.6	e	×
	e. Man	length	50	18.0	308.4	6.2	6.3	18.7~17.3	23.0~13.0		
		width	50	15.1	258.7	5.2	5.3	15.8~14.4	20.1~10.1	d~e	+
		average	50	16.8	211.5	4.2	4.3	17.4~16.2	21.1~12.5		
Spinal root fibres* (cervical nerves) Ventr. root	a. Berardius		50	17.1	145.4	2.9	2.95	17.6~16.6	20.5~13.7	a {b, c}	×
	b. Lagenorhynx		50	13.5	60.0	1.2	1.2	13.8~13.2	15.7~11.3	b~c	+
	c. Man		50	10.6	78.7	1.6	1.6	11.0~10.2	13.5~7.7	a′~b′ b′~c′	×
Dors. root	a′. Berardius		50	15.1	152.0	3.0	3.1	15.4~14.8	17.2~13.0	a′~c′	+
	b′. Lagenorhynx		50	11.8	59.8	1.2	1.2	12.1~11.5	13.9~9.7	a~a′ b~b′ c~c′	+
	c′. Man		50	10.0	92.0	1.8	2.0	10.4~9.6	12.9~7.1		

TABLE 1. (CONTINUED)

(1) Item		(2) Species	(3) Axis	(4) Sample size N	(5) Sample mean $\bar{x}(\mu)$	(6) $S(\mu^2)$	(7) $s^2(\mu^2)$	(8) $u^2(\mu^2)$	(9) Confidence interval of mother mean $(\alpha=0.05)$ (μ)	(10) Critical region for sample $(\alpha=0.05)$ (μ)	(11) Statistical comparison $(\alpha=0.05)$
Nerve cells*	Ncl. n. hypoglossi	a. Sei w.	Average of length and width	50	60.7	2377.0	47.5	48.5	62.7~58.7	75.0~46.4	a~b ×
		b. Man		50	29.4	466.6	9.4	9.5	30.3~38.5	35.7~23.1	b~c +
		c. Mouse		50	25.3	460.2	9.2	9.4	25.6~25.0	27.3~23.3	
	Purkinje cells	a. Sei w.		50	34.4	705.9	14.1	14.4	36.2~32.6	47.3~21.6	a~b −
		b. Man		50	31.1	674.6	13.5	13.8	32.2~30.1	38.6~23.6	b~c ×
		c. Mouse		50	15.4	150.1	3.0	3.1	15.9~14.9	19.0~11.9	
	Mesencephalic ncl. of trig. nerve**	(1) a. Sei w.		50	80.0	8051.6	161.0	164.3	83.6~86.4	105.7~54.3	a~b b~c ×
		(1) b. Man		50	40.5	2605.4	52.1	53.2	42.6~38.4	55.3~25.7	
		(1) c. Mouse		50	17.7	383.0	7.7	7.8	18.5~16.9	23.4~12.0	
		(2) a. Sei w.		50	68.9	2659.5	53.2	54.3	71.0~66.8	83.8~54.0	a~b b~c ×
		(2) b. Man		50	36.7	1485.2	29.7	30.3	38.3~35.1	478.~25.6	
		(2) c. Mouse		50	20.0	503.0	10.1	10.3	20.9~20.0	26.7~13.3	
Alveoli of the lung		a. Right w.	length	50	336.7	200857	4017.1	4099.1	354.6~318.8	464.5~208.9	
			width	50	217.1	131060	2621.2	2674.7	231.8~202.4	322.1~112.1	
			average	50	276.6	97344	1946.9	1986.6	289.3~263.9	367.3~185.9	a~b ×
		b. Man	length	50	195.0	73853	1473.1	1507.2	206.0~184.0	273.5~116.5	
			width	50	144.3	35913	718.3	732.9	152.0~136.6	199.3~89.3	
			average	50	170.7	35785	715.7	730.3	178.4~163.0	225.7~115.7	
Pancreatic acini		a. Blue w.		50	35.9	914.0	18.3	18.7	37.1~34.7	44.5~27.3	a~b a~c b~c −
		b. Right w.		50	35.3	841.6	16.8	17.2	36.5~34.1	43.7~27.7	
		c. Man		50	35.0	679.0	13.5	13.8	36.0~34.0	42.2~27.9	a b c ~d +
		d. Right w.***		50	32.0	855.5	17.1	17.5	33.2~30.8	40.6~23.4	

TABLE 1. (CONCLUDED)

(1) Item	(2) Species	(3) Axis	(4) Sample size N	(5) Sample mean $\bar{x}(\mu)$	(6) $S(\mu^2)$	(7) $s(\mu^2)$	(8) $u^2(\mu^2)$	(9) Confidence interval of mother mean ($\alpha=0.05$) (μ)	(10) Critical region for sample ($\alpha=0.05$) (μ)	(11) Statistical comparison ($\alpha=0.05$)
Langerhans islets	a. Right w.	length	50	175.5	80698	1614.0	1646.9	187.0~164.0	257.6~93.4	a~b ×
		width	50	111.8	50869	1017.4	1038.1	120.7~102.9	175.3~48.3	
		average	50	144.0	55820	1116.0	1139.0	153.6~134.4	212.5~75.5	
	b. Man	length	50	141.7	43687	873.7	891.6	150.2~133.2	202.4~81.0	
		width	50	109.2	16731	334.6	341.4	114.6~103.8	147.8~70.6	
		average	50	125.0	26026	520.5	531·1	131.5~118.5	171.4~78.6	
Renal corpuscles	a. Right w.	length	50	163.8	23660	473.2	482.9	170.0~157.5	208.1~119.5	a~b ×
		width	50	132.6	13013	260.3	265.6	137.2~128.0	165.4~99.8	
		average	50	148.0	12210	244.2	249.2	152.5~143.5	180.1~115.9	
	b. Man	length	50	165.1	39462	789.2	805.3	173.2~157.0	222.9~107.3	
		width	50	135.2	28730	574.6	586.3	142.1~128.3	184.5~85.9	
		average	50	151.0	31561	631.2	644.0	158.2~143.8	202.4~99.6	

* Stained by the Pal-carmin method.

** (1) at the level of rostral colliculus, (2) at the level of caudal colliculus.

*** Embedded in paraffin.

checking the F-distribution table, n_1 and n_2 being 1 and $M+N-2$ respectively. If 'F_0' is larger than 'F' ($F_0>F$), it means that there is statistically a rational difference between these two samples (+), while in case $F_0<F$, it is shown that there is no rational difference at all between these two (−).

RESULTS

All the results of observations and calculations are shown in table 1. Each of the items will be explained briefly. Accompanying figures and graphs are to help the explanation.

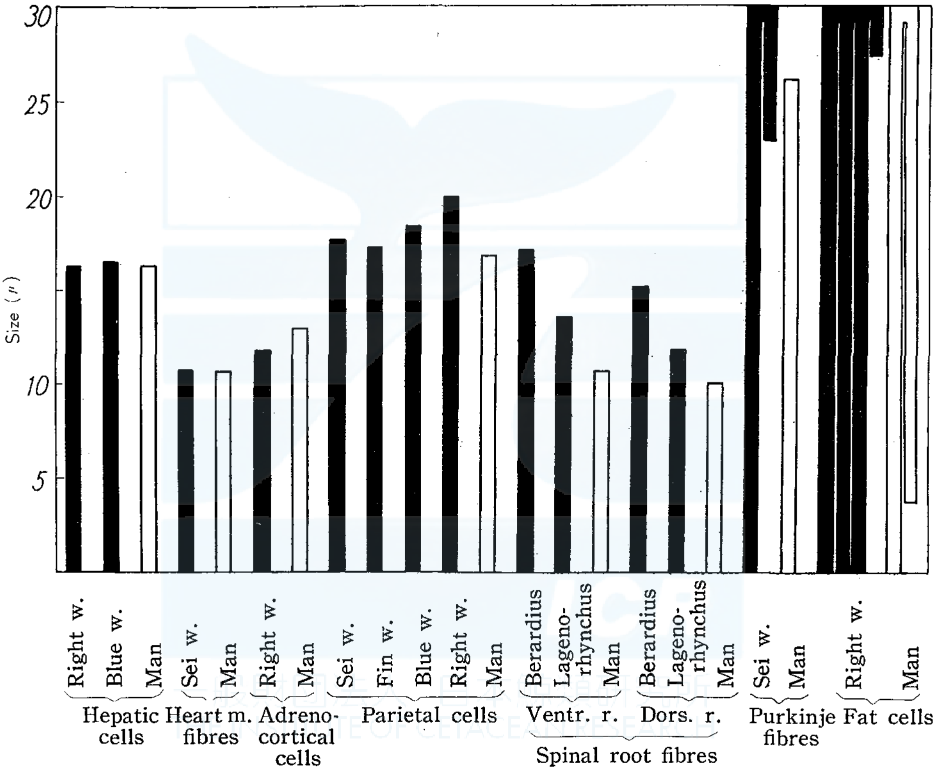

Fig. 1. Average means of the cell sizes.

Hepatic cells (Figs. 1, 2.)

Not only the microscopical appearances but also the size of the hepatic cells is quite similar to each other among the right whale, blue whale and man. The sample means of the longitudinal and transversal diameters are 18.6μ and 13.9μ for the right whale, 18.3μ and 14.9μ for the blue whale, and 18.0μ and 14.4μ for man. The averages of these

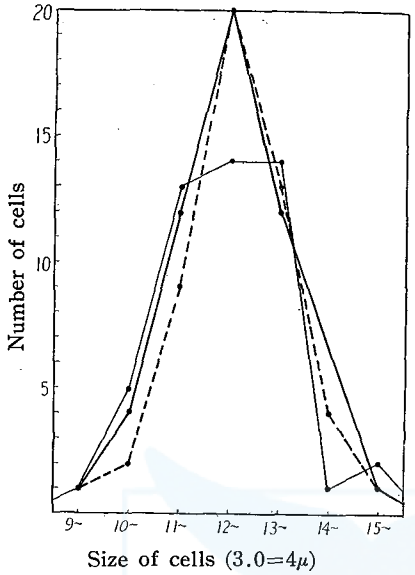

Fig. 2. Size distribution of hepatic cells.

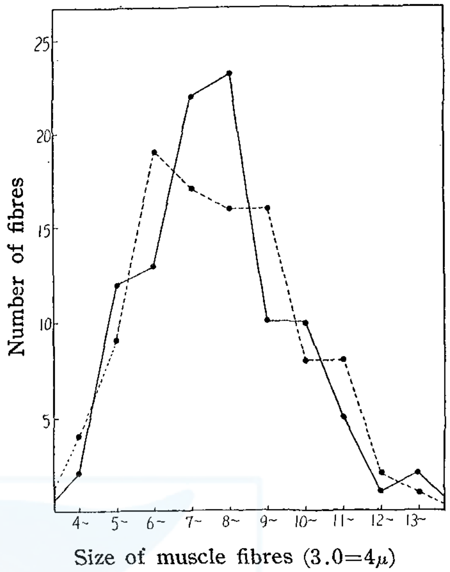

Fig. 3. Size distribution of heart muscle fibres.

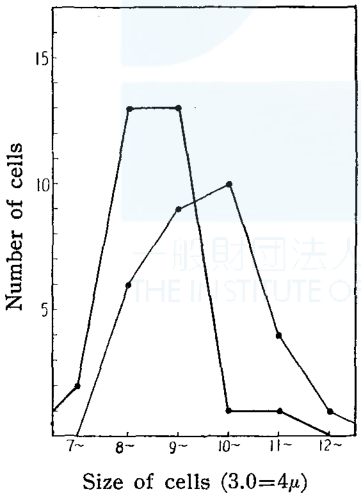

Fig. 4. Size distribution of adrenal cortical cells.

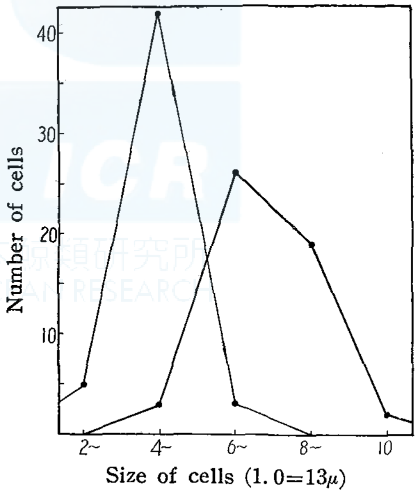

Fig. 5. Size distribution of fat cells (in the gastric submucosa).

two diameters are also of high similarity, being 16.3μ, 16.5μ and 16.3μ respectively. Furthermore, it is illustrated in figure 2 that these cells of whales and man show very similar mode of distribution of the size. The statistical comparison revealed that there were no rational differences among these three populations of cells.

Heart muscle fibres (Figs. 1, 3)

As shown in figure 3, muscle fibres constructing the heart of the sei whale and man are almost the same size in their thickness. The sample means are 10.7μ and 10.6μ respectively and the distribution curve for each takes a similar shape and position. The statistical calculations showed that no rational differences in thickness were recognizable between these two groups of muscle fibres.

Purkinje fibres (Fig. 1)

Contrary to the high similarity of the thickness of ordinary heart muscle fibres between the sei whale and man, Purkinje fibres present remarkable difference in size between these two species. The former, of which the average thickness is 37.1μ, exceeds the latter by more than 10μ. That the whale's heart is provided with very thick Purkinje fibres is interesting, when it is reminded of that the hearts of ungulates have also remarkably thick Purkinje fibres.

Cortical cells of the adrenal gland (Figs. 1, 4)

Adreno-cortical cells in the deep layer abutting on the medulla were measured. Although the sample means of these cells are not so different from each other between the right whale and man, their mode of distribution is noticably different. (Fig. 4) Necessarily a rational difference was encountered by the statistical comparison.

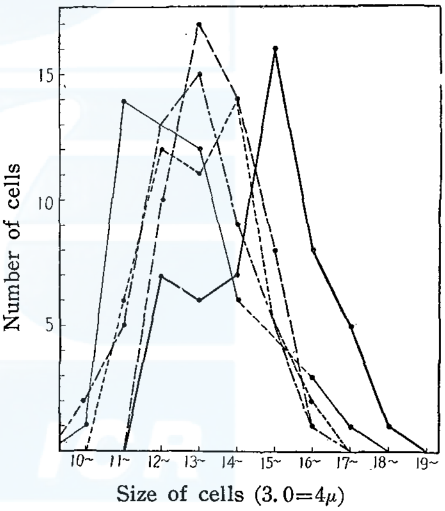

Fig. 6. Size distribution of parietal cells of the gastric mucosa.

·——· Right whale
·- - -· Blue whale
·—-—· Fin whale
········ Sei whale
·——· Human

Fat cells (Figs. 1, 5)

Fat cells in the gastric submucosa of the right whale and man showed a remarkable discrepancy in their sizes, the former being nearly twice as large as the latter. Their modes of distribution are also discrepant to such an extent that the statistical comparison turned out to be impossible.

Parietal cells of the gastric gland (Figs. 1, 6)

Parietal cells in the gastric mucosa were compared among the sei, fin, blue, right whale and man. Generally speaking these cells showed a considerable uniformity in size, the sample means ranging from 16.8μ in man to 19.9μ in the right whale. Figure 6 illustrates diagrammatically the mode of distribution for each species. According to the statistical calculations, however, the comparison of these whales and man gives rather un-uniform results. For in some cases there is no rational difference (*f. i.* between fin and sei whale or man), while in some other cases there is rational differences (*f. i.* between sei and blue, right whale or man, between right and fin whale or man), and still in other cases the comparison is impossible (*f. i.* between blue and fin, right whale or man).

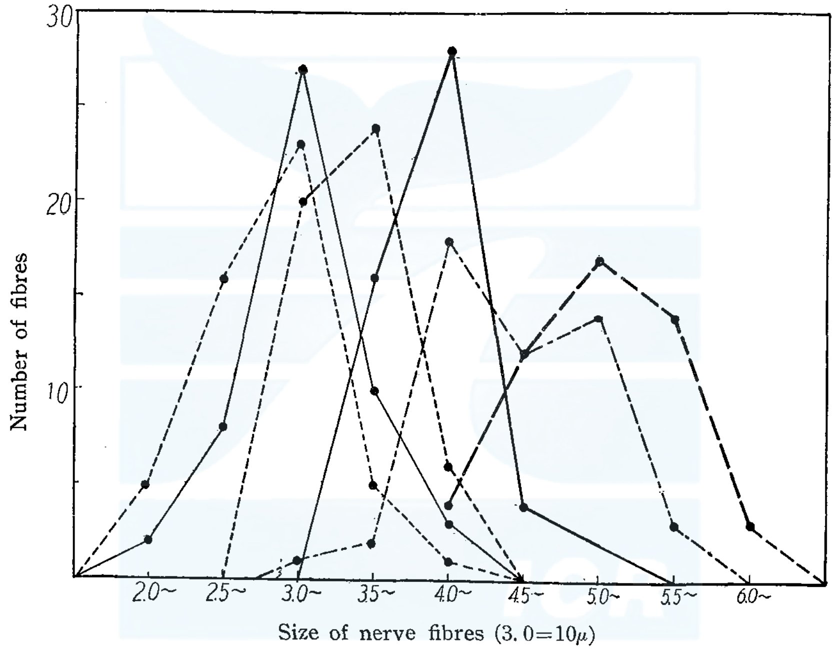

Fig. 7. Size distribution of spinal root fibres (large medullated fibres).

•—• ventral root } Human
•-------• dorsal root } Human
•▬▬• ventral root } Lageno-rhynchus
•-------• dorsal r. } Lageno-rhynchus
•▬ ▬ ▬• ventral r. } Berardius
•— — —• dorsal r. } Berardius

Spinal root fibres (Figs. 1, 7)

Thick-medullated fibres of the cervical nerves were chosen at random and measured in their thickness for the Berardius, Lagenorhynchus and man. The sample mean of the ventral root fibres as well as of the dorsal ones is largest in the Berardius and smallest in man, that of the Lagenorhynchus taking the mediate value in both groups of fibres. If the ventral root fibres are compared with the dorsal fibres, the former always exceed the latter in thickness. Hence the distribution curve for the ventral fibres takes a position left to that for the dorsal fibres for each of the species examined. (Fig. 7).

The results of the statistical comparisons among these six groups of nerve fibres are rather irregular. In some cases it was revealed that the comparison was impossible (*f. i.* between the ventral root fibres of Berardius and those of Lagenorhynchus or man, between the dorsal root fibres of Lagenorhynchus and those of Berardius or man). In other cases, however, the comparison turned out to be possible, although rational differences were recognized in most cases.

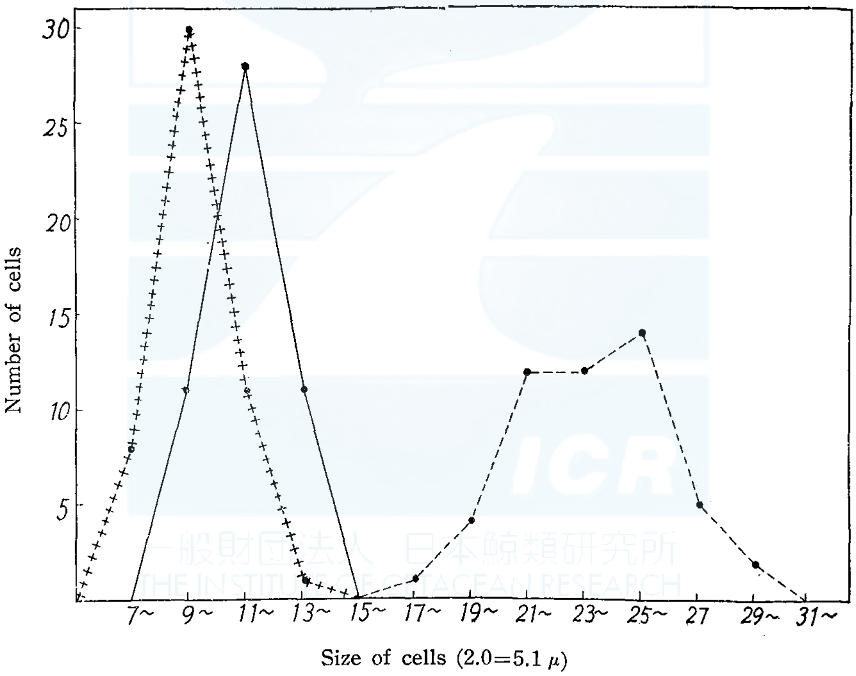

Fig 8. Size distribution of nerve cells of the hypoglossal nucleus.

·+++· Sei whale
·——· Human
·------· Mouse

Nerve cells (Figs. 8-13)

Nerve cells in the hypoglossal and trigeminal mesencephalic nuclei as well as the Purkinje cells in the cerebellum were measured and examined in the sei whale, man and mouse. The average of the longitudinal and transversal diameters of each cell was used for the statistical calculations. As shown in figures 8, 9 and 10, in every item of the invesitigation it was made clear that the brain of the sei whale was furnished with the largest cells and the mouse's were smallest, while the human materials were of the intermediate size. Statistical relations in size among these groups of nerve cells are not so intimate. So far as the size is concerned, most of them seem to belong to special kind of population.

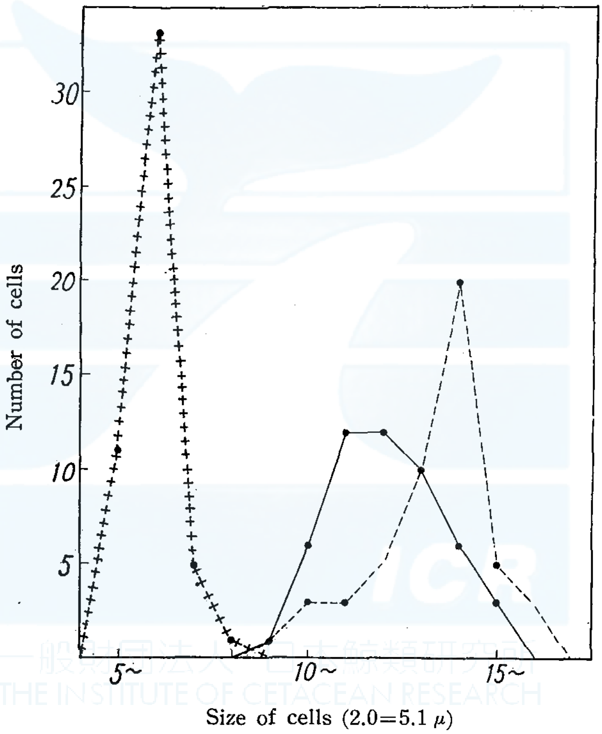

Fig. 9. Size distribution of the Purkinje cells.

·+++· Sei whale
·——· Human
·------· Mouse

When those three kinds of cells are compared to each other in each of the species examined, the cells of the hypoglossal nucleus are largest and the Purkinje cells are smallest for both the sei whale and mouse.

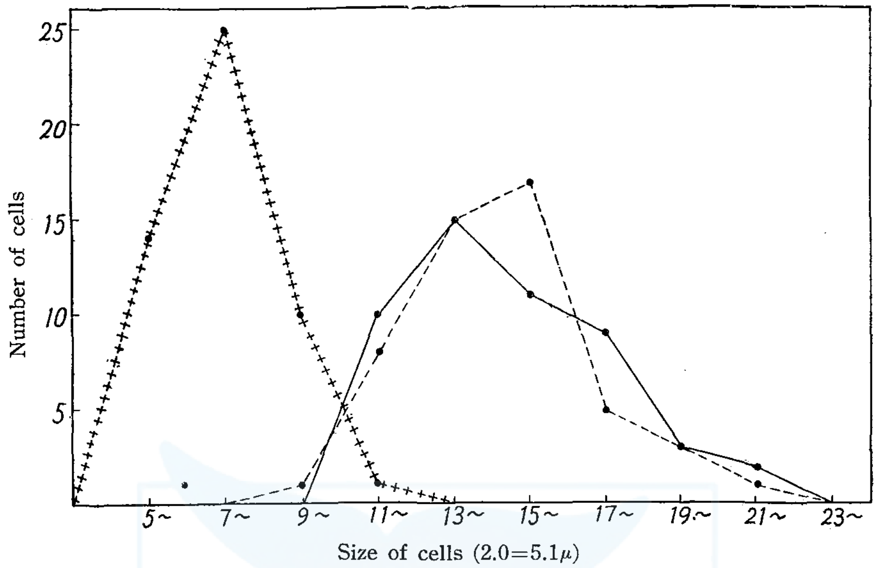

Fig. 10. Size distribution of nerve cells of the trigeminal mesencephalic nucleus.

·++++· Sei whale
·——· Human
·------· Mouse

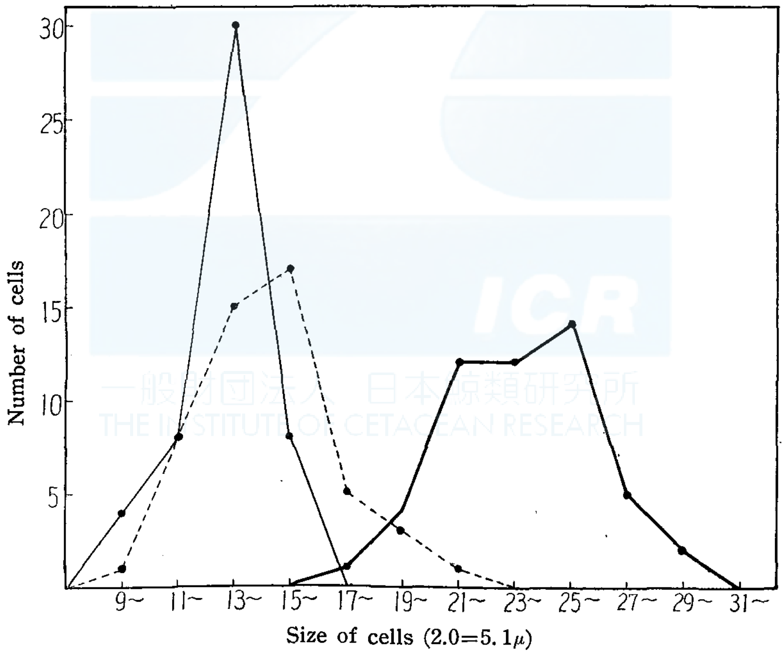

Fig. 11. Size distribution of nerve cells of the sei whale.

·——· Nucl. nervi hypoglossi
·——· Purkinje cells
·------· Nucl. mesencephalicus V

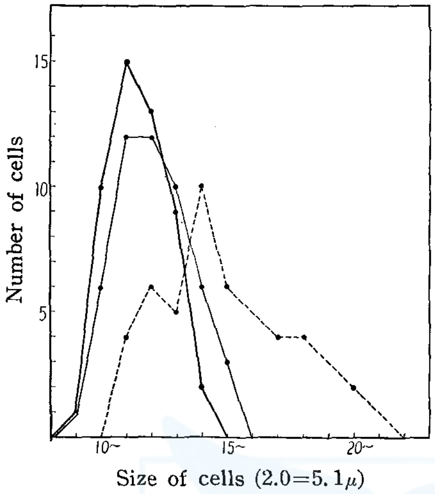

Fig. 12. Size distribution of nerve cells of man.

·▬▬· Nucl. nervi hypoglossi
·——· Purkinje cells
·-----· Nucl. mesencephalicus V

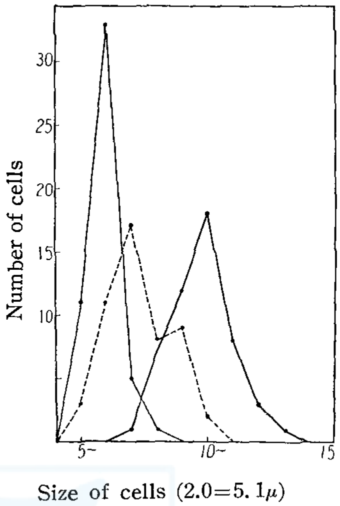

Fig. 13. Size distribution of nerve cells of the mouse.

·▬▬· Nucl. nervi hypoglossi
·——· Purkinje cells
·-----· Nucl. mesencephalcus V

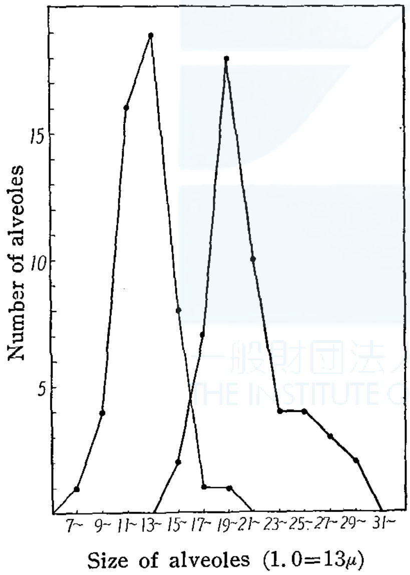

Fig. 14. Size distribution of alveoles of the lung.

·▬▬· Right whale
·——· Human

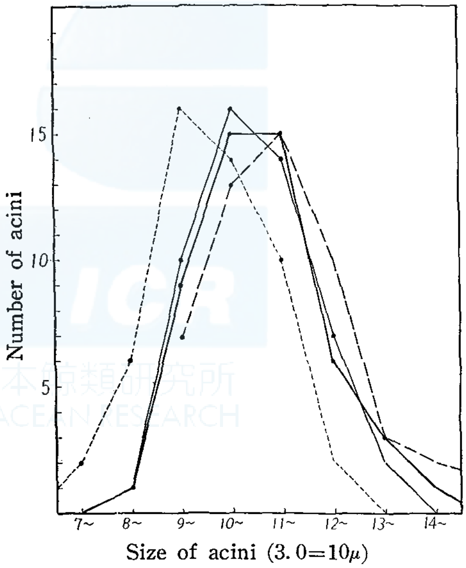

Fig. 15. Size distribution of the pancreas-acini.

·▬▬· Right whale
·— — —· Blue whale
·——· Human
·-----· Right whale (embedded in paraffin)

In the case of man, however, the cells of the hypoglossal nucleus are smallest, although the order in size of other two kinds of cells is the same as in the sei whale and mouse. (Figs. 11, 12 and 13)

Alveoli of the lung (Fig. 14)

The pulmonary alveoli of the right whale are by far larger than those of man, the sample mean of the inner diameters being 276.6μ and 170.7μ respectively. The distribution mode is also quite different from each other and the comparison is statistically impossible.

Pancreatic acini (Fig. 15)

Outer diameters of the pancreatic acini of the blue, right whale and man are fairly alike, the sample means being approximately 35μ in each case. Their distribution modes are, as shown in figure 15, also similar to each other so extremely that they can be regarded statistically, so far as the size is concerned, as belonging to one and the same mother population.

In the preparations of the right whale pancreas embedded in paraffin the acini were smaller than those in the celloidin preparations. This decrease in size is apparently due to the shrinkage. As the sample mean for the paraffin preparations is 32μ compared to 35.3μ in the celloidin preparations, the decrease is calculated to be 9.3%.[1] Because of this decrease in size the distribution curve for the paraffin preparations is shifted to the left considerably. The shape of the curve itself is however almost the same as that for the celloidin preparations, thus resulting merely in the rational difference statistically.

Langerhans islets

The Langerhans islets of the right whale pancreas are on the average a little larger than those in the human pancreas. The sample means of the measurements are 144μ for the former and 125μ for the latter. Their distribution shows an irregular curve in both cases and the statistical comparison turned out to be impossible.

Renal corpuscles

Malpighian corpuscles of the right whale kidney are exceeded slightly in size by the human equivalents. Furthermore the distribution for the right whale represents a steeper curve than that for the human material. The curve for the latter is provided with a broader foot contour.

Relation in size between the nucleus and cell body

By the measurement of the adreno-cortical cells and the parietal cells of the gastric glands their nuclei were measured too. The average

[1] According to FUJITA (1947) the radii of the renal corpuscles of the rabbit were in the average 32.9μ in the paraffin preparations, 36.2μ in the celloidin preparations and 42.3μ in the frozen sections. Thus the decrease in size of the paraffin preparations compared to the celloidin ones was 9.1%

sizes given by the arithmetic mean of the length and width of nuclei as well as of cell bodies are in table 2. The ratio between these two values seems to be approximately the same for each kind of cells of

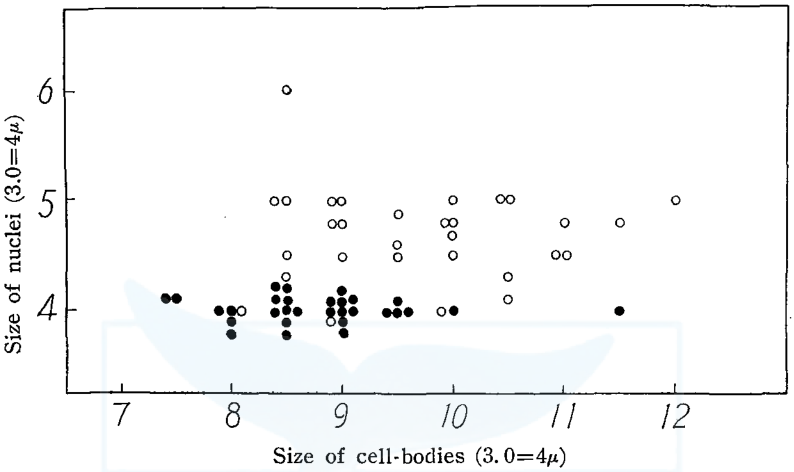

Fig. 16. Comparison of the size of cell-bodies and nuclei of the adreno-cortical cells

●: Right whale ○: Man

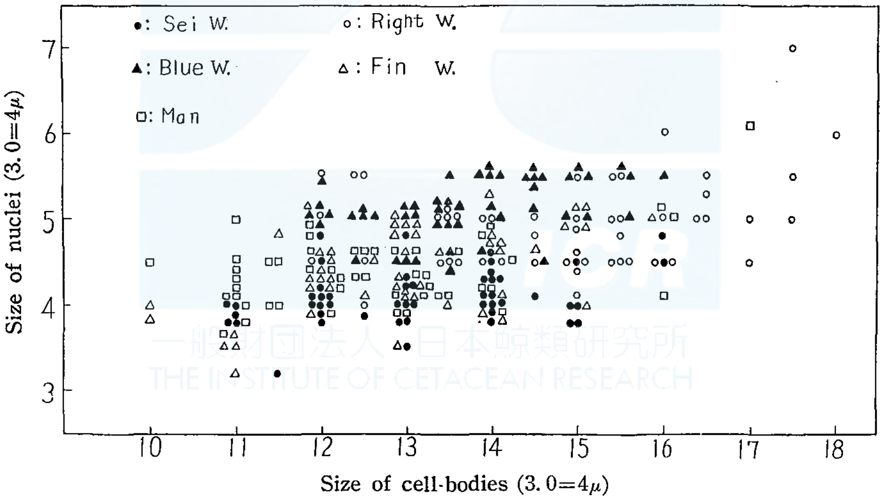

Fig. 17. Comparison of the size of cell-bodies and nuclei of the parietal cells of the gastric gland.

whales and man. In the adreno-cortical cells the proportion of the nucleus to the cell body is nearly 50% in both the right whale and man. The same ratio is shown to be considerably smaller and less than 40% in the parietal cells for man and every kind of whales examined.

The scatter diagrams in figures 16 and 17 are to show the correlation in size between the nuclei and the cell bodies. Judging from these diagrams there seems to be no simple relationship between these two. The cell bodies are by far more variant in size than the nuclei within them.

TABLE 2. RATIO IN SIZE BETWEEN THE NUCLEUS AND CELL BODY.

Item	Species	Cell body (μ)	Nucleus (μ)	Ratio
Adreno-cortical cells	Right w.	11.7	5.3	2.2:1=1:0.45
	Man	12.9	6.3	2.1:1=1:0.49
Parietal cells of the gastric gland	Sei w.	17.6	5.4	3.2:1=1:0.31
	Fin w.	17.2	6.0	2.9:1=1:0.35
	Blue w.	18.3	6.8	2.7:1=1:0.37
	Right w.	19.9	6.6	3.0:1=1:0.33
	Man	16.8	5.8	2.9:1=1:0.35

HISTORICAL REVIEW

*Cell size in general**

Since Schleiden and Schwann enunciated the cell-theory in 1838–1839, the cell has attained and kept its position as the most fundamental and essential subject in the fields of biology. More than half a century has elasped, however, before the problem of the size of this tiny mass of jelly-like substance called protoplasm attracted the notice of scholars. For it was Julius Sachs (1893) who for the first time paid special attention to the fact that the cells forming big plants are not necessarily larger than those of small plants. Amelung (1893), Strasburger (1893) and Rabl (1899) followed Sachs and Driesch (1900) mentioned of "the law of fixed largeness of the organ cells." It would be paraphrased that not the cell size but the number of cells of organisms varies in proportion to the body size. Studying on the Crepidula (gastropod) and rabbit respectively, Conklin (1912) and Painter (1928) reached to the same conclusion that the equivalent cells of animal bodies are, regardless of the individual variations in body size, almost the same.

Meanwhile, Hardesty (1902) stated, based upon the measurements of Cavazzani (1891) and Bühler (1898), that the variations in the size of cell-bodies of the spinal ganglia are not directly proportional to the variations in the size of the body of the animal, though in general the larger animal possesses larger cells. According to his own measurements of nerve cells in the spinal cord for several mammals, however, the average mean diameter of the cell-bodies of the columna anterior in

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* Among others, surveys of the pertinent literature by Chambers (1908), Wilson (1925), Wassermann (1928), Jacobj (1935), and Bucher (1954) are extensive and useful for reference.

the intumescentia cervicalis turned out to decrease gradually through a series of mammals of diminishing body weight. His observations showed further that the volume of the cell-body varies more nearly in proportion to the body size of animals and the volume of the entire neuron bears a still more constant ratio to the bulk of the animal body.

Comparative examinations of the cell size of several kinds of mammals led Levi (1905) to a noteworthy conclusion as follows. According to him, there are two categories of cells, one of which comprises such cells that show a notable uniformity in size all through the animals, while the cells of the second group vary in proportion to the body size. Epithelial and glandular cells belong to the first group and the large ganglion cells represent the typical example of the second group. Levi tried to explain the difference in relation to the histogenesis of each cells. For the cells of the first group maintain the potentiality of cell division during the whole life of animals, while the second ones lose the possibility early in the development. Observations of Obersteiner (1913) on Purkinje cells of the cerebellum of the sei whale, elephant and mouse gave the same relationship between the cell size and body size. Ganglion cells of the invertebrates were, however, shown by Erhard (1912) to vary capriciously and independently of the body size. Even for mammals he denied the intimate correlation between the size of cells and animal bodies.

Hatai (1902) measured the nerve cells in the spinal ganglia of the white rat and noticed the increase of cell size following the growth of animal. According to Pfuhl (1932), same kind of growth of the hapatic cells was reported by several authors for man and animals ; Harting (1845) and Toldt-Zuckerkandl (1876) for man, Kretschmar (1914) for the pig, Plenk (1911) for the rat, Heiberg (1907) for the mouse and Illing (1905) for domestic animals. Akiyama (1928) made a similar observation for the adrenocortical cells of the white rat. According to Berezowski (1910) the epithelial cells of the intestinal villi were observed to grow and lengthen too. Detailed investigation of the growth of cell size was made later by Rohrbacher (1927), who stated that each kind of cells has its specific size particular to the growth stages of animals.

Another factor influencing the cell size was pointed out by Chambers (1908), who noticed that the frog developed from a small ovum had smaller cells than the frog from a larger ovum. So it is possible, as Wassermann (1929) said, " dass bis zu einem gewissen Grad die difinitive Zellgrösse auch durch die Grösse der Ursprungszelle, des Eies, bestimmt sein kann."

The last and important matter to be considered in relation to the cell size is the quantitative correlation among the cell, the nucleus and the chromosomes. R. Hertwig (1903) was the first to notice the constancy of the ratio in volume between the cytoplasm and the nucleus and he established the theory of the nucleo-cytoplasmic relation or the karyoplasmic ratio (Lehre der Kern-Plasma-Relation). Erdmann (1908, 1909), Koehler (1912) etc. followed Hertwig and developed his theory. Erhard (1912) too stated that "die Grösse der Kerne (der Ganglienzellen) richtet sich nach der Grösse der Zellen, nur haben Zellen mit reichlicher Nisslsubstanz stets kleine, solche mit wenig oder gar keinem Tigroid stets grosse Kerne."*

Deviations of the nucleo-plasmic relation were studied by several authors such as Erdmann (1911), Lanz (1926), Stieve (1926), Tretjakoff (1928), etc. Excepting pathological cases, most of these changes of the nucleo-plasmic relation were apparently connected to the fluctuations of the hormonal condition. The functional hypertrophy is another element which causes the shifting of this relation in favour of the cytoplasm. According to Bucher (1948) the nucleo-plasmic relation changes as the aging progresses, resulting smaller nuclei in the cells of higher ages.

Studying upon the chromosomes of the sea-urchin larvae, Boveri (1905) found the parallelism between the cell size and the number of chromosomes or the amount of chromatin in the nucleus. Thus the cell body, nucleus and chromosomes are shown to be in quantitative correlation to one another, although no one knows whether one of these three takes the initiative in determining the volume or size of the others.

Such a harmonious balance prevailing in the intracellular structures fascinated Heidenhain (1907–) and he called it "syntonischer Zustand" or "Syntonie" or "Kanon der Teile und des Systems." The idea of "Syntonie" has developed hand in hand with that of the "dividing bodies" ("Teilkörper") such as protomeres, histomeres and histosystems. For both of these ideas represent important constituents of his famous "synthetische Morphologie" or "Synthesiologie." By means of these unique ideas Heidenhain tried to grasp the biological principle prevailing in the intra-, extra-, as well as the "supra"-cellular structures of the living body.

At least one part of Heidenhain's hypothetical theories was proved by fact, when Jacobj (1925) found the rhythmical variations of nuclear volumes in the hepatic cells of rats and mice. The so-called Jacobj's law or "das rhythmisches Verdoppelungswachstum" of the nuclear volume was tested and accepted by Voss (1928), Clara (1928, 1930) and

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* G. HERTWIG (1931) stressed upon the necessity of carefullness in considering the nucleo-plasmic relations. For he showed clearly that the cytoplasm reacts to fixatives with irregular shrinkages of higher grade than the nucleus.

many other scholars. Jacoby (1935) himself investigated later on many kinds of human cells and classified them into a series of classes, in which the nuclear volumes increase by doubling. Standard nuclear size for each class is as follows.

Class	Diameter (μ)	Volume (cub μ)
K 1/8	3.25	18
K 1/4	4.1	36
K 1/2	5.2	72
K 1	6.5	144
K 2	8.2	288
⋮	⋮	⋮
K 16	16.4	2304

In recent years new attention has been paid to Jacobj's doubling phenomenon of the nuclear volume. For some of the histochemical studies showed a parallelism between the nuclear volume and the DNA amount. (cf. Swift, 1953; Alfert, 1955 etc). New methods of precise caryometry are also being devised. (*f. i.* Bucher, 1954.) At the same time the nucleo-cytoplasmic relationship of R. Hertwig is increasing its importance in the fields of modern biology (cf. Frankenhauser, 1952; Hämmerling, 1953 etc.), and the ratio between nucleus and nucleolus too is becoming an interesting subject. (cf. Junqueira and Hirsch, 1956.)*

So far is the review of the literature on the problem of cell size in general. Concerning the items of the present writers' investigation some supplemental survey of the history will be added.

Hepatic cells

Several works on the quantitative study of the hepatic cells and nuclei have been mentioned already. Data given for the human hepatic cells are as follows.

v. Ebner (1899)	18-26 μ in diameter
Bucher (1948)	20-25
Kopsch (1955)	18-35
Bargmann (1956)	13-30

Average means of the cell size for several animals were tabulated by Pfuhl (1932) in the following way. Apparently the hepatic cells show a fairly uniform size among animals.

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* It would be noteworthy that Hsu (1954) studied in vitro on the chromosomes of human neoplasms and showed in graphs that the chromosome number distributes in the mode of doubling increase just like the nuclear volumes in Jacobj's graphs.

SIZE OF HEPATIC CELLS (PFUHL, 1932)

Animal (adult)	Cell (μ)	Nucleus (μ)	Author
Rat	23.0	8.0	Plenk
Rabbit	25.7	8.3	Schlater
Cat	21.1	—	Illing
Dog	20.0	7-8	Auerbach
	26.3	—	Illing
Horse	26.5	—	〃
Pig	21.4	—	〃
	23.3	—	Kretschmar
Ox	23.6	—	Illing
	29.0	—	Baum
Goat	21.5	—	Illing
Sheep	20.7	—	〃

Heart muscle fibres and Purkinje fibres

For the detailed survey of the literature Benninghoff (1930) and Häggqvist (1931, 1956) are to be referred to. Measurements of the width of the human cardiac fibres were reported as follows.

Letulle (1897)	5-25μ
v. Ebner (1899)	9-22
Marceau (1904)	5-40 (average 20)

The size of the human heart muscle fibres in relation to the aging was studied very extensively by Schiefferdecker (1916). According to him, the muscle fibres as well as the nuclei increase in size with aging.

For animals Schiebler's data (1953) will be cited.

Animal	Ordinary fibres of the heart muscle	Purkinje fibres
Ox	10 μ	35-45 μ
Calf	10	18-32
Pig	10	20-26
Dog	10	14-20
Cat	10	11

Notable uniformity seems to be prevailing in the size of heart muscle fibres, while the size of Purkinje fibres varies from one animal to another. According to Hirai (1943), however, the heart of such animals as with higher activity is made of compact bundles of thinner muscle fibres.

SIZE OF HEART MUSCLE FIBRES (HIRAI, 1943)

Animals with higher activity		Animals with lower activity	
Wild dog	157±5.3 μ	Rabbit	211±9.4 μ 225±10.5
Dog	182±5.8	Mouse	224±9.0 234±9.5
Japanese spaniel	181±7.1		
Hare	178±5.8		
Water rat	185±6.3 189±5.4		

Davies and Francis (1952) studied comparatively the hearts of mammals of various kinds and said that the ordinary myocardical fibres in all the animals examined showed a remarkable uniformity in diameter. On the other hand the fibres of the conducting system showed considerable difference in size among animals, the Purkinje fibres always exceeding the fibres of the atrio-ventricular bundle. Furthermore they examined the relationship between the size of the Purkinje fibres and the duration of QRS of the electrocardiogram for each animal, and got the suggestion that in hearts of thicker muscle fibres of the conducting system the cardiac impulse spreads through the ventricles at a higher rate than in those of thinner fibres.

DIAMETERS OF THE HEART MUSCLE FIBRES. (DAVIES AND FRANCIS, 1952)

Animal	Atrio-ventr. bundle (μ)	Subendocardial Purkinje fibres(μ)	Ventricular myocardium (μ)	QRS (1/100sec.)
Horse	35	88	12	7
Cow	30	40	〃	9
Human	11	18	〃	8
Wallaby	36	40	〃	3.5
Sheep	30	40	〃	3
Dog	12	18	〃	4
Cat	9	15	〃	4
Rabbit	10	14	〃	3
Rat	9	13	〃	2
Swan	35	44	9	3
Pigeon	11	12	8	2.7

Pulmonary alveoles

According to the survey of literature by Bargmann (1936), the number of alveoles of the human lungs are 300-500 millions and the total area of their internal surfaces amounts to 50-100 square meter. The average diameters of the human alveoles reported by several authors are as follows. (Data marked with (′) are cited from Bargmann, 1936.)

Rossignol (1847)′		200-250μ
Frey (1859)′		50-166.7
Kölliker (1880)′		60-90
v. Ebner (1899)		160-220-370
Schulze (1906)		200
Ogawa (1920)′		100-190
Wilson (1922)′		75 × 90 × 125
Marcus (1928)		150
Claus (1935)′	adult	300-600
	newborn	45-60
	infant	100-150
Kopsch (1955)		150-350
Braus (1956)		230
Bargmann (1956)		150-600

Concerning the lungs of various mammals, the extensive data given by Schulze (1906) and Marcus (1928) will be cited here. It would be added further that Fiebiger (1915) studied on the lung of a dolphin and stated the size of alveoles as 260×140μ.

MEASUREMENTS OF LUNG ALVEOLES. (SCHULZE, 1906)

Animal	Diameter of alveoles (μ)	Number of alveoles	Respiratory area (sq. meter
Cat	100	400 millionas	20
Sloth	400	6.25	5
Man	200	150	30
Dolphin	140	437	43

(Schulze regarded the difference of the respiratory area as indication of activity of animals.)

MEASUREMENTS OF LUNG ALVEOLES. (MARCUS, 1928)

Animal	Volume of lungs (ccm)	Respiratory mass (ccm)	Diameter of alveoles (μ)	Number of alveoles	Respirat. area (sq. m.)	Resp. area (sq. cm.) per gr. of body weight
Dolphin	50	40	200	5 millions	1	31
Mouse	0.9	7.2	30	266	0.1	54
Rat	7	5.6	50	45	0.6	33
Cat	180	144	100	144	7.2	28
Man	1880	1500	150	444	50	7
Bat	3	2.4	25	160	0.5	100
Galeopithecus	10	8	150	2.5	0.3	10
Young deer	420	336	120	200	14.4	21
Calf	3050	2440	160	600	76.8	13
Horse	17500	14000	140	5000	500	11

Renal corpuscles

Numerous papers have hitherto been published which treated directly or indirectly the size of the renal corpuscles of man and animals. Data given in those works will be arranged and tabulated as follows. (Values put in the brackets concern the corpuscles situated deep in the renal cortex. Data of authors with the mark (′) or (″) are cited from Möllendorff-1930- or Vimtrup-1928- respectively.)

Man:	217 μ	Bowmann (1842)′
	200	Schweigger Seidel (1865)
	200-300	Sappey (1879)″
	200-300	Toldt (1888)′
	213 (♂), 196 (♀)	Eckhardt (1888)″
	237	Külz (1899)″
	200 : 300, 149-212	Glantenay and Gosset (1901)′
	130 : 220	v. Ebner (1902)′
	210	Moore (1903)
	192 : 159	Peter (1909)
	200-300	Prenant (1911)′
	176-212	Moberg (1929)′

	159. 54 (paraffin) 169. 82 (celloidin) 193. 86 (frozen section)	Fujita (1947)
	218 : 171	Abe (1953)
	200	Greep (1954)
	130-220	Kopsch (1955)
	200–300	Bargmann (1956)
Pig	180–350	Kölliker (1863)′
	175	Schweigger-Seidel (1865)
	128 : 149 (167 : 219) 161 : 210 (212 : 270)	Peter (1909)
	176 : 192 (209 : 240)	Roost (1912)′
Mouse:	60	Schweigger-Seidel (1865)
	103 : 86	Peter (1909)
	136 : 110, 89 : 84	v. Möllendorff (1927)′
	88 : 68	Abe (1953)
Guinea gig:	128	Schweigger-Seidel (1865)
	84 : 101	Abe (1953)
Bat:	75	Schweigger-Seidel (1865)
Mole:	63	〃 〃
Cat:	122	〃 〃
	102	Miller and Carlton (1895)′′
	124 : 124 (175 : 153)	Peter (1909)
	96 : 80 (144 : 128)	Roost (1912)′
Sheep:	210	Schweigger-Seidel (1865)
	173 : 153	Peter (1909)
	144 : 128 (192 : 176)	Roost (1912)′
	158 : 132	Grundmann (1922)′
Weasel:	69	Schweigger-Seidel (1865)
Goat:	200 : 176 (240 : 208)	Roost (1912)′
	150 : 122	Grundmann (1922)′
Rabbit:	116 : 91	Peter (1909)
	34–40	Boycott (1911)
	76. 94 (paraffin) 84. 16 (celloidin) 101. 04 (frozen section)	Fujita (1947)
	114 : 89	Abe (1953)
Ox:	209 : 172	Peter (1909)
	224 : 193 (188 : 170)	Inouye (1909)
	200 : 176 (270 : 240)	Roost (1912)′
	225 : 153	Abe (1953)

Porpoise (Phocaena communis):

	130 : 103	Peter (1909)
	〃 : 〃	Inouye (1909)
Horse:	270 : 240 (272 : 240)	Roost (1912)′
Dog:	256 : 240 (288 : 272)	Roost (1912)′
	162 : 127	Abe (1953)
White rat:	127 (62, newborn)	Kittelson (1917)
	124	Arataki (1926)
	113 : 91	Abe (1953)

Supplemental data about the renal corpuscles will be added in the following.

MEASUREMENTS OF THE RENAL CORPUSCLES. (PÜTTER, 1927 AND MÖLLENDORFF, 1930)

Animal	Surface of each glomerulus (sq. mm.)	Total no. of glomeruli in both kidneys	Total surface area of glomeruli (sq. cm.)	Relative glomeruli surface per gr. of body weight
Mouse	0. 087	10 thousand	20. 5	1. 08 sq. cm.
Rabbit	0. 101	285	288	0. 144
Cat	0. 144	460	662	0. 221
Sheep	0. 249	1010	2520	0. 0718
Man	0. 293	1700	4950	0. 0708
Ox	0. 335	8050	27000	0. 0600
Pig	0. 425	1400	5980	0. 089
Echidna	0. 183	180	330	0. 165

According to " Biological Data " edited by Spector (1956) (Table 145), the volume of glomeruli (cub. mm.) per one gram of kidney is as follows, showing a considerable uniformity among animals and man; man: 29, cat: 28, dog: 40, elephant: 42, ground hog: 75, guinea pig: 42, monkey: 50, mouse: 21, opossum: 49, ox: 47, rabbit: 46, albino rat: 40, kangaroo rat: 30, swine: 37.

Langerhans' islets

Quantitative studies of the Langerhans' islets of man and animals were reviewed and surveyed extensively by Bargmann (1939) in v. Möllendorff's Handbuch der mikroskopischen Anatomie des Menschen, Bd. 6, 2 Teil, S. 209-. Among many papers treating this subject, merely the representative ones will be nominated here: Clark (1913) and Nakamura (1924) for man; Bensley (1911) for the guinea pig; Hess and Root (1938) for the white rat; Glaser (1926) for the mouse; Clara (1924) for birds.

So far as the size of the Langerhans' islets is concerned, however, the data of Heiberg (1909) are most extensive and some of them will be cited here.

AVERAGE DIAMETERS OF LANGERHANS' ISLETS. (HEIBERG, 1909)

Animal	Long axis : Short axis
Dog	64 : 43 μ
Cat	75 : 54
Pig	86 : 64
Monkey	122 : 75
Sheep	93 : 54
Goat	97 : 54
Ox	155 : 75
Horse	100 : 64
Pig	108 : 86 (cauda)
	75 : 55 (caput)
	75 : 52 (lobus dexter)
Ox	158 : 99 (cauda)
	108 : 82 (caput)
	126 : 82 (lobus dexter)

DISTRIBUTION OF SIZE OF L-ISLETS. (HEIBERG, 1909)

Animal	below 75 μ	76-125	126-175	176-225	226-275	276-325	above 325
Man	23	38	23	10	4	1	1
Mouse	24	33	27	11	4	1	
Guinea pig	35	37	18	8	2		
Dog	64	28	7	1			
Cat	48	40	11	1			
Pig	50	34	13	2	1		
Horse	24	47	18	5	5	1	
Sheep	51	31	14	4			
Ox	39	47	12	1	1		

DISCUSSION

Comparative observations of the cell size in whales and man revealed that some kinds of cells such as hepatic cells, adreno-cortical cells and parietal cells of the gastric gland as well as the heart muscle fibres show a considerable uniformity in the size. On the other hand there are other kind of cells which show a remarkable difference in the size between whales and man. The Purkinje fibres of the heart, fat cells, nerve cells and fibres represent examples belonging to the second catagory. A perusal of the pertinent literature suggests that the uniformity of size found in the cells of the first group holds good to a wider extent in the kingdom of animals, so far as the special attention is paid to mammals. As Levi (1905) pointed out, probably the epithelial and secretory cells may be representatives of this group.

The literature tells at the same time that the variability of cell-size encountered in the second group prevails also among the equivalent cells of other mammals. It is an interesting and perhaps noteworthy fact that the nervous elements, especially larger ones, are the typical examples of this group.

Surveying the members belonging to the second group, it would be noticed that they are represented by relatively large cells. Also many of those cells are furnished with some special intracellular structures or inclusions such as Nissl bodies for the ganglion cells and the large drop of neutral fat for the fat cells. The extraordinary richness in sarcoplasm of the Purkinje fibres may be reminded of too. The ovum containing yolk granules as well as the cells of the sebaceous gland furnished with coarse droplets of fatty substance doubtlessly represents another example. Also the pigment cells in which the pigment granules accumulate belong to the same category.

Nissl bodies of the nerve cell are, however, not to be regarded as corresponding to fat drops, yolk substance, pigment granules and so on. For the latter are merely cellular inclusions, while the Nissl bodies are certainly a sort of important cellular constituent of the nerve cell. The examination of the nucleo-plasmic relation will be probably useful, at least to some extent, to discern between these two categories of intracellular structures. Cellular inclusions such as fat drops in the fat cells do not affect the correlation between the size of nucleus and the amount of the proper cytoplasm. So the nucleus of such a cell is rather small for the considerable bulk of its cell body. In the case of Nissl bodies, on the contrary, the correlation holds good between the nucleus and the total volume of the cytoplasm, resulting thus in such a cell as furnished with nucleus of a fairly largeness.

By the way the present authors have no knowledge as to whether the volume of the neurite and dendrites is to be taken into account when the nucleo-plasmic relation of the neuron is considered. If it should be, supposing that there are two nerve cells or perikarya of a similar size which are though provided with axon or dendrites of different length and numbers, the cell with longer and more processes must have a larger nucleus.

Returning to the earlier discussion, let us bring up a question. Is there any way to explain the above mentioned difference between two groups of cells in the animal tissues? This question is necessarily related to the problem of what is the definitive factors to determine the size of cells.

In the literature, various factors have been stated by many authors as influencing the size of cells. For instance the activity of animals, the rate of metabolism, the innate potentiality for further cell divisions, the size of animal body, the grade of growth and aging, functional influences such as due to hormons and training, etc. have been examined and their correlations to the cell size were proved to some extent. Probably each of those factors is working in its own way and the sum of them, in cooperation with still other innate factors, will determine the size of cells, although its detailed mechanism is at present far beyond our knowledge.

So far as the morphology is concerned, the quantitative correlation between the cell body and nucleus, which was noticed by Hertwig (1903), developed and elaborated by Heidenhain (1912-) and Jacoby (1925-) et al, seems to be of an important meaning. Especially Jacoby's phenomenon of the "rhythmical, doubling growth of the volume of nuclei" is astonishing and must be of a great importance.

Checking Jacobj's review table (1935), the present authors cannot avoid such a suggestion that the discrimination of two cell groups mentioned in the beginning of this chapter is related to the difference of respective classes of those cells. That is to say, cells of lower classes or of smaller nuclear volumes (*f. i.* $K^1/_8$, $K^1/_4$, $K^1/_2$, $K1$) belong to the first group of the present description, where the cell size shows a considerable uniformity among animals. On the other hand, cells of higher classes or of larger nuclear volumes (*f. i.* $K8$, $K16$) are comprised in the second group, where the cell size varies from one animal to another. The higher variability of cell size found in the latter group is not difficult to understand, if it is taken into consideration that the standard nuclear volumes here are of high values. It is also easy to comprehend that the difference between those two groups of cells is not an absolute but relative one. For there can be intermediate classes of medium-sized cells (*f. i.* $K2$, $K4$). Probably nerve cells of small and intermediate sizes represent examples of this category.

On the size of some large histosystems.

The digestion, respiration and elimination of wastes are three principal functions which are indispensable for keeping the vegetative life. In the protozoa like amoeba all of these functions take place through the body surface. In higher animals, however, each of these three functions is carried out in a special part of the body; the intestinal canal, lungs and kidneys. Thus the intestinal villi, pulmonary alveoles and the renal corpuscles may be regarded as specialized equivalents of the body surface of amoeba.

By the way measurements of the lung alveoles and renal corpuscles revealed that the size of these both shows considerable differences between whales and man. Judging from survey of the pertinent literature, a similar discrepancy of size seems to be prevailing widely among animals. Although the variations in diameter are quite irregular from animal to animal, the relative respiratory as well as glomerular surface per unit of the body weight is in nearly inverse proportion to the body size of animals. Supposing a cell or amoeba shaped like a ball, the relative surface per unit volume is given by $4\pi r^2 / {}^3/_4 \pi r^3 = 3/\gamma$. Thus it is also inversely proportional to the size of the body. Probably this is one of the reasons for the limitation of cell size. For, if it enlarges beyond a certain size, its surface cannot take in food and oxygen fast enough to maintain its bulk.

In spite of the variability among animals the average diameter of pulmonary alveoles as well as of renal corpuscles for every mammal falls in a limited range of some 50–300μ. So we can still speak of a fairly uniformity in size for these histological structures. The pancreatic acini represent an example of a higher uniformity. According to Miziarsky (1900) the same relation was observed in the secretory alveoles of the parotis too.

To explain the size of these structures is as difficult as to explain the nature of the cell size. In his superb thinking way of "Synthesiologie", Heidenhain called those structures with a generic name "Histosysteme" (adenomeres, pneumomeres, etc.), and assumed that common biological factors for cell size would be responsible for determining the size of these "supra"-cellular units or systems too. The present writers have neither fact nor theory to develop the discussion further.

SUMMARY

1. Several kinds of cells and histological structures were measured and compared statistically between whales and man. Historical review of the literature extended the comparison to other mammals.
2. Some kinds of cells such as hepatic cells, adreno-cortical cells, parietal cells of the gastric glands, heart muscle fibres, etc. were shown to have a fairly similarity in size among animals and man.
3. Nerve cells and fibres, fat cells, Purkinje fibres of the heart and so on were shown to belong to other category, where the size varies considerably from one animal to another.
4. The problem of cell size in general was discussed, with special remarks on the difference between two groups of cells just mentioned.

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AMINO ACID COMPOSITION OF WHALE MEAT

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In Japan, the whale meat is an important source of animal protein supply. Knowledge of the amino acid composition of the whale meat protein is, therefore, of practical value in nutrition. Only a few reports on this subject have been published, and the methods used in them seem to be out of date.

The present work was carried out to know the amino acid composition of the whale meat employing the microbiological assay procedure. The amino acid composition of the meat of various parts was compared.

The present work was carried out at the request of Dr. Higashi, Chief of Tokyo Research Laboratory, and Mr. Kimotsuki, Chief of Yokosuka Factory of Taiyo Fishery Company.

MATERIAL

I. Meat materials, sampled by Dr. M. Nishiwaki, a member of the Whales Research Institute.

Date of capture are as follows:

Species of whale....Fin, Sex....Male.
Date of capture....Feb. 23rd, 1956.
Time of capture....8.45 A.M.
Time commenced treating....7.45 P.M.
Locality of capture....67-36 S, 122-36 W.
Thickness of blubber....P_1 80cm, P_2 14.5cm.

Three kinds of frozen meat — muscle of tail parts, dorsal muscle and muscle inside of the ventral grooves — were received on April 26th, 1956.

The preparative method for assay of 17 kinds of amino acid as follows. About 20 gm. piece was cut from the middle portion of each material, and taken into the previously weighed beaker. Standing for 30 min. at room temperature, each piece was weighed accurately, and then transferred to the 500 ml. pear-shaped flask. And then was hydrolyzed with 200 ml. of 6 N HCl at 120°C for 10 hrs in oil-bath. The hydrolyzate was filtered and recedues were washed with water, washings being added to the filtrate, filled up to volume. Thus prepared filtrate was used for the assay of 17 kinds of amino acid except tryptophane. An aliquot of the filtrate was used for the measurement of total nitrogen.

For the assay of tryptophane, the materials were prepared as follows: each middle portion of meats, as they were frozen, in case of muscle

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of tail parts and muscle inside of the ventral grooves, about 2 gm. piece and on dorsal muscle, c.a. 1 gm. piece was cut off respectively, sliced and weighed accurately in the weighing bottle. The weighed samples were taken into the tubes and cysteine, 40% of sample weight, was added. To muscle of tail parts and muscle inside of the ventral grooves, 15 ml. and to dorsal muscle, 10 ml. of 8 N NaOH were added, washing the wall respectively.

After shaking and homogenizing thoroughly, each tube was sealed and autoclaved, initially at 120°C for about 1 hr., and when somewhat cooled shaken enough, further autoclaved at 120°C for 5 hrs. The hydrolyzate were filtered with glass-filter and washed with hot water, when the filtrates were filled up to about 80 ml., they were placed in the refrigerator. When cooled enough, saponificate and lipid were separated. Being neutralized with 5 N HCl, the hydrolyzates were paper-filtered and had saponificate and lipid removed, they were filled up to volume and supplied to assay.

II. Whale meats supplied from Yokosuka Factory.

On April 18th, 1956, muscle of tail parts, dorsal muscle and muscle inside of the ventral grooves, each frozen, and salted meat were delivered, each meat was treated as I.

ASSAY OF AMINO ACIDS

Amino acids were determined approximately according to the micro-biological methods described by Tsunoda (1954). Assay procedures were modified as follows:

a) alanine: 750γ of G.B.I. "Liver Fraction L" per tube was added to the pyridoxal-free basal medium.

b) glutamic acid: the initial pH of the medium was 6.8.

c) glycine: the incubation period was prolonged to 96 hrs.

d) serine: the preculture was cultivated in the synthetic medium for 96 hrs. containing L-serine 1.5γ per 2 ml.

e) cystine: i) the hydrolyzate of the lanthionized casein was used for the amino acid source in the basal medium.
ii) the basal medium was preautoclaved at 15 lbs. pressure for 15 min. before it was dispensed.

ASSAY RESULTS

The results are shown in table 1 and table 2. Amino acid contents are calculated on the basis of the amount of total matters, and of the amount of total nitrogen. Amino acid content shown as % is, as a

TABLE 1. AMINO ACID COMPOSITION OF MATERIAL SAMPLED BY DR. NISHIWAKI

	Muscle of tail parts		Dorsal muscle		Muscle inside of the ventral grooves	
T-N %	2.06		3.85		3.26	
	%	:N	%	:N	%	:N
Leucine	0.90	0.44	1.82	0.47	1.41	0.43
Isoleucine	0.58	0.28	1.14	0.30	0.86	0.26
Valine	0.60	0.29	1.14	0.30	1.06	0.33
Threonine	0.53	0.26	1.06	0.28	0.86	0.26
Phenylalanine	0.47	0.23	0.92	0.24	0.78	0.24
Lysine	0.81	0.40	1.71	0.45	1.29	0.40
Methionine	0.29	0.14	0.60	0.16	0.43	0.13
Tryptophane	0.10	0.05	0.25	0.06	0.16	0.05
Glutamic acid	1.62	0.79	3.09	0.80	2.81	0.86
Aspartic acid	1.08	0.52	2.24	0.58	1.61	0.49
Glycine	0.49	0.24	0.99	0.26	1.70	0.52
Arginine	0.57	0.28	1.16	0.30	0.93	0.29
Proline	0.46	0.22	0.83	0.22	1.31	0.40
Histidine	0.53	0.26	0.98	0.26	0.46	0.14
Tyrosine	0.36	0.17	0.75	0.19	0.64	0.20
Alanine	0.63	0.30	1.24	0.32	1.26	0.39
Serine	0.52	0.25	1.06	0.28	0.82	0.25
Cystine	0.07	0.03	0.14	0.04	0.15	0.05

TABLE 2. AMINO ACID COMPOSITION OF THE MATERIALS FROM YOKOSUKA FACTORY

	Muscle of tail parts		Dorsal muscle		Muscle inside of the ventral grooves		Salted meat	
T-N %	2.26		3.54		3.19		4.86	
	%	:N	%	:N	%	:N	%	:N
Leucine	1.07	0.47	1.61	0.46	1.38	0.43	2.10	0.43
Isoleucine	0.66	0.29	1.05	0.30	0.78	0.25	1.26	0.26
Valine	0.65	0.27	1.05	0.30	1.10	0.35	1.62	0.33
Threonine	0.57	0.25	0.93	0.26	0.77	0.24	1.30	0.27
Phenylalanine	0.53	0.23	0.85	0.24	0.76	0.24	1.14	0.23
Lysine	0.88	0.39	1.52	0.43	1.14	0.36	1.74	0.36
Methionine	0.32	0.14	0.53	0.15	0.42	0.13	0.68	0.14
Glutamic acid	1.84	0.82	3.04	0.86	2.58	0.81	4.15	0.85
Aspartic acid	1.17	0.52	1.87	0.53	1.65	0.52	2.62	0.54
Glycine	0.48	0.21	0.81	0.23	1.78	0.56	2.74	0.56
Arginine	0.58	0.26	0.92	0.26	1.04	0.33	1.60	0.33
Proline	0.44	0.20	0.79	0.22	1.36	0.43	1.88	0.39
Histidine	0.54	0.24	0.85	0.24	0.41	0.13	0.68	0.14
Tyrosine	0.35	0.16	0.66	0.19	0.58	0.18	0.91	0.19
Alanine	0.67	0.30	1.11	0.31	1.33	0.42	1.99	0.41
Serine	0.56	0.25	1.00	0.28	1.00	0.31	1.56	0.32
Cystine	0.07	0.03	0.15	0.04	0.16	0.05	0.24	0.05

matter of cource, generally high in the sample of high nitrogen content.

Amino acid content of dorsal muscle is, therefore, higher than that of muscle inside of the ventral grooves, and is followed by that of muscle of tail parts. It should, however, be noticed that muscle inside of the ventral grooves contains more glycine, proline and alanine than other two muscles.

TABLE 3. COMPARISON WITH OTHER MEAT

Sample	Fish* (Sardin)	Cattle* (Beef)	Whale						
			Nishiwaki sample			Yokosuka factory sample			
Amino Acids			A	B	C	A′	B′	C′	D
Leucine	6.2	8.2	7.0	7.6	6.9	7.6	7.3	6.9	6.9
Isoleucine	4.3	5.2	4.5	4.8	4.2	4.7	4.7	3.9	4.1
Valine	4.9	5.0	4.7	4.8	5.2	4.6	4.7	5.5	5.3
Threonine	4.0	4.7	4.1	4.4	4.2	4.0	4.2	3.8	4.3
Phenylalanine	3.5	4.5	3.7	3.8	3.8	3.7	3.8	3.8	3.7
Lysine	8.3	9.3	6.3	7.1	6.3	6.2	6.9	5.7	5.7
Methionine	2.6	2.9	2.3	2.5	2.1	2.3	2.4	2.1	2.2
Tryptophane	1.1	1.3	0.8	1.0	0.8	—	—	—	—
Glutamic acid	12.3	15.9	12.6	12.8	13.8	13.4	13.7	12.9	13.7
Aspartic acid	8.7	9.8	8.4	9.3	7.9	8.3	8.5	8.3	8.6
Glycine	5.1	4.5	3.8	4.1	8.3	3.4	3.7	8.9	9.0
Arginine	4.9	5.4	4.5	4.8	4.6	4.1	4.2	5.2	5.3
Proline	—	3.6	3.6	3.4	6.4	3.1	3.6	6.8	6.2
Histidine	—	3.8	4.1	4.1	2.2	3.9	3.8	2.0	2.2
Tyrosine	—	4.1	2.8	3.1	3.2	2.5	3.0	2.9	3.0
Alanine	—	7.3	4.9	5.2	6.2	4.8	5.0	5.0	5.0
Serine	—	4.5	4.1	4.4	4.1	4.0	4.5	5.0	5.1
Cystine	—	4.5	0.5	0.6	0.7	0.5	0.7	0.8	0.8

A: Muscle of tail parts B: Dorsal muscle

C: Muscle inside of the ventral grooves D: Salted meat

* Cited from "Tables of the Amino Acids in Foods and Feedingstuffs" by Commonwealth Bureau of Animal Nutrition, Rowett Institute, Bucksburn, Scotland, 1956.

For comparison of muscle protein, values per total nitrogen had better be compared. Seeing the values calculated to total nitrogen, amino acid composition of muscle of tail parts well agreed with that of dorsal muscle with exceptions of lysine, tyrosine and serine. Muscle inside of the ventral grooves contains more glycine, proline and alanine, on the other hand, less lysine and histidine.

Entirely the same results were obtained on the samples supplied from Yokosuka Factory (Table 2). The amino acid composition of salted meat (probably made of muscle inside of the ventral grooves) is agreed with that of the source. Tryptophane was not determined.

Comparison of the present data with earlier reported ones is shown in Table 3.

SUMMARY

1. The amino acid composition of whale meat was determined by microbiological assay.

2. Muscle of tail parts, dorsal muscle and muscle inside of the ventral grooves respectively seem to have their own amino acid composition independent of individuals sampled.

3. The amino acid composition of muscle of tail parts is well agreed with that of dosal muscle with exceptions of lysine and serine. Muscle inside of the ventral grooves contains more glycine, proline and serine, less lysine and histidine, and is distinguished from the two others.

The present work was carried out under the order of late Mr. S. Hori, the former Manager of the Central Research Laboratory, Ajinomoto Co., Inc.

REFERENCE

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A CHARACTERISTIC PROPERTY OF WHALE OILS CONCERNING THE ABSORPTION OF GASES II.

ON THE ABSORPTION OF NITROGEN BY WHALE OILS

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In a previous paper (Ishikawa, 1956), we have reported on the absorption of carbon dioxide by the oily substances, including whale oils, in which it has been established that the kinds of whale oils, especially the sperm oil from *spermaceti*, far exceed the vegetable oils, in the absorption velocity of carbon dioxide.

In this paper, tests were made with the absorption of nitrogen by several kinds of oily substances, not only on its solubility but also on the absorption velocity.

In connection with the present subject, reference may be made to a profound investigation pertaining to deep sea diving and aviation, in which Albert R. Behnke, JR. (1941-42) had found the solubility of various gases, including nitrogen, in olive oil and in water, at ordinary pressures and at 38°C. So that he had determined the oil-water solubility ratio of various gases. However, in his investigation, emphasis is laid upon the solubility of various gases, in a kind of oil. On the contrary, our present subject is to study the property of various kinds of oils, as to the absorption of nitrogen.

As a result of the present experiments, it was proved that the solubility of nitrogen in various materials, was rather small, compared to that of carbon dioxide. As for the absorption velocity, it has been suggested in the earlier report (Ishikawa, 1956) that a equation, $\Delta V_0 = A(1-e^{-\alpha t})$, will hold for the processes of this kind, if the process were subjected to constant pressure. In the case of carbon dioxide, however, the measurements were carried out not at constant pressure, but at constant volume. Furthermore the change of pressures caused by absorption was so great, owing to the great solubility of carbon dioxide, that the processes could not in any way, be regarded as such. Whereas, in the present experiments, they can be approximately regarded as at constant pressure, because of the small solubility of nitrogen. Consequently it seems fully probable that this equation may be valid for the processes, though they were carried out at constant volume, as well as in the previous work.

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Indeed, as a result, it was ascertained that this equation was valid, within the limits of experimental error, for any of the processes included. Details of analysis will be described later.

EXPERIMENTAL

Materials.—Three kinds of whale oils*, sperm oil from *spermaceti*, sperm whale body oil and blue whale oil were chosen. The first two are marked by containing of a large amount of wax. The other is one from a blue whale and the majority of it, is constituted from glycerides, as is clear from table 1. On the other hand, three kinds of vegetable oils, olive-, camellia- and castor oil were tested for the sake of comparison.

TABLE 1. PHYSICAL AND CHEMICAL PROPERTIES OF THE MATERIALS

Materials	Specific Gravity D_4^{35}	Index of Refraction n_D	Acid Value	Saponification Value	Iodine Value	Unsaponified Matter %
Water	0.994	—	—	—	—	—
Sperm Oil	0.858	1.4530 (35°)	0.65	147.8	54.9	34.2
Sperm Body Oil	0.865	1.4612 (35°)	1.23	138.5	72.8	31.8
Blue Whale Oil	0.907	1.4736 (35°)	0.52	195.7	101.8	0.36
Olive Oil	0.913	1.4631 (30°)	2.46	196.3	88.4	0.43
Camellia Oil	0.903	1.4692 (30°)	2.30	192.3	81.3	0.86
Castor Oil	0.967	1.4747 (25°)	2.16	188.7	87.4	0.46
Liquid Paraffin	0.874	—	—	—	—	—

Distilled water and liquid paraffin were also added as materials. The water which is the most important physiological matter, seems reasonable to be tested in comparison with oily substances. Liquid paraffin was chosen from another interest, for it is expected as a matter of poor absorption.

Physical and chemical properties of the materials used, were given in table 1.

Apparatus and Procedure.—Apparatus and procedure employed, have been fully described in the previous paper (Ishikawa, 1956), and only a brief description on essentials is given below.

In every measurement, 100 g. of a material was taken. With each material, the measurements were carried out under five pressure-lebels, i.e. under the pressure, near but a little higher than 1, 2 and 3 atmos. pressures respectively, and under every intermediate lebel.

Deaeration of the materials to be tested, was performed in the very same way as described in the earlier report (Ishikawa, 1956): Deaeration in boiling water bath, was followed by the deaeration in thermostat

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* Kindly supplied by the Taiyo Fisheries Co., Ltd.

of 35°C, until the temperature of the contents became constant. Nitrogen gas was then introduced from the gas-reservoir into the pressure-vessel, up to the desired pressures, for which operation 30 to 40 sec. elapsed.

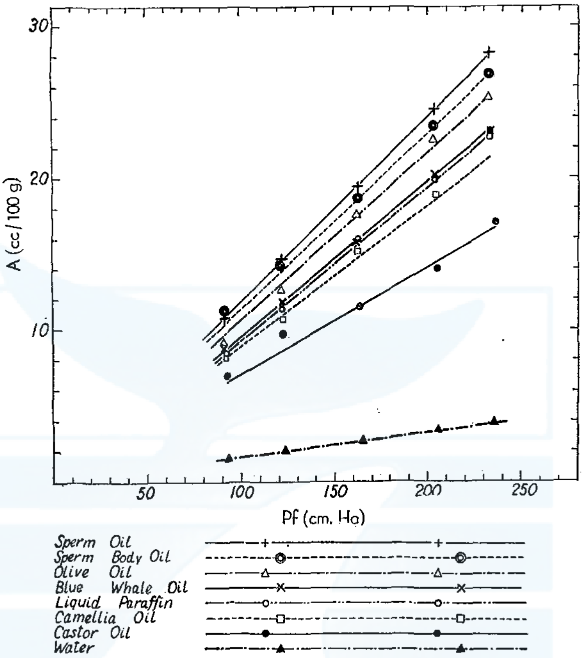

Fig. 1. Relation between probable solubility and pressure in various materials

The measurements were made at 35±0.05°C. The temperature was required to be closely constant, because the decrease in pressures caused by the absorption was relatively small, owing to the small solubility of nitrogen. On the other hand, with our apparatus, the temperature-gradient of pressure is 7.35 mmHg°C. This value is equivalent to about 5 cc/°C of the volume change. The fluctuation of the temperatures seems to be the largest error source.

Cooling effect which will occur on passing of the gas through the throttling cock, must be also a matter of consideration, on the same account. No preliminary test in this connection, has been done. But, granted that the process were entirely adiabatic, this effect can be estimated by the formula, $dT=\gamma\left(\frac{273}{T}\right)^2 dP$, where dT is the decrease in temperatures which will occur when the difference of pressures between both sides, is dP, γ, a empirical constant, characteristic of the gas; it amounts to 0.3°C atmos. for nitrogen.

According to this, we have 0.2 to 0.4°C, for the decrease in temperatures, with our operations. However, considering that our processes are not adiabatic, but will occur rather isothermally, the net decrease in temperatures must be far smaller than the adiabatic one. Indeed our measurements were scarcely interfered by this effect, except that a slight irregularity of the decrease in pressures was recognized at the very earliest interval of the measurements (within 1 min. from outset).

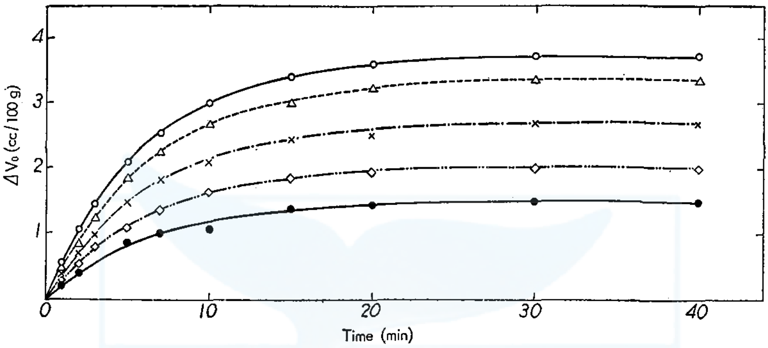

Fig. 2. Absorption curves for water under various pressure lebels.

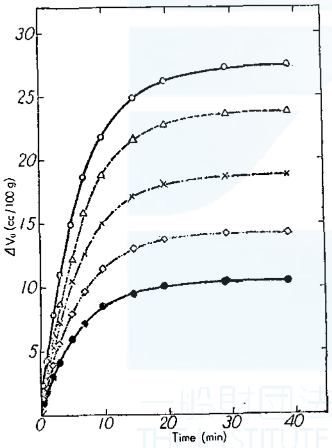

Fig. 3. Absorption curves for sperm oil under various pressure lebels.

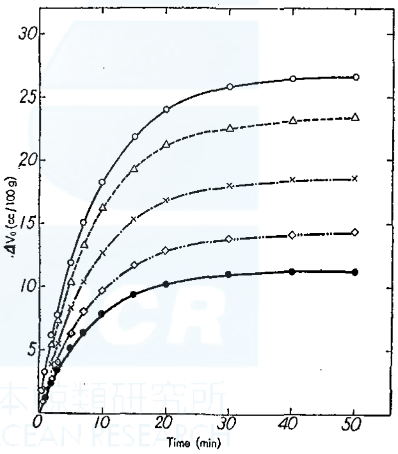

Fig. 4. Absorption curves for sperm body oil under various pressure lebels.

Mercury manometer employed, is of an open type, 2.2 m in height, graduated in mm interval, with a reading glass.

The mechanical conditions of the constant movement of the pressure-vessel and the other procedures were almost alike as those in the previous work (Ishikawa, 1956).

Obtaining of ΔV_0 from ΔP.—In the present work, as well as in the previous one, (Ishikawa, 1956) ΔP, the decrease in pressures caused by absorption, was punctually measured at constant volume. But, if supposed that the pressure were kept at initial constant value during the whole process, the decrease in volume will occur at this constant pressure and this decrease in volume at a initial definite P, must have been absorbed by the material, during the process.

This decrease in volume was obtained from ΔP, by the very same way as described in the earlier report (Ishikawa, 1956). The formula used, is

$$\Delta V_0 = \frac{T_0}{T}\frac{1}{P_0}V\cdot\Delta P \qquad (1)$$

where ΔV_0 is a decrease in volume (in cc) of a gas, reduced to standard state, $T_0=273°\mathrm{K}$, $T=308°\mathrm{K}$, $P_0=760$ mmHg, and V is the volume (684 cc) of the pressure-vessel less the volume of the material used. The formula (1) was deduced from the well known relation, $PV=$const., for a given amount of a gas.

Thus, in the formula (1), $\frac{T_0}{T}\frac{1}{P_0}$ is a common constant disregarding the materials, and V is a constant regarding the capacity of the vessel and the amount of the material taken into the vessel. So we obtain ΔV_0 from ΔP, by multiplying ΔP with this constant factor, $\frac{T_0}{T}\frac{1}{P_0}V$, for a fixed amount of a material.

RESULTS

Solubility** of Nitrogen in Various Materials.—In figure 1, each curve gives the values of A's for each material, plotted against the final pressure, P_f. Symbol A, essentially represents the solubility of the gas in a material. It was obtained by some mathematical means, on the basis of $\Delta V_{0\,\max}$, the maximal volume of the gas absorbed. Upon the method, by which, A was obtained, we will describe in the next chapter. At any rate, there exists no great difference between A and $\Delta V_{0\,\max}$, for our experiments, where the measurements were made so long till the saturation was practically reached.

In figure 1, it is corollary that every curve must pass the origin, and therefore it takes a form reading

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** The solubility is expressed in terms of the volume (in cc.) of the gas per 100 g. of a material, when the latter has absorbed the former to a possible maximal extent. It must be also mentioned that the volume was measured indirectly from ΔP. So it may be quite possible that this volume differs from that of the real solubility, by the amount of the gas taken into the material, in some labile state, say, in the form of visible or invisible bubbles suspending. Though it is again questionable that the bubbles in a liquid, can effect a decrease in pressures, to what extent.

$$A = cP$$

The coefficient c may be a characteristic of the material. But there exists no remarkable difference between the values of c's for the various oily materials. So it seems impossible that they can be characterized by the magnitude of c. Although the closer examination of the figure 1, reveals that the value of c is greater for the wax-oils than for the glyceride-oils and the minimum for castor oil, which possesses hydroxy-acids in its molecules: The value of c is 0.12 cc/cmHg, for sperm oil and it is near but a little less than that for sperm body oil. For blue whale oil, is 0.098 and those for camellia oil and liquid paraffin stand

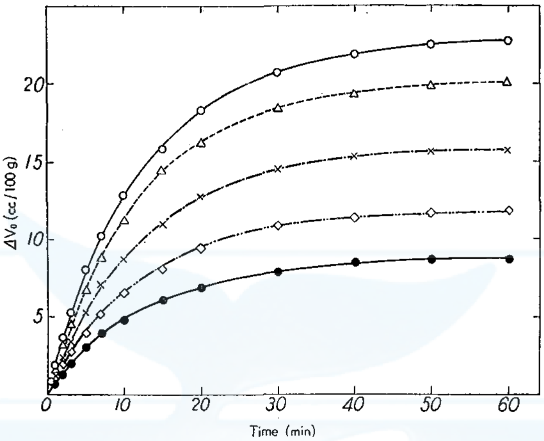

Fig. 5. Absorption curves for blue whale oil under various pressure lebels.

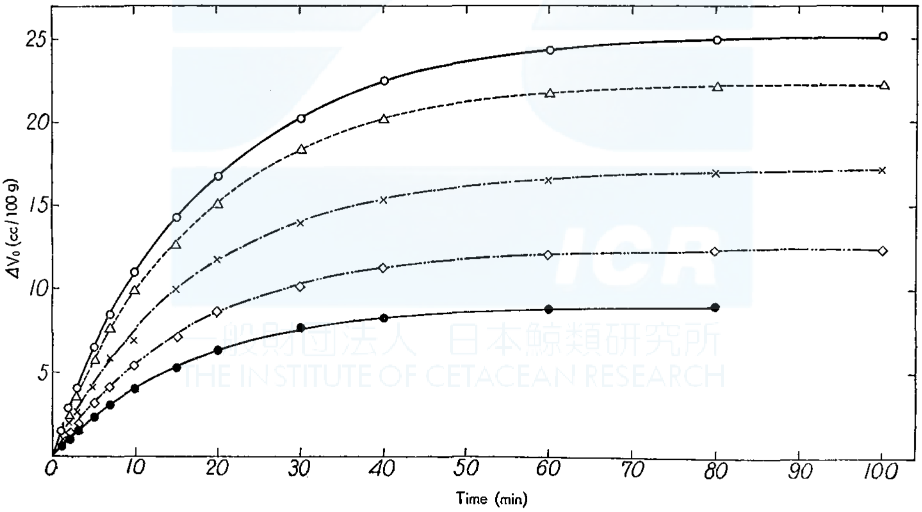

Fig. 6. Absorption curves for olive oil under various pressure lebels.

very close by that. For castor oil, c is 0.073.

On the other hand, it differs greatly therefrom and amounts to 0.016 cc/cmHg, for the water. Hence the coefficients for the oily materials

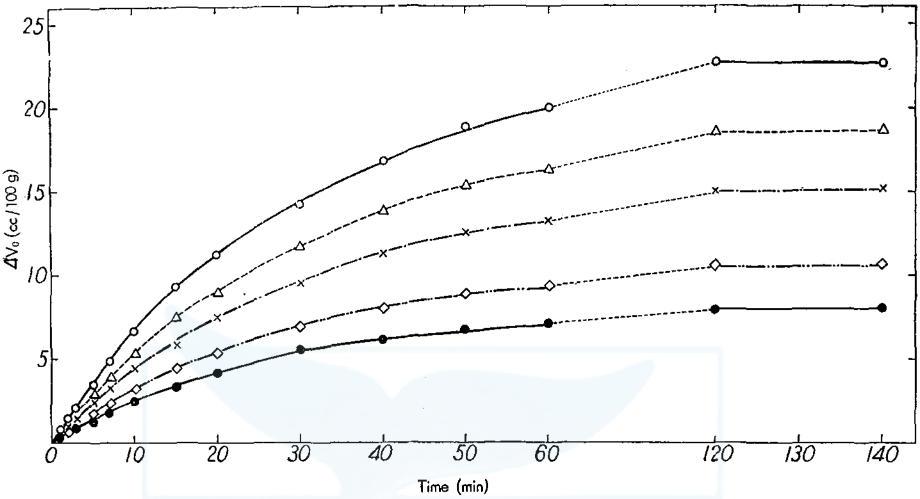

Fig. 7. Absorption curves for camellia oil under various pressure lebels.

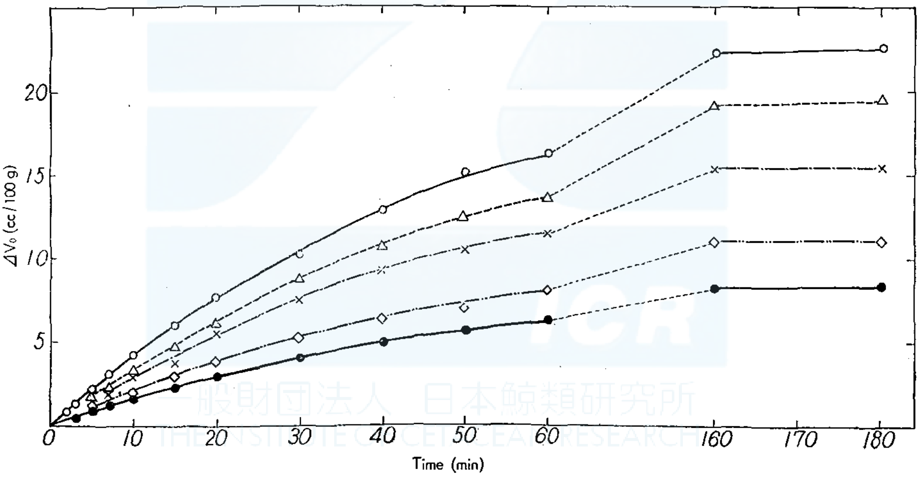

Fig. 8. Absorption curves for liquid paraffin under various pressure lebels.

(with the exception of caster oil), are 6 to 7.5 times as great as that for the water. In other words, the oily substances can absorb 6 to 7.5 times as much nitrogen as the water, at every pressure value. Even castor oil can absorb 4.5 times as much as the water.

In the case of carbon dioxide, it has been determined in the earlier paper, that c is 1.78 cc/cmHg, for sperm oil, and the values for the other oily substances, are of the magnitude close but less than that and the

c for water is 0.78 cc/cmHg. When compared within the oily materials, they can absorb nitrogen 1/10 or less, as much as carbon dioxide, at any pressure, and in the case of water, it can absorb nitrogen some 1/50 as much as carbon dioxide.

Absorption Curves.—In figure 2 to figure 9, each diagram shows absorption curves for each material respectively. Any of the diagrams consists of five curves, corresponding to five pressure lebels. Every curve was drawn based upon two or three times parallel experiments. In most of the cases, the discrepancy between the corresponding values of $\varDelta V_0$'s, is less than 5%.

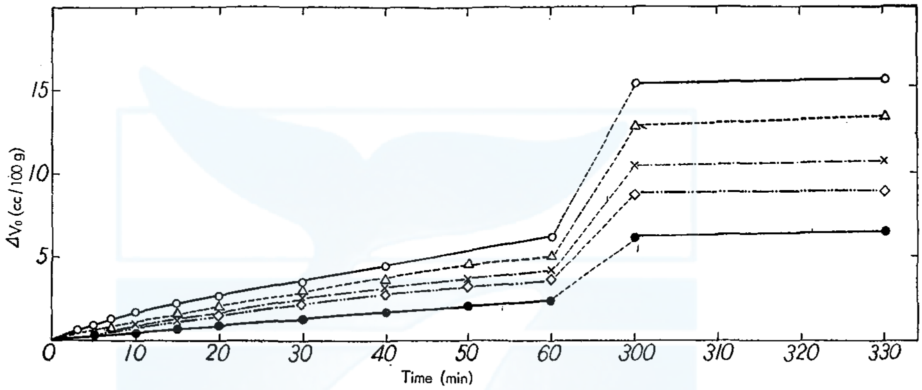

Fig. 9. Absorption curves for castor oil under various pressure lebels.

When comparing these 8 figures, there seems to exist a great difference in the absorption velocity of nitrogen, between the individual materials. But any quantitative evaluation about the velocity, can not be made without the analysis of the curves.

ANALYSIS

As noted in the foregoing chapter, it seems very probable that the equation

$$\varDelta V_0 = A(1 - e^{-\alpha t}) \tag{2}$$

will be valid for any of the curves included. If it were true, $\log(A - \varDelta V_0)$ must become linear against the time, t. Indeed, as illustrated in figure 10, it proved that in all of the cases, $\log(A - \varDelta V_0)$ showed the strong linear regression to the time t. In equation (2), $\varDelta V_0$ is a decrease in volume caused by absorption, A, the solubility of the gas, and α, a velocity constant, as seen in its differentiated form

$$\frac{d}{dt}(\varDelta V_0) = \alpha(A - \varDelta V_0) \tag{3}$$

Figure 10 was chosen altogether at random from 8 figures obtained for the 8 materials. Another 7 figures were given up to save space.

TABLE 2. THE VALUES OF A'S AND α FOR EACH MATERIAL

Materials	Pressure Lebels (mm. Hg)		Period (min.)	A (cc.)	α (min^{-1})	r
	P_i	P_f				
Water	931.8*	929.5*	40	1.5	0.155	20.0
	1,238.7	1,235.7	〃	2.0^5		
	1,651.0	1,647.0	〃	2.7		
	2,060.0	2,055.0	〃	3.4		
	2,364.0	2,358.5	〃	3.8		
Sperm Oil	929.0	912.7	40	10.8	0.154	20.0
	1,241.0	1,219.0	〃	14.6^5		
	1,652.2	1,623.0	〃	19.4		
	2,061.3	2,025.0	〃	24.5		
	2,365.0	2,322.0	〃	28.3		
Sperm Body Oil	926.7	909.6	50	11.3^5	0.114	15.0
	1,238.2	1,216.7	〃	14.3		
	1,651.0	1,623.0	〃	18.7		
	2,060.5	2,025.3	〃	23.4^5		
	2,361.0	2,321.0	〃	26.8		
Blue Whale Oil	930.0	916.7	60	8.8	0.081	10.5
	1,241.5	1,224.0	〃	11.8^5		
	1,649.7	1,625.6	〃	15.8^5		
	2,063.3	2,035.0	〃	20.2		
	2,364.6	2,330.6	〃	22.9		
Olive Oil	929.8	916.2	80	9.2	0.056	7.5
	1,240.2	1,221.5	100	12.6		
	1,649.0	1,623.2	〃	17.3		
	2,059.0	2,027.3	〃	22.6		
	2,360.2	2,326.7	〃	25.3		
Camellia Oil	930.7	919.0	140	8.1	0.035	4.5
	1,240.3	1,225.0	〃	10.7		
	1,650.0	1,627.8	〃	15.2		
	2,061.0	2,033.0	〃	18.8		
	2,365.3	2,331.3	〃	22.8		
Liquid Paraffin	931.7	919.5	180	8.4^5	0.021	3.0
	1,241.0	1,224.3	〃	11.3^5		
	1,649.7	1,626.3	〃	15.9		
	2,060.4	2,031.0	〃	19.8		
	2,365.6	2,331.6	〃	23.0		
Caster Oil	930.4	920.8	330	7.0	0.0076	1.0
	1,240.0	1,226.7	〃	9.7		
	1,649.7	1,633.7	〃	11.5		
	2,060.5	2,040.7	〃	14.1		
	2,361.5	2,338.6	〃	17.0		

* These values in water, were obtained by substracting 42 mm. Hg, the saturated vapor pressure of dist. water at 35°C, from the total pressure.

Determination of A.—It may be essentially possible to determine two unknown factors, A and α, respectively, when the values of ΔV_0's and t's, more than two sets are given. However it is very difficult to solve such simultaneous equations as involving the exponential functions.

To avoid such difficulties, a graphical method is adopted: The first estimated value of A, is obtained from the $\Delta V_0 - t$ diagram, by extrapolating the curve to the infinite value of t. Then, using this value of A, the values of $\log(A-\Delta V_0)$'s are plotted against t. Thus, if the equation is valid, it will be sure that the $\log(A-\Delta V_0)$ becomes rather linear against t, in the interval, where t is relatively small. But, with increase of t, the curve will show a tendency to bend upwards or downwards, according as the estimated value of A is too great or too small. If the curve is bending downwards, some value is to be added to the first estimated value of A, to get a straight line. Then we have a second estimated value of A, and so forth, when $\log(A-\Delta V_0)$ becomes really linear against t, over the whole interval, the then value of A must be the value to be found.

Of course, individual points may fall rather scattering, up and down on the line, we must pay attention to the tendency. In the case of the materials with slow absorption, as castor oil and liquid paraffin, difference between A and $\Delta V_{0\,\max}$ becomes somewhat considerable, and in those with rapid absorption, as sperm oils and other whale oils, the difference is almost negligible.

Determination of α.—α was obtained by the *method of averages*, using the formula derived from the equation (2)

$$\alpha=2.3026\frac{n\cdot\log A-\sum_1^n\log(A-\Delta V_0)}{\sum_1^n t}$$

Thus we have five different values of α, for each material. However, in all of the cases, the values of α's obtained within a given material, were found to be almost much the same, disregarding the pressure lebels. At least, we could not find any orderly relationship between the magnitude of α and pressure lebels. It seems likely that within such narrow range of pressures, α becomes approximately constant, though it is not a theoretical consequence. For this reason, by averaging the five values, a single value of α was given for each material, without regard to the pressure lebels.

As seen from table 2, the value of α is great in the decreasing order of water, sperm oil, sperm body oil, blue whale oil, olive oil, camellia oil, liquid paraffin and castor oil. This order proves to be consistent with that of the absorption velocity of carbon dioxide (cf. previous paper). Here again, the value of α is outstandingly greater for the whale oils than for the vegetable oils, and the greatest two are those for sperm oil and sperm body oil, both containing a large amount of wax.

In the table 2, the other descriptions were also given; in the second and third column, the pressure lebels, under which the measurements were carried out, in the fourth, the lapse of time, during which each measurement was made, in the fifth, the values of A, for each material, under various pressure lebels, and the last column headed by r, gives the ratio of α for each material to that for castor oil.

We shall now compare the absorption velocity of nitrogen with that of carbon dioxide, in various materials. Unfortunately, however, a general comparison is not possible, since another formulae are used in both cases: In the case of carbon dioxide, we have been obliged to use a experimental formula as

$$\frac{d}{dt}(\Delta V_0)=a'b\cdot t^{b-1} \tag{4}$$

and in the present work, we can do with the equation (3). Therefore the absorption velocity of the both gases must be compared in a fixed condition, i.e. under a definite pressure lebel and at a definite time.

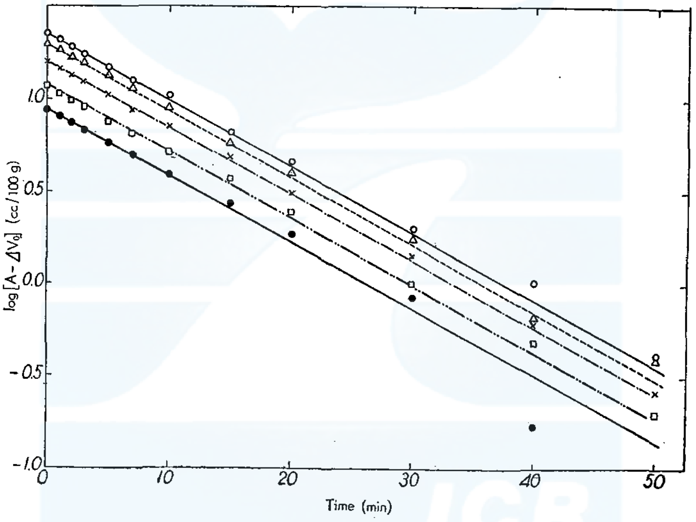

Fig. 10. Relation between $\log(A-\Delta V_0)$ and t. (In the case of blue whale oil, as an illustration.)

Nevertheless, in the equation (4), $a'b$ shows the velocity at 1 sec after outset, that is approximately regarded as the initial velocity, whereas αA represents the initial velocity itself, in the equation (3). Thus we can make a rough comparison of the initial velocity of the both gases, by comparing $a'b$ with αA. For instance, in the case of sperm oil, the value of $a'b$ was 1.68 cc/sec (cf. p. 204 of the earlier paper), i.e. 100.8 cc/min, under the pressure lebel, whose initial pressure was 2,364 mmHg. While αA is 4.36 cc/min, under the pressure lebel, initial pressure of which is 2,365 mmHg. So, in the case of sperm oil, the initial absorption velocity of carbon dioxide, is some 23 times as great as that of nitrogen, at the same pressure.

Such ratio, $a'b/\alpha A$, at the same pressure, remains almost constant, within any of the materials used, disregarding the pressure lebels, but varies with the kind of material. It ranges from 20 to 30, in the oily materials, except castor oil, in which it comes to about 70. On the other hand, it amounts to some 200, in the case of the water.

SUMMARY

1. Asborption of nitrogen was studied with 8 kinds of substances, i.e. distilled water, sperm oil from *spermaceti*, sperm body oil, blue whale oil, olive oil, camellia oil, liquid paraffin and castor oil.

2. Decrease in pressures, ΔP, caused by absorption, was punctually measured with each material, at constant temperature ($35 \pm 0.05°C$) and at constant volume, under five different pressure lebels, i.e. under the pressure, near but a little higher than 1, 2 and 3 atmos. pressures respectively and under every intermediate lebel.

3. Decrease in volume, corresponding to ΔP, was reduced to standard state, and designated by ΔV_0, this volume of nitrogen must have been absorbed by a given material, during the process.

4. From the results obtained, following conclusions were drawn:

a. The value of A was found to be approximately proportional to the pressure, with each material, where A stood for the solubility of nitrogen in a material. Therefore the relation, $A=cP$, was postulated.

b. Within the oils and oily substances tested, the value of c does not differ so greatly from each other. So, we consider, they can not be characterized by this magnitude. On the contrary, there existed a great difference between c for water and those for oily substances, the latters are 6 to 7.5 times as great as the former.

c. As compared to the solubility of carbon dioxide, the solubility of nitrogen is of the magnitude about one-tenth of the former in the oily materials, and some 1/50, in the water.

d. The results of the analysis indicated that the equation (2) was valid in good approximation, for all the curves included.

e. The absorption velocity constant, α, was prominently characteristic of the material, its value was far greater for the oils from whale kinds, especially for the oils from sperm whale, which contain a large amount of wax, than for the vegetable oils.

f. The value of α was great in the order, named in section 1. of this summary.

g. In the order of magnitude, the absorption velocity of nitrogen is consistent with that of carbon dioxide, within the materials, used in common to both the works.

ACKNOWLEDGEMENT

The author takes this opportunity to express his deep gratitude to Prof. Dr. T. Mori of the Tokyo University for his kind guidance and encouragement throughout the course of this work.

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COMPONENT FATTY ACIDS OF NORTHERN ELEPHANT SEAL OIL

HIDEO TSUYUKI*

The marine carnivores such as the whale and seal has generally a thick layer of fatty tissue under the skin, called as blubber, which is the source of the oil.

The seal and whale oils have been used for many purpose. A number of studies has been given to the whale family oil. While, as to the study on the component acid of the seal family oil, we can find the following reports: the common seal, *Phoca vitulina,* oil (Williams & Makhrov, 1935); Saghalien seal oil (Tsujimoto, 1916); common seal oil (Bauer & Neth, 1942); commercial Newfoundland seal oil (Burke & Jasperson, 1944); blubber and liver oils of Grey Atlantic seal, *Halichoerus grypus* and common seal (Hilditch and Pathak, 1947, 1949); milk oils of Grey Atlantic and common seals (Meara, 1952); blubber oils of leopard seal, *Hydrurga leptonyx* and crabeater seal, *Lobodon carcinophagus* (Winter and Nunn, 1950, 1953). Tsujimoto and Bauer supported the view that the seal oil and the ordinary whale oil are similiar in fatty acid composition from their works. In the elephant seal, there are two species, the northern elephant seal, *Mirounga angustirostris* and the southern elephant seal, *Mirounga leonina.*

Reviewing the works ever reported on the elephant seal oil, Winter and Nunn studied the fatty acid composition of the blubber oils from a wide range of specimens of the southern elephant seal caught at Macquarie and Heard Islands in the Antarctic (Winter & Nunn, 1950, 1953). On the other hand, the writer studied the differences in the properties of the oils contained in various blubbers and tongue of the northern elephant seal (Tsuyuki, 1957). However, there has not yet been a study of the component fatty acids of the northern elephant seal oil. So, the writer was fortunate enough to obtain the dorsal blubber oil of the northern elephant seal and examine its fatty acid composition.

It is a pleasure that the writer expresses here his sincere thanks to President of Whales Research Institute, Dr. Hideo Omura and Prof. of Nihon University, Dr. Akio Shionoya for their kind advices. He also wishes to express his thanks to Prof., Dr. Hideo Oguni and Prof., Dr. Hideo Hosoya who were kind enough to present him the sample oil.

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EXPERIMENT AND RESULT

The northern elephant seal, *Mirounga angustirostris* caught off the coast of Mexico in January, 1955 and died on the 7th of June, 1956 in Kyoto, Japan was used as the experimental material in the present work. This is the same as used in the previous report (Tsuyuki, 1957).

The oil contained in the dorsal blubber of the seal body was prepared by boiling the material with water and refined with a centrifugal separator.

Some properties of the obtained oil were examined in ordinary manners and iodine value was determined by the Wijs method. Saponification was continued for two hours in an atmosphere of nitrogen gas. The results obtained are shown in table 1.

TABLE 1. PROPERTIES OF OIL

Appearance (20°C.)	d_4^{15}	N_D^{30}	Acid value	Sapon. value	Iodine value	Unsapon. matter (%)
Reddish brown, semitransparent liquid	0.9224	1.4636	15.6	187.6	128.7	0.98

TABLE 2. PROPERTIES OF UNSAPONIFIABLE MATTER

Appearance (30°C.)	N_D^{40}	Melting point (°C.)	Iodine value
Yellowish brown, nontransparent solid	1.4246	28.5 ~ 32.5	99.5

Next, to some 400g. (I.V. 128.7) of the oil was added 400c.c. of absolute ethanol and further potassium hydroxide solution (KOH 176g. and H_2O 320c.o.) and heated in an atmosphere of nitrogen gas for two hours on a water bath, after which nearly 80% of alcohol was distilled off and the resulting soap solution was cooled and diluted with water. The unsaponifiable matters (Table 2) were removed from the soap solution with ether, and the 365.5g (I.V. 133.9) of the mixed fatty acids were recovered after decomposing the soap solution with 10% sulfuric acid solution. The 340g. of the mixed fatty acids thus obtained were subjected to the lead salt alcohol separation method (Twitchell, 1921), whereupon 51g. (I.V. 8.3) of solid (insoluble) fatty acids and 289g. (I.V. 155.8) of liquid (soluble) fatty acids were obtained.

The 280g. of the liquid fatty acids was then subjected to the lithium salt acetone separation method (Hilditch, 1956), when 222.4g. (I.V. 118.2) of lowly unsaturated (insoluble) fatty acids and 57.6g. (I.V. 301.3) of highly unsaturated (soluble) fatty acids were obtained.

Some characteristics of the fatty acids thus obtained were measured by the usual manner and the following results were obtained (Table 3).

Each group of the fatty acids were separately converted into methyl esters (Table 4) and fractionated as usual through Longenecker's E.H.P. column modified by the writer (Figs. 1, 2). Saponification values and iodine values of each of the subfractions of all the groups of methyl esters were determined, and the data are given in tables 5～7.

TABLE 3. PROPERTIES OF FATTY ACIDS

Kind of fatty acids	% in mixed fatty acids	Appearance (20°C.)	Refractive index	Melting point (°C.)	Iodine value	Neutral. value	Average molecular weight
Mixed fatty acids	—	Yellowish brown, nontransparent solid	1.4640 (30°C.)	27.5～29.5	133.9	198.3	282.9
Solid fatty acids	15.0	Brownish white, nontransparent solid	1.4352 (60°C.)	47.0～51.5	8.3	214.5	261.6
Lowly unsat. fatty acids	67.5	Reddish brown, transparent liquid	1.4621 (30°C.)	—	118.2	197.5	284.1
Highly unsat. fatty acids	17.5	Reddish brown, transparent liquid	1.4695 (30°C.)	—	301.3	187.1	299.9
Liquid fatty acids	85.0	Reddish brown, transparent liquid	1.4685 (30°C.)	—	155.8	195.3	287.3

TABLE 4. PROPERTIES OF METHYL ESTERS

Kind of ester	Appearance (20°C.)	Sapon. value	Iodine value
Ester of solid acids	Brownish white, nontransparent solid	205.2	6.2
Ester of lowly unsat. acids	Reddish brown, transparent liquid	188.0	113.1
Ester of highly unsat. acids	Reddish brown, transparent liquid	178.8	283.6

From the iodine value and saponification value of each ester fraction obtained by the fractional distillation, it seems that the following fatty acids are contained in the northern elephant seal oil:

Saturated fatty acids:

myristic acid $C_{14}H_{28}O_2$, palmitic acid $C_{16}H_{32}O_2$, stearic acid $C_{18}H_{36}O_2$, arachidic acid $C_{20}H_{40}O_2$, behenic acid $C_{22}H_{44}O_2$.

Unsaturated fatty acids:

mono- ethenoid C_{14} acid.
mono- and tri- ethenoid C_{16} acids.
mono-, di-, tri- and tetra- ethenoid C_{18} acids.
mono- and tetra- ethenoid C_{20} acids.
mono-, tetra- and penta- ethenoid C_{22} acaids.
mono- and penta- ethenoid C_{24} acids.

The composition of each of the ester fractions was calculated from saponification values and iodine values according to the method described by Hilditch (Hilditch, 1956). The mean unsaturation expressed as the fractional number of hydrogen atoms short of saturation, for example, −2.0 (monoethenoid), was determined by interpolation and extrapolation from the respective ester fractions in each of the groups from which the mean saponification value of each of the homologous ester groups (C_{16}, C_{18}, C_{20}, etc.) follows. The results calculated are shown in Tables 8～10.

TABLE 5. FRACTIONAL DISTILLATION OF METHYL ESTERS OF SOLID FATTY ACIDS

Fraction	Yield		Appearance (10°C.)	B.P. °C./3.5mmHg	Sapon. value	Iodine value
	Wt.(g.)	%				
S- 1	1.83	6.2		~150	223.6	0.6
S- 2	1.41	4.8	White, nontransparent solid	150~153	220.1	1.9
S- 3	1.88	6.3	White, nontransparent solid	153~156	218.8	2.4
S- 4	1.97	6.7	White, nontransparent solid	156~159	215.3	2.6
S- 5	2.01	6.8	White, nontransparent solid	159~159	214.5	3.2
S- 6	2.38	8.0	White, nontransparent solid	159~160	212.2	3.4
S- 7	2.13	7.2	White, nontransparent solid	160~161	210.3	3.7
S- 8	1.93	6.5	White, nontransparent solid	161~163	207.1	3.8
S- 9	1.96	6.6	White, nontransparent solid	163~165	204.6	4.0
S-10	2.11	7.1	White, nontransparent solid	165~167	202.8	5.1
S-11	2.23	7.5	White, nontransparent solid	167~173	199.7	7.7
S-12	2.09	7.1	White, nontronsparent solid	173~179	196.8	8.0
S-13	2.01	6.8	White, nontransparent solid	179~188	190.7	11.5
S-14	1.50	5.1	White, nontransparent solid	188~195	186.8	12.5
S-15	1.36	4.6	Light yellowish white, semitransparent solid	195~200	184.4	16.3
S-16	0.80	2.7	Yellowish brown, nontransparent solid	Residue	171.5	30.0
Total	29.60	100.0	—	—	—	—

TABLE 6. FRACTIONAL DISTILLATION OF METHYL ESTERS OF LOWLY UNSATURATED FATTY ACIDS

Fraction	Yield		Appearance (10°C.)	B.P. °C/2mmHg	Sapon. value	Iodine value
	Wt.(g.)	%				
LU- 1	9.88	8.2	Yellow, transparent liquid	~150	214.6	38.6
LU- 2	7.20	6.0	Yellow, transparent liquid	150~155	209.4	49.3
LU- 3	8.62	7.2	Yellow, transparent liquid	155~157	200.4	73.7
LU- 4	6.88	5.8	Yellow, transparent liquid	157~160	194.7	84.2
LU- 5	5.96	5.0	Light yellow, transparent liquid	160~161	192.5	91.9
LU- 6	5.64	4.7	Light yellow, transparent liquid	161~163	190.9	93.7

TABLE 6 (Continued)

Fraction	Yield		Appearance (10°C)	B.P.°C/2mmHg	Sapon. value	Iodine value
	Wt.(g.)	%				
LU- 7	7.80	6.5	Light yellow, transparent liquid	163∼165	188.6	97.9
LU- 8	8.90	7.4	Light yellow, transparent liquid	165∼167	186.3	99.8
LU- 9	8.86	7.3	Light yellow, transparent liquid	167∼168	185.1	106.3
LU-10	7.16	6.0	Light yellow, transparent liquid	168∼169	184.2	110.1
LU-11	6.38	5.3	Light yellow, transparent liquid	169∼171	183.6	114.5
LU-12	5.08	4.2	Light yellow, transparent liquid	171∼172	183.2	122.6
LU-13	7.18	6.0	Light yellow, transparent liquid	172∼176	180.1	127.5
LU-14	7.34	6.1	Light yellow, transparent liquid	176∼183	175.4	172.0
LU-15	7.02	5.9	Light yellow, transparent liquid	183∼185	172.5	214.9
LU-16	4.70	3.9	Yellow, transparent liquid	185∼193	164.9	246.4
LU-17	5.40	4.5	Reddish brown, nontransparent solid	Residue	164.0	177.8
Total	120.00	100.0	—	—	—	—

TABLE 7. FRACTIONAL DISTILLATION OF METHYL ESTERS OF HIGHLY UNSATURATED FATTY ACIDS

Fraction	Yield		Appearance (10°C.)	B.P. °C./1mmHg	Sapon. value	Iodine value
	Wt.(g.)	%				
HU- 1	2.24	4.4	Yellowish orange, transparent liquid	∼163	219.8	181.6
HU- 2	2.73	5.4	Yellowish orange, transparent liquid	163∼169	212.8	190.4
HU- 3	2.91	5.8	Yellowish orange, transparent liquid	169∼176	198.5	194.7
HU- 4	3.64	7.2	Yellowish orange, transparent liquid	176∼184	188.0	216.0
HU- 5	4.19	8.3	Yellowish orange, transparent liquid	184∼185	186.5	300.5
HU- 6	4.66	9.2	Yellowish orange, transparent liquid	185∼188	183.3	310.7
HU- 7	5.23	10.4	Yellowish orange, transparent liquid	188∼190	179.8	319.3
HU- 8	4.86	9.6	Yellowish orange, transparent liquid	190∼194	175.1	330.2
HU- 9	5.07	10.1	Dark yellowish orange, transparent liquid	194∼196	168.5	334.3
HU-10	4.50	8.9	Reddish brown, transparent liquid	196∼197	164.8	358.0
HU-11	5.57	11.0	Reddish brown, transparent liquid	197∼198	163.5	340.3
HU-12	4.90	9.7	Reddish brown, transparent liquid	Residue	156.4	175.0
Total	50.50	100.0	—	—	—	—

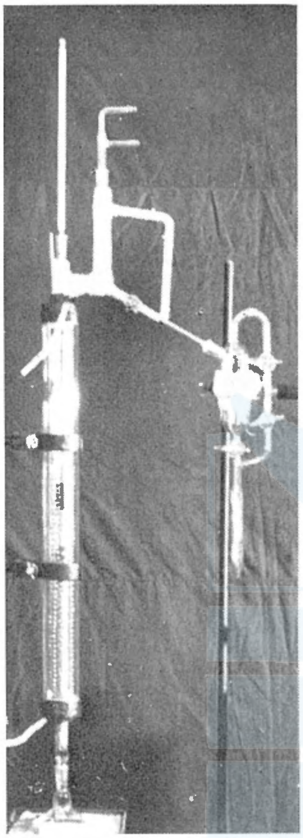

Fig. 1. E.H.P. Column modified by the writer column: 65 c.m.

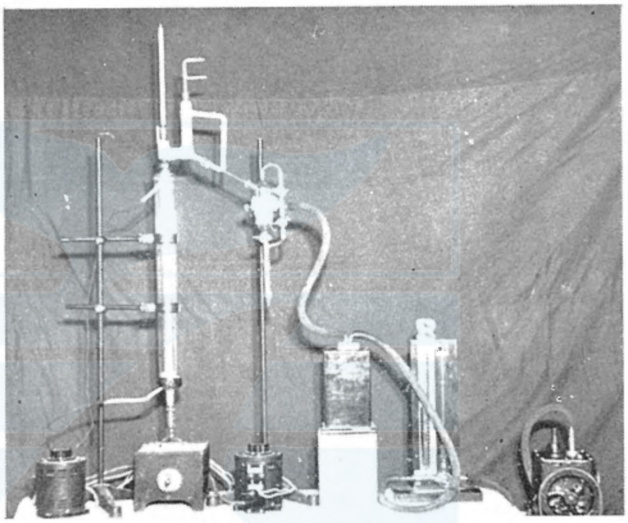

Fig. 2. Fractional distillation apparatus.

According to the results obtaind, it is noticed that the total saturated fatty acid content is 20.37% (myristic acid $C_{13}H_{27}COOH$: 3.5%, palmitic acid $C_{15}H_{31}COOH$: 12.82%, stearic acid $C_{17}H_{35}COOH$: 3.61%, arachidic acid $C_{19}H_{39}COOH$: 0.41%, behenic acid $C_{21}H_{43}COOH$ 0.01%) of the total. The unsaturated counterpart is 79.63% (C_{14} acids : 0.96%, C_{16} acids : 10.2%, C_{18} acids : 33.22%, C_{20} acids : 24.57%, C_{22} scids : 10.27%, C_{24} acids : 0.59%) of the total. In this case, the degree of unsaturation are as follows ; The C_{14} series : $-2.0H$, C_{16} series : $-2.5H$, C_{18} series : $-3.0H$, C_{20} series : $-4.4H$, C_{22} series : $-7.1H$, C_{24} series : $-6.6H$ (Fig. 3).

It is apparent that large amounts of the unsaturated C_{18} acids, unsaturated C_{20} acids, palmitic acid, unsaturated C_{22} acids and unsaturated C_{16} acids are contained in the northern elephant seal oil.

TABLE 8. CALCULATED COMPOSITION OF ESTER-FRACTIONS OF SOLID FATTY ACIDS

Fraction	Saturated					Unsaturated					Tatal solid acids
	C_{14}	C_{16}	C_{18}	C_{20}	C_{22}	C_{14} (−2.0H)	C_{16} (−2.0H)	C_{18} (−2.0H)	C_{20} (−2.0H)	C_{22} (−2.0H)	
S-1	1.23	0.59	—	—	—	—	0.01	—	—	—	1.83
S-2	0.73	0.66	—	—	—	0.01	0.01	—	—	—	1.41
S-3	0.86	0.97	—	—	—	0.02	0.03	—	—	—	1.88
S-4	0.62	1.29	—	—	—	0.01	0.05	—	—	—	1.97
S-5	0.57	1.38	—	—	—	0.02	0.04	—	—	—	2.01
S-6	0.45	1.85	—	—	—	0.01	0.07	—	—	—	2.38
S-7	0.24	1.81	—	—	—	trace	0.08	—	—	—	2.13
S-8	—	1.81	0.04	—	—	—	0.07	0.01	—	—	1.93
S-9	—	1.60	0.28	—	—	—	0.07	0.01	—	—	1.96
S-10	—	1.51	0.48	—	—	—	0.08	0.04	—	—	2.11
S-11	—	1.27	0.85	—	—	—	0.10	0.01	—	—	2.23
S-12	—	0.86	1.04	—	—	—	0.07	0.12	—	—	2.09
S-13	—	0.24	1.50	—	—	—	0.02	0.25	—	—	2.01
S-14	—	—	1.18	0.09	—	—	—	0.19	0.04	—	1.50
S-15	—	—	0.85	0.24	—	—	—	0.19	0.08	—	1.36
S-16	—	—	—	0.48	0.01	—	—	—	0.28	0.03	0.80
Weight(g.)	4.70	15.84	6.22	0.81	0.01	0.07	0.70	0.82	0.40	0.03	29.60g.
Percentages (in total acids)	2.38	8.03	3.15	0.41	0.01	0.03	0.35	0.42	0.20	0.02	15.00%

TABLE 9. CALCULATED COMPOSITION OF ESTER-FRACTIONS OF LOWLY UNSATURATED FATTY ACIDS

Fraction	Saturated			Unsaturated					Total lowly unsat acids
	C_{14}	C_{16}	C_{18}	C_{14} (−2.0H)	C_{16} (−2.0H)	C_{18} (−2.7H)	C_{20} (−3.3H)	C_{22} (−6.2H)	
LU-1	1.76	4.18	—	0.91	3.03	—	—	—	9.88
LU-2	0.27	3.17	—	0.06	3.70	—	—	—	7.20
LU-3	—	1.05	0.60	—	3.95	3.02	—	—	8.62
LU-4	—	0.11	0.22	—	1.82	4.73	—	—	6.88
LU-5	—	—	trace	—	0.83	5.13	—	—	5.96
LU-6	—	—	—	—	0.45	5.19	—	—	5.64
LU-7	—	—	—	—	—	7.42	0.38	—	7.80
LU-8	—	—	—	—	—	7.30	1.60	—	8.90
LU-9	—	—	—	—	—	6.45	2.41	—	8.86
LU-10	—	—	—	—	—	4.78	2.38	—	7.16
LU-11	—	—	—	—	—	4.01	2.37	—	6.38
LU-12	—	—	—	—	—	0.68	4.40	—	5.08
LU-13	—	—	—	—	—	2.87	4.31	—	7.18
LU-14	—	—	—	—	—	0.55	6.79	—	7.34
LU-15	—	—	—	—	—	—	5.87	1.15	7.02
LU-16	—	—	—	—	—	—	1.21	3.49	4.70
LU-17	—	—	—	—	—	—	1.38	4.02	5.40
Weight(g.)	2.03	8.51	0.82	0.97	13.78	52.13	33.10	8.66	120.00g.
Percentages (in total acids)	1.14	4.79	0.46	0.54	7.75	29.33	18.62	4.87	67.50%

TABLE 10. CALCULATED COMPOSITION OF ESTER-FRACTIONS OF HIGHLY UNSATURATED FATTY ACIDS

Fraction	Unsaturated						Total highly unsat acids
	C_{14} (−2.0H)	C_{16} (−4.4H)	C_{13} (−6.0H)	C_{20} (−8.1H)	C_{22} (−7.9H)	C_{24} (−6.6H)	
HU- 1	0.87	1.37	—	—	—	—	2.24
HU- 2	0.27	2.46	—	—	—	—	2.73
HU- 3	—	1.72	1.19	—	—	—	2.91
HU- 4	—	—	2.96	0.68	—	—	3.64
HU- 5	—	—	2.68	1.51	—	—	4.19
HU- 6	—	—	2.03	2.63	—	—	4.66
HU- 7	—	—	1.14	4.09	—	—	5.23
HU- 8	—	—	—	4.42	0.44	—	4.86
HU- 9	—	—	—	2.20	2.87	—	5.07
HU-10	—	—	—	0.66	3.84	—	4.50
HU-11	—	—	—	0.39	5.18	—	5.57
HU-12	—	—	—	—	3.20	1.70	4.90
Weight(g.)	1.14	5.55	10.00	16.58	15.53	1.70	50.50g.
Percentages (in total acids)	0.39	1.92	3.47	5.75	5.38	0.59	17.50%

TABLE 11. CALCULATED COMPOSITION OF TOTAL ACIDS

Acid	Sloid (15.00%)	Lowly unsaturated (67.50%)	Highly unsaturated (17.50%)	Total (100.00%)
Saturated:				
Myristic	2.38	1.14	—	3.52
Palmitic	8.03	4.79	—	12.82
Stearic	3.15	0.46	—	3.61
Arachidic	0.41	—	—	0.41
Behenic	0.01	—	—	0.01 (Total sat.) 20.37%
Unsaturated:				
C_{14}	0.03 (−2.0H)	0.54 (−2.0H)	0.39 (−2.0H)	0.96 (−2.0H)
C_{16}	0.35 (−2.0H)	7.75 (−2.0H)	1.92 (−4.4H)	10.02 (−2.5H)
C_{18}	0.42 (−2.0H)	29.33 (−2.7H)	3.47 (−6.0H)	33.22 (−3.0H)
C_{20}	0.20 (−2.0H)	18.62 (−3.3H)	5.75 (−8.1H)	24.57 (−4.4H)
C_{22}	0.02 (−2.0H)	4.87 (−6.2H)	5.38 (−7.9H)	10.27 (−7.1H)
C_{24}	—	—	0.59 (−6.6H)	0.59 (−6.6H) (Total unsat.) 79.63%

The component fatty acids in the ester fractions are given in Table 11 along with the composition of the original oil built up from these figures.

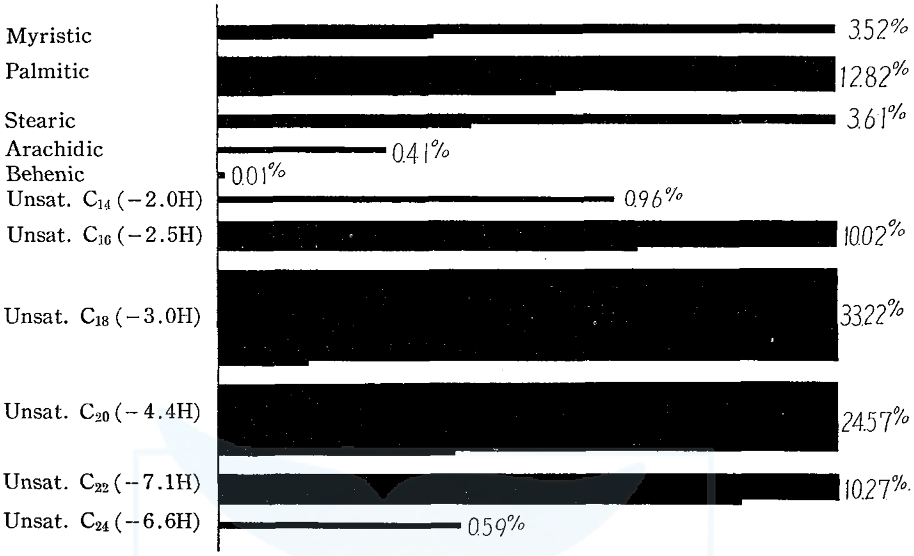

Fig. 3. Calculated composition of total acids in northern elephant seal oil.

DISCUSSION

According to the results reported by Burke & Jasperson (1944), Hildtich & Pathak (1947, 1949), Winter & Nunn (1950, 1953), the main portions of the fatty acid composition (percentages of weight) of the Newfoundland seal oil, Grey Atlantic seal oil and Antarctic elephant seal, *Mirounga leonina*, oil show the following ranges:

	North Atlantic seals	Antarctic seals
Total saturated	16 - 23	13 - 20
Palmitic	9 - 17	7 - 12
Unsaturated C_{16}	15 - 49(−2.1 to −2.2H)	8 - 16(−2.0 to −2.2H)
Unsat. C_{18}	16 - 37(−2.3 to −2.7H)	33 - 45(−2.1 to −2.7H)
Unsat. C_{20}	11 - 19(−5.7 to −7.2H)	13 - 28(−2.8 to −6.7H)
Unsat. C_{22}	5 - 18(−10.1 to −11.1H)	7 - 15(−4.9 to −10.5H)

by Hilditch (1956)

On the other hand, the component acids of the northern elephant seal, *Mirounga angustirostris*, oil studied by the writer show the following tendency:

The chief component acids belong to the unsaturated C_{18} series(33.22% ; mainly oleic with some polyethenoid), the next prominent are those of the unsaturated C_{20} series (24.57% ; mainly mono-ethenoid), palmitic acid (12.82%), the unsaturated C_{22} series (10.27% ; mainly tetra-ethenoid) and the unsaturated C_{16} series (10.02% ; mainly mono-ethenoid), whilst the saturated acids such as myristic, stearic, arachidic, behenic, and the unsaturated C_{14}, C_{24} series are present in somewhat lower proportions.

Therefore, the composition of the northern elephant seal, *Mirounga angustirostris*, oil is on the whole similar to that of the Antarctic elephant seal, *Mirounga leonina*, oil and north Atlantic seal oil

SUMMARY

The fatty acid composition of the northern elephant seal, *Mirounga angustirostris*, oil was studied by the fractional distillation through Longenecker's E.H.P. column modified by the writer. The analysis in the present work was based on lithium and lead salt separations of the mixed fatty acids. According to the results obtained, the component acids are as follows:

The total saturated fatty acids content is 20.3% (myristic 3.52%, palmitic 12.82%, stearic 3.61%, arachidic 0.41% and behenic 0.01%) of the total. While, the total unsaturated acids content is 79.63% (C_{14} acids 0.96%, C_{16} acids 10.02%, C_{18} acids 33.22%, C_{20} acids 24.57%, C_{22} acids 10.27%, C_{24} acids 0.59%) of the total with the degree of unsaturation having -2.0H in C_{14} acids, -2.5H in C_{16} scids, -3.0H in C_{18} acids, -4.4H in C_{20} acids, -7.1H in C_{21} acids and -6.6H in C_{24} acids.

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