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BRYDE'S WHALE FROM THE COAST OF JAPAN

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INTRODUCTION

It was not until 1910 that a whale known by Japanese as the 'Iwashi Kujira' (Sardine Whale) was discovered by Andrews that it was none other than the Pacific counterpart of *Balaenoptera borealis* Lesson. He remained in Japan during the spring and summer of 1910, and about 75 specimens of the 'Iwashi Kujira' came under his observation and it was thus possible to him to make an extensive study of the life history, external anatomy and individual variation of the species. But, unfortunately he could not discover the existence of another species of whale, the Bryde's whale, which is also generally known as the 'Iwashi Kujira'.

The Bryde's whale, *Balaenoptera brydei* Olsen, was firstly described by Olsen in a Norwegian newspaper 'Tidens Tegn' dated November 12, 1912. In the following year a full description of the external characters and biology of this species was given by the same author (1913). Andrews (1916) in his monograph on sei whale, based on the material gathered during his stay in Japan in 1910, treats briefly *B. brydei* under the heading of 'Doubtful Species Related to *B. borealis*' and thought that this species, although very similar in proportions and color and closely allied to *B. borealis,* is probably distinct from that species. He regretted that no osteological details are supplied in Mr. Olsen's account. It was in 1931 that a detailed description of the skeleton by Lönnberg appeared and some distinctions in the skeleton were noted. Thus it seemed probable that the two species are distinct, though the question was not regarded as finally settled (Mackintosh, 1947). Of the distribution of *B. brydei* it has long been thought that it occurs only in the South African waters and rarely elsewhere.

On the 18th June 1871 a whale stranded in a creek named Thaybyoo Choung near Sittang river which runs into the Gulf of Martaban, Burma. This whale was examined by Anderson (1878) and was named *Balaenoptera edeni,* in recognition of the Hon'ble Ashley Eden, then Chief Commissioner of British Burma, having been the means of saving this whale to science. Andrews (1916) treats also this species in his monograph on sei whale and thought that *B. edeni* is either identical with, or closely allied to *B. borealis* and he describes that "It is highly desirable that this skeleton be re-examined in the light of present knowledge of the large Cetacea, but until this is done, or other specimens have been obtained from the same waters, it appears to me that it is wisest to leave *Balaenoptera edeni* as a very doubtfully established species". In 1918 he examined the skeleton of *B. edeni* in the Calcutta Museum and came to a conclusion that it was difficult to believe that the differences between the skeletons of *B. edeni* and *B. borealis* were individual and he mentioned the possibility that *B. edeni* was identical with *B. brydei*, though at that time only the external characters of *B. brydei* were known.

A rorqual was cast ashore on the coast of Pulu Sugi, one of the smaller islands of the Rhio Archipelago between Singapore and the Sumatran coast in July 1936. The specimen was saved and after cleaning it was sent to the Rijksmuseum van Natuurlijke Historie, Leiden. Junge (1950) studied this skeleton in detail, as well as the skeletons of *B. brydei* from Saldanha Bay, South Africa and those of *B. edeni* kept in the British Museum, the South African Museum, and in the Calcutta Museum. After comparing these skeletons he came to a conclusion that we can consider *edeni* and *brydei* conspecific, which makes the name *Balaenoptera brydei* Olsen a synonym of *Balaenoptera edeni* Anderson and the species occurs in South African waters as well as in the waters of South-eastern Asia.

In 1950 (a), while engaging in an analysis of weights of various parts of the body of the 'Iwashi Kujira' taken in the waters around Japan, I noticed that there is a striking difference in weight, especially in the weight of blubber between those taken in the Bonin Island's waters and those from the north-eastern part of Honshu (Japan proper). Also in the average body length of maturity they showed some difference, those from the Bonin Island's waters being shorter by 2–3 feet (1950, b). I thought, for the time being, there might exist two local races of sei whale in the adjacent waters of Japan, viz. southern and northern types, the former being frequent in the waters around Bonin Islands. After studying the body proportions and baleen plates of the two types, cooperated by Messrs. Nishimoto and Fujino, I came to a conclusion that the southern type is more closely related to the Bryde's whale, *Balaenoptera brydei*, than to the ordinary sei whale, *B. borealis*, though the northern type hardly differ from *B. borealis* (1952). Further studies on external characters led to the conclusion that the southern type is identical with *B. brydei* (=*edeni*), while the northern type is nothing but *B. borealis* (Omura & Fujino, 1954). Movements of these two species were studied in relation to the water temperature (Omura & Nemoto, 1955). Omura & Fujino (1954), however, raised a question as to the number of the vertebrae of *B. edeni*. Total numbers of vertebrae of *B. brydei* and *B. edeni* are reported as 52 (or perhaps 53) by

Anderson (1878), Lönnberg (1931), and Junge (1950), while according to our investigations at whaling landstations on fresh bones of our Bryde's whales they number 54–55. This problem had been remained unsolved until our osteological study being concluded.

In 1953 a skeleton of *B. edeni* was preserved at Ayukawa landstation in Miyagi prefecture and in the following year it was sent to the National Science Museum in Tokyo, where it was mounted. But unfortunately this skeleton was incomplete and its vertebrae were mixed with some of vertebrae of other species, which was sent also from the same landstation.

It was not until 1958 that the second skeleton of *B. edeni* was preserved at Ayukawa. This skeleton was nearly perfect when fresh, but most of the left ribs, right scapula and left flipper were lost during the course of preparation as sample. The fresh bones had been burried in sand of beach for removal of soft parts attached and oil contained for about five months, during which period a heavy storm came and washed these above listed bones away. But other bones have been saved in good condition and they are available for the osteological study.

During a visit in 1958 to the Rijksmuseum van Natuurlijke Historie, Leiden I was able to examine the Pulu Sugi specimen of *B. edeni*, by courtesy of Dr. G. C. A. Junge. He also gave me all the help I needed. I am much indebted to Dr. M. Nishiwaki and Mr. T. Ichihara for their co-operation in examining and taking photographs of the skeleton of *B. edeni* at Ayukawa. Messrs. S. Aizawa and N. Kimura of the Whale Museum at Ayukawa undertook the laborious work of making a sample of skeleton, which was presented in fresh by the kindness of the Nippon Kinkai Hogei K. K. My sincere thanks are due to my colleagues Messrs. S. Nishimoto, K. Fujino, and T. Nemoto in concluding my work on identification of the Bryde's whale from the coast of Japan.

OSTEOLOGY

On 15th July 1958 a Bryde's whale was taken by a whale catcher belonging to the Nippon Kinkai Hogei K.K at 37°15′ N and 144°40′ E. The surface water temperature of the position was recorded as 22.6°C. This whale, female of 45 feet in length, was treated on the following day at the Ayukawa landstation and was proved that its skeleton had no damage by grenades and harpoon. Accordingly it was decided to preserve the skeleton as specimen and all of the fresh bones were burried in sand of nearby beach, except some small caudal vertebrae which were kept in a jar contained with water.

On 25th November 1958 these bones were digged out from sand and after cleaning they were examined by me assisted by Dr. M. Nishiwaki and Mr. T. Ichihara of the Whales Research Institute. Since then this skeleton has been kept in the Whale Museum at Ayukawa.

Skull (Plates I–III). The most striking feature of the skull of *B. edeni* is the flat and straight forward pointing shape of the rostrum. Anderson (1878) describes that the leading characteristics of the skull, as compared with the skulls of known *Balaenoptera*, are the great length of the maxillary portion and the little downward shelving of the upper surface of the maxillaries. Junge (l. c., p. 4) reports that in his Pulu Sugi specimen the premaxillaries, especially their posterior ends, are sunk in between the maxillaries cause the flat appearance, when the skull is viewed laterally. Lönnberg also notes to the fact that the rostrum of *B. brydei* is flat and straight as compared with skulls of *borealis*. Junge (l. c., p. 5), however, points out that there is some variation in *brydei*. He describes that the skull of *brydei* in the British Museum has a rostrum of more curved to the rostral side and in this specimen and in Lönnberg's the maxillaries are also slightly more curved to the lateral side.

TABLE 1. SELECTED PROPORTIONAL SKULL MEASUREMENTS OF *borealis*, *brydei* AND *edeni* (After Junge 1950)

	borealis 6 specimens	*brydei* 3 specimens	*edeni* 3 specimens
Length of skull in mm	2,080–3,900	2,770–3,300	2,920–3,160
From nasals to tip of premaxillaries[1]	62.2–72.0%	65.6–81 %	71.2–75 %
Breadth of rostrum basally[1]	26.5–30.7%	32 –45 %	26.2–28.1%
Breadth of rostrum at its middle[1]	16.6–18.7%	20 –21.5%	19.6–27.8%

1) Expressed as percentage of the skull length.

Our Ayukawa specimen resembles to the skull of *brydei* in the British Museum in this respect. It's rostrum is more curved downwards than the Thaybyoo Choung and Pulu Sugi specimens of *edeni* reported by Anderson (1878) and Junge (1950), but in lesser extent when compared with *borealis* (Plate XLII of Andrews 1916). Also in the Ayukawa specimen major parts of the premaxillaries are sunk in between the maxillaries, but their anterior ends rise slightly above them. These are caused by more downward curving of the maxillaries. The ventral sides of the outer edge of the maxillaries are slightly bent down in both ends, whereas in the Pulu Sugi specimen practically horizontal anteriorly. The undersides of the maxillaries are rather straight anteriorly and more curved posteriorly. In these characters it quite agrees with the specimen of *brydei* in the British Museum (Plate VI of Junge 1950).

The another point which Anderson (1878) describes as the leading characteristics of the skull is the great length of the maxillary portion.

Junge (l. c., p. 7) gives a table of selected proportional measurements of skulls of *borealis*, *brydei* and *ededi*, which is summarized in Table 1.

The proportional distances from nasals to tip of premaxillaries of *borealis*, *brydei* and *edeni* are 62.2–72.0%, 65.6–81% and 71.2–75% respectively and he concludes that the range of rostrum length is longer in *brydei* and *edeni* than in *borealis*, though there is overlapping. Lönnberg (1931) remarks, however, that the rostrum of Bryde's whale compared with that of a sei whale is comparatively shorter and broader.

In Table 2 are shown the skull measurements of the Ayukawa specimen of *edeni*, compared with those of *borealis*, which was taken on 3rd July 1957 and processed at Ayukawa on the following day. This skeleton of *borealis* was later sent to the Staatliches Museum für Naturkunde, Stuttgart, Germany. In this Ayukawa specimen of *edeni* the proportional distance from nasals to tip of premaxillaries is 70.1% of the length of the skull, which falls within the overlapping range of *borealis* and *brydei* and a little shorter than *edeni* in Table 1. I was not able to measure the same length in the specimen of *borealis*, because the nasals were missed in this specimen. However, in the specimen of Andrews (1916) from the coast of Japan this length is only 62.2% of the length of the skull, measured by Junge from the plate. Shorter proportional distance in this portion in *borealis* than *edeni* is anticipated also in the specimens from the coast of Japan.

On the other hand the length of beak, measured from its base, is 64.1% of the skull length in *edeni*, whereas in *borealis* 67.0%. Our specimen of *edeni*, therefore, supports the remarks of Lönnberg too. The proportional length of premaxillaries is also shorter in *edeni*, though the length of maxillaries is practically similar with *borealis*. The breadth of beak at its base is similar, when reduced in percentage against length of skull, but broader in *edeni* at its middle. This means the rostrum of *borealis* is more tapering distally. The outer edges of maxillaries are more curved in *edeni* (Plate I), whereas in *borealis* nearly straight. This gives an impression that in *edeni* the rostrum is comparatively shorter and broader than *borealis*.

Junge (l. c., p. 8) stresses the fact that in *brydei* and *edeni* the nasal processes of the maxillaries are narrower than in *borealis*. According to him the breadth at the anterior border of the nasals is less than 1/5 of their length and even about 1/7 in a specimen of *brydei*, whereas in *borealis* about 1/3 or less. In the Ayukawa specimen this value is about 1/4. This means that in this specimen the nasal processes of the maxillaries are shorter than in any specimens of *edeni* and *brydei*, but still longer than *borealis*. This is also observed if the photograph of Andrews (l. c., Plate XLI, Fig. 1) is compared with Plate I, Fig. 1, though

TABLE 2. SKULL MEASUREMENTS OF *edeni* FROM THE COAST OF JAPAN, COMPARED WITH *borealis*

Measurements		*B. edeni* Ayukawa, 45 ft. ♀			*B. borealis* Ayukawa, 43 ft. ♀	
	in mm	% of length	% of breadth	in mm	% of length	% of breadth
Length of skull (straight)	3,480	**100.0**	215.5	3,062	**100.0**	229.4
〃 〃 beak	3,230	64.1	138.1	2,052	67.0	153.7
〃 〃 premaxillary (straight)	2,640	75.9	163.5	2,433	79.5	182.2
〃 〃 maxillary along upper surface R	2,495	71.7	154.5	2,163	70.6	162.0
〃 〃 maxillary along upper surface L	2,500	71.8	154.8	2,145	70.1	160.7
Tip of premax. to post. end of maxillaries	2,670	76.7	165.3	—	—	—
〃 〃 〃 〃 vertex	2,695	77.4	166.9	—	—	—
〃 〃 〃 〃 tip of nasals (mesial)	2,440	70.1	151.1	—	—	—
〃 〃 〃 〃 ant. end of palatines	2,445	70.3	151.4	—	—	—
〃 〃 〃 〃 post. end of palatines (mesial)	2,909	83.6	180.1	—	—	—
〃 〃 〃 〃 post. end of pterygoids	3,225	92.7	199.7	2,795	91.3	209.4
〃 〃 〃 〃 ant. end of maxillaries	183	5.3	11.3	—	—	—
〃 〃 〃 〃 ant. end of vomer	439	12.6	27.2	—	—	—
Length of supraoccipital from foramen magnum	835	24.0	51.7	768	25.1	57.5
Greatest breadth of skull (squamosal)	1,615	46.4	**100.0**	1,335	43.6	**100.0**
Breadth of skull (frontal)	1,540	44.3	95.4	1,266	41.3	94.8
〃 〃 〃 (maxillary)	1,445	41.5	89.5	1,144	37.4	85.7
〃 〃 beak at base	955	27.4	59.1	844	27.6	63.2
〃 〃 〃 〃 middle	645	18.5	39.9	507	16.6	38.0

Breadth across premaxillaries, greatest		330	9.5	20.4	—	—	—
〃 〃 〃 at base of beak		302	8.7	18.7	255	8.3	19.1
〃 〃 〃 at middle of beak		219	6.3	13.6	217	7.1	16.3
Length of nasals mesially		198	5.7	12.3	* —	—	—
〃 〃 〃 laterally		266	7.6	16.5	—	—	—
Breadth of nasals at anterior ends (distal)		175	5.0	10.8	—	—	—
〃 〃 〃 〃 〃 〃 (proximal)		137	3.9	8.5	—	—	—
〃 〃 〃 〃 posterior ends		49	1.4	3.0	—	—	—
〃 〃 frontal plane post. to premax.		217	6.2	13.4	—	—	—
〃 〃 orbit (frontal wing)		234	6.7	14.5	233	7.6	17.5
Breadth of occiput between squamosal sutures		1,118	32.1	69.2	876	28.6	65.6
〃 across occipital condyles		266	7.6	16.5	251	8.2	18.8
Height of occipital condyle		174	5.0	10.8	167	5.5	12.5
Breadth of foramen magnum		53	1.5	3.3	84	2.7	6.3
Height of foramen magnum		45	1.3	2.8	97	3.2	7.3
Length of mandible (straight)	R	3,305	95.0	204.6	2,891	94.4	216.6
	L	3,315	95.3	205.3	2,898	94.6	217.1
〃 〃 〃 (on curve)	R	3,540	101.7	219.2	2,970	97.0	222.5
	L	3,645	104.7	225.7	3,009	98.3	225.4
Height of mandible at coronoid	R	397	11.4	24.6	342	11.2	25.6
	L	392	11.3	24.3	339	11.1	25.4
〃 〃 〃 〃 proc. articularis	R	302	8.7	18.7	268	8.8	20.1
	L	301	8.6	18.6	276	9.0	20.7
〃 〃 〃 〃 middle	R	214	6.1	13.3	225	7.3	16.9
	L	217	6.2	13.4	223	7.3	16.7

* Nasals missed.

the latter photograph is taken from a slightly obliquely posterior position and does not show correct proportion on this point.

The nasals of the Ayukawa specimen of *edeni* are more tapering backwards than in the Pulu Sugi specimen of *edeni* and the specimens of *brydei* in the British and South African Museums, and their posterior ends are separated by a forwardly directed process of the frontals. These characters are, however, less important for the taxonomic purpose. The most remarkable difference between *edeni* (and *brydei*) and *borealis* in the form of nasals is observed in the front margin. In all the specimens of *edeni* and *brydei* ever reported the front margin of nasals is bent forward on the outer side, whereas in *borealis* straight. The Ayukawa specimen of *edeni* agrees quite well in this character as shown in Plate I, Fig. 1.

The another important point which separates *edeni-brydei* from *borealis* is the relation between the front margin of nasals and the anterior border of the posterior maxillary concavity. In *edeni* and *brydei* the front margin of the nasals is situated far behind this concavity, but in *borealis* they reach almost to this level. The Ayukawa specimen of *edeni* agrees in this respect too, the front margin of nasals (median) being situated about 15 cm behind this concavity.

Lönnberg stresses the point that the flat area formed by the nasals and the hind part of the maxillaries is longer than broad in *brydei*, whereas in the sei whale it is square or broader than long. Junge (l. c., p. 9), however, describes that this character is variable therefore to be of no use. In our specimen of *edeni* this area is broader than long, as in the case of Pulu Sugi specimen, and does not agree with the Lönnberg's description.

The length of the supraoccipital bone measured from the foramen magnum to the frontal suture is 24.0% of the length of skull in the Ayukawa specimen of *edeni*, whereas 25.1% in *borealis* taken in the same locality. Junge (l. c., p. 9) found the range for *brydei* to be 23.9–24.9%, and for *edeni* 22.2–23.8%. He concludes that the supraoccipital is therefore longer in *brydei* than in *edeni*, though he deems this character is of no essential value. Our specimen of *edeni* falls within the range for *brydei* and does not fall in that for *edeni*.

The breadth of occiput between squamosal sutures is 32.1% of the skull length in the Ayukawa specimen of *edeni*. Junge (l. c., p. 9) also describes that the measured skulls of *brydei* (32.4–35%) and *edeni* (28.3–31.3%) are different in this respect, but our specimen of *edeni* is more closely related to the above figures for *brydei* than those for *edeni*.

The deep and narrow sulcus between the articular and squamosal parts of the temporal is present in the specimen of *borealis*, but nearly absent in the specimen of *edeni*, both from Ayukawa. There are also each one specimen of *edeni* and *borealis* in the National Science Museum in Tokyo. In these specimens too the sulcus is present in *borealis* and absent in *edeni*. This sulcus is also present in *physalus*, but absent in any specimens of *acuto-rostrata* from the coast of Japan. According to Junge (l. c., p. 10) this sulcus, but feebly developed, is also present in the two skulls of *edeni* in the Calcutta Museum and absent in his Pulu Sugi specimen. He concludes that though variable in development this sulcus is narrower and deeper in most specimens of *borealis* than it is in *brydei* or *edeni*, and this is also supported by specimens of both species from the coast of Japan.

In the ventral region of the skull there are also some characters which are said as separating *brydei* and *edeni* from *borealis*. One character is that the palatines do not reach so far backwards in *brydei* and *edeni* as in *borealis*. Junge (l. c., p. 10) reports that the proportional length between the posterior ends of the palatines in the mesial line and the occipital condyles against skull length are 8.5–12.9% in *borealis* (5 specimens) and 11.8–14.8% in *brydei* and *edeni* (5 specimens). In our specimen of *edeni* the length from the tip of premaxillaries to posterior end of palatines (mesial) is 83.6% of the skull length (Table 2), and agrees in this respect. In the Andrews' specimen of *borealis* from the coast of Japan (l. c., Plate XLI, Fig. 2) this part of the skull is rather short, being about 11% of the skull length measured from the photograph. But in the specimen of *borealis* from Ayukawa this length is about 16% of the skull length. In the both specimens of *borealis* the vertebral epiphyses are all free, hence physically immature. This character, therefore, may subjects to individual variation.

Another character which is said also to separate *brydei* and *edeni* from *borealis* is the form of the basicranial part exposed behind the palatines. This part of the skull is about squarish in outline in *borealis*, whereas in *brydei* and *edeni* much longer than broad in general though to a varying degree. In our specimen of *edeni* this part of the skull is much longer than broad when compared with the skull of the Andrews' specimen, but also in the specimen of *borealis* from Ayukawa this part is much longer than broad. And I can not distinguish the two species from Ayukawa in the above noted two characters.

It is also reported that the skull of *brydei* and *edeni* has more longer and slender hammular processes of pterygoids. In our specimen of *edeni* their lengths are 101 and 103 mm respectively and more slender compared with that of *borealis*.

The tympanic bullae of our specimen measure: right 117 mm in length and greatest breadth 90 mm, left 118 mm in length and 89 mm breadth. They are larger than those of Pulu Sugi specimen and similar in general to those of Lönnberg's specimen of *brydei*.

Lacrymals (Fig. 1) are generally flat and their proximal ends are very thin, but distal ends thickend. The lengths of right and left are 273 and 270 mm respectively, and their breadths are 87 and 94 mm at distal ends and greatest breadth at middle 114 and 112 mm respectively. They articulate between frontals and maxillaries.

Fig. 1. Lacrymals (left) and malars (right) of *edeni* from the coast of Japan.

Malars (Fig. 1) are short and curved towards posterior ends, and broadened at their anterior ends, where they articulate with lacrymals and maxillaries. Length of the right and left bones are 285 and 282 mm, and breadth at anterior ends are 211 and 205 mm respectively. Breadth at middle is 42 mm in both bones.

Mandible (Plate III, Figs. 2 & 3). Measurements of mandibles of our specimen of *edeni* are also given in Table 2, together with those of *borealis* processed at the same landstation. As shown in this table practically there is no difference in the proportional length of the mandibles against skull length between the two species when measured in straight line, but when measured on curve *edeni* has more longer mandibles than *borealis*. This means that the mandibles are more curved inwardly in *edeni* and this fact corresponds to the more curved outer edges of maxillaries in this species than *borealis*. In the height of the mandibles the measurements of two specimens agree well each other, except the height of mandible at its middle, in which *edeni* shows less value. But I had an impression that the mandible of *edeni* is much thicker and heavier than that of *borealis*. In other words the cross section of mandible at its middle is more rounded in outline in *edeni* and flat in *borealis*. In the specimens of *borealis* and *edeni* kept in the National Science Museum in Tokyo the thickness of mandible at their middle are 124 and 137 mm respectively, their length being 3390 and 2925 mm measured in straight. And these thickness are 53.7% in *borealis* and 64.3% in *edeni*, when expressed as percentages of the height at the same points. We can safely conclude, therefore, that *edeni* has more thicker mandibles than *borealis*.

There are some characters in mandible which are said also to separate *brydei* and *edeni* from *borealis*. One of these is the groove between the angular and articular parts of the mandible. This groove is deeper in *borealis*, but much less developed in *brydei* and *edeni*. Our specimens of *borealis* and *edeni* agree quite well in this respect.

Another difference between *borealis* on the one hand and *brydei* and *edeni* on the other is the relation between angular and articular portions. According to Junge (l. c., pp. 11–2), in *brydei* and *edeni* the angular portion is at equal level or projects behind the articular part, whereas in *borealis* the former ends before the hind edge of the latter. And moreover in *borealis* the angular portion is found much more on the medial side of the mandible than *edeni*, where they are much in a vertical line above each other. Our specimens of *edeni* and *borealis* from Ayukawa agree in these characters too.

Vertebrae (Plates IV & V). The vertebral formula of our specimen of *edeni* is C 7, D 13, L 13, Ca 21, which makes the total number of vertebrae 54. The measurements of the vertebrae are shown in Table 3. The total number of vertebrae of *brydei* and *edeni* is reported as 52 or 53. Lönnberg (1931) reports that in his specimen of *brydei* there are 52 vertebrae. Anderson (1878) gives the vertebral formula of his type specimen of *edeni* as C 7, D 10, L 14, Ca 21=52. But in this case, actually only 47 vertebrae have been preserved and he thought that there are 2 more probably after the 41st vertebra, and, at the termination of the caudal portion, 3 to be wanting. Junge (l. c., pp. 17–8) describes that in the London specimen of *edeni* there are 7 cervical, 12 dorsal, 12 lumbar and 16 caudal vertebrae present, but four or five of the hindmost vertebrae are lost, which makes the total 52 or 53 vertebrae. And in the London specimen of *brydei* 7 cervical, 12 dorsal, 14 lumbar and 19 caudals (perhaps the last one lost) are found, which makes a total of 52, perhaps 53 vertebrae. Further he reports that in his Pulu Sugi specimen there present 7 cervical, 13 dorsal, 13 lumbar and 18 caudal, but certainly one, perhaps two of the last caudals have been lost, and this makes a total of 52 or perhaps 53.

As stated above there remains still some question as to the total number of vertebrae in *edeni* and also in *brydei*. Omura & Fujino (1954) report that *edeni* processed at Ayukawa in 1953 had 54–55 vertebrae, out of a total number 13 investigated 5 being 54 and 8 samples 55. The present specimen of *edeni* from Ayukawa agrees in this res-

TABLE 3. MEASUREMENTS OF VERTEBRAE OF *edeni* FROM THE COAST OF JAPAN (in mm)

Serial No.	Vertebral No.	Greatest breadth	Greatest height	Centrum			Neural canal	
				Breadth in front	Height in front	Length	Breadth	Height
1	C 1	471	298	2) 260	2) 186	84	81	133
2	2	750	311	2) 270	2) 165	48	118	92
3	3	645	311	220	142	50	118	81
4	4	658	304	213	159	62	121	73
5	5	623	311	210	165	59	129	70
6	6	565	333	215	175	63	136	69
7	7	586	366	218	172	75	134	71
8	D 1	583	362	219	170	86	138	72
9	2	601	304	218	166	106	128	73
10	3	566	423	228	167	123	118	75
11	4	632	466	233	168	141	111	76
12	5	695	490	230	165	151	102	83
13	6	752	524	226	165	157	97	74
14	7	807	551	222	165	174	82	77
15	8	838	576	219	164	185	74	73
16	9	853	601	221	171	187	75	68
17	10	889	620	226	174	197	68	60
18	11	930	627	225	176	201	68	67
19	12	1) 970	630	228	176	202	68	64
20	13	950	645	233	174	215	60	59
21	L 1	922	662	233	182	220	59	57
22	2	920	658	235	184	228	55	73
23	3	913	647	237	186	233	57	73
24	4	915	655	243	188	240	56	74
25	5	889	672	240	197	242	58	64
26	6	872	676	241	198	248	57	52
27	7	844	681	243	201	252	57	55
28	8	821	686	248	197	257	51	58
29	9	802	688	251	199	260	55	45
30	10	761	689	253	206	268	52	50
31	11	742	689	258	212	273	45	55
32	12	730	682	266	215	278	42	53
33	13	651	680	273	221	273	34	53
34	Ca 1	630	660	277	233	270	33	49
35	2	582	600	273	238	271	30	40
36	3	571	530	277	237	272	27	42
37	4	505	457	277	235	265	27	37
38	5	432	409	277	232	260	24	28
39	6	362	366	271	231	254	23	22
40	7	335	344	273	228	246	17	13
41	8	307	317	262	225	237	15	7
42	9	281	288	254	221	226	10	7
43	10	266	260	243	219	213	13	6
44	11	237	238	222	209	182	12	7
45	12	199	220	190	198	124	8	6
46	13	180	160	165	152	85	—	—
47	14	—	139	151	129	70	—	—
48	15	—	130	129	119	76	—	—
49	16	—	120	108	107	75	—	—
50	17	—	102	91	93	67	—	—
51	18	—	78	78	71	55	—	—
52	19	—	—	63	57	46	—	—
53	20	—	—	51	41	42	—	—
54	21	—	—	38	27	38	—	—

1) Left transverse process broken. Twice right half.

2) Articulating face.

pect, having 54 vertebrae. I had an opportunity to observe the Pulu Sugi specimen kept in the Rijksmuseum van Natuurlijke Historie, Leiden, by the courtesy of Dr. G.C.A. Junge, and measured some of the caudal vertebrae, which are shown in Table 4 compared with those of the Ayukawa specimen of *edeni*.

TABLE 4. SELECTED MEASUREMENTS OF VERTEBRAE OF *edeni* (in mm)

Vertebral No.	Pulu Sugi specimen			Ayukawa specimen		
	Greatest breadth	Greatest height	Length	Greatest breadth	Greatest height	Length
45	201	199	131	199	220	124
46	175	166	108	180	160	85
47	149	143	94	151	139	70
48	131	128	90	129	130	76
49	116	116	86	108	120	75
50	100	98	77	91	102	67
51	78	87	69	78	78	55
52	—	—	—	63	57	46
53	—	—	—	51	41	42
54	—	—	—	38	27	38

As seen from this Table each corresponding vertebra agrees in general in dimension, except in length of vertebra where Pulu Sugi specimen has somewhat greater value. In all vertebrae of the Pulu Sugi specimen the epiphyses are coalesced completely with the rest of the vertebral body. In the Ayukawa specimen, on the other hand, such fusions are only observed in the anterior region up to the anterior epiphysis of the 4th, and in the posterior region in the last lumbar (33rd vertebra) and in all of the caudals. We can conclude, therefore, that the Pulu Sugi specimen is older in age than the Ayukawa specimen. But it seems that the former is somewhat shorter in body length than the latter. The body length and sex of the Pulu Sugi specimen was unknown, and the length of the skeleton is reported as slightly over 12 m. The Ayukawa specimen was a female of 45 feet in length. The skull length of the two specimens are 3160 and 3480 mm, the Pulu Sugi specimen being shorter than the other. It is possible, therefore, that the Pulu Sugi specimen was shorter in body length than the Ayukawa specimen, regardless of its higher age. But, still we can not deny the possibility that in the Pulu Sugi specimen there were present 3 more caudal vertebrae, instead of 2, though in some of its caudal vertebrae their lengths are a bit larger than the corresponding vertebrae of the Ayukawa specimen. And if we assume that this is a matter of fact, then the vertebral formulae of the two specimens are exactly the same, i.e. C 7, D 13, L 13, Ca 21=54.

The cervical vertebrae of our specimen of *edeni* are all free and no fusion among these bones were observed. The atlas has short and much twisted transverse processes. In the specimens of *brydei* and *edeni* ever reported these processes are much pointed than in *borealis,* but in our specimen no such character is observed and I can not distinguish it from *borealis.* It is possible, however, that such form is much changeable according to age. Our specimen of *edeni* was adolescent one, because most of the epiphyses are not fused to their centra as stated before.

The posterior process on the lower edge of the body and pointing to the axis is short and obtuse. The canal for the first spinal nerve is open. The articular facets for the occipital condyles are separated in major parts, but confluent in the lower parts, being placed obliquely each other.

The axis of our specimen of *edeni* resembles in general to that of Pulu Sugi specimen. The distal ends of the wing-like processes are more squarer than those of *borealis,* which are generally rounded. The holes on these wing-like processes are rather small in our specimen, their long diameters being 80 and 83 mm.

In the 3rd cervical vertebra the ring formed by dia- and parapophyses is closed on both sides. And at each distal end of both rings, a bit apart from the ring, there present a small bone (Plate V, Fig. 1). The one on the left side is nearly rounded in outline, their diameters being 60 and 77 mm. This bone was connected with the ring by cartilage. Another one on the right was not ossified yet, but cartilage of 114 mm long and 37 mm width. These facts show that the rings were still in the process of growth.

In the 4th, 5th and 6th vertebrae also such rings present. They are all closed, but the parapophyses on the left side of the 4th and on the both sides of the 6th have no communication with the vertebral body. The diapophyses are well developed in the 7th, but the parapophyses of the vertebra are found as small tubercles on the vertebral body. Since there are great variability in the formation of ring and form of the dia- and parapophyses in specimens of *brydei* and *edeni* hitherto reported, such characters are of doubtful value for the diagnostic purpose.

The most remarkable difference which separate *brydei* and *edeni* from *borealis* in the form of vertebrae is the strong backward inclination of the spinous processes in the former. This inclination begins in the 7th dorsal vertebra in the Pulu Sugi specimen and increases till it reaches its maximum in the 7th lumbar (Junge, l. c., p. 14). And the similar is reported for the Anderson's specimen of *edeni* and also in specimens of *brydei*. They all agree in general in this character. Lönnberg and Junge measured the distance at which the vertical plane along the posterior surface of the vertical body reaches the upper margin of the spinous process reckoned from the anterior and posterior upper angle of the process. These measurements are more or less approximate for it is difficult to take exact measurements. But still useful in general comparison.

In our specimen of *edeni* too, the backward direction of the spinous process is notable (Plate IV). It begins in the 7th dorsal vertebra (14th vertebra) and increases till it reaches its maximum in the 5th lumbar (25th vertebra). In all vertebrae from the 2nd lumbar (22nd vertebra) to the 10th lumbar (30th vertebra) the vertical plane along the posterior surface of the vertebral body falls before the anterior angle of the spinous process. I also took similar measurements as taken by Lönnberg and Junge, which are shown in Table 5. These figures show close agreement each other.

TABLE 5. BACKWARD INCLINATION OF SPINOUS PROCESSES IN *edeni* AND *brydei* (in cm)

Vertebral number	Distance of posterior angle of processus spinous		
	Pulu Sugi *edeni*	Lönnberg *brydei*	Ayukawa *edeni*
13	4.5	5	—
14	8	7	—
15	9	7	—
16	11	7.5	—
17	12	10	—
18	13	13.5	12
19	14	13	13
20	18	13	17
21	20	—	16.5
22	20	—	21
23	20.5	—	23.5
24	23	—	24.5
25	26	—	25.5
26	—	—	25
27	—	—	25
28	—	—	23
29	—	—	20.5
30	—	—	21.5
31	—	—	18.5
32	—	—	15
33	—	—	10

Our specimen of *edeni* has 13 dorsals and 13 lumbars as stated above. The spinous process in the 1st dorsal vertebra is rather low and blunt pointed. From the 2nd on they show a square top and increase in height. The first 12 dorsal vertebrae have more or less well marked facets at the distal ends of the transverse processes for the articulation of the ribs. The 13th dorsal vertebra has a well marked facet at the distal end of the right transverse process, but on the left no such facet present, though the distal end of the process somewhat thickened (Fig. 2).

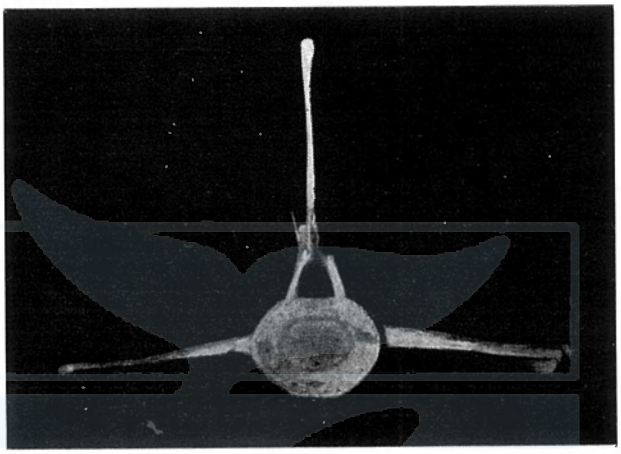

Fig. 2. 13th dorsal vertebra of the Ayukawa specimen of *edeni*. Posterior view.

As seen in Table 7 the 13th right rib is similar in size to the preceding two ribs, but unfortunately all of the left ribs, except the foremost 3, were missed. I can not able, therefore, to discuss this point in relation to ribs.

The transverse process in our specimen of *edeni* are directed forward in the first 6 dorsal vertebrae, those of 7th, 8th and 9th outward, from 10th dorsal on backward till 1st of lumbar, and those of remaining again outward.

The 1st caudal vertebra is detected by the presence of bifurcated median carina on the inferior side of the vertebral body. In the caudal vertebrae the spinous process diminishes its height rapidly and it disappears completely in the 13th caudal (46th vertebra), and rudimental in the preceding two. The neural canal in our specimen is closed to the 13th caudal. Also the transverse process decreases its length rapidly and diminishes on the 12th caudal (45th vertebra). The first vertebra with transverse processes perforated by vertical foramen is the 4th caudal (37th vertebra) in our specimen of *edeni*. In this vertebra the perforation is visible on both transverse processes.

In the above mentioned characters in the caudal vertebrae our specimen of *edeni* is somewhat different from the Pulu Sugi specimen and other specimens of *edeni* and *brydei*. But, it is possible that these are matters of individual variations. Junge (l. c., p. 18) reports that in his Pulu Sugi specimen spinous process has disappeared by the 9th, and neural canal is closed to the 11th. But, up to 12th caudal there remain still some tubercles on the superior sides of vertebrae, and nothing on the 13th (Plate VIII, Fig. 3 of his report). Our specimen of *edeni* agrees quite well in this respect (Plate IV, Fig. 3).

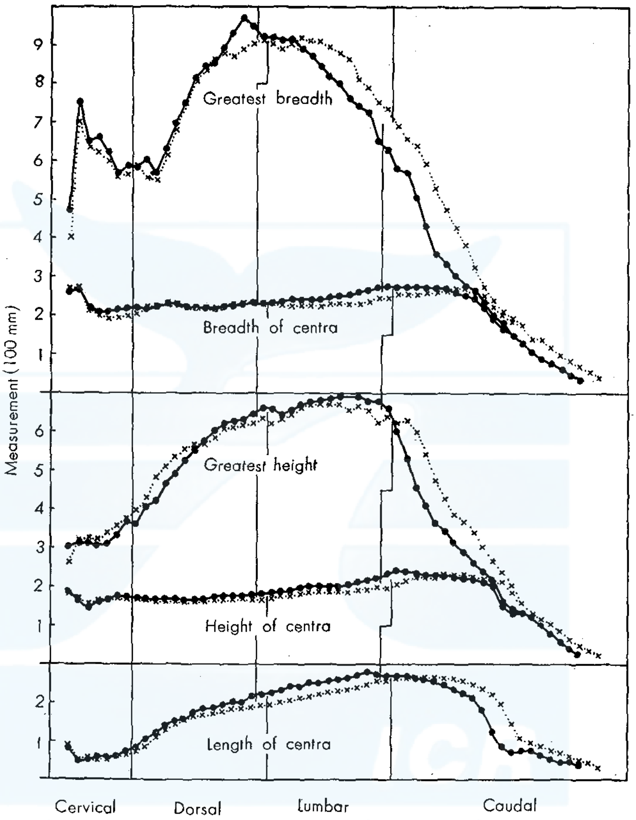

Fig. 3. Dimensions of vertebrae in *edeni* and *borealis*.

In Fig. 3 the measurements of vertebrae of our specimen of *edeni* are compaired with those of *borealis*. The vertebral formula of this *borealis* is C 7, D 14, L 13, Ca 22=56. The measurements of skull of this specimen are included in Table 2. As shown in Fig. 3 the curves for *edeni* and *borealis* are similar in general, if we consider the different number of vertebrae of both specimens.

Chevron bones (Fig. 4). Our specimen of *edeni* has 12 chevron bones. The 1st attached to the inferior and posterior part of the 34th vertebra. The right and left laminae of the first and the last are not united each other, and in all of the rest united. Measurements of each bone are shown in Table 6. The 6th is the largest, and the last smallest. In the Pulu Sugi specimen 11 chevron bones have been secured, but Junge deems probably the first two have been lost. In the Lönnberg's specimen of *brydei* 9 chevron bones present, but 2 last are lacking. Our specimen of *edeni* was confirmed at fresh that it had 12 chevron bones.

Fig. 4. Chevron bones of *edeni* from the coast of Japan.

TABLE 6. MEASUREMENTS OF CHEVRON BONES OF *edeni* FROM THE COAST OF JAPAN (in mm)

No.	Breadth	Height	Remark
1	78 69	103 109	not united
2	83	197	
3	116	218	
4	170	208	
5	155	239	
6	179	250	
7	175	239	
8	157	171	
9	129	157	
10	130	111	
11	115	73	
12	72 74	50 54	not united

Pelvic bone (Fig. 5). Both pelvic bones have been secured. They are nearly straight entally, while ectally the region of junction of ilium and ischium is marked by the small projection of the pubis, and the ilium constricted around the middle. The lengths of right and left bones are 259 and 257 mm and their breadth at pubis are 43 and 41 mm respectively.

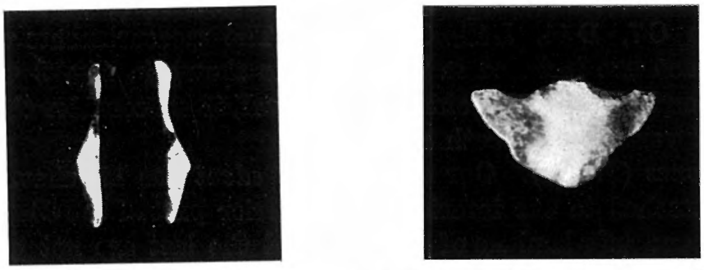

Fig. 5. Pelvic bones (left) and sternum (right) of *edeni* from the coast of Japan.

Sternum (Fig. 5). In our specimen of *edeni* the sternum is cross shaped as in other specimens of *edeni* and *brydei*, but the anterior process is much reduced and the posterior process less pronounced. The length is 180 mm, the breadth across the transverse arms 288 mm. The proportional length is 62.5% of the breadth, which is very near to that of the Pulu Sugi specimen (61.2%).

Ribs (Plate VI). Our specimen of *edeni* has 13 pairs of ribs. All of the right ribs have been saved, but in the left only the first 3 secured. The 1st rib is deeply bifurcated at the head, by a narrow cleft of about 10 cm deep, and broadly expanded at the distal end. The head for the last cervical is longer and broader than that for the 1st thoracic vertebra.

TABLE 7. MEASUREMENTS OF RIBS OF *edeni* FROM THE COAST OF JAPAN (in mm)

Rib No.	Right		Left[1]	
	Length, straight	Breadth, distal end	Length, straight	Breadth, distal end
1	910 (875)[2]	215	908 (875)[2]	190
2	1,233	73	1,203	72
3	1,390	77	1,370	76
4	1,495	79		
5	1,547	73	—	—
6	1,572	broken	—	—
7	1,573	58	—	—
8	1,516	51	—	—
9	1,468	47	—	—
10	1,308	40	—	—
11	1,256	39	—	—
12	1,243	32	—	—
13	1,258	37	—	—

1) All ribs other than nos. 1, 2 and 3 were missed.
2) Figures in brackets show the length from the second head.

Anderson (1878) reports that in his type specimen of *edeni* only a fragment of the first rib of the left side and the entire sixth rib of the same side were saved. As to the former he describes that it is single-headed, and the head and tubercle are well-developed. Other specimens of *edeni* and *brydei* ever reported all have bifurcated first rib, as in the case of *borealis*.

In our specimen of *edeni* there is a rudiment of a capitulum and collum in the 2nd rib of both sides, but absent in the 3rd and 4th of the right side. In the left side, however, collum is also present in the 3rd (Plate VI, Fig. 2), but unfortunately all ribs from the 4th on have not been saved. In the Pulu Sugi specimen the rudiment of capitulum and collum is present in the 2nd, 3rd and 4th ribs.

The measurements of the ribs in our specimen are shown in Table 7. As stated before, practically no difference in size is noted in the last 3 ribs on the right side.

Hyoid bone (Fig. 6). In our specimen of *edeni* basihyals and thyrohyals are united completely into a mass. It is more slender than that of *borealis* used for comparison. Its transverse diameter is 745 mm, and the length mesially between the forward projecting processes 153 mm. This length is 20.7% of the overall breadth, whereas in *borealis* the same length is 25.5% of the breadth. The median notch is narrow and deep, its depth being 94 mm. In our specimen one of the forward projecting processes is broken. Stylohyals are also more slender and less curved than those of *borealis*. This point may be of some importance, because in the Andrews' specimen of *borealis* stylohyals are also more curved. In our specimen of *edeni* one of the stylohyals is 444 mm in length and 133 mm breadth, and the another 444 and 143 mm respectively. The breadths are 30.0% and 32.4% of their lengths, and the corresponding figures in *borealis* are 34.5% and 36.4%.

Fig. 6. Stylohyals (upper) and combined bone of basihyal and thyrohyals of *edeni* from the coast of Japan.

In these respects our specimen of *edeni* agrees well with the Pulu Sugi specimen.

Scapula (Fig. 7). In our specimen of *edeni* only the left scapula has been saved. It has a form generally found in *borealis* or other species of balaenopterid whales. The greatest length measured from angle to angle is 910 mm and its height is 537 mm. The height is 59.0% of the length, which is similar to those of other specimens of *edeni* and *brydei* reported. But, it is also similar to the measurements in *borealis* used for comparison. In this specimen of *borealis* the corresponding figures for the right and left scapulae are 58.8% and 58.1% respectively.

In our specimen of *edeni* the length of the acromion is 248 mm and not broadening toward the end. The coracoid is 154 mm in length, which is much longer than that of *borealis* used for comparison. It is longer than that of Pulu Sugi specimen by about 70%, though in other measurements any particular differences are noted between the two specimens. The glenoid fossa of our specimen is 195 mm in length and 139 mm width.

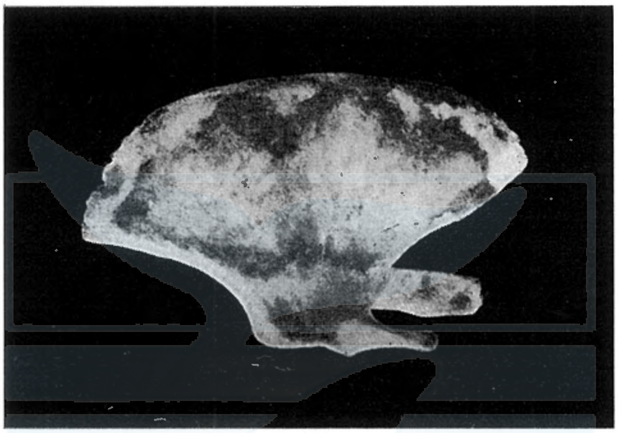

Fig. 7. Scapula of *edeni* from the coast of Japan.

Humerus, Radius, and Ulna (Plate V, Fig. 3). In our specimen of *edeni* these bones were saved only from right side. The length of the humerus is 371 mm and the breadth at its middle 154 mm. Its proximal and distal epiphyses are united completely to the body. In the radius and ulna their proximal epiphyses are united to their bodies but the distal epiphyses are not united. The radius measures 607 mm in length, excluding the distal epiphysis, and breadth at its middle 105 mm. The corresponding figures in the ulna are 568 (between articulating surfaces) and 59 mm, also excluding the distal epiphysis, and the length from orecranon is 640 mm. In our specimen the length of the humerus is 61.1% of the length of the radius. Junge (c. l., p. 21) found that this proportional length is 51.9–54.2% in *edeni* and 56.9–63.3% in *brydei*. He does not think, however, that this differences is an essential one, for this proportional length of humerus can vary to a large extent. His opinion is well supported by our specimen of *edeni*.

Carpals and Phalanges (Plate V, Fig. 3). Carpals and phalanges were also secured only from the right side. Carpals were still embedded in cartilages when I examined, and the ossifications of the radiale, intermedium, ulnare, as well as 2 carpalia were observed. The phalanges were incompletely saved, and surely some of the digits were missed. I can not give, therefore, the formula for the phalanges. In Table 8 the measurements of the saved phalanges are shown for reference.

TABLE 8. LENGTHS OF PHALANGES OF *edeni* FROM THE COAST OF JAPAN (RIGHT SIDE) (in mm)

		II	III	IV	V
1	Phalanx	115	125	115	90
2	〃	117	119	106	70
3	〃	93	93	92	70
4	〃	66	67	70	—
5	〃	44	50	67	—
6	〃	45	—	—	—

Discussion. Junge (l. c., pp. 22–3) points out many characters in the skeleton, which separate both *Balaenoptera edeni* and *B. brydei* from *B. borealis* as follows:

1. The dorsal surface of the rostrum is mostly more straight and flat in *edeni-brydei.*
2. The ventral surface of the maxillaries is less concave in *edeni-brydei.*
3. The range of the rostrum length is larger in *edeni-brydei.*
4. The rostrum at its middle is broader in *edeni-brydei.*
5. The nasal processes of the maxillaries are narrowed in *edeni-brydei.*
6. The front margin of the nasals is bent forward on the outer side in *edeni-brydei,* straight in *borealis.*
7. The front margin of the nasals falls strinkingly behind the anterior border of the posterior maxillary concavity in *edeni-brydei,* at about the same level in *borealis.*
8. The sulcus between articular and squamosal parts of the squamosal is not so deep and narrow in *edeni-brydei.*
9. The palatines do not extend so far back in *edeni-brydei.*
10. The basicranial part of the skull exposes behind the palatines is much longer than broad in *edeni-brydei.*
11. The posterior horns of the pterygoids are longer and more slender in *edeni-brydei.*
12. The groove on the inner side of the mandible between articular and angular parts is shallower in *edeni-brydei.*
13. The angular portion of the mandible ends at level of, or behind, the articular part in *edeni-brydei,* in front of it in *borealis.*
14. The angular and articular parts are more vertical above each other in *edeni-brydei.*
15. The transverse processes of the atlas are smaller and more pointed in *edeni-brydei,* the process pointing to the axis is shorter and more obtuse.

16. The distal ends of the wing-like processes of the axis are squarer in *edeni-brydei*.

17. The spinous processes of the dorsal and first lumbar vertebrae show a strong backward inclination in *edeni-brydei*.

18. The total number of the vertebrae is 52–53 in *edeni-brydei*, against 56–57 in *borealis*.

In these characters he deems especially nos. 1, 2, 5, 6, 7, 13, 17 and 18 to be important. As shown above our specimen of *edeni* agrees strikingly in these important characters, except no. 18. In characters other than listed above our specimen of *edeni* agrees in nos. 4, 8, 11, 12, 14, and 16. Of 18 characters, therefore, our specimen agrees in 13, and these may need no further explanation.

In our specimen of *edeni* the rostrum length (no. 3) is larger as in *edeni-brydei* when this length is measured from the tip of the premaxillaries to the tip of the nasals, but it is not proved if measured from the same to the base of the rostrum, i.e. middle of the curved border of maxillaries. These facts mean that the nasals are situated more posteriorly in *edeni* than *borealis*. From a study on the external characters by Omura, Nishimoto and Fujino (1952) it is shown that the lengths from tip of snout to blow-hole and from the same to centre of eye are greater in *edeni* than *borealis*, though there is overlapping. But, in the length from tip of snout to angle of gape the difference between two species is not conspicuous. As shown above our specimen of *edeni* agrees with the the description of Junge also in no. 3, if we understand the meaning of rostrum length as that measured from nasals.

As regards nos. 9 and 10 our specimen of *edeni* agrees in these respects too, but another specimen of *borealis* from the coast of Japan also shows these characters, and I can not distinguish the two species from these points. These characters, however, may subject to age variation and it is hoped that adult specimens of the both species be compared in future.

Also in no. 15 our specimen of *edeni* shows a difference from what are described. The transverse process of the atlas are rather small and the process pointing to the axis is shorter and more obtuse in our specimen too, but the form of transverse processes are not pointed. There is a possibility, however, that this character is also subject to the age variation. Further the form of the transverse processes of the cervical vertebrae is deemed as of doubtful value as a diagnostic character.

The number of vertebrae (no. 18) is very important. All of our specimens of *edeni* ever recorded have 54–55 vertebrae in all, which are two vertebrae more than those recorded from other authors, but still less than that of *borealis*, which is 56–57. As already shown, however, there is a question as to the counting of vertebrae by other authors, because they all include some guesswork. Further there is a possibility that the Pulu Sugi specimen of *edeni* has actually had 54 vertebrae, judged from the measurements of some of them from the caudal region. Careful counting on complete skeleton in future is needed. In the total number of the vertebrae of *borealis* from the coast of Japan we see no difference from those from other regions.

In conclusion above our specimen of *edeni* differs not in important characters which separate *edeni-brydei* from *borealis*. Further I noted some other differences between *edeni* and *borealis* from the coast of of Japan as follows:

1. The mandible is more thicker and more rounded in cross section in *edeni* and flat in *borealis*.
2. Stylohyals are less curved in *edeni* and more curved in *borealis*.

As to the differences between *edeni* and *brydei* Junge (l. c., p. 23) found the following characters in the skeleton, though he does not stress their importance.

1. The rostrum basally is broader in *brydei*, more slender in *edeni* than in *borealis*.
2. The proportional length of the supraoccipital is greater in *brydei*.
3. The proportional breadth of the occiput between the squamosal sutures is greater in *brydei*.
4. The proportional breadth of the frontal wing above the orbits is less in *brydei*.
5. The proportional length of the humerus is greater in *brydei*.

Our specimen of *edeni* resembles more to *brydei* in nos. 2, 3, and 5, and no difference is noted in the breadth of rostrum basally between our specimens of *edeni* and *borealis*. The breadth of the frontal wing above the orbits is very difficult to take the exact measurement. It may differ greatly according to the method of measurement. In conclusion our specimen of *edeni* supports the Junge's opinion that we can consider *edeni* and *brydei* conspecific, which makes the name *Balaenoptera brydei* Olsen a synonym of *Balaenoptera edeni* Anderson.

The Japanese common name for *edeni* has not being authentically given yet, but its dialectal name by whalers is 'Nitari', meaning of which is simply 'resemble' or 'like' and it originated from 'finwhale-like-seiwhale'. I should like to propose herewith the name 'Nitari-kujira' as the Japanese common name of *edeni*, in recognition of unknown whaler who firstly discovered the distinction of this species from the coast of Japan prior to 1950 when I started this study.

EXTERNAL AND OTHER CHARACTERS REVIEWED

External characters of *edeni* from the coast of Japan were studied by Omura, Nishimoto & Fujino (1952) and Omura & Fujino (1954), which are summarized as follows:

1. From a study of the body proportions it is proved that the anterior part of the body is larger and the posterior part is shorter in *edeni* compared with *borealis*; viz. the head is longer and broader, the blowhole and eye situated more posteriorly, the ear more apart from the eye, and the flipper attached more posteriorly; and to compensate for the increase of the head and shoulders the tail region undergoes a proportional decrease in the lengths from notch of flukes to posterior emargination of the dorsal fin and from the same to the anus and umbilicus. Further the dorsal fin is shorter in length and lower in height, hence smaller than *borealis*. On the other hand tail flukes are more wider at their insertion. The most important difference is, however, lying in the ventral grooves. In *borealis* the system of ventral grooves ends before or at an half way of the body and always anterior to the umbilicus, whereas in *edeni* it always extends after the half way of the body and ends posterior to or at the umbilicus.
2. In *edeni* the baleen plates are shorter in length, coarse in texture, greyish black in color and with thick bristles. The proportional lengths of baleen plates are 120–220% of their breadth, while in *borealis* the corresponding figures are 190–330%. The number of baleen plates is somewhat fewer in *edeni*.
3. In *edeni* the palate between the rows of the right and left baleen plates is broader than *borealis*.

The average body length at which sexual maturity is attained is reported by Omura (1950 b) as 40 feet or still smaller by one foot in males and 41 feet in females. Nishiwaki, Hibiya & Kimura (1954) studied the matter more closely and got to a conclusion that the sexual maturity is reached at 40 feet in males and 41 feet in females, being nearly the same to what found by Omura. It is possible from their study, however, that this length is 39 feet in males and 40 feet in females, if the length is understood as an average length which divides the catch figures into two groups of immature and mature whales for the examination of the condition of the stock (see Figs. 7 and 10 of Nishiwaki et al 1954).

Since 1955 catches of *edeni* on the coast of Japan have been recorded as this species, separated from *borealis*. We have now, therefore, full records of the catch of *edeni* for four years, in addition to those from the waters around Bonin Islands. These catch figures are shown

TABLE 9. CATCH OF *edeni* FROM THE COAST OF JAPAN

Year	Bonin Islands1)			Sanriku2)							Oshima2)				West coast of Kyushu2)					Total
	May	Jun.	Total	May	Jun.	Jul.	Aug.	Sept.	Oct.	Total	May	Jun.	Jul.	Total	Jul.	Aug.	Sept.	Oct.	Total	
1950	202	41	243																	243
1951	204	76	280																	280
1952	235	176	411																	411
1953																				
1954																				
1955				5	45	7	8	1	0	66	12	10	1	23	0	2	0	0	2	91
1956				0	12	6	2	3	1	24	0	0	0	0	0	0	2	1	3	27
1957				1	9	10	17	2	0	39	0	0	0	0	1	3	0	0	4	43
1958				2	5	46	127	0	0	180	2	60	12	74	0	5	37	5	47	301
Total	641	293	934	8	71	69	154	6	1	309	14	70	13	97	1	10	39	6	56	462
Monthly %	68.6	31.4	100.0	2.6	23.0	22.3	49.8	2.0	0.3	100.0	14.4	72.2	13.4	100.0	1.8	17.9	69.6	10.7	100.0	
Female %	46.3	36.2	43.1	50.0	62.0	62.3	59.1	83.0	100.0	60.8	64.3	51.4	30.8	50.5	100.0	40.0	48.7	50.0	48.2	

1) not operating since 1953.

2) not specified until 1955.

in Table 9.

As shown in Table 9 comparatively few *edeni* were taken in 1955, 1956 and 1957, but in 1958 a good number was taken. In Fig. 8 are shown the size distributions of *edeni* and *borealis* taken in 1958 on the coast of Japan, separately for both sexes.

It is clear from this figure that there is a marked difference in size distribution between *edeni* and *borealis*, the former being smaller than the latter by 4–5 feet. The biggest *edeni* is 47 feet in length for both sexes, whereas in *borealis* the longest is 51 feet in male and 52 feet in female. The curve for male *borealis* is nearly normal, but in male *edeni* and in females for the both species they draw bi-modal curves.

In these 3 curves we can consider that the first maxima represent the immature group and the second matured. In male *edeni* the first maximum is at 37 feet and the second at some length between 39 and 42 feet. In females the first maximum is at 37 feet and the second 43 feet in *edeni*, while in *borealis* at 41 feet and 46 feet respectively. The differences between the corresponding maxima of the two species are 4 feet and 3 feet.

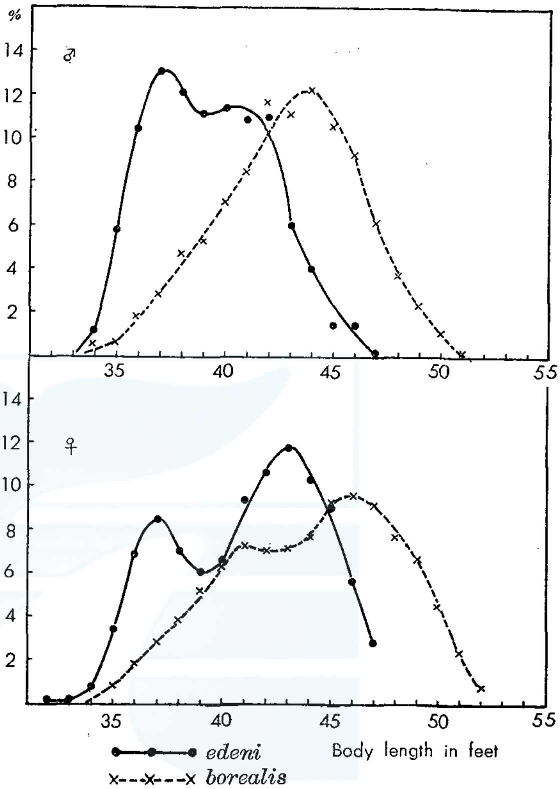

Fig. 8. Size distribution of *edeni* and *borealis* from the coast of Japan 1958. Smoothed.

Chittleborough (1959) reports that three Bryde's whales were taken off Shark Bay, Western Australia in October 1958. And he remarks that both mature individuals (out of three) were far smaller than mature specimens recorded from the Bonin Islands and the South African coast. The one is a female of 38 feet 6 inches in length and contained 11 corpora albicantia in its ovaries, and the another is a male of 36 feet 10 inches long and the weight of its testes are 2.7 and 2.6 Kg. It is true that these specimens are far smaller than our specimens from the coast of Bonin Islands.

As already stated it is probable that the Junge's specimen from Pulu Sugi is also smaller than our specimen from Ayukawa. The Pulu Sugi specimen was a full grown adult and our specimen was an adolescent one, but still the former has a shorter skull length than the other by 32 cm. It is probable, therefore, that the size of Bryde's whale differs according to locality where it was taken, from which it is suggested that there might occur some local races.

The difference in weight of various parts of body between *edeni* and *borealis* was reported briefly by Omura (1950 a) and more in detail by Fujino (1955). From those reports it is concluded that *edeni* is more heavier than *borealis* of similar size in total weight as well as in weights of blubber and bones, but weight of meat is lesser. In bones the weights of skull, jaw bones and back bones are all heavier than those of *borealis*.

The fact that the skull is heavier than that of *borealis* agrees to the larger head portion in *edeni*, found from a study of body proportions. We should consider however in this relation the probability that this is caused by the difference in age. In blue and fin whales the anterior part of the body up to the axilla becomes relatively larger and the posterior part correspondingly smaller with increasing total length, up to a point (Mackintosh & Wheeler, 1929). The specimens of *edeni* we used in these studies were all taken in the waters around Bonin Islands by pelagic whaling, in which 40 feet is the size limit for this species. As stated above the average body length of sexual maturity of *edeni* is around this size limit for both sexes. Accordingly most of them were sexually matured. On the other hand the specimen of *borealis* were taken from landstations on the northeast coast of Honshu (Japan proper), where whalers are allowed to take smaller whales by 5 feet. Further the average body length of sexual maturity of *borealis* is longer than *edeni* by about 4–5 feet. It is true, therefore, that the specimens of *edeni* we used were older in general than those of *borealis*. According to Matthews (1938), however, in sei whale from the southern hemisphere growth is much more evenly distributed throughout the body and that marked differential growth in favour of the anterior region does not occur to anything like the extent that it does in the larger whales. This was foreseen also in *borealis* from the coast of Japan as well as in matured *edeni* by Omura (1952). No sufficient material has been obtained since then, which enables us to examine in detail in this point, and still there remains some doubts which need future study, though in general we can consider that these differences may occur among different species.

DISTRIBUTION

As shown in Table 9 *edeni* has been taken in the waters around Bonin Islands, off Sanriku (northeast coast of Japan proper) and Oshima (on the south coast of Japan proper) and also in the west coast of Kyushu (East China sea). Omura & Fujino (1954) describe that herds of *borealis* come near to Bonin Islands in a period from December to middle of April, while those of *edeni* approach to the islands from the middle or end of April, and most frequently in May. In the waters off Sanriku also *edeni* is taken, but lesser in number than *borealis*. But in the waters off Oshima and in the west coast of Kyushu only *edeni* was recorded in the catch in the four years from 1955 and no *borealis* has been taken. We can consider, therefore, that *borealis* immigrates only to the east side of Japan, and *edeni* occurs not only in these waters but also on her south and west coasts.

Fig. 9 shows the monthly catch of *edeni* in the coast of Japan, based on the percentage figures shown in Table 9. In the Bonin Islands' waters about 70% of the total catch was taken in May and 30% in June. In April the catch is nil, but this is because of the restriction on whaling imposed which prohibited the taking of baleen whales in April. On the coast of Oshima over 70% was taken in June and in the waters off Sanriku about 50% of the catch was attained in August. In the west coast of Kyushu the highest catch was recorded in September. From above we may conclude that *edeni* is also migratory animal like other balaenopterid whales, though its range is restricted within tropical and sub-tropical waters. Omura & Nemoto (1955) report that the northern limit of distribution of *edeni* on the coast of Japan is nearly coincide with the isotherm of 20°C of surface water. Very roughly it can be expressed by a straight line of 40°N Latitude, though the whale may straggle beyond this line on some occasions. On the other hand the distribution of *borealis* extends up to south of Komandorskie Islands (55°N) and Aleutian Chain (Omura, 1955). Nemoto (1959) presents supposed migration routes of *edeni* on the coast of Japan.

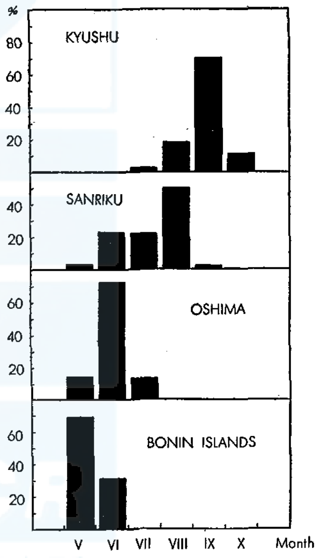

Fig. 9. Monthly catch of *edeni* in the coast of Japan, based on the material shown in Table 9. (Percentage figures)

As seen in Table 9 the sex ratio of the catch of *edeni* in the waters of Bonin Islands is quite different from that of Sanriku. In the former region females consist about 43% of the total catch, while in the latter about 40% of the catch is male. This will suggest that segregation between both sexes takes place in some extent in the migration of *edeni*. In other regions no such segregation between sexes is observed.

As to the world distribution of *edeni* various authors report that this species occurs on the coasts of Durban and Saldanha Bay (Olsen, 1913), Angola, Congo, French Equatorial Africa (Ruud, 1952), Burma (Anderson, 1878), Singapore (Junge, 1950), Borneo (Harrisson and Jamuh, 1958), West coast of Australia (Chittleborough, 1959), Lower California (Kellogg, 1931) and it is said that it has also been recorded from the West Indies and Norway (Mackintosh, 1947; Fraser, 1937), but the identification at the last locality is very doubtful. Records of occurrences in these localities are shown in Fig. 10, in which the isotherms of 20°C in August (Northern hemisphere) and in February (Southern hemisphere) were drawn according to Sverdrup, Johnson and Fleming (1942).

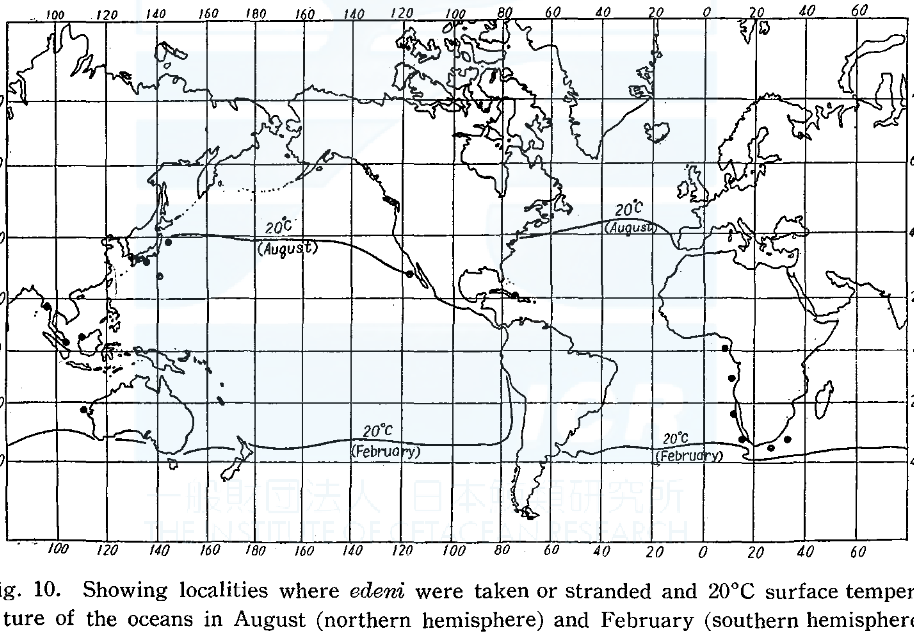

Fig. 10. Showing localities where *edeni* were taken or stranded and 20°C surface temperature of the oceans in August (northern hemisphere) and February (southern hemisphere).

As seen from this Figure all records of occurrence of *edeni*, except from Norway, are within the range between 40°N and 40°S Latitudes, and in the surface water temperature between the isotherms of 20°C in summer in the Northern and Southern hemispheres. We can assume safely, therefore, that the Bryde's whale distribute in tropical and subtropical waters of the world between 40°N and 40°S Latitudes.

SUMMARY

1. From an osteological study it is concluded that the Bryde's whale from the coast of Japan is identical with *Balaenoptera edeni* (=*brydei*) Anderson. The number of vertebrae is 54–55 in our specimens of *edeni*, having 2 more vertebrae than those reported by other authors. But there is a possibility that this is the correct number for this species. The name ' Nitari-kujira ' is proposed as the Japanese common name for *edeni*.

2. The external and other characters are reviewed. There is a marked difference in size distribution of the catch between *edeni* and *borealis*, the former being shorter in body length by 4–5 feet.

3. The sei whale (*borealis*) immigrates only to the eastern side of Japan, but *edeni* occurs not only in these waters but also on her south and west coasts.

4. We can assume that *edeni* distribute in tropical and subtropical waters of the world between 40°N and 40°S Latitudes.

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EXPLANATION OF PLATES

PLATE I

Skull of the Ayukawa specimen of *edeni*, 45 feet female
Fig. 1. Dorsal view.
Fig. 2. Ventral view.

PLATE II

Lateral view of the same skull.
Fig. 1. Left side view.
Fig. 2. Right side view.

PLATE III

Skull and mandibles of the same whale.
Fig. 1. Skull. Posterior view.
Fig. 2. Mandibles. Dorsal view.
Fig. 3. Lateral view of the left mandible.

PLATE IV

Vertebrae of the same whale. Lateral view.
Fig. 1. Cervical and dorsal vertebrae.
Fig. 2. Lumbar vertebrae.
Fig. 3. Caudal vertebrae.

PLATE V

Cervical vertebrae and bones of flipper of the same whale.
Fig. 1. Atlas, axis and 3rd cervical. Anterior view.
Fig. 2. 4th-7th cervicals. Anterior view.
Fig. 3. Humerus, radius, ulna, carpals and phalanges in the right flipper.

PLATE VI

Ribs of the same whale.
Fig. 1. Right ribs.
Fig. 2. 1st, 2nd and 3rd ribs of the left side.

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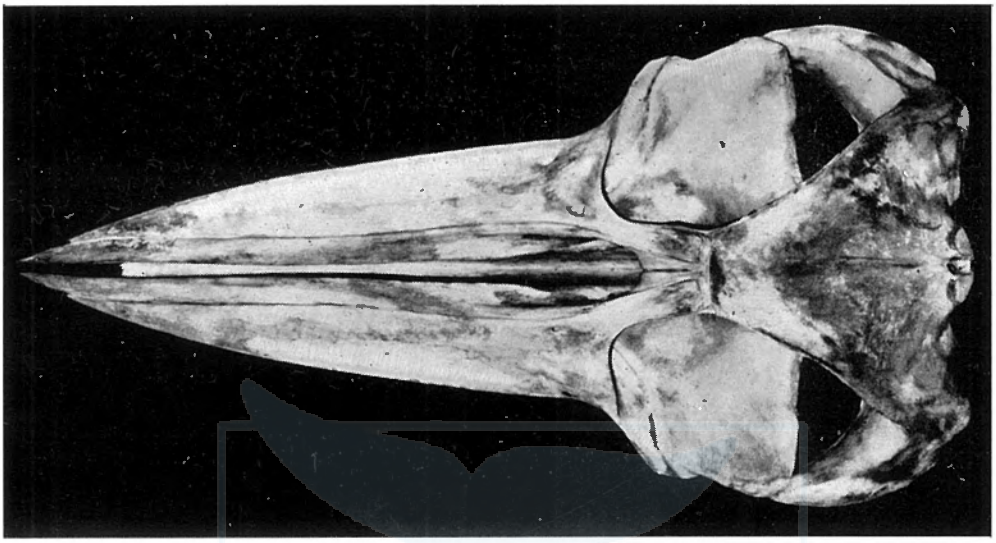

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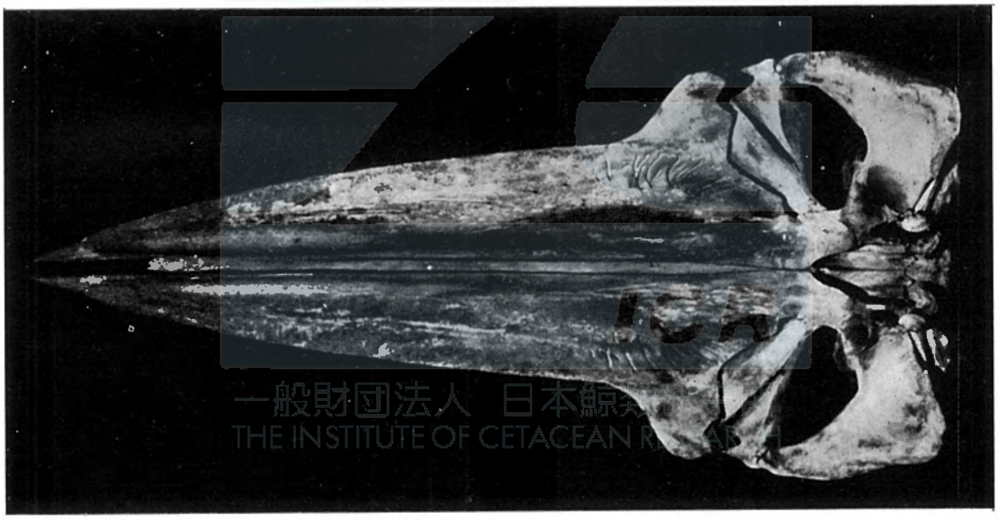

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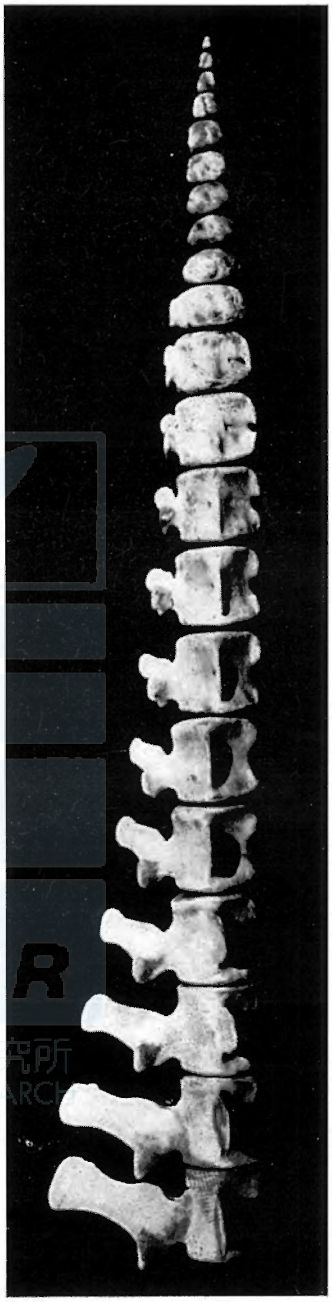

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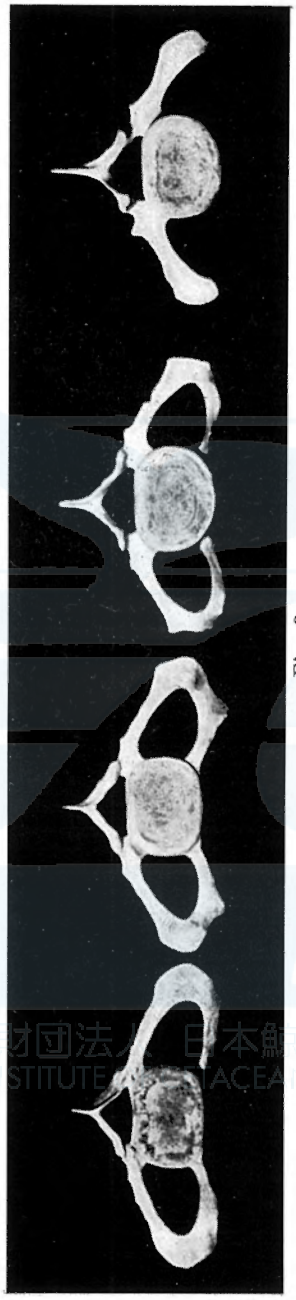

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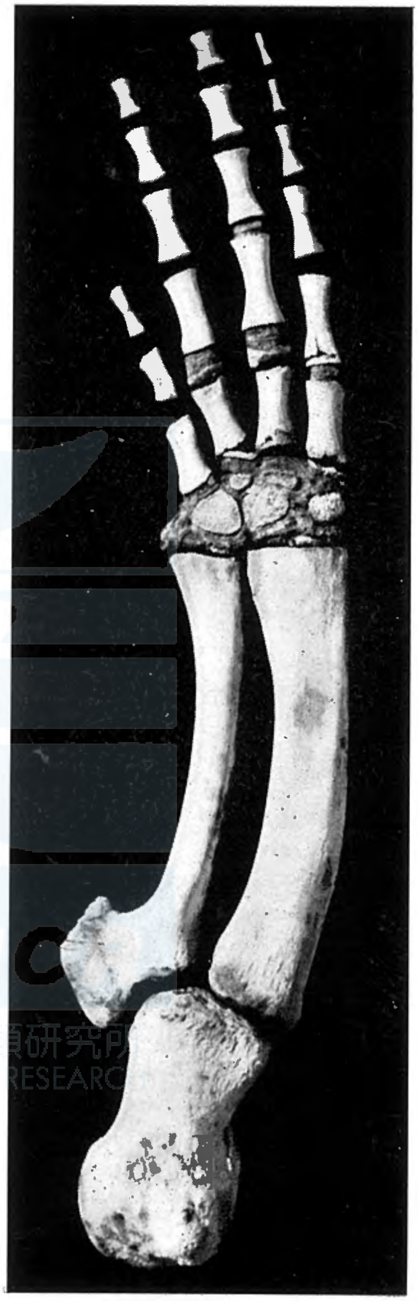

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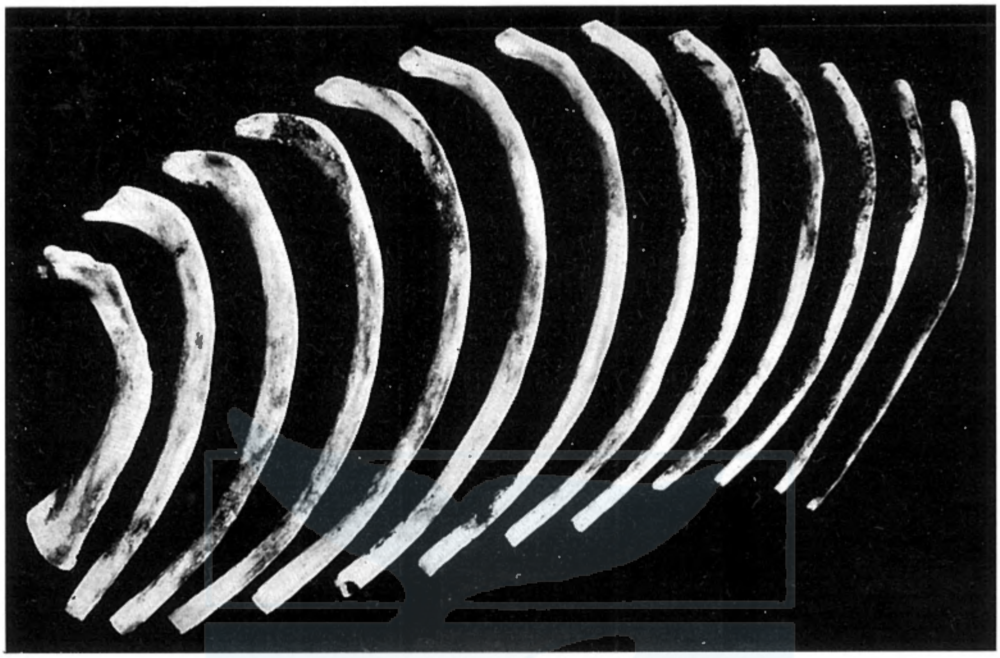

Fig. 1

Fig. 2

MESOPLODON STEJNEGERI FROM THE COAST OF JAPAN

MASAHARU NISHIWAKI AND TOSHIRO KAMIYA*

INTRODUCTION

The name of Ayukawa is well known in Japan, as a place, where many whales of large and small size are landed and treated. On August 26th, 1958, a small strange whale was seen in a whaling company at Ayukawa. Only one pair of square topped teeth was found at the middle of the lower jaw. The teeth were very wide and flat, so the upper jaw was narrowed. This news was brought to Mr. Yoshinori Kimura, who is a strenuous co-operator in our research group on whales, and soon he went to the whaling company for the purpose of observing the object. He arrived at the whaling company, however, after the dissection had been finished. He could neither examine nor take photograph of the whale ; so, he collected as much as possible the remains of the whale body. Fortunately the almost complete skeleton remained. It was buried in the sand of the Kugunari beach.

At that time, the gunner of that catcher boat wished to have the curious teeth for souvenir. Mr. Y. Kimura had a tooth of the same species which had been collected in there bone-yard, so he asked the gunner to exchange it with the newly taken teeth and it was agreed. Considering the situation above mentioned, this is not the first time of the catch of this species. It is presumable that this species might be taken by the whalers for *Ziphius cavirostris*, which is not a rare whale in Japan.

About three months later, the senior author visited the whaling station of Ayukawa with Dr. H. Omura, Messrs. T. Ichihara and K. Nasu of the Whales Research Institute and exhumed the buried remains with Mr. Y. Kimura. The skeleton had been macerated to the perfection and it was transported to the Whales Research Institute of Tokyo for further study. The whale in question was captured on August 25th, by a catcher boat, about 65 miles SE off Ayukawa (37°27′ N. 142°30′ E.). It was a male and measured about 5.3 m, in length, has black coloured skin on the whole body except on the jaws.

Mesoplodon had hitherto been reported from many districts of the

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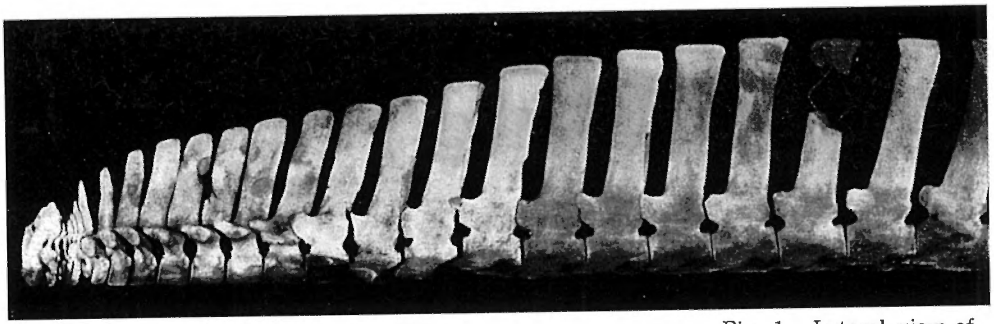


Fig. 1. Lateral view of

world. In Japan, there have been two precedents, one was reported by Professor T. Ogawa (1938) and the other was reported by us last year. Therefore, this specimen seems to be the third one so far as scientifically reported, and represents perhaps the most southern catch of *M. stejnegeri* in the world.

ACKNOWLEDGEMENT

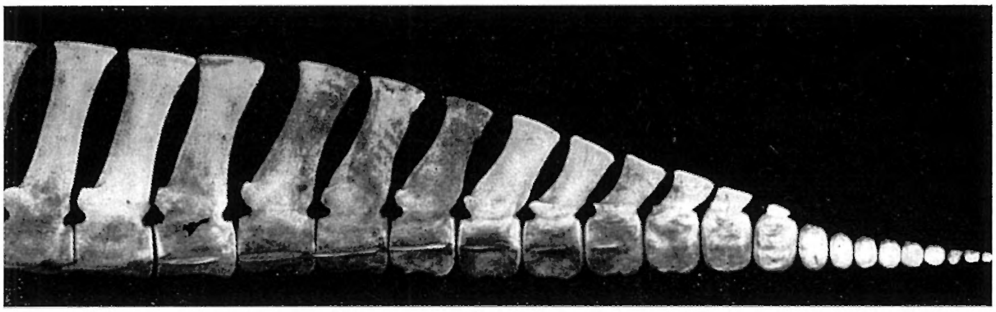
The authors should like to thank to Mr. Yoshinori Kimura and to the personnels of the Whales Museum of Ayukawa for their kindness in allowing us to have the opportunity of studying this precious material. The authors are much indebted also to Professor T. Ogawa, Director of the anatomical department of Tokyo University for his guidance and to Dr. H. Omura and his staff Messrs. T. Ichihara and K. Nasu for their collaboration in examination of the skeleton.

NOTES ON THE EXTERIOR

The external appearance of this specimen is very poorly known, only several sheets of photographs were taken by Mr. Tokinori Watanabe of Nippon Medical College. These photographs are concerned to about the head part only, but are serviced as coloured transparencies. So it is shown as colour print in the Plate I, because seeing is better than reading.

OSTEOLOGY

Skull. Measurements of the present specimen are shown in Table 1 and the two skull measurements from precedent reports are shown in Table 2 for the purpose of comparison. The photographs of the skull in lateral, dorsal and ventral views are shown Plate II. The most noticeable character of the skull is that the peculiar shaped large teeth are seen



vertebral column. C7+D11+L9+Ca19=46

at the mandible behind the symphysis and the lateral basirostral grooves are clearly present.

Vertebrae. The total number of the vertebrae amounts to 46, with the formula of C: 7, D: 11, L: 9, Ca: 19. The first and second cervical vertebrae are ankylosed together at the bodies as well as at the neural arches.

The vertebral bones show some deficit; namely the transverse processes of the 7th cervical vertebra, the 11th dorsal vertebra and the spinous processes of the 5th and 6th lumbar vertebrae are missing. Unfortunately, 17th caudal vertebrae was bitten by a dog. We have to apologize for the latter accident. The first caudal vertebra is determined by existence of the first chevron. The first chevron was found only in the left joint region, because the other parts of it was cutted off at the dissection. All the chevrons are 9 in number and were collected except the second chevron.

In all the vertebrae the epiphyses are fused to the diaphyses, which tells evidently the physical maturity of the present specimen.

Ribs. The ribs were collected in perfection. They are shown in Fig. 3 and Table 6. Two headed ribs are seven, the eighth and nineth are lengthened but the most posterior two ribs are very shortened.

Pectoral limb. The scapulae are nearly symmetrically fan-shaped as in other species of *Mesoplodon*. The humerus, radius and ulna are not conspicuously different from the correspondent bones in other species of *Mesoplodon* and the proximal and distal epiphyses of those bones are all ankylosed. The phalangeal formula including the metacarpals is as follows; I: 1, II: 5, III: 5, IV: 4, V: 3. This formula is equal on both sides. The authors suggested at that occasion that it is necessary to take the Röntogen photographs for studying the bones of the pectoral limbs in fresh condition, but in reality Röntogen photograph of the present specimen was not taken.

Measurements of the bones of the pectoral limb are given in Tables

TABLE 1. SKULL DIMENSIONS OF THE AYUKAWA SPECIMEN

		mm	percentage to the length	percentage to the breadth
1.	Total (condylo-basal) length	800	100.0	201.5
2.	Length of rostrum (median)	491	61.4	123.7
3.	Breadth of rostrum at base	158	19.8	39.8
4.	Breadth of rostrum at middle	61	7.6	15.4
5.	Breadth of rostrum at the position just above the teeth	41	5.1	10.3
6.	Breadth of rostrum at the highest point of anterior palatine suture	82	10.3	20.7
7.	Breadth of rostrum between the antorbital notches	200	25.0	50.4
8.	Depth of rostrum at middle	101	12.6	25.4
9.	Depth of rostrum at the position just above the teeth	88	11.0	22.2
10.	Depth of rostrum at the highest point of anterior palatine suture	89	11.1	22.4
11.	Length of premaxilla*	656	82.0	165.2
12.	Breadth of premaxillae at middle of rostrum	47	5.9	11.8
13.	Breadth of premaxillae at expanded proximal ends	178	22.3	44.8
14.	Breadth of premaxillae in front of anterior nares	129	16.1	32.5
15.	Breadth of premaxillae opposite premaxillary foramina	89	11.1	22.4
16.	Breadth of premaxillae opposite maxillary foramina	78	9.8	19.6
17.	Greatest breadth of premaxillae opposite anterior nares	178	22.3	44.8
18.	Least breadth of premaxillae opposite anterior nares	129	16.1	32.5
19.	Least distance between the postero-dorsal margins of the maxillary foramina	107	13.4	27.0
20.	Least distance between the postero-dorsal margins of the premaxillary foramina	46	5.8	11.6
21.	Least distance between the maxillary foramina and premaxillary foramina	L: 23 R: 29	2.9 3.6	5.8 7.3
22.	Distance from posterior border of maxillary foramina to anterior extremity of maxillary protuberance*	90	11.3	22.3
23.	Length of nasal suture line	52	6.5	13.1
24.	Greatest breadth of nasals	82	10.3	20.7
25.	Greatest breadth of superior nares	65	8.1	16.4
26.	Diameter of orifice of posterior nares immdeiately behind pterygoid processes	121	15.1	30.5
27.	Distance from tip of rostrum to bottom of maxillary notches	L: 499 R: 496	62.4 62.0	125.7 124.9
28.	——— anterior end of vomer	18	2.3	4.5
29.	——— anterior margin of superior nares	581	72.6	146.3
30.	——— nasal vertex	603	75.4	151.9
31.	——— medial suture line of posterior end of pterygoides	603	75.4	151.9
32.	——— line joining antero-lateral processes of maxillaries	480	60.0	120.9

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

			mm	percentage to the length	percentage to the breadth
33.	——— occipito-frontal vertex		666	83.3	167.8
34.	——— posterior median end of maxillae on palate		466	58.3	117.4
35.	——— bottom of tubal notch (median)		473	59.1	119.1
36.	——— most anterior point of the palatines		389	48.6	98.0
37.	Length of vomer visible on palate		225	28.1	56.7
38.	Breadth across middle of orbits		371	46.4	93.5
39.	Diameter of orbit (antero-posterior)	L:	98	12.3	24.7
		R:	101	12.6	25.4
40.	Greatest breadth across supra-orbital plates of maxillae		359	44.9	90.4
41.	Greatest breadth across post-orbital processes		397	49.6	100.0
42.	Breadth across zygomatic processes		379	47.4	95.5
43.	Breadth across posterior margins of temporal fossae		203	25.4	51.1
44.	Greatest breadth of cranium at parietal region in temporal fosseae		218	27.3	54.9
45.	Length of temporal fossae	L:	105	13.1	26.4
		R:	107	13.4	27.0
46.	Depth of temporal fossae*		75	9.4	18.9
47.	Length of tympanic bone	L:	45	5.6	11.3
		R:	46	5.8	11.6
48.	Greatest breadth of tympanic bone	L:	33(+)	4.1	8.3
		R:	35	4.4	8.8
49.	Breadth of occipital condyles		121	15.1	30.5
50.	Breadth of foramen magnum		44	5.5	11.1
51.	Length of occipital condyle*		78	9.8	19.6
52.	Height, vertex to inferior border of pterygoids		342	42.8	86.1
53.	Length of mandible (median)		683	85.4	172.0
54.	Length of mandibular ramus	L:	690	86.3	173.8
		R:	699	87.4	176.1
55.	Distance from anterior end of mandible to coronoid process	L:	685	85.6	172.5
		R:	687	85.9	173.0
56.	Length of symphysis		176	22.0	44.3
57.	Distance from anterior end of mandible to anterior end of alveolus	L:	131	16.4	33.0
		R:	129	16.1	32.5
58.	Distance from anterior end of mandible to posterior end of alveolus	L:	226	28.3	56.9
		R:	230	28.8	57.9
59.	Depth of mandible at posterior margin of tooth*		80	10.0	20.2
60.	Depth between angle and coronoid process	L:	130(+)	16.3	32.7
		R:	132	16.5	33.2
61.	Minimum depth of mandible between tooth and coronoid process	L:	69	8.6	17.4
		R:	66	8.3	16.6
62.	Breadth across mandibular condyles*		363	45.4	91.4
63.	Greatest height of mandible at coronoid process*		131	16.4	33.0
64.	Length of tooth	L:	163	20.4	41.1
		R:	166	20.8	41.8
65.	Breadth of tooth (antero-posterior at crown)	L:	91	11.4	22.9
		R:	89	11.1	22.4
66.	Breadth of tooth (transverse)*		14	1.8	3.5

* equal on both sides

Fig. 2. Dorsal view of pectral limb

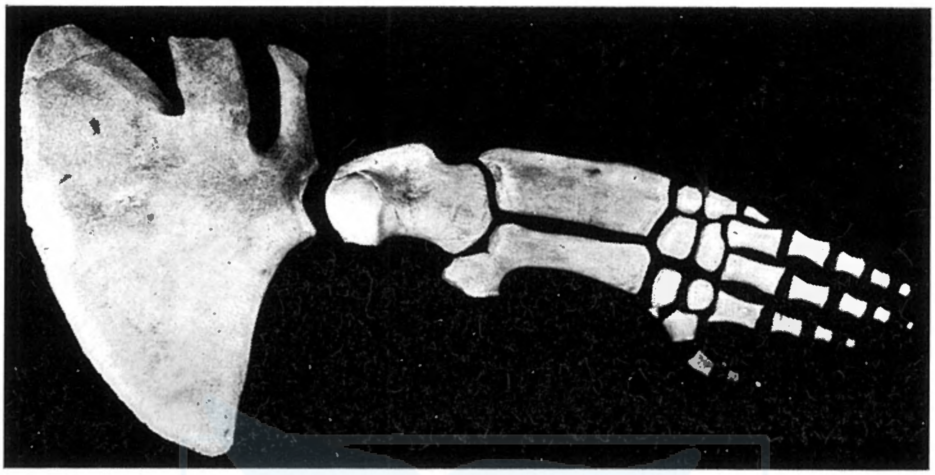
TABLE 2. SKULL PROPORTIONS IN PER CENT OF TOTAL SKULL LENGTH

Measurements	U.S.N.M.[1] No. 21112 (Young) Sex ?		U.S.N.M.[1] No. 143132 (Adult) Sex ?		Ayukawa specimen (Adult) ♂
	mm.	per cent	mm.	per cent	per cent
Total length	633[2]	100.0	715	100.0	100.0
Length of rostrum	325[2]	51.3	413	57.7	61.4
Breadth between centers of orbits	279	44.1	309	43.2	46.4
Breadth between zygomatic processes	278	43.9	310	43.3	47.4
Breadth between temporal fossae	212	33.5	228	31.9	25.4
Breadth of rostrum at base (between maxillary notches)	158[3]	25.0	172	24.1	19.8
Breadth of rostrum at middle	44	7.0	40	6.0	7.6
Depth of rostrum at middle	42	6.6	52	7.3	12.6
Greatest breadth of anterio nares	54	8.5	56	7.8	8.1
Greatest breadth of premaxillae proximally	118	18.6	130	18.2	22.3
Greatest breadth of premaxillae in front of nares	109	17.2	108	15.1	16.1
Length of temporal fossa	86	13.6	92	12.9	13.1
Depth of temporal fossa	46	7.3	63	8.8	9.4
Antero-posterior length of orbit	82	13.0	96	13.4	12.6
Breadth of foramen magnum	39	6.2	38	5.3	5.5
Length of manible	—	—	610	85.3	85.4
Length of symphysis	—	—	138	19.3	22.0
Distance from anterior end of mandible to alveolus	—	—	166	23.3	22.7

1) Cited from True, F. W. (1910): Trans. Zool. Sco. London, X, part 11.

2) Tip of rostrum lacking.

3) The skull is much worn around the left notch and the measurements is only approximate.



with scapula attached.

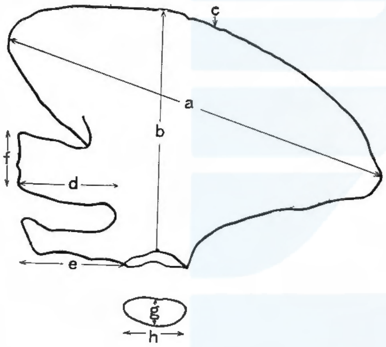


TABLE 3. DIMENSIONS OF SCAPULAE (mm)

		Left	Right
a.	Length along vertebral border	474	470
b.	Length of glenoid cavity	41	43
c.	Breadth of glenoid cavity	422	412
d.	Length of acromion, along medial border	125	105
e.	Length of coracoid, from supraglenoid edge to tip	96	95
f.	Greatest breadth of acromion	50	57
g.	Breadth of articular surface	49	49
h.	Height of articular surface	66	67

TABLE 4. DIMENSIONS OF HUMERUS, RADIUS AND ULNA (mm)

	Measurements	Left	Right
Humerus	Greatest length	146	146
	Breadth at proximal end	65	65
	Breadth at distal end	78	79
Radius	Length at middle	173	173
	Breadth at proximal end	47	48
	Breadth at distal end	57	60
Ulna	Length at middle	147	144
	Breadth at proximal end	43	43
	Breadth at distal end	44	44

TABLE 5. DIMENSIONS OF THE VERTEBRAE (mm)

Number of vertebrae		Length of body at center	Height of body at front end	Breadth of body at front end	Total height from anterior bottom	Breadth of transverse processes	Greatest height of neural canal	Greatest breadth of neural canal
C	1st	24	44	119	141	209	41	54
	2nd					186	41	50
	3rd	6	58	74	115	157	39	44
	4th	5	56	73	108	126	42	41
	5th	5	54	74	117	129	48	42
	6th	8	56	72	143	137	46	45
	7th	15	55	75	183	154 1)	48	45
D	1st	22	57	69	235	164	52	50
	2nd	35	54	68	274	167	55	48
	3rd	48	54	65	288	171	60	51
	4th	58	49	65	299	168	60	48
	5th	66	52	67	310	168	61	46
	6th	72	54	70	327	163	62	40
	7th	79	56	75	341	156	56	38
	8th	88	58	81	352	195	52	31
	9th	93	60	84	368	247	47	29
	10th	100	63	85	387	290	48	29
	11th	107	68	86	405	300 1)	40	28
L	1st	111	72	88	421	317	40	28
	2nd	114	75	89	434	313	39	27
	3rd	117	77	91	441	315	39	28
	4th	123	80	93	458	314	37	28
	5th	137	89	97	— 1)	310	32	18
	6th	130	85	95	464 1)	315	33	20
	7th	143	93	98	461	309	24	18
	8th	148	96	99	456	304	16	14
	9th	149	96	100	439	301	10	11
Ca	1st	145	101	104	428	273	13	13
	2nd	140	101	107	399	251	10	10
	3rd	132	100	110	373	238	9	11
	4th	124	100	112	341	224	3	8
	5th	121	102	113	310	197	—	7
	6th	116	103	113	274	155	—	7
	7th	111	103	110	227	123	—	6
	8th	104	102	100	192	106	—	6
	9th	92	100	92	158	94	—	3
	10th	77	96	89	123	91	—	2
	11th	52	84	80	85	85	—	—
	12th	43	63	69	68	76	—	—
	13th	42	56	63	61	69	—	—
	14th	40	46	59	53	65	—	—
	15th	38	42	50	46	59	—	—
	16th	34	37	44	40	52	—	—
	17th	—	—	—	—	—	—	—
	18th	27	25	30	26	32	—	—
	19th	20	16	25	20	27	—	—

1) It has some deficit.

3 and 4 and the photographs are shown in Fig. 2.

Sternum and Hyoid bone. The sternum consists of four segments. But the third and fourth one was ankylosed conjointly. Dimension of several parts are shown in Table 7. Photograph and some dimensions of the hyoid bone are shown in Fig. 5 and Table 8. The basihyal and thyrohyals are ankylosed loosely.

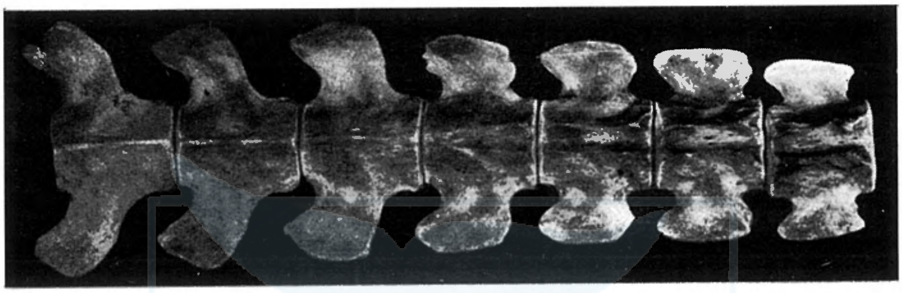


Fig. 3. Ventral view of vertebrae, showing the first caudal region.

Fig. 4. Lateral view of chevron bones, left is anterior.

TABLE 6. DIMENSIONS OF CHEVRON BONES (mm)

Number of chevron	Greatest length (antero-posterior)	Greatest breadth (transverse)	Greatest height (supero-inferior)
1[1)]	—	—	—
2[2)]	—	—	—
3	75	64	114
4	92	62	169
5	101	63	119
6	89	64	97
7	87	61	72
8	78	54	53
9	58	46	35

1) Not given, for it is broken.
2) Missed.

TABLE 7. DIMENSIONS OF THE RIBS (mm)

Rib No.	Straight length		Curvilinear length[1]		Breadth at middle		Depth at middle	
	Left	Right	Left	Right	Left	Right	Left	Right
1st	350	327	295	320	57	59	22	23
2nd	557	552	585	587	46	48	17	19
3rd	620	633	715	715	34	34	20	20
4th	659	670	780	785	32	32	18	17
5th	665	667	720	810	32	31	17	17
6th	578	661	800	810	29	29	16	16
7th	579	698	790	790	30	28	19	21
8th	605	646	660	690	29	27	20	22
9th	562	610	600	625	30	26	19	22
10th	195	228	195	240	36	31	10	12
11th	187	112	190	120	19	17	7	5

1) Along the vertebral border
2) It has some deficit

Fig. 5. Medial view of left and right sides vertebral ribs.

TABLE 8. DIMENSIONS OF STERNUM (mm)

	1st element	2nd element	3rd element	4th element	5th element
Greatest length	252	142	215		
Greatest breadth of anterior part	175	125	123	96	69
Greatest breadth of posterior part	140	138	115		
Greatest thickness at middle	25	21	16	14	10

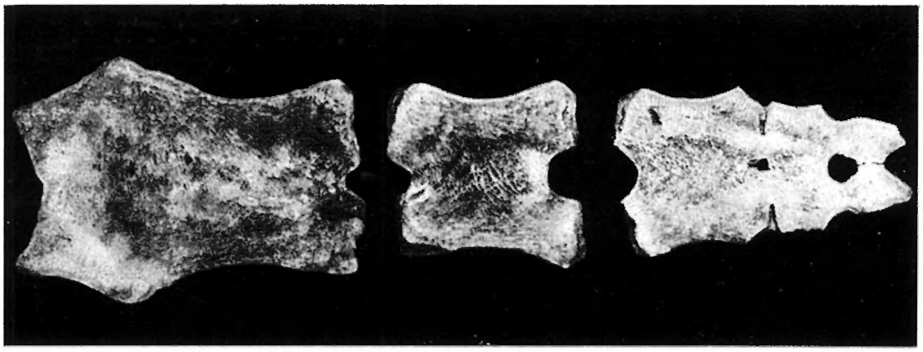
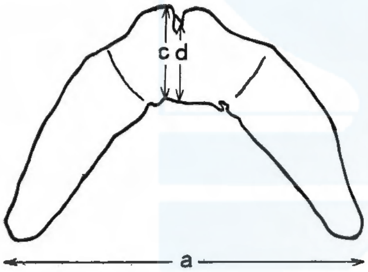


Fig. 6. Sternum. Third and fourth segments was ankylosed.

TABLE 9. DIMENSIONS OF BASIHYAL, THYROHYALS AND STYLOHYALS (mm)



a–198
b–135
c– 59
d– 50

Stylohyals

	Greatest length	Greatest breadth	Greatest depth
L:	167	41	28
R:	169	41	26

Fig. 7. Hyoid bones. Basihyal and thyrohyals were ankylosed.

Bone of pelvic region. It was collected on one side only, and it is difficult to decide which side it belonged to and which end of the bone is the anterior. Its photograph is shown in Fig. 8.

Addendum. The salivary gland of this whale is being studied at Department of Pathology, Nippon Medical College.

Fig. 8. Bone of pelvic region.

Fig. 9. Lateral view of skull, showing the lateral basirostral groove clearly visible.

DISCUSSION

As shown in the precedent report of the authors (1958), four distinctive characters are especially to consider in classifying the species of *Mesoplodon*. The first is the relative position of the premaxillary and maxillary foramina. In the present specimen the premaxillary foramina are situated in the same level or slightly caudal to the maxillary foramina. The second is the presence or absence of the lateral basirostral groove, and this groove is clearly found in the present specimen (Fig. 9). The third is the position, where the teeth are situated in the mandible. In the present specimen the teeth are situated at the caudal end of the symphysis. The fourth character is the shape of the teeth, especially the ratio between the transverse thickness and the antero-posterior breadth at the place of insertion into the mandibular alveole. This ratio gives an important key for classifying the species more in details. The teeth are large flat and square topped in the present specimen. The ratio of thickness to antero-posterior breadth of the teeth is 1:6.5 on the left tooth, 1:6.4 on the right tooth. This ratio is higher than in any other *Mesoplodon* species. From the above mentioned results applying the keys upon the species of *Mesoplodon* reported by Raven (1937) and by the authors (1958), the present specimen might be classified as *Mesoplodon stejnegeri*.

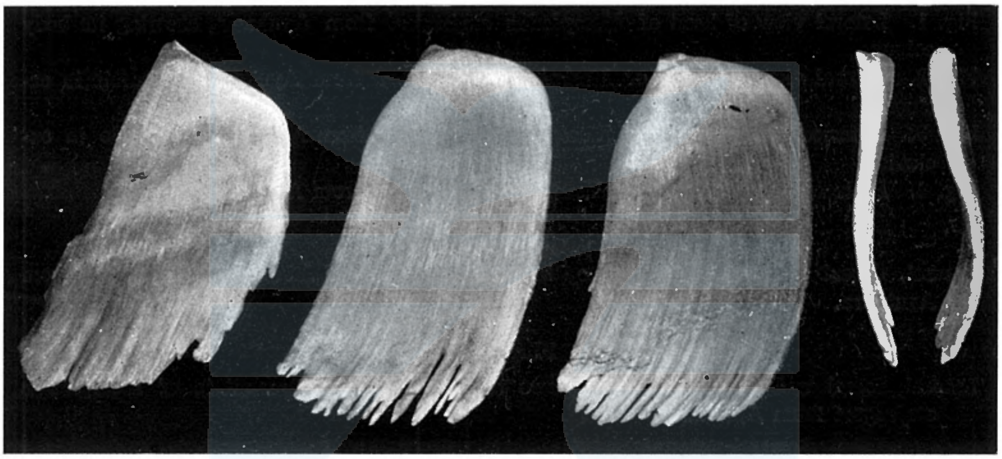


Fig. 10. Shape of the teeth. Left; *M. stejnegeri* from Aleutian waters. Middle two; outer surface of left tooth and inner surface of right tooth of *M. stejnegeri* from Ayukawa. Right two; frontal view of the teeth of *M. stejnegeri* from Ayukawa.

SUMMARY

An adult male beaked whale that belongs to the genus *Mesoplodon* was captured on August 25th, 1958, off Ayukawa in Japan.

The external characters of the whale body could not be observed, but the skeleton was almost perfectly collected and is preserved in the Whales Museum of Ayukawa. From the osteological examination the present specimen may sufficiently be classified as *Mesoplodon stejnegeri*.

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EXPLANATION OF THE PLATES

PLATE I

Fig. 1. Lateral view of head of *Mesoplodon stejnegeri* from Ayukawa, showing its body colour.

Fig. 2. Lateral view of skull of *Mesoplodon stejnegeri* from Ayukawa, mandible in occlusion.

Fig. 3. Anterior view of skull of *Mesoplodon stejnegeri* from Ayukawa, mandible in occlusion.

Fig. 4. Posterior view of skull of *Mesoplodon stejnegeri* from Ayukawa.

PLATE II

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

PLATE III

Lateral, dorsal and reversed lateral views (top to bottom) of mandible of *Mesoplodon stejnegeri* from Ayukawa.

PLATE IV

Fig. 1 and 2. Lateral and caudal views of cervical vertebrae of *Mesoplodon stejnegeri* from Ayukawa.

Fig. 3 and 4. Cranial and caudal views of each cervical vertebrae of *Mesoplodon stejnegeri* from Ayukawa; from left to right, 1～2, 3, 4, 5, 6, 7th of cervicals.

Fig. 5. Lateral view of skeleton of *Mesoplodon stejnegeri* from Ayukawa, which was set uped by Mr. Y. Kimura.

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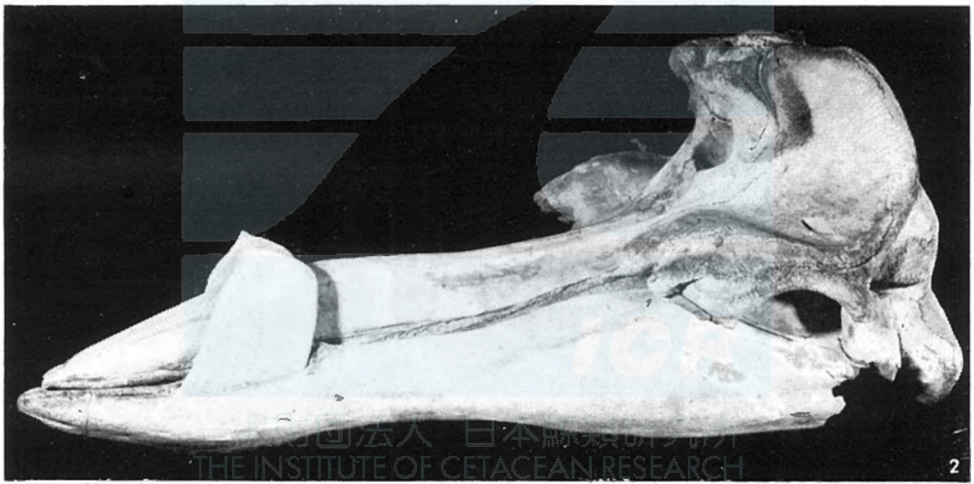

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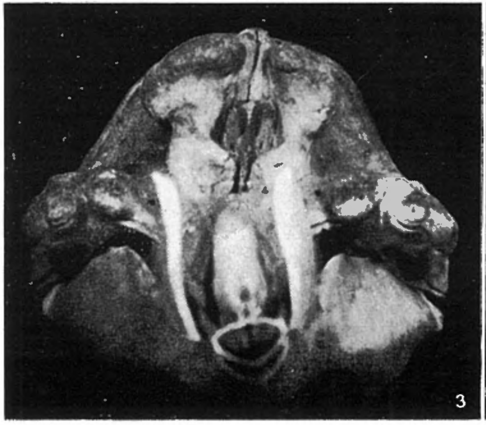

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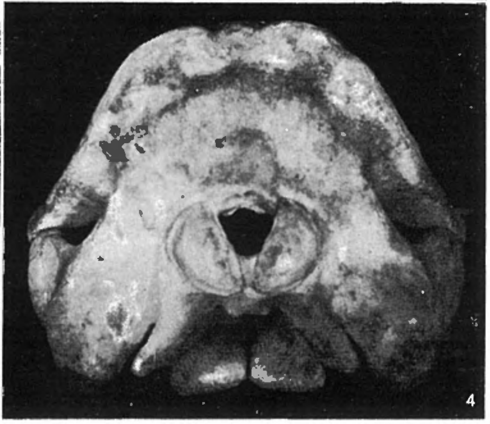

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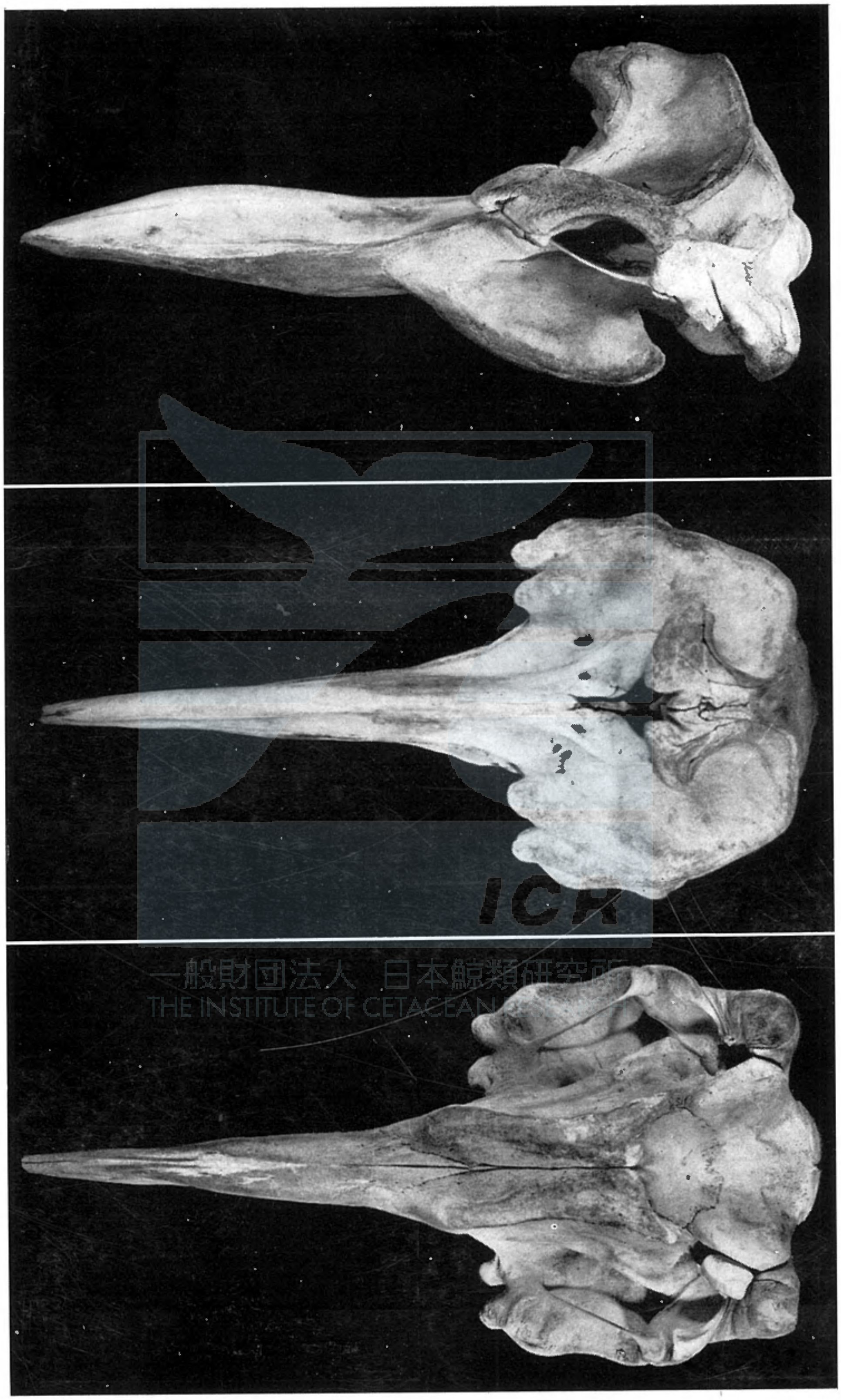

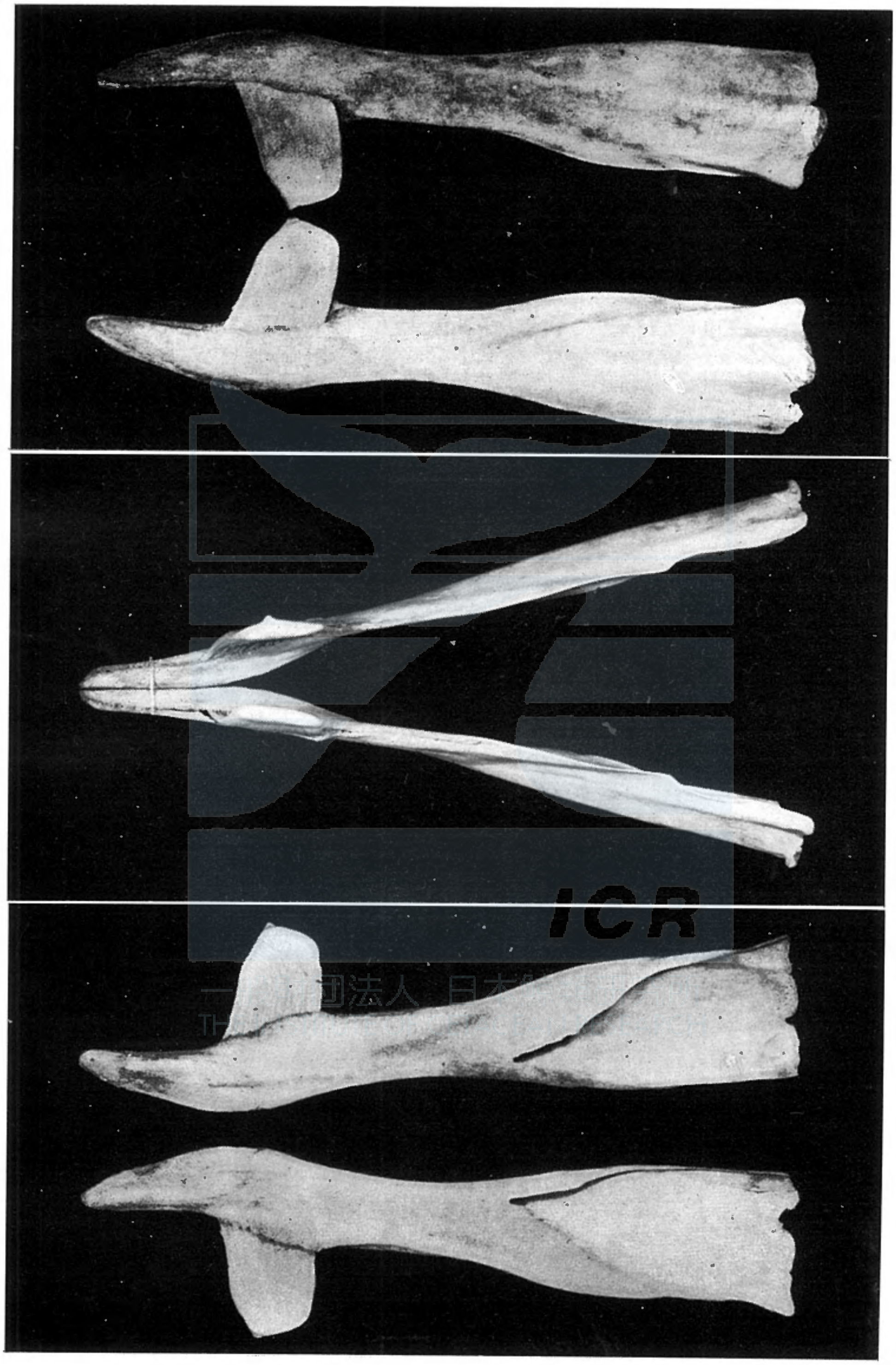

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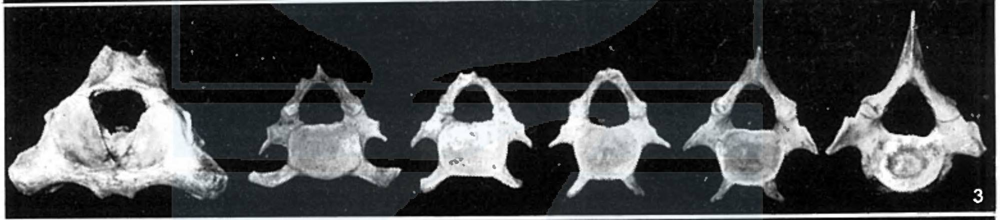

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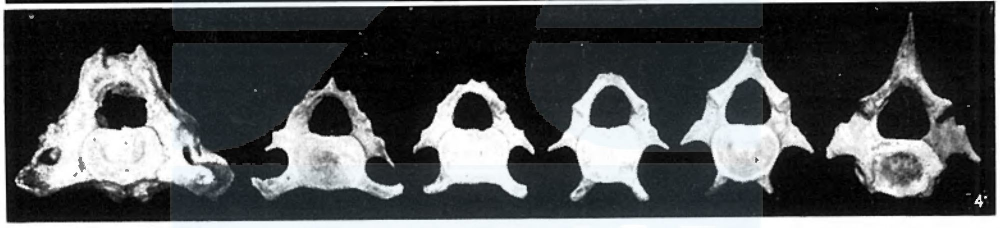

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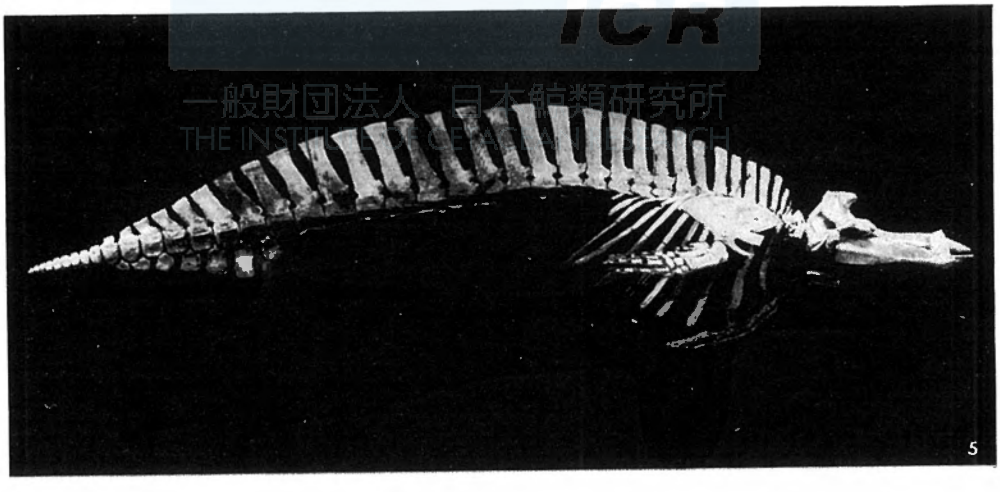


5

HUMPBACK WHALES IN RYUKYUAN WATERS

MASAHARU NISHIWAKI

INTRODUCTION

The statistical table for the past 50 years shows that the number of humpback whales caught in northern Pacific is much less than in the southern hemisphere.

The table attached in Appendix I, showing the combined catch of humpback whale caught in Alaska, British Columbia, Washington state, California State, Lower California and the coastal waters off Japan since 1910, is based on data already published so far.

According to the table the largest number of catch was made in 1927 amounting to 1144 whales which includes 554, 472 and 95 whales caught in Alaska, Lower California and the adjacent waters of Japan, respectively.

After 1920-30 which was the most prosperous era of whaling, the number of catch has been gradually decreased year after year. The average number of whales killed annually in the North Pacific Ocean is 424, 111 and 73 in 1910-30, 1931-45 and 1946-56 respectively.

The detail statistic of annual catch in the coastal waters of Japan, that is the west side of the North Pacific, is also given in the table attached in Appendix II. During the year of 1910-30, most of the catch was made in both east and west side of Honshu including the waters around Kurile Islands Chain. The whaling operation around Formosa has started since 1920, while that around Bonin Islands started since 1924. Both of Formosa and Bonin whaling ground were closed because of the significant decrease of catch since the start of the operation.

Even the biggest catch in Bonin waters does not exceed 86 whales in a year.

It is easily understood that the decrease of catch, mentioned above, was mainly caused by over-exploitation. Since 1940, however, whaling of this species has hardly been carried out in the North Pacific except in British Columbia, so that the abundance of humpback whale is believed to have been recovered gradually thereafter. In recent years, the average catch in a year was about 300 including the catch off San Francisco which has been established since 1956.

In Ryukyuan waters, fishermen often reported the occurrence of humpback whales for these several years. Nago Fisheries Association started to kill them since 1954, using the 25 mm caliber of valley gun.

They caught 13 whales in 1956 and 23 in 1957. At that time, Japanese whaling industry begun to have interest in Ryukyuan whaling.

In the season of 1958, two new whaling companies are constructed in co-operation with Ryukyuan and Japanese companies. These companies expected to kill 50 humpback whales and 30 sperm whales. Actually, however, no sperm whales was caught. On the other hand, they caught 290 humpback whales throughout the season.

United States Civil Administration of Ryukyu Islands (USCAR) has great concern to the number of catch and stated that this amount of catch of humpback whales would not be favorable. In 1959, it presented a quota of 90 humpback whales for three companies. At that time, the author was requested by Japanese Whaling Industry to take care of Ryukyuan whaling. This is the motive of the examination trip to Ryukyuan Islands.

METHOD OF INVESTIGATION

Methods applied to this investigation are quite similar to those used for whale examination in Antarctic, North Pacific and the coastal waters of Japan. Items to be examined are as follows: sex, body length, the time of killed, the time of commence of treating, location of catch, body color, parasites both external and internal, thickness of blubber, thickness and color of mammary gland, contents of the first stomach, weight of testis, careful examination of ovaries, fetuses if any, and osscification of vartebrae. Special attention was paid to ear plug this time which is a important and effective clue to age determination. Furthermore, blood samples were collected to study the frequency of blood type which may be indicative of intermixture with other group of whales. The details of methods applied are not given in this report, because most of those methods were already published.

OUTLINE OF THE WHALING SEASON IN 1959

The author was invited by the Government of the Ryukyuan Islands to make estimation of the total number of whales migrating to the Ryukyuan waters and determination of optimum number of catch for this season. It was also aimed to develop methods in whale research to train investigators of the Government and finally to make suggestion for the improvement of the Ryukyuan whaling industry.

Before the author arrived at the Ryukyuan Islands, the quota of 90 humpback whales had been extended by USCAR to 190 with a condition to help the research activity by reporting the occurrence of other species of whales. The author recommended to USCAR to make further extention of the quota, because the catch amounting to 190 whales is not sufficient to make reliable study on the migrating whales for a shorter time.

Needless to say, however, the catch should not exceed the optimum level. From the view point of research, a larger sample size is better, but the quota of catch could not be increased limitlessly. So the author tried to estimate the total number of migrating whales basing on the number of observed whales in the last season. According to the data, made by one company, 350 whales were observed during the season in which 120 were actually killed. Since the author considers these figures are reasonable but not exaggerated, this numerical relationship is applied to estimate the migrating whales from the number of catch. Basing on the catch records by three companies, the estimated number is calculated as 850 (350+350+150).

But some individuals would be observed and counted more than once. To eliminate this source of over-estimation, 150 is substracted from the total. Outside of the whaling ground, that is Miyako, Yaeyama and Amami areas, many whales were also observed by other fishing boats than whaling one, therefore, 100 individuals are added to the estimated number within the whaling area. Hence, finally estimated number amounts to 800 whales.

According to the general concept that the number of migrating whales is about 2 or 3 times of the observed number, 1600–2400 individuals may be migrate around Ryukyuan waters.

It is also a general belief that one-tenth of the migrating whales may be caught without harmful influence to a abundance. Basing on these estimation, the author suggested to USCAR 160 as a standard number of an annual catch. The suggested number is unexpectedly quite equal to the standard number made by USCAR.

It is considered that the kill up to 216 whales, that is ninety percent of the maximum number available as mentioned above, may be permissible to be caught this year. Then the author requested 220 whales as a quota this year which includes 60 whales taken for the additional purposes. To this request, USCAR accepted the quota of 220 whales. In such a course of consultation, the quota of this season was settled but the problem of the period of whaling operation was still in question.

Shooting mother whale accompanied with calf is prohibited by a stipulation of the Whaling Convention and the custom of gunners. According to the growth of fetuses the hight of the parturition in the North pacific is probably in November. Ryukyuan waters are certainly considered as a mating and nursing area but may neither parturition nor feeding area. This is based on the evidence that whales in mating were observed at several places in this area for the whaling season, and Ryukyuan whaling had no fetus in the previous seasons. Anyhow, it is desirable to open the whaling season in the time when most of pregnant whales have given birth to culves. One of other reason is that the author had received some opinions on protection of the whales from the American scientists. If the height of the parturition period would be sometime in November, it is quite effective to open the whaling season in a little more later date for protection of calves.

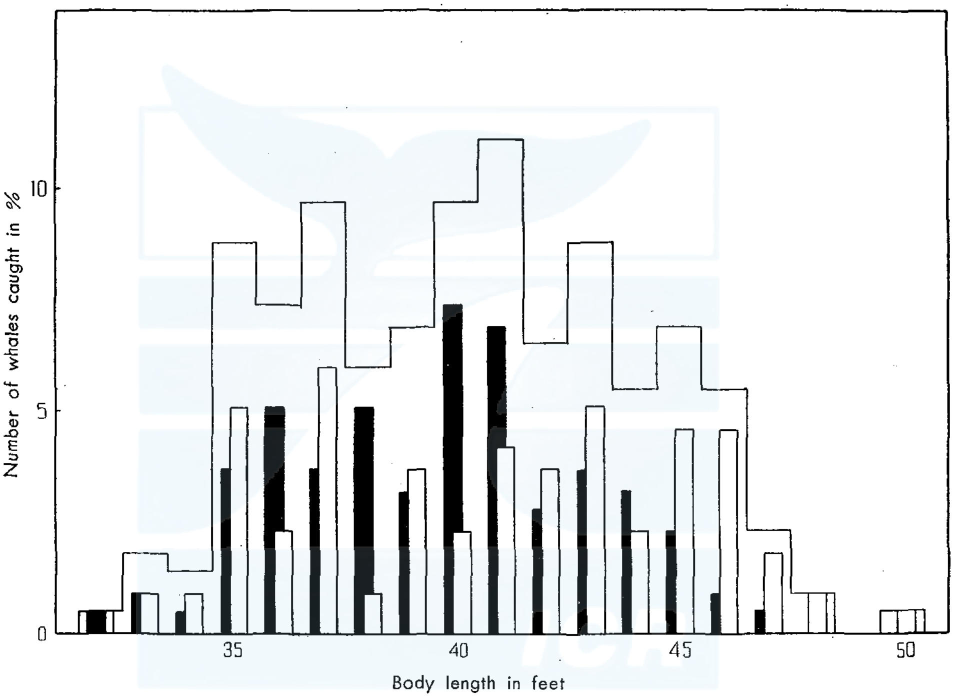


Fig. 1. Size distribution of Ryukyuan humpback whales in this season.

For this reason, the author suggested the Ryukyuan Government to open the whaling season in the middle of January instead of 1st December. So the Government decided 7th January as the date of removal of a ban.

Now, on January 7, catcher boats began to operate for whaling, and some larger boats brought several whales to the whaling stations. The author was surprised in a glance by more fresh, fat and fine whales than those taken in the adjacent waters of Japan. It is general concept that the whales migrating to the warmer waters are more or less thinner than those in colder waters, because of exhaustion of energy for their breeding. Because of smaller boats, Nago Fisheries Association could not catch any whales.

In the middle of January, when air and water temperature went down, the whaling season came to the height. However, the water temperature in February when the temperature were used to be coldest was higher by 2°C-3°C this year than the normal year.

According to the weather reports in Far East Asia, the Chinese Continent had drought in the last summer. By the drought, the water volume of the river flowing to the East China Sea (Yangtze River, Yellow River and etc.) might be reduced. The decrease of colder water from rivers might probably cause a higher temperature around Ryukyuan Islands. A higher temperature around there was also noticed by the fishermen for tuna, bonito and mackerels.

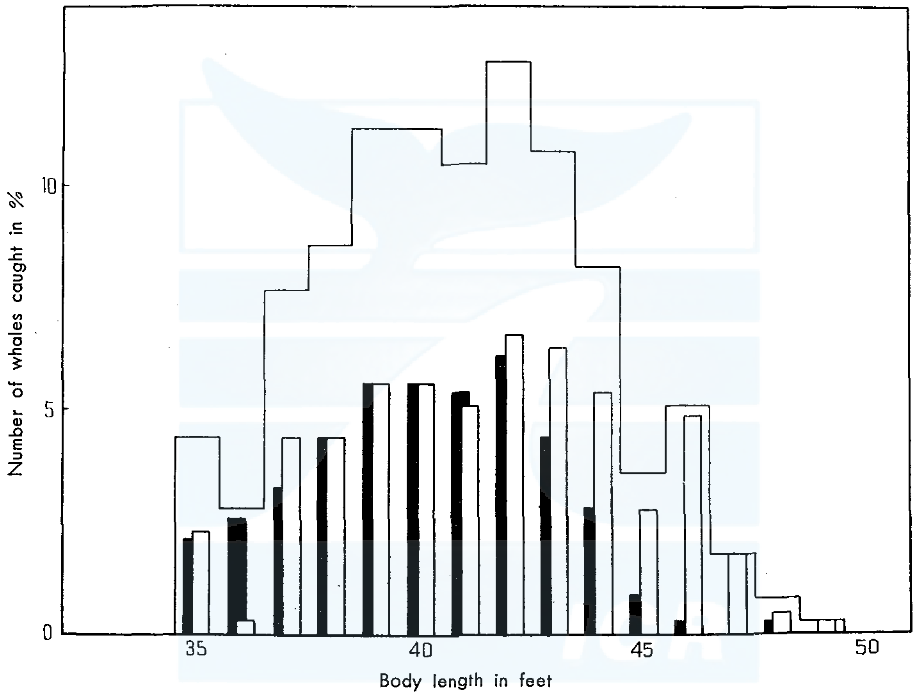


Fig. 2. Size distribution of Aleutian humpback whales in the years 1952-1958.

The significant change in water temperature may be a decisive factor to the migration of whales. They migrated not only in a earlier time but also in the northern part of the whaling area. For instance, whales are scarcely sighted in Miyako and Yaeyama where many whales were usually observed. On the contrary, a considerable amount of whales were seen around Amami where they had scarcely seen in the normal year.

In spite of the unfavorable condition this year, one whaling company with two larger boats had rather satisfactory catch and quitted the operation on March 19th, Nago Fisheries Association also filled up the quota in the comparatively earlier time. One other whaling company with only one larger boat could not fill up the quota until the middle of April, because of the poor efficiency in scouting whales.

Seven sperm whales were caught for four months from January 7th. This is considered to be a very important clue to the development of the Ryukyuan whaling industry in future. In other words, the profit from the catch of sperm or Bryde's whales should be spent for conservation measures of humpback whales. In the case of this year, one company took two and the other caught five sperm whales. These catch mean the reduction of the number of humpback whales killed. Then, the total catch actually treated amounted to 217 whales.

Beside them, four "Dauvhal" were picked up by fishermen. As these were used only as fertilizer, they were not included in the statistic mentioned above.

COMPOSITION OF BODY LENGTH

The number of catch by body length is given in Table 1 and Fig. 1. In Fig. 2 is given the composition by body length of the total catch, amounting to 390 whales, which was taken by Japanese Whaling Fleet in the Aleutian waters from 1952 to 1958.

It is noticed from the figures that these two compositions are quite similar. The similarity might indicate that the stocks in the Ryukyuan waters and the Aleutian waters are of same origin. This is also supported by the results from the recovery of whale making. In the Ryukyuan waters, three and one whales marked in the Aleutian waters were recovered last year and this year respectively. This fact indicates the close relationship between these two waters.

Without accurate calculation, it is easily considered that a high rate of whale marking recovery indicates that the abundance is not so large. It is quite strange that no marked whale has been recovered in the waters off British Columbia and California.

MONTHLY CHANGE OF CATCHES

The monthly change in the average body length of catch is given in Fig. 3. Female is longer than male by two feet in January. But the difference is getting smaller in February and March. According to the

TABLE 1. SIZE DISTRIBUTION OF THE WHALES CAUGHT ACCORDING TO PHYSICAL CONDITIONS

Body length in feet	Male whale			Female whale							Grand total
	Immature	Mature	Total	Immature	Mature					Total	
					Ovulating	Pregnant	Lactating	Resting	Sum		
31											
32	1		1								1
33	2		2	2						2	4
34	1		1	2						2	3
35	8		8	11						11	19
36	8	3	11	4	1				1	5	16
37	3	5	8	12	1				1	13	21
38	6	5	11	1			1		1	2	13
39	1	6	7	5	2		1		3	8	15
40	2	14	16	1	2		1	1	4	5	21
41		15	15		5	1	1	2	9	9	24
42		6	6		5	1	2		8	8	14
43		8	8		5		4	2	11	11	19
44		7	7		3		1	1	5	5	12
45		5	5		7		2	1	10	10	15
46		2	2		6		4		10	10	12
47		1	1				3	1	4	4	5
48					2				2	2	2
49											
50					1				1	1	1
Total	32	77	109	38	40	2	20[1)]	8	70	108	217
Average length	36.2	41.0	39.6	36.3	43.3	41.5	43.7	43.0	43.3	40.8	40.2
Sex ratio			50.2							49.8	100.0
Maturity	29.4	70.6	100.0	35.2					64.8	100.0	
rate	Immature male and immature female were 32.3					Mature male and mature female were 67.7					100.0
Rate of					37.0	1.9	for total female			100.0	
pregnancy					57.1	2.9	for matured female		100.0		
Rate of							18.5			100.0	
lactating							28.6		100.0		
Rate of	3.7		100.0	3.7						100.0	
under size	$MS+FS=3.7$										100.0

In this lactating whales, 10 whales are included which had been ovulated in lactating stage also.

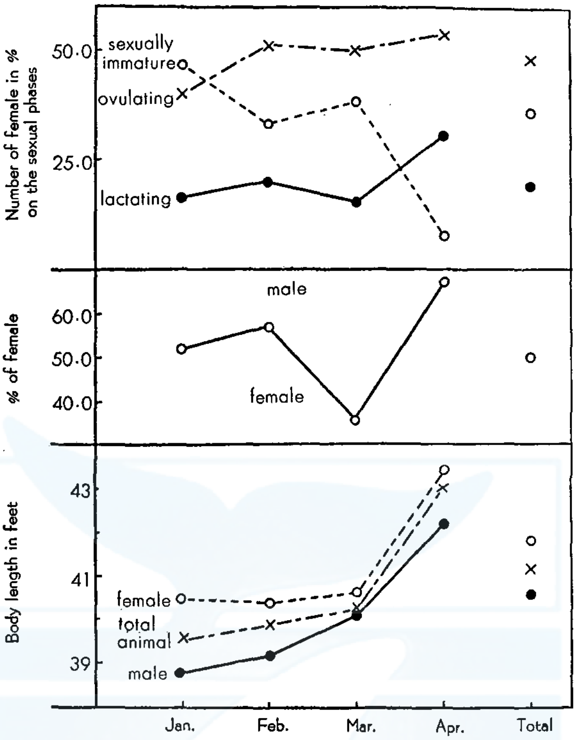


Fig. 3. Monthly average length, sex ratio and percentage of sexual conditions in the females.

Upper; open circle and dotted line: sexually immature,
solid circle and solid line: lactating stage,
cross and broken line: ovulating stage.
Lower; open circle and dotted line: females,
solid circle and solid line: males,
cross and broken line: both sexes.

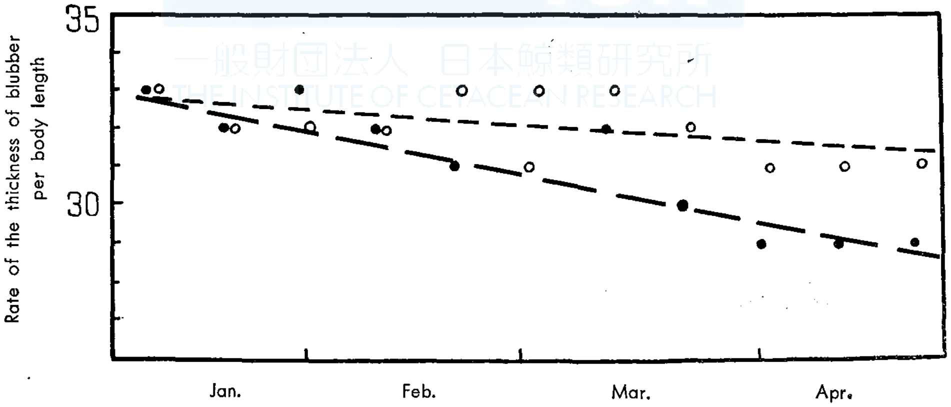


Fig. 4. Monthly decreasing rate of the thickness of blubber.

progress of the season, male is getting longer, compared to female. In April, the body length of catch both male and female is significantly longer, although the number of sample is a few.

These facts reveals that whales migrated to this waters in the beginning of the season are rather small, but gradually they are taken place by the matured group and eventually only the larger whales remain in this waters.

During January and February, the sex ratio is about 1:1. In March the male is slightly more than the female. In April, however, the female is predominant. From the view point of physiological condition of female, more than half of them are immature in January, but the number of the matured whales is increasing through February and March. In April, the number of immature one is very few.

On the contrary, the rate of the ovulating female is more or less lower in January, but after February it is in fairly high level. This may suggest that the ovulation might occur until the end of February. The rate of the lactating whale is rather low during January, February and March, but it becomes higher in April.

In brief, younger and smaller whales migrate in the beginning of the season but later, according to the progress of time, larger and matured whales appear in this waters. From the middle of March, many of the immatured whales move to the northern waters for feeding. Therefore, the whales still remaining in the warmer and nursery waters are mostly of the whales in lactating or mating stage. Since thirty percent of the remainning whales in April is in lactation, there are many mother whales accompanied by their calves being born in this season. These findings, mentioned above, is quite identical to the results on the humpbacks in the Australian waters reported by Chittlebourough.

As is shown in Fig. 4, the thickness of blubber is decreasing in either male or female from January to April. Male is getting thinner from the middle of February more significantly than in female. Infering this fact from behavior of dog in the mating season, male whales become absorbed in chasing female for reproduction.

PHYSIOLOGY OF OVULATION AND LACTATION

Classifing the female whales in more detailed physiological condition, the maximum diameters of Graafian follicles and corpora lutea and the thickness of the mammary glands are given in Fig. 5.

The immatured whales listed in the extremely left side in the figure have no corpus luteum, very small Graafian follicle, about 16 mm in diameter, and the mammary gland up to 35 mm in thickness. Afterwards, the diameters of the Graafian follicles are around 50 mm and the mammary gland is getting thicker when they reach to the pre-puberty stage. In this stage, however, no ovulation has been occurred and no corpus luteum is seen. By the first ovulation, the Graafian follicle changes to a corpus luteum. Immediately after the change, the size of a corpus luteum becomes as large as 65 mm in its diameter in average. Other Graafian follicles than that ovulated in the first place and changed to a corpus luteum are rather small in their size, amounting to 20 mm in average diameter. The mammary gland of the lactating whale reaches up to 165 mm in its thickness and the size of the

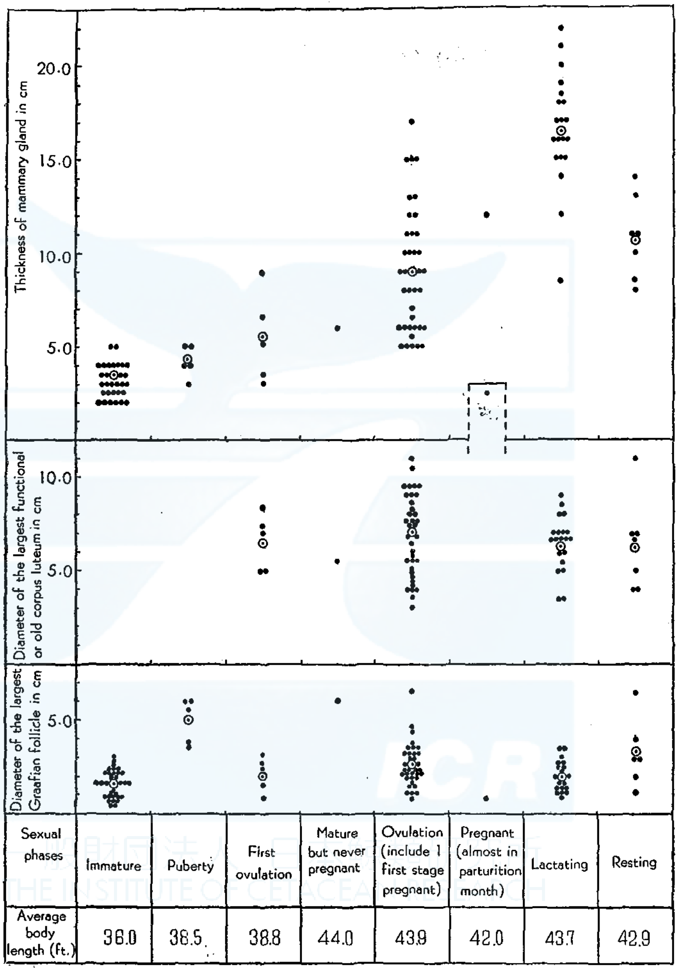
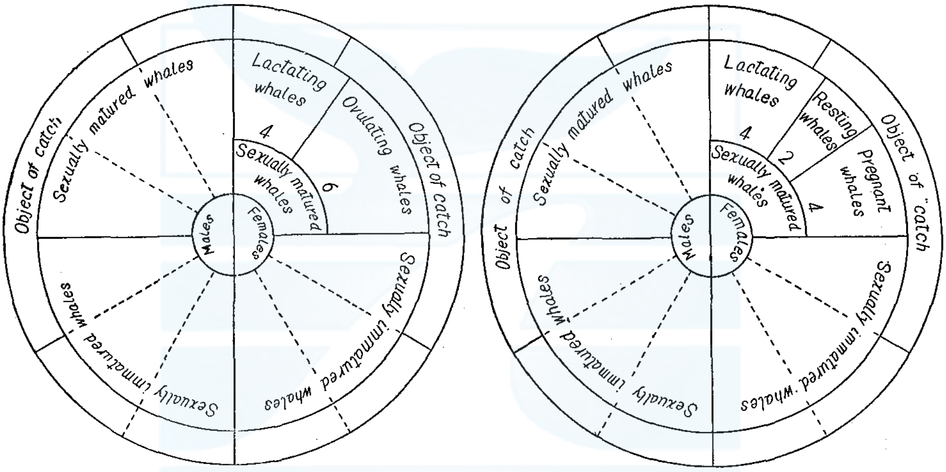


Fig. 5. The largest diameter of the Graafian follicle, functional or old corpus luteum and thickness of mammary gland are showing on the sexual conditions of female whales.

functioning luteum is around 65 mm in diameter. Graafian follicles of the lactating whales are usually shrunk into 20 mm in diameter.

In the extremely right column of Fig. 5 are indicated the conditions of the whale ovaries which are in the resting stage, neither pregnant, ovulating nor lactating. Some of the ovaries of the resting whales in the breeding area have much larger Graafian follicles than those in the feeding area. This indicates that the former whales are just about to ovulate in this breeding season. On the other hand, some ovaries of the resting whales in just after the lactation have rather smaller Graafian follicles and thicker mammary glands. The so-called resting whale, therefore, occupies a important part of the whales in the feeding area. In the breeding area, however, they are caught in a very short period, that is just finished the lactation or just before the ovulation. Hence, they are better be included in the stage of ovulation.



Breeding area Feeding area

Fig. 6. Schematic figures of the North Pacific humpback stock.

One pregnant whale having the fetus amounting to 12′10″ in length was caught in the breeding area. This may be considered to be in the lactating stage, because she must begin to lactate very soon.

Taking considerations mentioned above into account, the ratio given in Table 1 should be changed a little. In other words, the ovulating stage includes the stage of pre-puberty, ovulating in lactation and resting with larger Graafian follicles. And the pregnant one may be included in the lactating stage.

By the above mentioned definition, twenty-one whales are in the lactating stage, but less than 10 of these are actually in lactating.

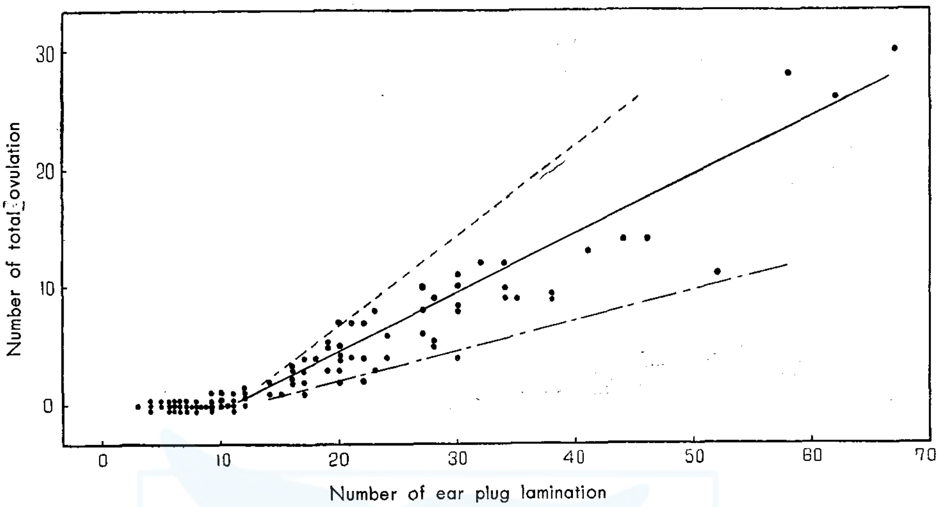


Fig. 7. Relation between number of lamination in ear plug and total ovulation number of the Ryukyuan humpback whales in this season.

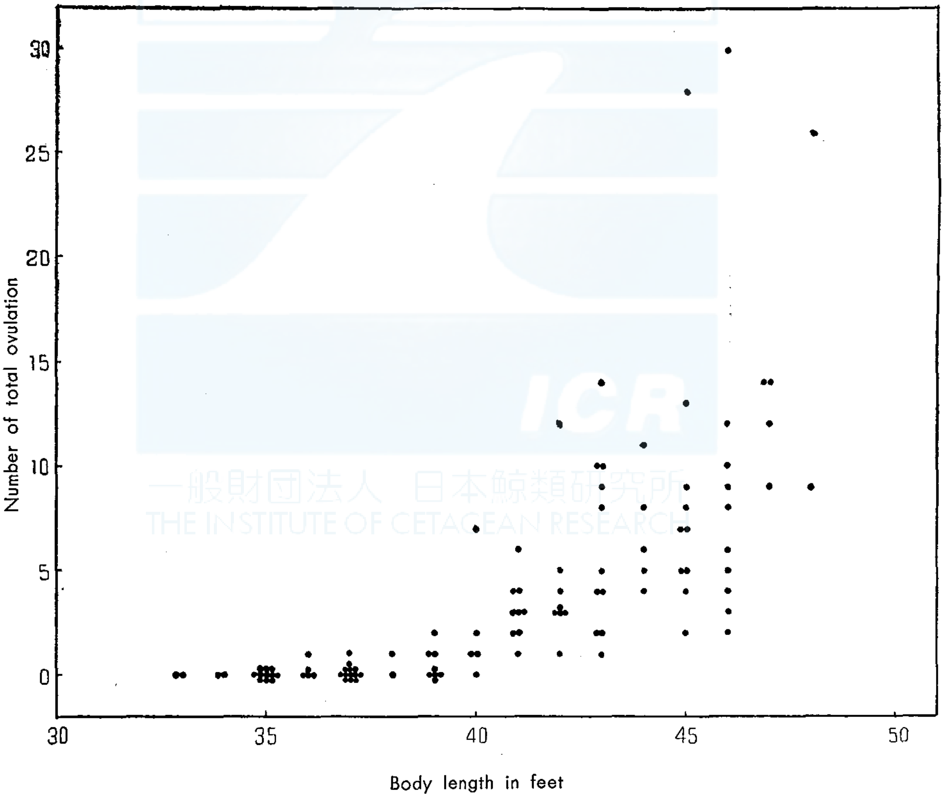


Fig. 8. Relation between body length and total ovulation number of the Ryukyuan humpback whales in this season.

These whale actually in lactating could not be killed because of the international regulation and the custom of gunners. Since these should not be subjected to killing, the whales in lactating must be eliminated from the kill. In that case, other matured whales are mostly in the stage of ovulation. Some of them may conceive in this season.

The pregnancy rate of the whales in the Ryukyuan waters is not known yet, so the pregnant rate in the Aleutian waters, that is feeding area, may be applied. The average pregnancy rate of the matured humpback whales in the Aleutian waters from 1952 to 1958 is estimated to be around 65 percent.

Basing on the age composition of whales determined from the lamination of ear plugs, it is estimated that a half of the whales is immature. As is shown in Fig. 6, the half of a stock is male and the other half is female. Both in male and female, half of them is immature. In the breeding area, 4/10 of the mature females were pregnant in the last season and are now in lactating. The remaining 6/10 of them are in ovulating, 2/3 of the ovulating females may be pregnant this year. In the next season, the whales now in pregnancy would be delivered of a calf and begin to lactate. And the whales now in lactating would be in ovulating stage together with these in the resting whales in the feeding area.

Now, the age when they reach to the sexual maturity after the prepuberty stage is considered. For this purpose, the relation between the total ovulation number and the lamination of ear plug which is considered to be the best index of age is given in Fig. 7. Fig. 8 is shows the relation between the total ovulation number and the body length. According to the figure, it is noticed that the first corpus luteum is seen when the number of the lamination amounts to nine. In the whales with 12 laminations in ear plug, there is only one immatured whale with no corpus luteum in its ovaries. Therefore, it is possibly presumed that the sexual maturity is reached when they are in the stage with 11 laminations in ear plug. Since two laminations are formed in a year, the whale just reaching to the sexual maturity is five years old or slightly old than that.

COMPOSITION OF MALE WHALES AND THE CHANGE IN THE WEIGHT OF TESTIS

All of the testis collected were weighed and some of them were processed and preserved for the histological observation if they are less than 5 kg in their weight. The testis with the closed seminiferous tubules is considered to be immature and with the open one is classified

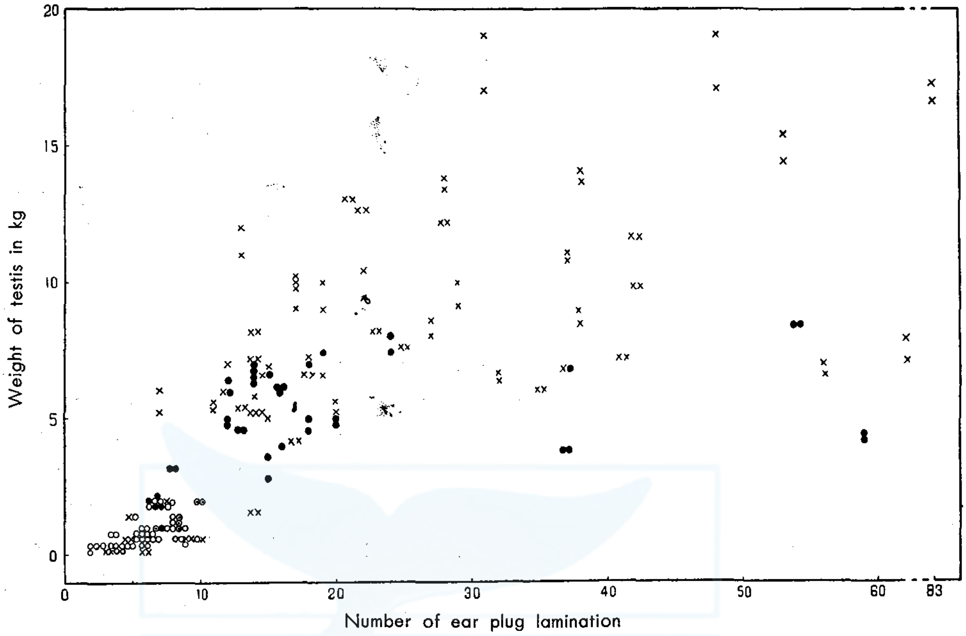


Fig. 9. Relation between number of lamination in ear plug and weight of testis that was examined histologically.

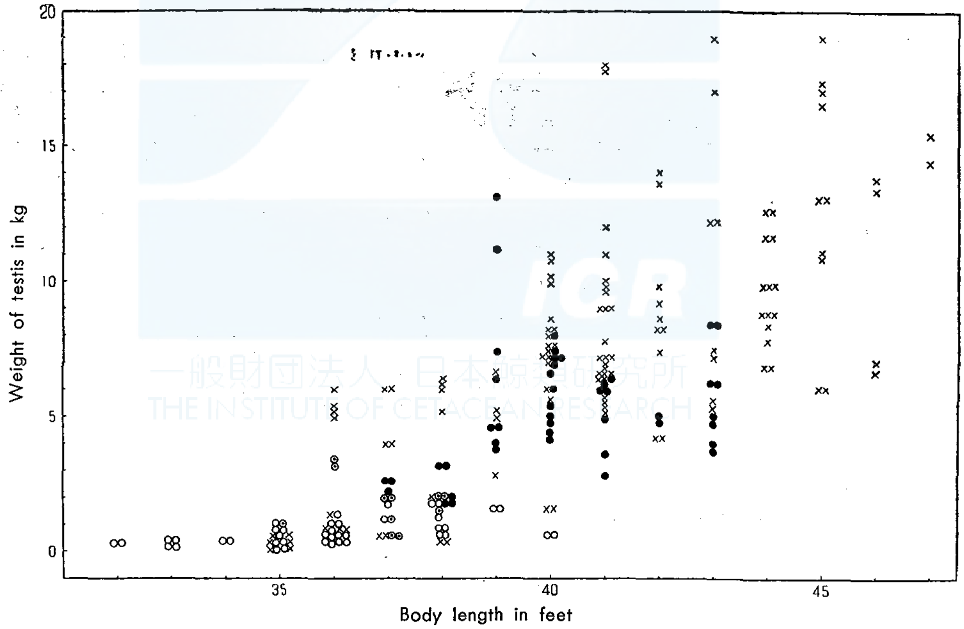


Fig. 10. Relation between body length and weight of testis that was examined histologically.

Explanation of Fig. 9 and Fig. 10.

solid circle: spermatozoa were found,

point in a open circle: some tubules were enlarging with a lumen and few spermatocytes were cited,

open circle: all of tubules were closed,

cross: these were not examined histologically.

to be mature. This classification is similar to that used by Chittleborough (1955), but both results may involve some errors to certain extent, because the identification of the puberty stage is very difficult.

The relation between weight of testis and lamination of the ear plug which is considered to be the most reliable clue to age determination is plotted in Figs. 9. Fig. 10 is shows the relation between weight of

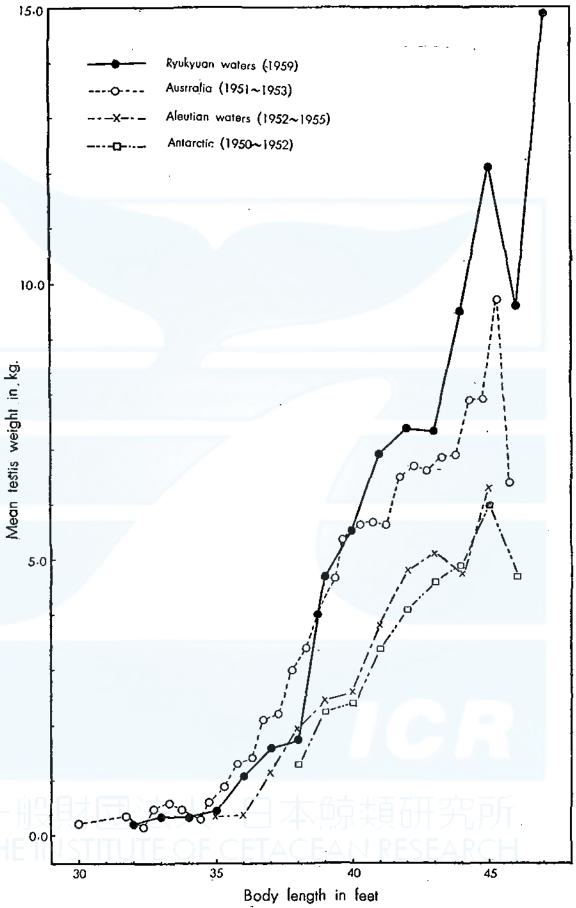


Fig. 11. Geometric means of testis weight according to body length. It is showing the differences between breeding and feeding area.

testis and the body length. Judging from the figure, the whale with testis of about 2 kg in weight, that is of five years old in age, reaches to the sexual maturity.

Fig. 11 shows the average weight of testis by body length in various waters. The result of the present investigation is shown by the solid line. Glancing over these four lines, the relationship in Ryukyuan and Australian waters, both of them are the breeding area, is quite similar, while that in the northern part of the North Pacific and the Antarctic waters being considered as the feeding area is also quite equivalent.

The figure also shows that after the sexual maturity the weight of a testis of a given body length is much heavier in the mating area than in the feeding area. The result by Symons is not referred here, because his finding given in the Norwegian Whaling Gazette No. 2 1958, is quite same to that obtained by Omura.

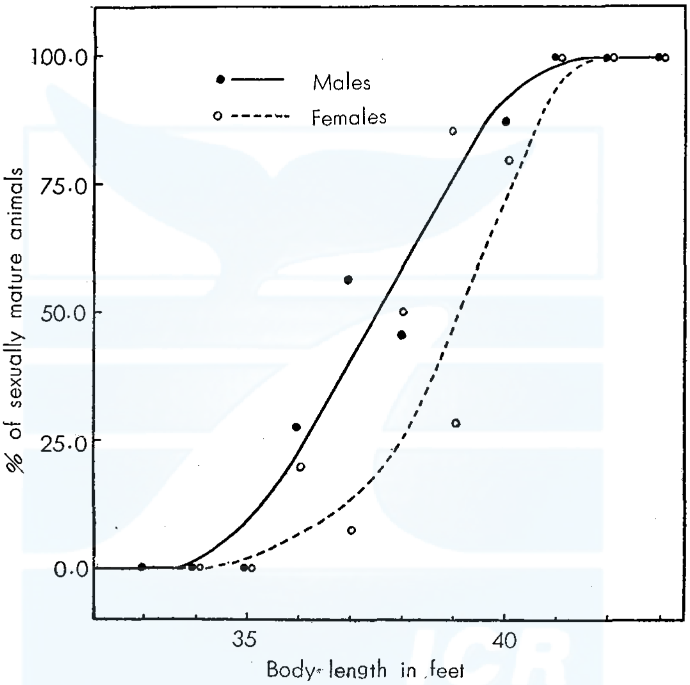


Fig. 12. Percentage of sexually mature animals according to body length.

It is very interesting that the weight of testis differs significantly between in the breeding and the feeding area regardless the hemisphere. Such a finding is made only on humpback whale so far but not realized in any other whale species.

BODY LENGTH IN THE SEXUAL MATURITY

In order to decide the average body length when matured sexually, the frequency distribution of the rate of sexual maturity by body length is shown in Fig. 12 on the basis of the above mentioned classification which defines the male whale with testis less than 2 kg as immature and more than that as mature. In case of female, the whale, with no corpus luteum is defined as immature. As is shown in the figure, whales reach to the sexual maturity when they are about 37–39 feet in body length in case of the male, and 39–40 feet in case of the female. This is quite identical to the result obtained by Chittleborough on the Australian humpback whales in the southern hemisphere. In case of the other whale species such as blue or fin whale, the body length in the sexual maturity is different between the south and the north hemisphere. However, no such a difference is observe in this investigation. This merits more detail study on other aspects of whale biology.

GROWTH OF FETUS

It is believed that the most accurate data on the fetus in the northern hemisphere have been obtained in the Aleutian waters, because these have been collected every year directly by scientists of the Whales Research Institute. In addition to these data, all other data on the growth of fetus obtained so far even in foreign country are plotted in Fig. 13. The cross mark in the figure indicates the average length of fetus by month. Fitting those points, the solid curve is drawn as growth curve of fetus. This curve, however, looks like slightly different from the real growth curve. Hence, the author calculated other growth curve, using the accurate data collected in the Aleutian waters from May to August. As is noticed in the figure, the calculated curve (represented by the dotted line) is different from the fitted one. This discrepancy may be interpreted as follows. The average length observed are longer than the calculated values in September and October. This may be due to looking over some smaller fetuses. On the contrary, the dotted line proceeds the solid line after October. This is because paturition begins from October and the samples observed are more or less limited to the whales being conceived in later time than the normals.

The broken line is the fetal growth curve of humpback whales in the southern hemisphere obtained by Laws this year. In this figure, Laws's curve is drawn as shifted by the time-lag for six months. The author considers that Laws's curve is not appropriate, because it is also based on the biased samples. Judging from the fetal growth of humpback whale in the northern hemisphere, the height of paturition occurred in November and the body length at birth is around 13–14 feet. The gestation period lasts for 10 and half months (or slightly longer than that).

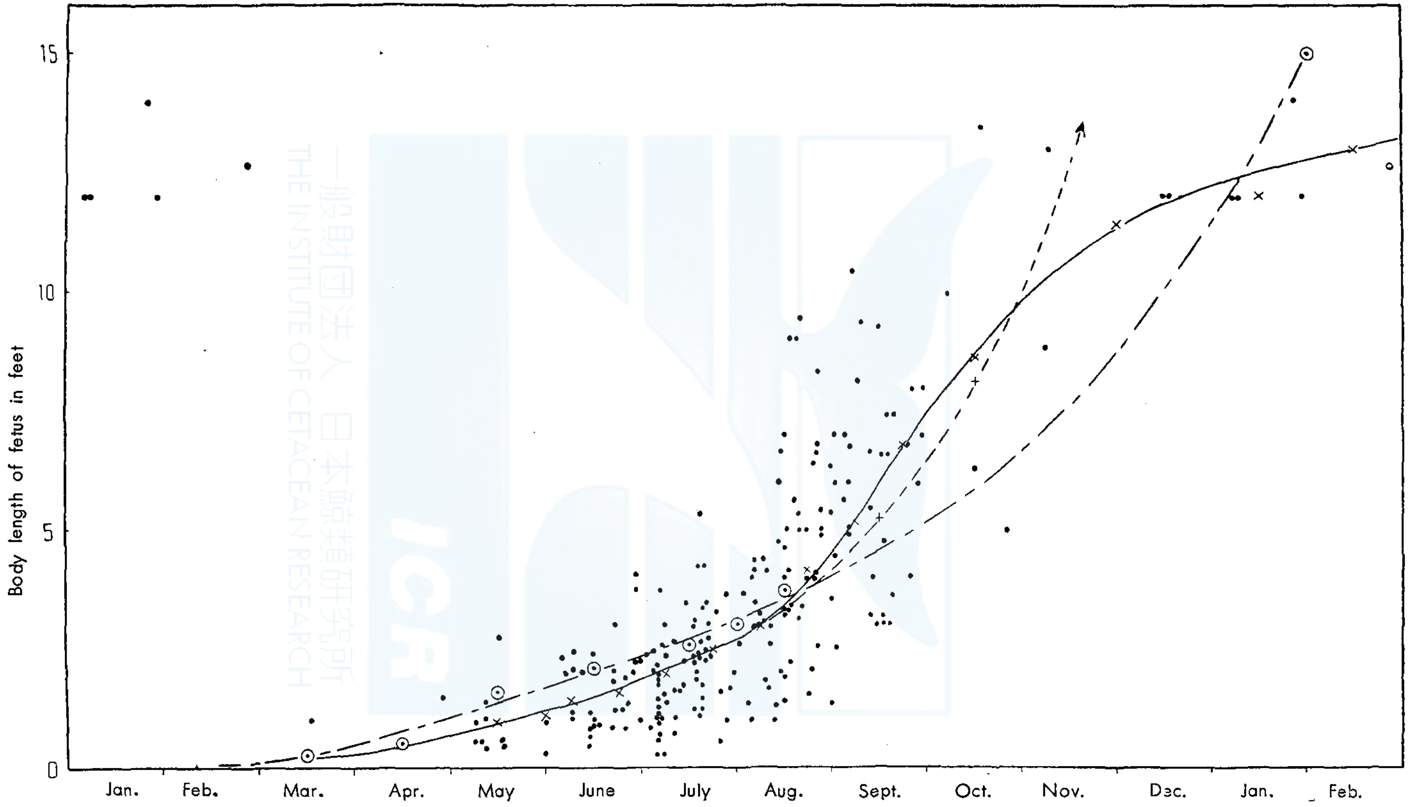


Fig. 13. Fetal growth in length of the North Pacific humpback whale.

Black dots: individuals, open circle: observed in this reason, cross and solid line: mean growth, dotted line: estimated growth curve. Point in open circle and broken line: data after Laws (six months shifted). The individuals that found in Jan. and Feb. are shifted in next year.

GROWTH IN BODY LENGTH

Fig. 14 indicates the growth of body length according to age estimated from the lamination of ear plug.

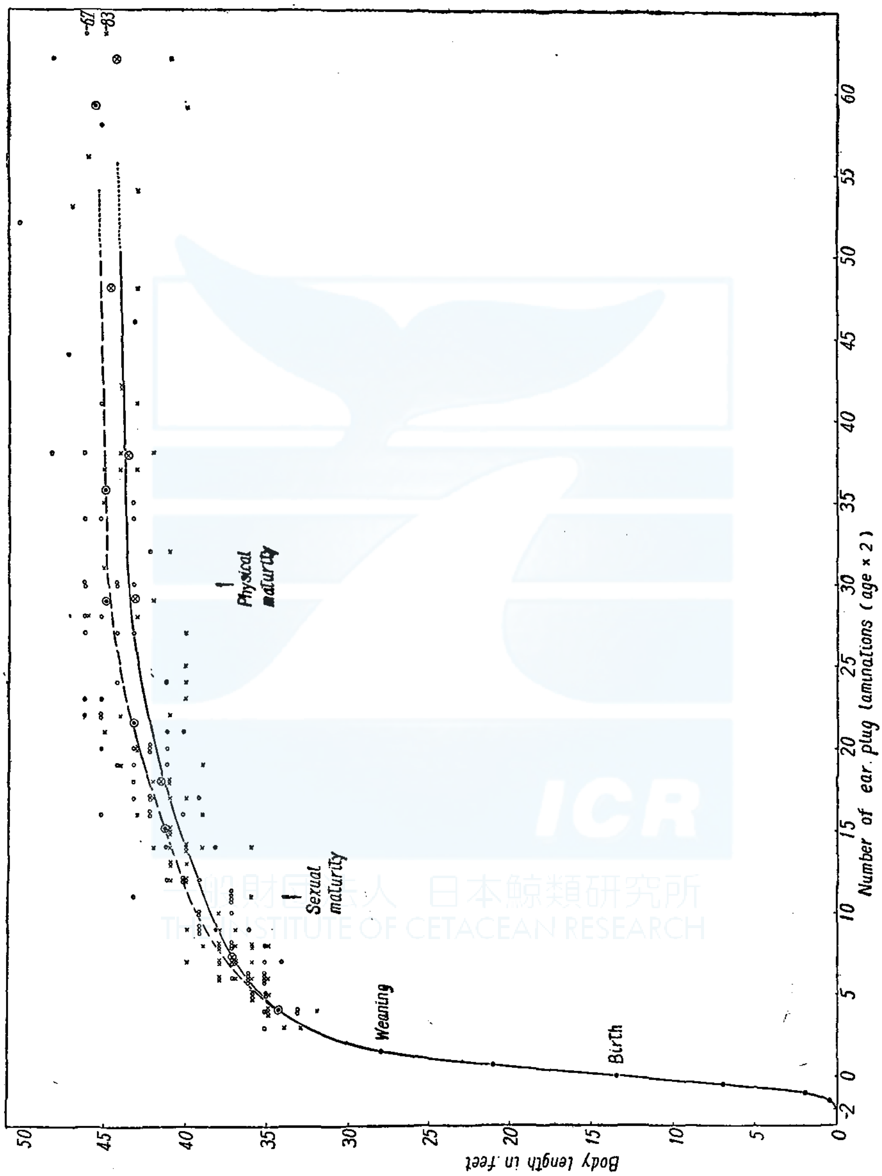


Fig. 14. Growth curve of body length according to the number of laminations in ear plug (age). Cross and solid line: male, opencircle and broken line: female.

It is estimated that the body length at birth is about 13–14 feet and the gestation period is 10–11 months. However, since no data has been obtained from birth to the stage of 30 feet in length, the curve during this period is drawn by free hand. According to the fitted curve, a suckling calf, 21 feet in length, found accidentally on the coral reef in Miyako Island on 31st March this year, is estimated to be about 4 months old.

It is noticed that the female is longer than the male by $1^{1}/_{3}$ feet in a given age class of the adult stage. This species of whale reaches to the physical maturity about ten years after the sexual maturity. A growth curve usually comes down to certain extent from sometime at the older stage, but no such a tendency is observed in this case.

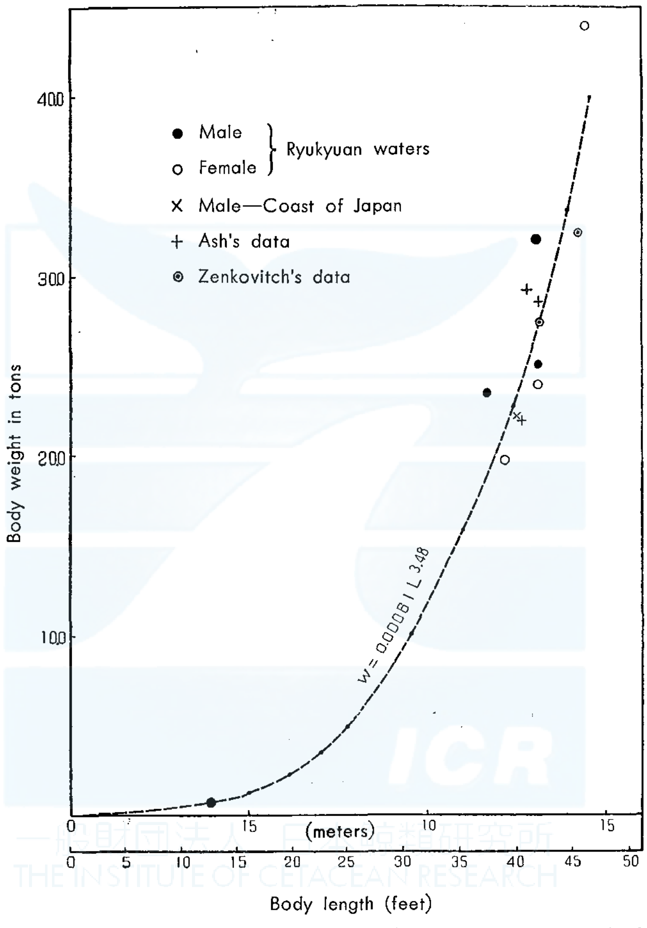


Fig. 15. Increase of body weight according to growth of body length.

BODY WEIGHT

Informations of body weight bring us many essential knowledges concerning the growth of whale as well as informations for regulation and the commercial value. This most voluminous work even been done on the body weight study of humpback whale is Ash's which considered the oil content of this species in the Antarctic waters.

All data concerning length weight relationship are plotted in Fig. 15, in which the data by Ash are the mean value only, because no individual value was given in his report. Six whales and one fetus were weighed for this investigation by the same method to others already reported so far. These results together with weight of separate part of the body are given in the Appendix VI. As is shown in Fig. 15, the dots plotted are scattered rather widely. This wide variation can be easily understood by the fact already mentioned in this report that the thickness of blubber is getting thinner from the middle of February.

Basing on the data given in the figure, the following equation is obtained in the relationship between body length and weight,

$$W=0.00061\,L^{3.48}$$

where W is in the unit of tons and L in feet.

Although adequate data is not available yet, the length-weight relationship of this species may be represented by the above equation either in the northern or the southern hemisphere.

OTHER OBSERVATIONS

Other observations and their results than those mentioned above are considered here.

Basing on the lamination of ear plug, the mortality and survical curves are given in Figs. 16 and 17. The detailed data used for these figures are recorded in Appendix VII. On the other hand, data of the age composition based on the total ovulation number are tabulated in Appendix VIII.

Eleven humpback whales were measured on detail part of the body. These results, however, could not be compared to those already measured on 9 humpback whales caught in the Aleutian waters, because the number of samples is too few for such a comparison. The growth pattern of each part measured, represented by proportional rate to body length, is shown in Fig. 18. The detailed data is tabulated in Appendix IX.

As to the body color, many scientists reported on humpback whales caught in the various waters. Since the standard applied to those study, is rather complex and confusable, the author classified the color of whales, into four categories is illustrated in Fig. 19, and its result is shown in Table 2. 92 percent of the total catch belongs to the Grade

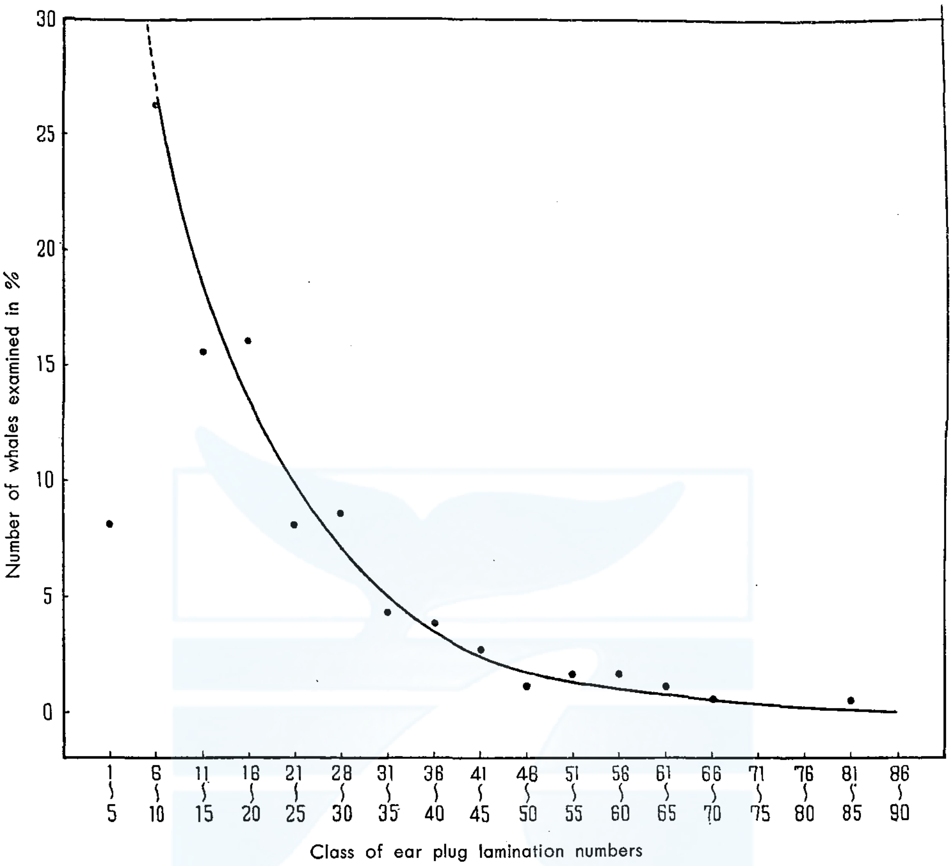


Fig. 16. Frequency curve of whales caught according to ear plug lamination

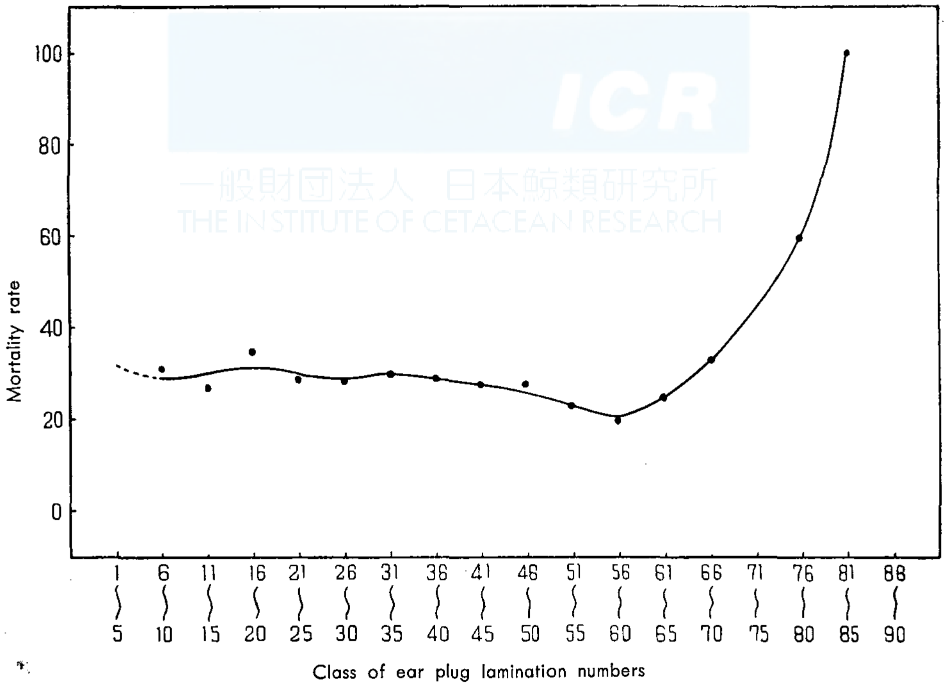


Fig. 17. Mortality curve according to ear plug lamination

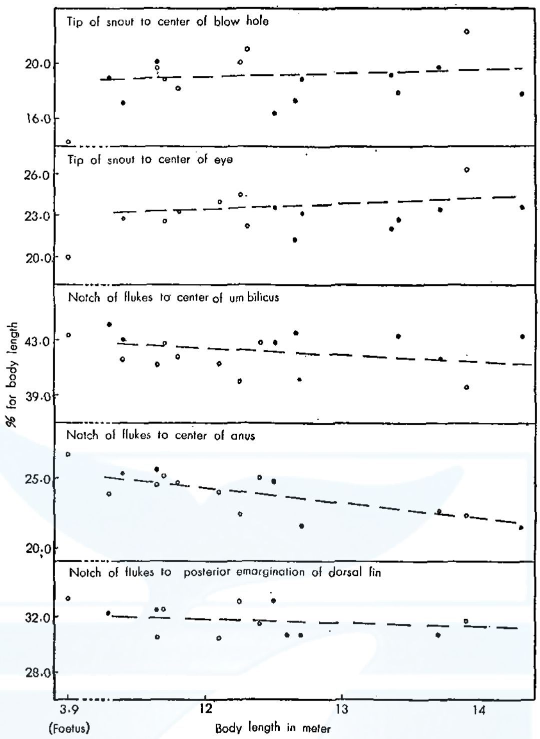


Fig. 18. Increase or decrease tendencies according to the growth of length in body proportions.

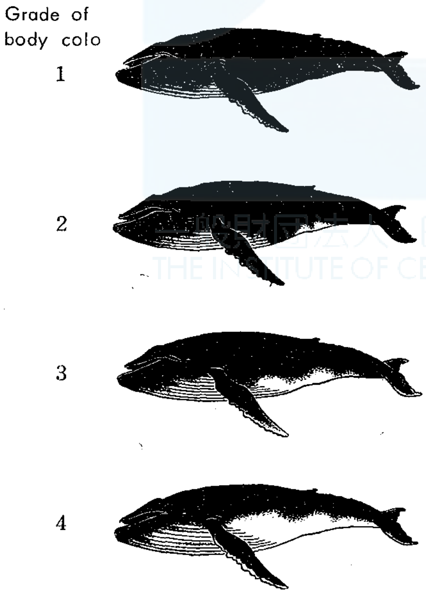


TABLE 2. OCCURRENCE OF BODY COLOR OBSERVED

Month	Sex	Grade of body color 1	2	3	4
Jan.	Male	25	3	0	0
	Female	26	3	1	0
Feb.	Male	27	2	0	0
	Female	34	4	1	0
Mar.	Male	44	2	0	0
	Female	25	0	1	0
Apr.	Male	6	0	0	0
	Female	13	0	0	0
Total	Male	102	7	0	0
	Female	98	7	3	0
Percentage of occurrence		200	14	3	0
		92.2	6.4	1.4	0.0

← Fig. 19. Grade of color pattern. (almost same as Lillie's pattern types in Matthews' report, 1938)

1, but none to the Grade 4. The whale of the Grade 4, however, is not rare in the Antarctic waters.

As to the external parasite observed for this investigation, no special finding is obtained. Pennella attached to the whale in the feeding area has the shape like a writing brush. But in the Ryukyuan waters their shape is just like a thin string. Therefore, some of them must be over looked.

At the field station, the author collected some of diatom film, but later he realized that they are not diatom, but just rust come from catcher boat. So no diatom infection was observed this time.

Special survey for barnacles, which has been observed on their species, numbers and diameters of the shells, was made on six whales. These results would be reported in other paper co-operate with Dr. Joe Connel of the California University.

TABLE 3. INFECTION RATE OF EXTERNAL PARASITES

Sex		Male				Female				Total	Rate of infection
Month		Jan.	Feb.	Mar.	Apr.	Jan.	Feb.	Mar.	Apr.		
No. of whales caught		28	29	46	6	30	39	26	13	217	
No. of whales examined		26	29	45	6	29	38	26	13	212	
White scar	not infected										100.0%
Cyamus sp.				1						1	99.5%
Coronula sp.				1						1	99.5%
Conchoderma sp.			1	1						2	99.1%
Pennella sp.	infected	1	2	1	1	2			1	8	3.8%
Diatom film											0.0%

In the report of the last season, neither stomach content nor fetus was found in the whales caught in the Ryukyuan waters. People around there could not understand this phenomena. From the scientific common sence of whales, this is not curious at all, because the foods are not abundant in the breeding waters and whales are not active in feeding there.

There could not be obtained any evidence that the foods for humpback whale in this waters is abundant. One individual of *Euphausia similis* could be identified in a small mass of the stomach content, and some piece of looks like *Euphausian* carapace was found in the intestine contents.

They say a whale with small *Euphausia* in its stomach was contained in the catch made by a company in 1958 season. Judging from its size, Mr. T. Nemoto of our Institute considers they are *Pseudoeuphausia latifrons* which distributes in the sub-tropical coast. They also say that one whale with stomach being full of small squid and one other being full of small mackerel were observed in the catch made in 1957 season.

To identify the breeding populations of the North Pacific humpback whales, blood samples of 105 individuals were collected with glycerol-freezing technique and were sent by air to our Institute for the successive analysis. After dialysing against 1.5 percent saline and washing several times centrifugally with saline, cells enough to tests were successfully recovered in 100 bottles, but were not obtained in other 5 bottles because of complete hemolysis. Possible causes of hemolysis have not yet been studied at present, but these results show that the glycerol-freezing technique has a potential value in the large scale of blood typing investigation on whales from broad geographical areas.

TABLE 4. TEMPORARY CLASSIFICATION OF BLOOD TYPES OF HUMPBACK WHALES CLASSIFIED BY ABSORPTION TEST OF ANTI-FINBACK JU_2 SERUM

	Cells of:			
Observed with cells of:	Type-1	Type-2	Type-3	Type-4
Type-1	−	−	−	−
Type-2	+	−	−	−
Type-3	+	+	−	−
Type-4	+	+	+	−

TABLE 5. FREQUENCY OF OCCURRENCE OF BLOOD TYPES OF HUMPBACK WHALES FROM RYUKYUAN WATERS IN THE YEAR 1959

Blood Type	1	2	3	4	2 or 3	No. of whales exam.
Occurrence	1	4	6	88	1	100

Isohemagglutinins were detected in the supernatant parts recovered from frozen materials. Natural antibodies were also found in the sera from several kinds of domestic animals. Absorption tests were undertaken by using anti-finback "Ju" immune sera. Results of these experiments show that the erythrocytes of humpback whales have the antigenic individual differences which are like to finback "Ju" antigens and can be classified temporarily into the four types (Table 4). Individuals of these four types occurred in the Ryukyuan waters in 1959 as shown in Table 5. Detail descriptions on the present study are reported by Cushing, Fujino and Takahashi (1959) in this issue.

RESULTS AND CONSIDERATIONS

Some considerations and results are made hereinafter basing on the data already described above.

In the first place problems concerning to a quota is considered. As was cleary described above, a quota was calculated from the estimated number of the migration whales which is figured out from number of whales observed. The number of observed whales amounted to about 800 last year but 500 this year. This decrease in the number of observed whales is not due to the exploitation in the last season but to a remarkable change in the oceanographic condition in this area. Therefore, 800 is much more reliable than 500 as the factor of calculation.

In general, 2 to 3 times of the number observed is considered to be number of the migrating whales. However, since the whales in the breeding area may stay longer there than in the feeding area, a factor, 1.5 to 2 times would be applied for the calculation instead of 2 to 3. Hence, the numbers of the migrating whales this year is estimated to be around 1,200–1,600 individuals.

Another approach to this problem is to estimate the total abundance which maintains the annual recruitment, being equivalent to a catch in a year. Although 220 whales were caught this year. The number of whales actually killed, however, must be slightly more than that. Taking the number of calves accompanied by the lactating whales and the wounded and lost one into account, the actual kill may amount to about 250 individuals. Therefore, neglecting the natural mortality, 250 individuals should be recruited in a year in order to maintain abundance at the present level. Half of the total are the female whales, half of which are the matured. 1/3 of the matured whales are in the lactating stage, 2/3 of the rest are in the ovulating stage. 2/3 of the ovulating whales are pregnant. Assuming that the number of the pregnant whales is 250, the total abundance amount to 2,250 individuals. According to the assumption mentioned above, catch of this year exceeds the optimum level. 1,600, the optimum level of this year is calculated to be about 180 whales.

However, the estimation of the total abundance as 1,600 whales is made on a condition that the whale stock in this waters is independent to other populations. Whale marking experiments clearly indicate that the whales in this area are more or less intermingled with those in the Aleutian waters. The optimum catch, therefore, should be calculated from the total stock in the North Pacific. Since the author estimated that the total number of humpback whales in the North Pacific is about 5,000–6,000, the catchable number amounts to about 600 whales, if applied the above-mentioned way of calculation.

The number of landed humpback whales in these years in the North Pacific amounts to about 370–390 individuals, of which 200 are caught in U.S.A. (San Francisco), 80 in Canada (British Columbia), 60 in the

Aleutian waters and 30–50 in U.S.S.R. region. Apart from the considerations on which foreign countries decide their catch, the catchable number in Ryukyuan waters is the difference between the estimated total catchable number in the North Pacific, that is 600, and the overall catch made in other areas. This is figured out as 210–230 individuals. This figure is quite equivalent to the quota permitted this year in this area for this year. Same amount of quota, therefore, would be applicable in the coming season.

The author considers it is quite favorable that the average body length of landed whales this year is 40.2 feet which is significantly longer than that of the previous season. This is partly due to the fact that each companies tried to catch larger whales because of the limitation by quota. Main reason, however, is by the migration pattern.

TABLE 6. NUMBER OF WHALES CAUGHT AND AVERAGE SIZE OF WHALES IN FEET

Season	Total number of catch	Average body length	Remarks	
1954	4	?		
1955	11	?		
1956	13	41.7	Male	2 : 40.5
			Female	11 : 41.9
1957	23	40.2	Male	14 : 40.5
			Female	9 : 39.7
1958	290	38.9	Male	176 : 38.8
			Female	114 : 39.1
1959	217	40.2	Male	109 : 39.6
			Female	108 : 40.8

Judging from the fact that in the early time of a season smaller whales migrate first to this waters, following by larger one according to the progress of a season, larger whales were mostly killed this year because of the later migration of whales, due to the change of oceanographic condition. One of other reason is that the author, considering some opinions of the American scientists, recommended to delay the whaling season.

The author suggests to open the whaling season of the coming year on 1st December, because many female whales, accompanied by calves, must be killed in the later part of the season, if the opening day is delayed. In December and January, the price of whale meat in Japan rises up because of the shortage of the Antarctic whale meat. Commercially speaking, therefore, the whale industry may pay off even if the quota is not so large. This is also a reason. Fatness of whales is also an important reason. Thickness of blubber is getting thinner from the middle of February.

Compared to the older time, abundance of whales has been decreasing in any waters in the world. The whaling industry comes to a standstill in the direction to expect more catch. The possible way to develop the whaling industry is to increase the profit by rationalization of administration with consideration on conserving whale resource. For this purpose, several important aspects should be studied further. First is the way to supply whale meat to market in more fresh condition. Second is the most favorable way for processing meat. Third is the most efficient proportion of the total catch by whale species. In case of the Ryukyuan whaling, industry should not rely on the catch of humpback whale but try to catch other whale species in order to decrease the catch of humpback whale. Although there is an opinion that it is much better to catch as many whales as possible than to leave them to the unregulated operation by U.S.S.R. whaling industry, the author believes that U.S.S.R. would not deplete the whale stock on which her industry is depended. It is quite desirable to exploit within the level which is figured out in the basis of scientific research.

As is described in the introduction of this report, the humpback whale stock is liable to be depleted. Therefore, any country having concern to whaling should co-operate for conserving the stock, although the abundance of this whale species seems to increase a little after the World War II. For this purpose, all countries having interest in the humpback whale stock of the North Pacific should decide the optimum catch, basing on scientific data and information from countries concerned. In this sence, it is great regret that no investigation was carried out despite that 290 whales was caught last year. The author believes that the thorough research for coming several seasons basing on the results obtained for this season, must be very helpful to the international negotiation in future. Expense required for such a research is only a small part of the total income by the whaling.

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APPENDIX I NUMBER OF HUMPBACK WHALES CAUGHT IN THE NORTH PACIFIC (1910~1957)

Area Year	Alaska	British Columbia	Washington State	California State	Lower California	Japan	Total
1910	—	—	—	—	—	18	18
11	—	—	—	—	—	59	59
12	—	—	—	—	—	—	—
13	28	—	—	—	—	—	28
14	131	—	—	—	—	160	291
15	153	—	—	—	—	28	181
16	121	—	—	—	—	22	143
17	44	—	—	—	—	16	60
18	—	—	—	—	—	15	15
19	132	65	122	223	—	52	594
20	75	98	138	383	—	35	729
21	75	—	—	124	—	101	300
22	95	50	124	600	—	89	958
23	155	78	99	392	—	70	794
24	71	47	98	197	—	158	571
25	208	40	21	43	403	158	873
26	388	25	—	21	498	109	1041
27	554	21	—	2	472	95	1144
28	220	21	—	10	179	91	521
29	214	9	—	—	23	74	320
30	191	12	—	—	—	62	265
31	—	—	—	—	—	70	70
32	—	—	—	—	—	89	89
33	—	—	—	—	—	92	92
34	166	14	—	—	—	57	237
35	141	1	—	—	6	78	226
36	118	14	—	—	—	79	211
37	104	7	—	3	—	73	187
38	12	4	—	—	—	67	83
39	26	—	—	59	—	80	165
40	—	2	—	19	—	2	23
41	—	27	—	16	—	40	83
42	—	7	—	12	—	30	49
43	—	7	—	5	—	69	81
44	—	—	—	1	—	64	65
45	—	—	—	—	—	11	11
46	—	—	—	—	—	20	20
47	—	—	—	13	—	9	22
48	—	115	—	16	—	11	142
49	—	76	—	11	—	4	91
50	—	95	—	—	—	5	100
51	—	51	—	4	—	4	59
52	—	61	—	—	—	3	64
53	—	47	—	—	—	7	54
54	—	106	—	—	—	12	118
55	—	37	—	—	—	20	57
56	—	28	—	113	—	27	168
57	—	49	—	199	—	32	280
Average number of whales caught during the years							
1910 ≀ 1930	179	42	100	200	315	74	424
1931 ≀ 1945	94	9		16	6	60	111
1946 ≀ 1956		68		31		9	73

APPENDIX II NUMBER OF OF HUMPBACK WHALES CAUGHT IN THE COASTAL WATERS OF JAPAN (1910–1957)

Area / Year	Okhotsk sea	Pacific coast of Japan 31°～50°N	Japan sea and Yellow sea	Bonin waters	Ryukyuan waters 24°～31°N	Formosan waters	Total
1910	—	15	3	—	—	—	18
11	3	37	19	—	—	—	59
12	—	—	—	—	—	—	—
13	—	—	—	—	—	—	—
14	—	47	23		90	—	160
15	—	19	9	—	—	—	28
16	—	8	14	—	—	—	22
17	—	3	13	—	—	—	16
18	—	4	11	—	—	—	15
19	—	16	10	—	26	—	52
20	—	3	4	—	—	28	35
21	13	31	7	—	8	42	101
22	11	15	17	—	3	43	89
23	8	11	9	—	—	42	70
24	—	15	4	86	—	53	158
25	8	14	7	86	—	43	158
26	3	6	2	52	—	46	109
27	3	15	8	14	—	55	95
28	2	3	5	25	—	56	91
29	—	7	2	5	—	60	74
30	—	6	14	2	—	40	62
31	—	3	3	27	—	37	70
32	—	7	9	34	—	39	89
33	1	7	8	48	—	28	92
34	—	6	4	28	4	15	57
35	1	6	8	34	—	29	78
36	1	5	2	53	—	18	79
38	—	7	—	50	—	16	73
38	—	4	3	44	—	16	67
39	—	4	8	60	—	8	80
40	—	1	1	—	—	—	2
41	—	12	4	19	—	5	40
42	—	7	4	14	—	5	30
43	—	4	8	57	—	—	69
44	—	3	2	59	—	—	64
45	2	2	7	—	—	—	11
46	2	3	3	12	—	—	20
47	—	6	2	1	—	—	9
48	2	5	1	3	—	—	11
49	—	—	—	4	—	—	4
50	3	2	—	—	—	—	5
51	1	3	—	—	—	—	4
52	—	3	—	—	—	—	3
53	—	7	—	—	—	—	7
54	3	5	—	—	4	—	12
55	2	7	—	—	11	—	20
56	—	12	2	—	13	—	27
57	—	5	—	—	23	4	32
Average number of caught during the years							
1910 ～ 1924	9	17	10	86	32	42	63
1925 ～ 1939	3	7	6	37	4	34	85
1940 ～ 1957	2	5	3	21	13	5	21

APPENDIX III SIZE DISTRIBUTION OF HUMPBACK WHALES CAUGHT IN THE COASTAL WATERS OF JAPAN (1910∼1922)

Body length in feet	Okhotsk sea	Pacific coast of Japan 31°-50	Japan sea and Yellow sea	Bonin waters	Ryukyuan waters 24°-31°N	Formosan waters	Total
22	—	1	—	—	—	—	1
24	—	1	—	—	—	—	1
23	—	1	—	—	—	—	1
25	—	2	—	—	1	—	3
26	—	1	1	—	—	—	2
27	—	1	—	—	—	—	1
28	—	5	1	—	—	—	6
29	—	—	1	—	—	—	1
30	1	14	3	—	3	—	21
31	—	9	—	—	3	1	13
32	2	8	4	—	6	2	22
33	—	7	2	—	3	2	14
34	—	6	—	—	3	—	9
35	1	13	7	—	5	5	31
36	—	10	4	—	5	4	23
37	1	6	3	—	2	4	16
38	—	7	7	—	4	6	24
39	—	1	—	—	3	3	7
40	2	10	6	—	3	8	29
41	—	6	3	—	7	4	20
42	1	6	3	—	14	12	36
43	2	4	—	—	3	9	18
44	—	6	2	—	13	3	24
45	3	5	3	—	19	9	39
46	—	8	5	—	13	8	34
47	3	8	5	—	9	3	28
48	2	2	6	—	3	1	14
49	—	2	1	—	3	1	7
50	1	6	8	—	2	—	17
51	—	2	2	—	—	—	4
52	1	—	1	—	—	—	2
53	—	—	1	—	—	—	1
54	—	1	—	—	—	—	1
55	—	—	—	—	—	—	—
56	—	—	—	—	—	—	—
57	—	—	—	—	—	—	—
58	—	—	—	—	—	—	—
59	—	1	—	—	—	—	1
60	—	1	—	—	—	—	1
Total	20	161	79		127	85	472
Average length	42.4	38.0	41.2		41.4	41.1	40.2

APPENDIX IV SIZE DISTRIBUTION OF HUMPBACK WHALES CAUGHT IN THE COASTAL WATERS OF JAPAN (1940~1956)

Body length in feet	Okhotsk sea	Pacific coast of Japan 31°-50°N	Japan sea and Yellow sea	Bonin waters	Ryukyuan waters 24°-31°N	Formosan waters	Total
30	1	—	—	1	—	—	2
31	—	—	—	—	—	—	—
32	—	—	—	—	—	—	—
33	—	—	—	—	—	—	—
34	—	—	—	—	—	—	—
35	2	22	2	16	—	1	43
36	1	13	3	6	—	1	24
37	3	4	—	10	—	3	20
38	—	2	2	7	—	—	11
39	—	3	2	5	—	—	10
40	—	7	3	13	—	2	25
41	1	1	5	10	—	3	20
42	1	5	5	21	—	2	34
43	1	6	1	11	—	—	19
44	1	4	1	6	—	—	12
45	2	11	4	19	—	1	37
46	—	3	3	7	—	—	13
47	—	4	1	7	—	—	12
48	2	1	—	3	—	1	7
49	—	—	—	—	—	—	—
50	—	1	1	5	—	—	7
51	—	—	1	—	—	—	1
52	—	—	—	1	—	—	1
53	—	—	—	1	—	—	1
Total	15	87	34	149		14	299
Average length	40.2	39.8	41.8	41.6		40.1	40.9

APPENDIX V SIZE DISTRIBUTIONS OF HUMPBACK WHALES CAUGHT IN THE RYUKYUAN WATERS DURING THE SEASON (1956~1958)

Body length in feet	1956			1957			1958		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
31	—	—	—	—	—	—	—	—	—
32	—	—	—	—	—	—	—	—	—
33	—	1	1	—	—	—	—	—	—
34	—	—	—	—	—	—	—	—	—
35	—	1	1	—	3	3	16	12	28
36	—	1	1	1	—	1	30	21	51
37	—	—	—	1	—	1	22	13	35
38	1	1	2	3	1	4	19	11	30
39	—	—	—	1	—	1	25	7	32
40	—	—	—	1	2	3	17	10	27
41	—	1	1	1	—	1	16	11	27
42	—	—	—	4	—	4	10	11	21
43	1	1	2	—	1	1	13	8	21
44	—	—	—	1	—	1	6	4	10
45	—	1	1	—	1	1	2	4	6
46	—	1	1	—	1	1	—	2	2
47	—	1	1	—	—	—	—	—	—
48	—	1	1	1	—	1	—	—	—
49	—	1	1	—	—	—	—	—	—
50	—	—	—	—	—	—	—	—	—
Total	2	11	13	14	9	23	176	114	290
Average length	40.5	41.9	41.7	40.5	39.7	40.2	38.8	39.1	38.9
Sex ratio	15.4	84.6		60.9	39.1		60.7	39.3	

APPENDIX VI BODY WEIGHTS OF NORTH PACIFIC HUMPBACK WHALES CAUGHT IN RYUKYUAN WATERS

Serial number	K57	K92	R82	R85	N38	R94	Fetus of R43	—
Date of killed	23, Feb. 1959	26, Mar. '59	3, Apr. '59	9, Apr. '59	14, Apr. '59	24, Apr. '59	27, Feb. '59	2, June '57
Position of killed	26°–09′N 127°–14′E	26°–06′N 127°–11′E	26°–53′N 127°–35′E	26°–21′N 127°–31′E	26°–41′N 127°–59′E	26°–41′N 127°–21′E	26°–00′N 129°–29′E	Off Kinkasan
Body color	1	1	1	1	1	1		
Weight of testis in kg.	1.8 1.8	— —	— —	6.0 6.0	4.5 4.5	— —	— —	} 9.0
Number of ovulations	—	30	1	—	—	1	—	—
Thickness of blubber in cm.	12.0	14.5	11.5	13.0	13.0	11.5	—	—
Fatness	Fat	Fat	Thin	Fat	Normal	Normal	—	Normal
Sex	M	F	F	M	M	F	M	M
Body length in feet	38′	46′	42′	42′	42′	39′	12′–10″	40′
Weight of blubbers	6428.6	11563.8	8711.5	12456.5	6385.4	8592.5	228.0	4871.6
%	**27.3**	**26.3**	**37.9**	**38.9**	**26.0**	**43.5**	**31.0**	**21.9**
〃 meats	9711.4	18125.2	7460.0	10818.0	11041.0	5778.0	123.0	7785.2
%	**41.3**	**41.3**	**32.5**	**33.8**	**45.0**	**29.3**	**16.7**	**35.1**
〃 bones	3309.0	5849.0	3422.5	4487.5	3636.5	2620.0	242.0	3362.5
%	**14.1**	**13.3**	**14.9**	**14.0**	**14.8**	**13.3**	**32.9**	**15.1**
〃 internal organs	2190.6	5848.0	2457.0	3243.0	2719.5	2031.0	118.3	1864.0
%	**9.3**	**13.3**	**10.7**	**10.1**	**11.1**	**10.3**	**16.1**	**8.4**
〃 others	1874.0	2541.0	904.5	977.0	752.6	717.0	24.0	4318.3
%	**8.0**	**5.8**	**3.9**	**3.1**	**3.1**	**3.6**	**3.3**	**19.5**
Total weight of body parts in kg.	23513.6	43927.0	22955.5	31982.0	24535.0	19738.5	735.3	22201.6

APPENDIX VII CALCULATION OF MORTALITY RATE ACCORDING TO EAR PLUG LAMINATIONS (RYUKYUAN WATERS 1959)

	Male					Female					Total animals				
Number of ear plug lamination	Number of whales examined	Number of whales examined in %	Number of whales from smoothed curve (×10)	Number of whales dead (×10)	Mortality rate	Number of whales examined	Number of whales examined in %	Number of whales from smoothed curve (×10)	Number of whales dead (×10)	Mortality rate	Nubmer of whales examined	Number of whales examined in %	Number of whales from smoothed curve (×10)	Number of whales dead (×10)	Mortality rate
1～5	9	9.9	340	80	23.6	6	6.3	340	80	23.6	15	8.1			
6～10	24	26.4	260	73	28.1	25	26.3	260	73	28.1	49	26.3	270	83	30.7
11～15	17	18.7	187	55	29.4	12	12.6	187	49	26.2	29	15.6	187	51	27.3
16～20	12	13.2	132	34	25.8	18	18.9	138	36	26.1	30	16.1	136	47	34.6
21～25	6	6.6	98	27	27.6	9	9.5	102	30	29.4	15	8.1	99	29	29.3
26～30	5	5.5	71	21	29.6	11	11.6	72	23	31.9	16	8.6	70	20	28.6
31～35	3	3.3	50	15	30.0	5	5.3	49	17	34.7	8	4.3	50	15	30.0
36～40	5	5.5	35	10	28.6	2	2.1	32	12	37.5	7	3.8	35	10	28.6
41～45	3	3.3	25	5	20.0	2	2.1	20	6	30.0	5	2.7	25	7	28.0
46～50	1	1.1	20	4	20.0	1	1.1	14	3	21.4	2	1.1	18	5	27.8
51～55	2	2.2	16	3	18.8	1	1.1	11	2	18.2	3	1.6	13	3	23.1
56～60	2	2.2	13	2	15.4	1	1.1	9	2	22.2	3	1.6	10	2	20.0
61～65	1	1.1	11	3	23.3	1	1.1	7	2.5	35.7	2	1.1	8	2	25.0
66～70	—	—	8	3	37.5	1	1.1	4.5	2.5	55.6	1	0.5	6	2	33.3
71～75	—	—	5	2	40.0	—	—	2.5	2.5	100.0	—	—	4	1.5	37.5
76～80	—	—	3	2	66.7	—	—	0	—	—	—	—	2.5	1.5	60.0
81～85	1	1.1	1	1	100.0	—	—	—	—	—	1	0.5	1	1	100.0
86～90	—	—	0	0	—	—	—	—	—	—	—	—	—	0	

APPEDIX VIII CALCULATION OF MORTALITY RATE ACCORDING TO TOTAL OVULATION NUMBER

	Ryukyuan waters (1959)					Aleutian waters (1952–1958)				
Number of total ovulation	Number of whales	Number of whales in % of matured female	Number of whales from smoothed curve (×10)	Number of whales dead (×10)	Mortality rate	Number of whales	Number of whales in % of matured female	Number of whales from smoothed curve (×10)	Number of whales dead (×10)	Mortality vate
0	38									
1	10	14.3	176	36	20.6	18	12.5	260	40	15.4
2	8	11.4	140	24	17.1	19	13.2	220	39	17.7
3	8	11.4	116	19	16.4	29	20.1	181	38	21.5
4	8	11.4	97	15	15.5	22	15.3	143	32	22.4
5	6	8.6	82	13	15.9	15	10.4	112	27	24.1
6	3	4.3	69	10	14.5	14	9.7	85	25	29.4
7	3	4.3	59	9	15.3	6	4.2	60	17	28.3
8	4	5.7	50	7	14.0	4	2.8	43	11	25.6
9	5	7.1	43	5	11.6	7	4.9	32	7	21.9
10	3	4.3	38	4	10.5	1	0.7	25	5	20.0
11	2	2.9	34	3	8.8	—	—	20	3	15.0
12	3	4.3	31	2.5	8.3	3	2.1	17	2.5	14.7
13	1	1.4	28.5	2.5	8.8	2	1.4	14.5	2.5	17.2
14	3	4.3	26.0	2.0	7.7	1	0.7	12.0	1.5	12.5
15	—	—	24.0	1.5	6.3	1	0.7	10.5	1.0	9.5
16	—	—	22.5	1.5	6.7	—	—	9.5	0.75	7.9
17	—	—	21.0	1.5	7.2	—	—	8.75	0.75	8.6
18	—	—	19.5	1.5	7.7	—	—	8.0	0.75	9.4
19	—	—	18.0	1.5	8.3	—	—	7.25	0.75	10.3
20	—	—	16.5	1.5	9.1	1	0.7	6.5	0.5	7.7
21	—	—	15.0	1.25	8.3	—	—	6.0	0.5	8.3
22	—	—	13.75	1.25	9.1	—	—	5.5	0.5	9.1
23	—	—	12.5	1.25	10.0	—	—	5.0	0.5	10.0
24	—	—	11.25	1.25	11.1	—	—	4.5	0.5	11.1
25	—	—	10.0	1.25	12.5	—	—	4.0	0.5	12.5
26	1	1.4	8.75	1.25	14.3	—	—	3.5	0.5	14.3
27	—	—	7.5	1.25	16.7	—	—	3.0	0.5	16.7
28	1	1.4	6.25	1.25	20.0	—	—	2.5	0.5	20.0
29	—	—	5.0	1.25	25.0	—	—	2.0	0.5	25.0
30	1	1.4	3.75	1.25	33.3	—	—	1.5	0.5	33.3
31	—	—	2.5	1.25	50.0	—	—	1.0	0.5	50.0
32	—	—	1.25	1.25	100.0	1	0.7	0.5	0.5	100.0
33	—	—	0	—	—	—	—	0	—	—

EXPLANATION OF APPENDIX IX

Number of measurement	Name of measured part of the body
1	Total length.
2	Lower jaw, projection beyond tip of snout.
3	Tip of snout to blowhole.
4	Tip of snout to angle of gape.
5	Tip of snout to centre of eye.
6	Tip of snout to tip of flipper.
6′	Tip of snout to anterior insertion of flipper.
7	Eye to ear, centres.
8	Notch of flukes to posterior emargination of dorsal fin.
10	Notch of flukes to anus.
11	Notch of flukes to umbilicus.
12	Notch of flukes to end of ventral grooves.
13	Anus to reproductive aperture, centres.
14	Dorsal fin, vertical height.
15	Dorsal fin, length of base.
16	Flipper, tip to axilla.
17	Flipper, tip to anterior end of lower border.
18	Flipper, length along curve of lower border.
19	Flipper,. greatest width.
21	Skull, greatest width.
22	Skull, length, condyle to tip of premaxilla.
24	Tail, depth at dorsal fin.
24′	Tail, dorsal fin to anus.
24″	Tail, depth at insertion of flukes.
25	Flukes, notch to tip.
25′	Flukes, notch to tip. Left.
25″	Flukes, notch to tip. Right.
26	Flukes, total spread.
27	Flukes, shortest length of notch to anterior border.
31	Length of lower jaw bone.
32	Skull, tip of premaxilla to tip of pterygoid.
33	Skull, distance between tips of both pterygoid.
34	Skull, length of rostrum.
35	Skull, width of base of rostrum.

APPENDIX IX BODY PROPORTIONS OF NORTH PACIFIC HUMPBACK WHALES CAUGHT IN RYUKYUAN AND ALEUTIAN WATERS

Serial number	Caught in	Date of killed	Sex	Number of measurement																															
				1	2	3	4	5	6	6′	7	8	10	11	12	13	14	15	16	17	18	19	21	22	24′	24″	25′	25″	26	27	31	32	33	34	35
R 4	Ryukyuan waters	9, Jan. 1959	F	1340	14 1.0	240 17.9	300 22.4	305 22.8		420 31.3	57 4.3		260 19.4	580 43.3	580 43.3	60 4.5	15 1.1	70 5.2	314 23.4	387 28.9		100 7.5								103 7.7					
K10	〃	18, Jan. 1959	F	1140	15 1.3	195 17.1	245 21.5	260 22.8		390 34.2	52 4.6	360 28.3	290 25.4	310 27.2	490 43.0	40 3.5	25 2.2	110 9.6	288 25.3	350 30.7	370 32.5	95 8.3			245 21.5	70 6.1	200 17.5	195 17.1		90 7.9					
K31	〃	31, Jan. 1959	F	1370	20 1.5	270 19.7	310 22.6	315 23.0		405 29.6	62 4.5	420 30.7	310 22.6	570 41.6	530 38.7	43 3.1	25 1.8	130 9.5							290 21.2	90 6.6	250 18.3		500 36.4	110 8.0					
K37	〃	4, Feb. 1959	F	1265	15 1.9	220 17.4	270 21.3	270 21.3		325 25.7	56 4.4	390 30.8	335 26.5	550 43.5	565 44.7	37 2.9	28 2.2	95 7.5	310 24.5	380 30.0	400 31.6	95 7.5			240 20.0	80 6.3	210 16.6		385 30.4	100 7.9					
K43	〃	15, Feb. 1959	M	1130	13 1.2	215 19.0	265 23.5	265 23.5		340 30.1	52 4.6	365 32.3	330 29.2	500 44.2	480 42.5	100 8.8	25 2.2	90 8.0	285 25.2	340 30.0	365 32.3	90 8.0			215 19.0	75 6.6	210 18.6		390 34.5	88 7.8					
K54	〃	19, Feb. 1959	F	1250	15 1.2	205 16.4	280 22.4	295 23.6		400 32.0	53 4.2	415 33.2	310 24.8	535 42.8	560 44.8	50 4.0	23 1.8	95 7.6	320 25.6	390 31.2	415 33.2	95 7.6			265 21.2	90 7.2	220 17.6		420 33.6	95 7.6					
K57	〃	23, Feb. 1959	M	1165	13 1.2	220 20.1	280 25.6	280 25.6		365 33.4	49 4.5	355 32.5	280 25.6	520 47.5	520 47.5	110 10.0	25 2.3	115 10.5	370 33.8	300 27.4	405 37.0	100 9.1			250 22.8	85 7.8				90 8.2					
R84	〃	7, Apr. 1959	F	1333	17 1.3	256 19.2	294 22.1	294 22.1			58 4.4																								
R88	〃	11, Apr. 1959	F	1430	17 1.9	255 17.8	340 23.8	339 23.7		422 29.5	62 4.3	440 30.7	308 21.5	580 43.3	550 41.2	43 3.0	35 2.4	150 10.5	360 25.2	430 30.1	456 31.9									103 7.2					
N38	〃	14, Apr. 1959	M	1270	15 1.2	240 18.9	300 23.6	295 23.2		390 30.7	58 4.6	390 30.7	275 21.6	530 41.7	510 40.2	90 7.1	25 2.0	130 10.2	335 26.4	415 32.7	460 36.2	110 8.7			240 18.9	95 7.5	235 18.5			110 8.7					
Fetus of R43	〃	27, Feb. 1959	M	390	5 1.3	55 14.1	70 17.9	74 20.0		113 5.0	22 5.6	130 33.3	104 26.7	169 43.3	173 44.4	35 9.0	12 3.1	42 10.8	103 26.4	127 32.6	140 35.9	33 8.5			75 19.2	35 9.0	60 15.4		100 25.6	41 10.5					
28	Aleutian waters	26, July 1952	M	1238 41 feet		260 21.0		275 22.2			45 3.6	390 31.5	310 25.0	530 42.8	510 41.2	100 8.1	25 2.0	60 4.8		410 33.1		110 8.9	195 15.8	350 28.3							335 27.1	345 27.9	150 12.1	235 19.0	98 7.9
96	〃	24, July 1952	M	1170 38 feet		220 18.8		265 22.6	410 35.0		50 4.3	380 32.5	295 25.2	500 42.7	500 42.7	85 7.3	22 1.9	95 8.1		355 30.3		86 7.4	200 17.1	330 28.2							330 28.2	325 27.8	150 12.8	240 20.5	100 8.5
133	〃	19, Aug. 1952	M	1129 37 feet				290 25.7			40 3.5	300 26.6	270 23.9	470 41.6	460 40.7	40 3.5	16 1.4	83 7.4		370 32.8		90 8.0	207 18.3	345 30.6							352 31.2	330 29.2	149 13.2	220 19.5	103 9.1
570	〃	3, Sept. 1953	M	1225 40 feet		245 20.0		300 24.5	445 36.3		55 4.5	405 33.1	275 22.4	490 40.0	490 40.0	105 8.6	23 1.9	85 6.9		355 29.0		100 8.2	205 16.7	350 28.6							355 29.0	355 29.0	185 15.1	250 20.4	105 8.6
594	〃	6, Sept. 1953	F	1390 46 feet		310 22.3		365 26.3	595 42.8		50 3.6	440 31.7	310 22.3	550 39.6	525 37.8	45 3.2	21 1.5	100 7.2		440 31.7		110 7.9	235 16.9	430 30.9							435 31.3	430 30.9	190 13.7	315 22.7	125 9.0
661	〃	24, Sept. 1953	F	1210 40 feet		270 22.3		290 24.0	360 29.8		45 3.7	370 30.6	290 24.0	500 41.3	500 41.3	50 4.1	28 2.3	115 9.5		380 31.4		100 8.3	170 14.0	345 28.5							360 29.8	350 28.9	145 12.0	250 20.7	100 8.3
674	〃	25, Sept. 1953	M	1165 38 feet		230 19.7		300 25.8	385 33.0		55 4.7	355 30.5	285 24.5	470 40.3	480 41.2	110 9.4	23 2.0	110 9.4		355 30.5		100 8.6	195 16.7	345 29.6							365 31.3	345 29.6	145 12.4	245 21.0	100 8.6
676	〃	25, Sept. 1953	F	1180 39 feet		215 18.2		275 23.3	400 33.9		55 4.7	380 32.2	290 24.6	505 42.8	515 43.6	50 4.2	27 2.3	105 8.9		375 31.8		89 7.5	180 15.3	335 28.4							345 29.2	335 28.4	145 12.3	240 20.3	90 7.6
Fetus of 676	〃	25, Sept. 1953	M	245 8 feet		32 13.1		45 18.4			15 6.1	77 31.4	58 23.7	95 38.8	118 48.2	19 7.8	6 2.5	17 6.9		75 30.6															

Data from Aleution waters were measured by Messrs. K. Fujino and T. Nemoto of the Whales Research Institute.

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GLYCEROL-FREEZING TECHNIQUE AS AN AID IN BLOOD TYPING OF WHALES*

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This paper describes the application of the glycerol-freezing preservation technique to blood type studies on whales. Following the lead of recent trends in anthropology (cf. Mourant, 1954), blood type antigens are receiving increasing attention as "genetic tags" useful as aids in the definition of intraspecific populations of marine animals (cf. Fujino, 1956; Ridgway et al., 1958; Suzuki et al., 1958). Method for preserving intact erythrocytes between the time of their collection and serological characterization are therefore of considerable interest. In contrast to samples of human or animal bloods which often can be taken and preserved under controlled conditions (Stormont et al., 1958; Strumia, 1958), the erythrocytes of marine forms are usually collected where sterile and other precautions are not practical. (Of note is the fact that whale erythrocytes can be preserved for one month or longer by the addition of the antimicrobial, guanofuracin, 5-Nitro-2-furfurylidine-aminoguanidine Hydrochloride, Toyama Chemical Co., Tokyo).

Preliminary studies on fish (Cushing, 1956; Cushing et al., 1957) having shown that the glycerol-freezing technique offered considerable promise, efforts were made to learn of its suitability for large scale research. This technique has been in use in various laboratories concerned with human and domestic animal blood type studies since it was first applied to blood bank research (cf. Kabat, 1956, p. 92 for a review of this subject). The general method employed here is based on consideration of the various researches noted above. The typing techniques and methods used are the same as described in earlier papers on the blood typing of marine animals (see above). (Of basic significance are the facts that erythrocytes hemolyze completely if frozen and thawed in the absence of glycerol (or related preservatives such as ethylene glycol), and that glycerol inhibits agglutination reactions very markedly in concentrations suitable for preservation.

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The application of the glycerol-freezing technique will be taken up by separate species.

Finback whales (*Balaenoptera physalus*).

Samples of blood from finback whales were first preserved by glycerol-freezing in the summer of 1957, when six were obtained through the courtesy of Mr. Charles Caito, Whaling Station, Del Monte Fishing Co., San Francisco, California. There were part of a collection made by Mr. Caito from whales captured off San Francisco by his company. The success of these efforts and of a small collection of finback samples taken in 1957 (Fujino) led to the collection of 460 finback samples from the north Pacific during the months of June, July and August 1958. This collection was made under the supervision of Mr. K. Nasu, Whales Research Institute, Tokyo.

Samples from these whales were taken during the flensing of carcasses on the factory ship. While these whales had been dead for from a half to twenty six hours (seven and a half hours in average) at the time of sampling, the biological log showed that this variability had no effect on subsequent sample condition. 2.5 ml. or 125 ml. of whole blood were mixed with an approximately equal volume of a solution consisting of four parts of glycerol and six parts of a five percent solution of trisodium citrate. (As an additional precaution against accidental warming guanofuracin had been added to this mixture at 200 mg. per 100 ml. However, the use of antimicrobials is not essential to the success of the glycerol-freezing method). The samples were kept at 5°C for 2 to 16 days on the factory ship until a box of 50 was accumulated. This box was then transferred to a refrigerator ship and kept at −20°C until the eventual recovery of samples for study at Tokyo University.

Analysis started four months after collection of the last samples and included a set of fifteen 125 ml. samples taken eight months before in the Antarctic. Intact erythrocytes were recovered by dialysis at room temperatures for two hours against 1.5% saline, followed by several times' washing. Cells prepared in this manner remained in good condition for several days at refrigeration temperatures, being rewashed at the start of each day's work. It was found convenient to handle from fifteen to twenty 10 ml. aliquots of samples per day, but this number could have been greatly expanded with additional assistance. Aliquots could be removed with a spatula without thawing samples, or obtained by thawing the samples under running tap water. Several freezings and thawings did not appear to affect the fragility of the cells.

Varying degrees of initial hemolysis were found in almost all samples, but good yields of cells were obtained from all the large samples (total=15 bottles), and from all but 30 of the small samples (total=450 bottles). Of these 19 came from a single box of fifty which apparently had not been refrigerated properly. The reasons for hemolysis have not yet been studies, but it was found that smaller samples (e.g. 5 ml.) showed more tendency to hemolyze than larger ones (e.g. 250 ml). In addition to hemolysis, the yield of cells also is influenced by internal sedimentation and clotting in the body of the whale following death, so that care should be taken to collect from blood vessels that appear to contain relatively high concentrations of erythrocytes.

The Ju system of antigens (Fujino, 1956, 1958) was selected for detailed study. The authors have found no reason to believe that either the specificities or titers of the serological reactions of this system were altered during the period of freezing. Various absorptions also showed that the cells were as useful in this work as unfrozen ones. Table 1 shows that the frequencies of antigens as distributed

TABLE 1. COMPARISON OF FREQUENCIES OF FINBACK Ju TYPES EXAMINED BY FRESH AND GLYCEROL PRESERVED CELLS

Area	East China Sea				off Kamchatka				off Navarin			
Ju blood type	1	1.2	2	Sum	1	1.2	2	Sum	1	1.2	2	Sum
Fresh cells a)	95	13	21	129 c)	329	27	73	429 d)	—	—	—	no data
Frozen cells b)	—	—	—	no data	113	1	5	119 e)	71	2	3	76

Area	off Oleutorskie				South of east Aleutian				North of east Aleutian			
Ju blood type	1	1.2	2	Sum	1	1.2	2	Sum	1	1.2	2	Sum
Fresh cells a)	—	—	—	no data	29	1	2	32	1401	9	17	1427
Frozen cells b)	13	0	0	13	167	4	6	177	74	0	1	75 f)

a) East China Sea examined in 1956 and 1957, other areas in 1954 and 1955.
b) Examined in 1958 only.
c) Fujino, unpublished data.
d) Yearly and seasonal fluctuations have been observed.
e) May be distinguished into two separate operating seasons in 1958 in which seasonal fluctuations were seen.
f) May be distinguished into two operating seasons in 1958 in which no seasonal fluctuation was seen.

in the north Pacific finbacks are comparable with those observed in earlier studies.

Various observations suggest that cells with Ju 2 specificities may tend to slightly more fragile than those of Ju 1 type. These include field observations on fresh cells, and laboratory observations on recovered cells. This possibility has not yet been confirmed, but it is important to keep in mind in general, as the rejection of badly hemolyzed samples without typing might conceivable bias frequency counts in future studies. In this particular study, observations on the agglutination of ghosts and residual cells, as well as inhibition tests (Table 2), made it possible to type all the badly hemolysed samples.

TABLE 2. EXAMPLES OF THE AGGLUTINATION-INHIBITION TESTS OF FINBACK JU 2 TYPE CELLS (NO. 14) BY SUCCESSIVE DILUTIONS OF THE DIALYSED SUPERNATANT FROM JU 2 TYPE WHOLE BLOODS (NO. 14)

Dilutions of no. 14 supernatant:	Dilution of horse serum				
	32	64	128	256	512
2	+	−	−	−	−
4	+	−	−	−	−
8	+	+	−	−	−
16	++	+	±	−	−
32	+++	+++	+	−	−
64	+++	+++	++	+	−
Saline control	+++	+++	++	++	+

Each test was made by mixing one drop of supernatant with one drop of serum diluted, and fifteen minutes later, adding one drop of cell suspension. Reaction were read thirty minutes later.

The availability of frozen cells also made it possible to discover antibodies in the normal serums of the horse, pig and sheep (only one individual each was studied) that reacted specifically with cells carrying the Ju 2 factor. The use of horse and pig serum, combined with rabbit immune serum, has revealed variations in the agglutination titer of Ju 2 cells of different types that resemble similar variations in other species. Examples of these differences are shown in Table 3. At present it is not known whether these are due to quantitative or qualitative variations among the factors involved. The specificity and relative avidity of horse and pig serums for different Ju types were found to parallel exactly the reactions of immune serums with these types. All these serums were used in this series of typings and the relative frequencies of homozygotes and heterozygotes were found to be same as in previous years.

Inspection of these observed relative frequencies (Table 1) shows that they deviate from those that would be expected for a two allele system

TABLE 3. VARIATIONS IN THE AGGLUTINATION TITERS OF CELLS WITH DIFFERENT FINBACK Ju SPECIFICITIES

a) Examples of reactions with normal animal serums

		Dilution of animal serums												
Finback whale cells:		Horse						Pig						
		16	32	64	128	256	512	4	8	16	32	64	128	256
Ju 2 type	No. 2	⧻	⧻	⧻	⧻	+	+	⧻	⧻	⧻	⧻	⧻	⧺	+
	No. 14	⧻	⧻	⧻	⧻	⧺	+	⧻	⧻	⧻	⧻	⧻	⧺	+
Ju 1 Ju 2 type	No. 116	⧻	⧺	+	−	−	−	⧺	+	−	−	−	−	−
	No. 184	+	+	−	−	−	−	⧺	±	−	−	−	−	−
Ju 1 type	No. 12	−	−	−	−	−	−	−	−	−	−	−	−	−
	No. 13	−	−	−	−	−	−	−	−	−	−	−	−	−

b) Examples of reactions with immune serums

		Dilution of anti-Ju 2 immune no. 34 serum												
Finback whale cells:		Unabsorbed								Absorbed by Ju 1 cells				
		80	160	320	640	1280	2560	5120	10240	80	160	320	640	1280
Ju 2 type	No. 2	⧻	⧻	⧻	⧻	⧻	⧺	⧺	+	⧻	⧻	⧺	⧺	+
	No. 14	⧻	⧻	⧻	⧻	⧻	⧻	⧺	+	⧻	⧻	⧻	⧺	+
Ju 1 Ju 2 type	No. 116	⧻	⧻	⧻	⧺	+	−	−	−	⧻	+	−	−	−
	No. 184	⧻	⧻	⧺	+	+	−	−	−	⧻	±	−	−	−
Ju 1 type	No. 12	⧺	+	±	−	−	−	−	−	−	−	−	−	−
	No. 13	⧺	+	−	−	−	−	−	−	−	−	−	−	−

		Dilution of anti-Ju 1 immune no. 47 serum								
Finback whale cells:		Unabsorbed					Absorbed by Ju 2 cells			
		80	160	320	640	1280	5	10	20	40
Ju 2 type	No. 2	⧻	⧻	⧻	⧺	+	−	−	−	−
	No. 14	⧻	⧻	⧻	⧺	+	−	−	−	−
Ju 1 Ju 2 type	No. 116	⧻	⧻	⧻	⧺	+	⧻	⧺	+	−
	No. 184	⧻	⧻	⧻	⧺	+	⧻	⧺	+	−
Ju 1 type	No. 12	⧻	⧻	⧻	⧺	+	⧻	⧺	+	−
	No. 13	⧻	⧻	⧻	⧺	+	⧻	⧺	+	−

of antigens in populations in Hardy-Weinberg equilibria. It is too early to state which of the several possible factors that might be expected to cause this deviation are actually the responsible ones. (cf. Srb and Owen, 1952 for an introductory discussion of the Hardy-Weinberg equilibrium).

Blue white dolphins (Stenella caeruleo-albus).

Blood samples were taken from thirty blue white dolphins captured January 1, 1959 on the east side of the Izu Peninsula, Shizuoka Pref., Japan. These samples, 25 ml. of whole blood each, were collected into glycerol solution, frozen with dry ice and returned to Tokyo. A parallel set of samples from the same individuals was collected into citrate-guanofuracin solution, as described above, and returned to Tokyo unfrozen. Almost all samples gave good yields of cells after one month, and the frozen samples gave good yields of cells after three months. The agglutinin titers and specificities of cells obtained at this time did not differ materially from those of freshly collected, unfrozen and frozen cells as determined in January. These dolphin cells were used in various studies, including the work on radioactive antibodies reported in this volume (Fujino et al., 1959).

Humpback whale (*Megaptera nodosa*).

Cells from twenty five humpback whales were among the samples obtained from Mr. Charles Caito at San Francisco. These were preserved by freezing (50 ml. of whole blood per sample) and almost all gave sufficient cells for study, although like the finback whales, varying degrees of hemolysis occurred.

A second collection of one hundred and five humpback whale bloods (25 ml. of whole blood per sample) were obtained from shore stations on Okinawa, Ryukyu Islands. These were collected under the supervision of Dr. M. Nishiwaki, Whales Research Institute, whose special efforts in this regard are greatly appreciated (see Nishiwaki, this volume). These samples were stored at −20°C and were returned to Tokyo by air where they were examined two months after collection. Sufficient cells were obtained from all samples excepting 5. Of these, 3 were left in the room temperatures (20∼22°C) before freezing for 8 hours or longer in which decomposition had started.

Table 4 shows the reactions of anti-finback Ju 2 no. 34 serum (sent to California by Fujino) with finback and humpback erythrocytes collected

TABLE 4. THE REACTIONS OF ANTI-FINBACK JU 2 No. 34 SERUM WITH FINBACK AND HUMPBACK ERYTHROCYTES COLLECTED OFF SAN FRANCISCO, U.S.A.

	Unabsorbed				Absorbed by finback Ju 1 cells 4:			
Finback cells:	50	100	200	400	50	100	200	400
Ju 1 (4)	⧻	⧻	⧻	+	−	−	−	−
Ju 1 (10)	⧻	⧺	⧺	+	−	−	−	−
Ju 1 (25)	⧻	⧺	+	−	−	−	−	−
Ju 2 (31)	⧻	⧻	⧻	⧻	⧻	⧻	⧻	⧺
Humpback cells:								
8	⧻	⧻	⧻	⧺	⧻	⧻	⧺	−
19	⧺	+	−	−	−	−	−	−
24	⧻	⧻	±	−	−	−	−	−
27	⧻	⧺	+	−	−	−	−	−
33	⧺	+	±	−	−	−	−	−
34	⧻	⧻	+	−	−	−	−	−

This table presents evidence that the humpback varies individually with respect to an antigen with specificities related to the Ju 2 antigen of the finback. Additional evidence for a Ju-like system in humpbacks is shown Tables 5 and 6.

off San Francisco. As the reactions show, humpback cells vary individually with respect to an antigen with Ju2-like specificities (cf. Fujino, 1958). Further studies on humpbacks collected off Okinawa have led to a tentative grouping of individuals into four types with respect to the Ju-like antigens. The first three of these types react positively to varying degrees with Ju 2 specific serums, while the fourth does not. The individuals in the different types are as follows: Type 1, K-9; Type 2, K-24, K-61, N-12 and R-82; Type 3, R-10, R-29, R-48, R-66, K-12 and K-81; Type 4, K-4 and all other individuals excepting R-45. This individual reacted positively with Ju 2 serums, but could not be studied sufficiently to decide whether it belonged to type 2 or type 3.

Table 5 illustrates typical reactions of each cell type with respect to anti-finback Ju serums. These show that a reciprocal relationship exists among the types that strengthens the argument that humpbacks vary with respect to Ju-like antigens.

TABLE 5. AGGLUTININ TITERS OF IMMUNE ANTI-FINBACK Ju SERUMS AGAINST DIFFERENT TYPES OF HUMPBACK ERYTHROCYTES FROM OKINAWA

Humpback whale cells: Type	no.	Anti-finback Ju 1 serum												
		Unabsorbed								Absorbed by K9 cells				
		40	80	160	320	640	1280	2560	5120	40	80	160	320	640
1	K 9	⧻	⧺	⧺	⧺	+	−	−	−	−	−	−	−	−
2	K24	⧻	⧻	⧻	⧻	⧻	⧺	+	−	⧻	⧺	+	−	−
3	R29	⧻	⧻	⧻	⧻	⧻	⧺	+	−	⧻	⧺	+	−	−
4	K 4	⧻	⧻	⧻	⧻	⧻	⧺	+	+	⧻	⧻	⧺	+	−

Humpback whale cells: Type	no.	Anti-finback Ju 2 serum												
		Unabsorbed							Absorbed by K4 cells					
		40	80	160	320	640	1280	2560	20	40	80	160	320	640
1	K 9	⧻	⧻	⧻	⧻	⧻	⧺	+	⧻	⧻	⧻	⧺	+	+
2	K24	⧻	⧻	⧺	+	−	−	−	⧻	⧺	+	±	−	−
3	R29	⧺	+	−	−	−	−	−	+	−	−	−	−	−
4	K 4	+	−	−	−	−	−	−	−	−	−	−	−	−

That the relations among the Ju 2 positive types (1, 2 and 3) are complex is illustrated by Table 6 which summarizes the results of reactions of different cell types with anti-finback Ju 2 no. 34 serum following absorption with different type cells.

Isoagglutinins, similar to those described by Fujino (1952), were easily recovered in the supernatants of dialysed samples at approximate dilutions of one in two from whole blood. These could be used directly, or freed from excessive hemoglobin through salting-out by one third saturation with ammonium sulfate. The relationship of isoagglutinins to antigenic types is shown in Table 7. These parallel the results of Ju 2

TABLE 6. THE REACTIONS OF DIFFERENT CELL TYPES WITH ANTI-FINBACK Ju 2 No. 34 SERUM ABSORBED IN VARIOUS WAYS

a) Cross-absorption reactions, serum dilution one in ten

Absorbing cells: Type	no.	Test cells: K 9	N12	K24	K61	R10	R29	R48	K 4
1	K 9	−	−	−	−	−	−	−	−
2	N12	⧻	−	−	−	−	−	−	−
2	K24	⧻	−	−	−	−	−	−	−
2	K61	⧻	−	−	−	−	−	−	−
3	R10	⧻	⧺	⧺	⧺	−	−	−	−
3	R29	⧻	⧺	⧺	⧺	−	−	−	−
3	R48	⧻	⧺	⧺	⧺	−	−	−	−
4	K 4	⧻	⧻	⧻	⧻	⧺	⧺	⧺	−

b) Agglutinin titers after progressive absorptions

	Test cells: Type	no.	Dilution of serum: 10	20	40	80	160	320	640	1280
Absorbed by K4 cells	1	K 9	⧻	⧻	⧻	⧻	⧺	+	+	−
	2	N12	⧻	⧻	⧺	+	±	−	−	−
	2	K24	⧻	⧻	⧺	+	±	−	−	−
	2	K61	⧻	⧻	⧺	+	±	−	−	−
	3	R10	⧺	+	−	−	−	−	−	−
	3	R29	⧺	+	−	−	−	−	−	−
	4	K 4	−	−	−	−	−	−	−	−
Absorbed by K4 and R29 cells	1	K 9	⧻	⧻	⧺	+	−			
	2	N12	⧺	+	−	−	−			
	2	K24	⧺	+	−	−	−			
	2	K61	⧺	+	−	−	−			
	3	R10	−	−	−	−	−			
	3	R29	−	−	−	−	−			
	4	K 4	−	−	−	−	−			
Absorbed by K4, R29 and K61 cells	1	K 9	⧻	⧻	⧺	+	−			
	2	N12	−	−	−	−	−			
	2	K24	−	−	−	−	−			
	2	K61	−	−	−	−	−			
	3	R10	−	−	−	−	−			
	3	R29	−	−	−	−	−			
	4	K 4	−	−	−	−	−			

TABLE 7. THE RELATIONS OF HUMPBACK ISOAGGLUTININS TO CELL TYPES

Isoagglutinins in serum from supernatant:	Type of test cells: 1 K 9	2 K24	3 R10	3 R29	4 K 4	4 R38
K 9	−	−	−	−	−	−
K24	⧻	−	−	−	−	−
R10	⧻	+	−	−	−	−
R29	⧻	−	−	−	−	−
K 4	⧻	⧺	+	+	−	−
R38	⧻	+	−	−	−	−

The isoagglutinins in the undiluted supernatants of dialysed samples. Additional data were obtained from the other Ju 2 positive types and eight negative individuals that conformed with the observations shown above.

serum absorptions, excepting for the individual serum variations within types as shown. (One explanation for this variation simply could be differences in titers of the antibody fractions concerned).

As in the finback whale, natural antibodies were found in the serums of various animals that reacted positively with cells showing Ju 2-like specificities (Table 8). As far as studied the reactions of these serums appears to be similar to that of the immune serums and isoagglutinins already described, and shows that normal serums will provide a useful source of antibody for further research.

TABLE 8. INDIVIDUAL VARIATIONS IN THE REACTIONS OF HUMPBACK ERYTHROCYTES WITH NORMAL ANIMAL SERUMS

Okinawa sample

Humpback erythrocytes: Type no.		Pig				Sheep-1				Sheep-2			
		4	8	16	32	4	8	16	32	4	8	16	32
1	K 9	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++
2	N12	+++	++	+	−	+	±	−	−	++	+	−	−
3	R48	−	−	−	−	−	−	−	−	−	−	−	−
4	R14	−	−	−	−	−	−	−	−	−	−	−	−

Type	no.	Horse (unabsorbed)							Horse (absorbed with R-45 cells)						
		8	16	32	64	128	256	512	8	16	32	64	128	256	512
1	K 9	+++	+++	+++	+++	+++	++	+	+++	+++	+++	+++	+++	++	+
2	K24	+++	+++	+++	+	−	−	−	+++	++	±	−	−	−	−
3	R48	++	+	−	−	−	−	−	−	−	−	−	−	−	−
4	K 4	−	−	−	−	−	−	−	−	−	−	−	−	−	−
2 or 3	R45	+++	+++	+++	±	−	−	−	−	−	−	−	−	−	−

San Francisco samples

No.	Sheep (unabsorbed)						Sheep (absorbed with 1 cell)					
	2	4	8	16	32	64	2	4	8	16	32	64
1	++	+	±	±	−	−	−	−	−	−	−	−
8	+++	+++	+++	++	+	±	+++	+++	++	+	±	−
15	+++	++	+	±	−	−	+	+	−	−	−	−
28	+++	++	+	±	−	−	+	±	±	−	−	−
29	+++	+++	+++	+	+	±	+++	++	±	−	−	−

This table shows the potential usefulness of normal animal serums in population studies on humpbacks.

While not enough work has been done to establish a genetic hypothesis explaining the interrelations of humpback blood types, it is obvious that more than two Ju-like alleles are involved, and probable that these can exhibit both quantitative and qualitative differences with respect to each other.

Table 9 shows that even in the present state of our knowledge the humpback Ju antigens provide us with genetic markers that will be very useful in population research.

TABLE 9. THE RELATIVE FREQUENCIES OF OCCURRENCE OF DIFFERENT CELL TYPES IN THE POPULATION OF HUMPBACK SAMPLES FROM OKINAWA

	Type				unclassified	not tested (hemolysed)	total no. of samples
	1	2	3	4			
No. of samples of each type	1	4	7	87	1	5	105

TABLE 10. SUMMARY OF TEMPORARY CLASSIFICATION OF HUMPBACK BLOOD TYPES AS DETERMINED BY FINBACK Ju SPECIFICITIES

		Type of test cells:			
		1	2	3	4
Type of absorbing cells:	1	−	−	−	−
	2	+	−	−	−
	3	+	+	−	−
	4	+	+	+	−

Additional species.

Two samples of sperm whale (*Physeter catodon*) blood from San Francisco, and one of the True's Porpoise (*Phocaena dallii truei*) from northern Japan have been collected and successfully recovered. Studies on the preservation of fur seal (*Callorhinus ursinus*) blood also are proving successful. Recently Suzuki et al. (1958) have reported successful use of the glycerol-freezing technique in the investigation of antigenic differences in tunas. They have evidence, from cells collected in this manner, that shows population differences between the blood types of albacore from the Pacific and Indian Oceans.

DISCUSSION AND SUMMARY

The above survey shows that it is possible to adapt on a large scale the glycerol-freezing method of erythrocyte preservation as an aid in whale blood type studies. The method is simple and well suited to the rough conditions of field collection, providing refrigeration and freezing equipment is available, and reasonable care is taken by the collector. While the technique has proven adequate in its present form, further research is desirable in order to control hemolysis, determine optimum sample size, examine the effectiveness of ethylene glycol and related compounds etc. (cf. Strumia et al., 1958; Stone, 1957). Attention is called in this regard to the facts that some species of fish vary with respect to the relative fragility of their erythrocytes (Cushing, Ridgway, Suzuki, unpublished data), that marine teleosts are variable with respect to the isotonicity of their blood (Green, 1953) and that the erythrocytes of some fishes are remarkably sensitive to traces of silver ion in sodium chloride solutions (Ball, 1933).

The usefulness of the glycerol freezing technique is illustrated in several specific ways in the present study. These include the accumulation of additional data on the frequencies of Ju blood types in finback whales, the discovery of antigens in humpback whales that are closely related to the Ju antigens of finback whales, and the demonstration of antibodies in the serums of various domestic animals that are highly specific for the Ju2 type antigens in both whale species.

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BLOOD TYPING OF DRIED WHALE ERYTHROCYTES WITH ^{131}I LABELLED ANTIBODY[*]

KAZUO FUJINO AND JOHN E. CUSHING[**]

Blood typing techniques and concepts are now being applied in population studies of several species of marine vertebrates important in fisheries (Fujino, 1956; Suzuki, Shimizu & Morio, 1958; Ridgway, Cushing & Durall, 1958). A major problem of this work is the preservation of samples of blood until they can be brought into a laboratory for analysis. One method of preservation that has been found to be useful is that of glycerol-freezing (Cushing, Fujino & Takahashi, 1959). The present paper is a continuation of research initiated by the senior author (Fujino, 1958) on the possibility of developing another method, using dried blood and radioactive antibody. The usefulness of ^{131}I labelled antibody for this purpose was suggested by a variety of researches (for example, Pressman & Eisen, 1950; Bournsnell, Coombs & Rizk, 1953).

MATERIAL AND METHOD

Blood samples from blue-white dolphins (*Stenella caeruleo-albus*) were taken from individuals captured at Ito, Shizuoka Prefecture. Dried samples were prepared by diluting one part of fresh whole blood with nine parts of 1.5% NaCl solution, being careful to equilibrate the colorimetric concentration of different samples. Single drops of diluted blood were spotted on pieces of filter paper (Toyo filter paper No. A.5) and allowed to dry at room temperatures. These samples were then preserved in a dessicator until they were used, approximately three months after collection. A second set of dolphin bloods was preserved by glycerol-freezing as described in the paper on this subject cited above (Cushing, Fujino & Takahashi, 1959).

The antiserum used was prepared by injecting a rabbit with fresh dolphin cells from a single individual (S. 23). Absorption of the antiserum obtained with heterologous dolphin cells (S. 25) left antibodies specific to the homologous cells as shown in Table 1. (The antigen

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TABLE 1. AGGLUTININ TITER OF ANTI-23 DOLPHIN SERUM IN EACH STAGE OF TREATMENT

Treatment of antibody	Before or after absorb. by S. 25. dolphin cells	Dolphin cells used for agglutination	Dilution of antibody							
			8	16	32	64	128	256	512	1024
Before salting-out	before	S.23	⧺	⧻	⧻	⧻	⧻	⧺	+	−
		S.25	⧻	⧻	⧻	⧺	+	−	−	−
	after	S.23	⧻	⧺	+	+	−	−	−	−
		S.25	−	−	−	−	−	−	−	−
After salting-out	before	S.23	⧻	⧻	⧻	⧻	⧺	+	−	−
		S.25	⧻	⧻	⧻	⧺	+	−	−	−
	after	S.23	⧻	⧺	+	±	−	−	−	−
		S.25	−	−	−	−	−	−	−	−
After iodination	before	S.23	⧻	⧻	⧻	⧺	⧺	+	−	−
		S.25	⧻	⧻	⧺	+	−	−	−	−
	after	S.23	⧻	⧺	+	±	−	−	−	−
		S.25	−	−	−	−	−	−	−	−

involved has not yet been related to the Dc system previously described for this species by Yamaguchi & Fujino, 1952).

Iodination procedures followed those described by Pressman & Eisen (1950). Antibody gamma-globulin was precipitated from the immune serum following one third saturation with ammonium sulfate at ph 7.0. The ammonium sulfate was removed from the gamma-globulin fraction by a series of dialysis against isotonic saline, and against carbowax of molecular weight 1,500 (Arai, Sakagishi & Nomiyama, 1956). The solution was restored to its original volume following dialysis. The success of dialysis was checked with barium chloride indicator.

The protein concentration of the final preparation was determined chemically by the semi-micro Kjeldahl method, and colorimetrically with the Beckman spectrophotometer at wave length 545 *mμ* using Sols' Biuret reagent (Sols, 1947; Matsumoto & Kanamitsu, 1955). A conversion factor was calculated as follows: $P=1.16 \cdot D$, where P is the concentration of protein nitrogen in *mg.* per *ml.* and D ($= ln\, I_0/I$) is the optical density per 1 *cm.* depth of solution at wave length 545 *mμ*.

Radioactive iodine ^{131}I, manufactured by the Radiochemical Centre, Amersham, England, was used for labelling the antibody. This is prepared as the sodium iodide in 0.01 *N* sodium thiosulfate. Iodination was accomplished by adding the iodinating solution (0.1 *ml.* of 0.01 *M* potassium iodide, 1.0 *ml.* of carrier free ^{131}I at 0.1 *mc.*, 1 drop of 1 *M* sodium nitrite and 0.2 *ml.* of 2.5 *N* hydrochloric acid) to a solution containing 15.0 *mg.* of gamma-globulin in 2 *ml.* of borate buffer at ph 8.0 (0.16 *N* sodium hydroxide, 0.2 *M* boric acid in 0.16 *M* sodium chloride). After five minutes the ph of this solution was adjusted to 8.0 with 2.5 *N* sodium hydroxide. Twenty minutes later dialysis was started against saline and carbowax as before.

After dialysing, completion of removal of the uncoupled ^{131}I was checked by the radioautography from paperchromatograph of iodinated antibody as well as by counting of radioactivity of dialysates with G-M counter. Fig. 1 shows an example of radioautographs made of an anti-finback whale serum that demonstrate the method used. These show that the serum proteins have been successfully iodinated and that the free ^{131}I was removed successfully by dialysis.

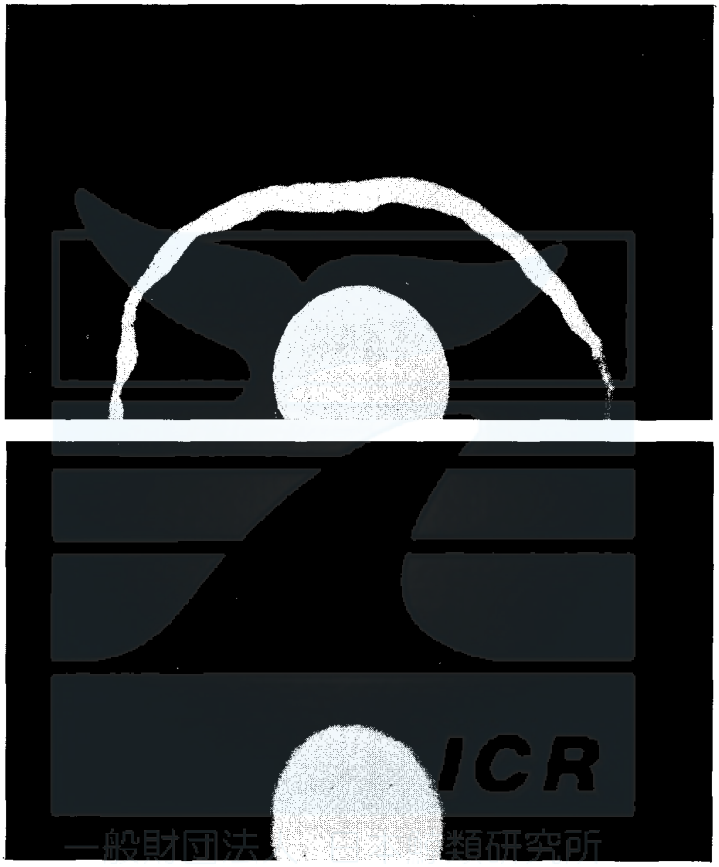

Fig. 1. Radioautographs from paperchromatograms of iodinated antibody, showing the complete removal of uncoupled ^{131}I from iodinated anti-finback antibody, Toyo filter paper 5A, 50 minutes diffusion in solvent which consists of 1 part of acetic acid, 3 parts of normal butyl alcohol and 4 parts of distilled water, Fuji-X-ray film, 6 hrs. exposed, upper: just after iodination, lower: after removal of uncoupled ^{131}I by dialysis. The central spot in each autograph shows the location of iodinated anti-body-gamma-globulin. The band in the upper figure shows the location of migrating uncoupled ^{131}I. This band is absent in the lower figure after a comparable time of diffusion.

TABLE 2. RESULTS OF COUNTING TOTAL RADIOACTIVITY OF BLOOD SPOTS ON FILTER PAPER

Experiment	Dolphin cells	Count of radioactivity in c.p.m.[1]
Preliminary test with intact cells	S. 23	1811±294
	S. 25	51± 31
Test with dried materials	S. 23	4077±748
	S. 25	221± 76

[1] Mean values and standard deviations of five separate experiments. Cells were treated at a dilution 1:8 with iodinated antibody previously absorbed with S. 2.5 cells.

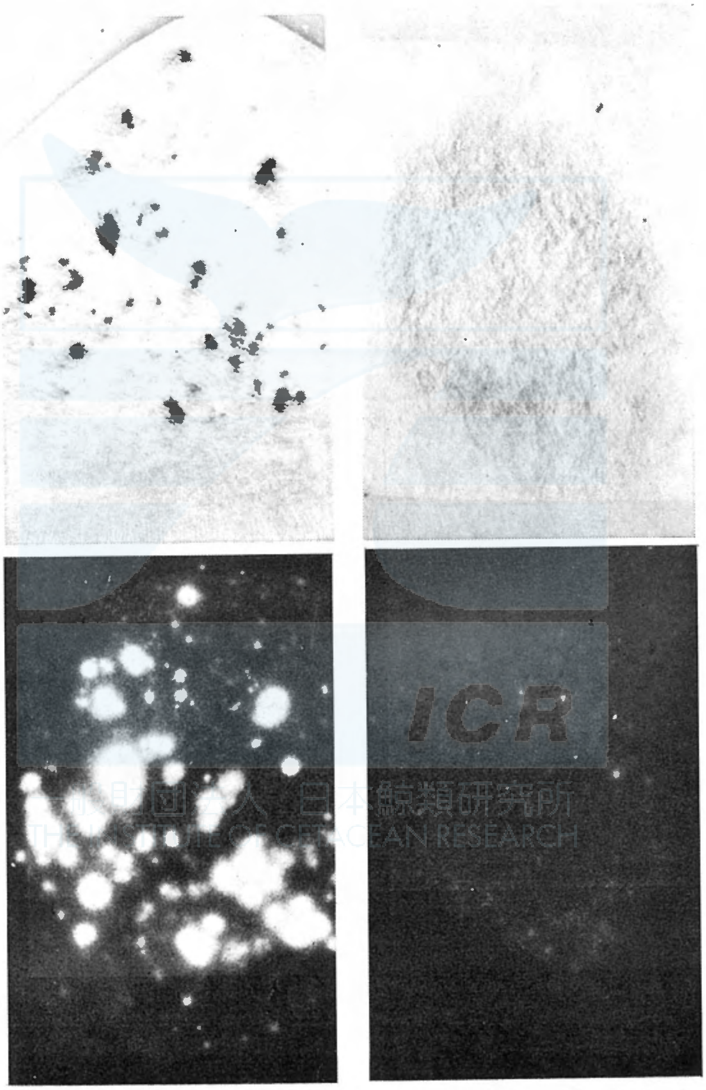

Fig. 2. Spots of dolphin cells on filter paper and their radioautographs after treatment by ^{131}I-labelled antibody, Fuji-X-ray film, 100 hrs. exposed, left: positive antigen-antibody reaction of S. 23 cells, right: negative antigen-antibody reaction of S. 25 cells.

BLOOD TYPING PROCEDURE

After titration the labelled antiserum was absorbed three times with the cells of dolphin S-25 which removed antibodies capable of reacting with antigens common to both individuals, as well as the remaining traces of uncoupled ^{131}I (Table 1).

The reactions of the absorbed antiserum with intact erythrocytes were observed first. Three drops of a two percent cell suspension from dolphin S-23 were added to a test tube containing three drops of one in eight dilution of the absorbed antiserum. A similar mixture was made with S-25 cells as a control. After thirty minutes each of the cell suspensions was centrifuged and was washed twelve times with saline to remove uncombined antibody. The whole washed cells were spotted on filter paper, dried at room temperatures, and their total radioactivity was determined by G–M counter and radioautograph. The results of these determinations, Table 2 and Fig. 2, show that the cells of dolphin S-23 absorbed much more labelled protein than did those of S-25.

Samples of blood dried on filter paper strips were moistened by diffusion in four percent ammonium sulfate and then placed with their ends in the same solution (Fig. 3). When diffusion had started, equal sized drops of absorbed antiserum (one in eight dilution) were placed so that they could diffuse through the blood spots. After two hours the filter papers were allowed to dry at room temperature and the total radioactivity of the blood spots was determined by G–M counter. This experiment was repeated five times with replicated samples from each individual. The results are shown in Table 2. These agree very well with those obtained with intact cells in the first experiment.

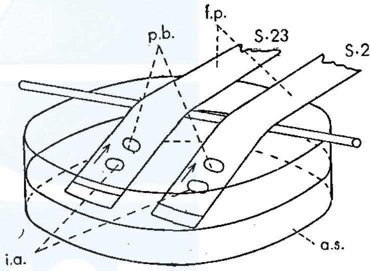

Fig. 3. Preparation of antigen-antibody reaction on filter paper, p.b.: spots of blood preserved by drying, i.a.: spots of iodinated antibody, f.p.: filter paper, a.s.: 4 percent ammonium sulfate.

CONCLUSION

These experiments show that it is highly probable that ^{131}I labelled antibodies can be used to distinguish individual antigenic differences in samples of dired blood. Such samples have great potential value in blood type studies on marine vertebrates where it may be difficult to preserve intact erythrocytes.

In order to expand these techniques for use in large scale investigations of fisheries problems, further research will be necessary on such matters as the extent of the variability introduced during the preparation of dried samples, as well as the general practicability of the method used.

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FORMATION MECHANISM OF EAR PLUG IN BALEEN WHALES IN RELATION TO GLOVE-FINGER

TADAYOSHI ICHIHARA

INTRODUCTION

Since the important paper of the ear plug in the Mysticeti was contributed by Purves (1955), the relations between the ear plug lamination and the other valuable age characters have been researched in several papers, Laws & Purves (1956), Nishiwaki (1957), Symons & Weston (1958), Nishiwaki, Ichihara & Ohsumi (1958) and Purves & Mountford (1959). In particular the valuable suggestions are given in the last two papers which are described based on a great numbers of ear plug from the fin whale. The comparisons of the biological information from the lamination counting with that from the baleen plate reading in the young stage and with that from the corpora counting in the ovary of female whale have confirmed the validity of lamination numbers of ear plug for the age determination as seen in the papers mentioned above.

However, the accurate rate of annual increment of laminae is necessary to advance the whale biology and it finally should be checked by the marking experiment and so on to avoid the interpretation favoured by individual scientists.

As another approaching method to know the increment rate, it remains the fascinating problem when the alternation of the dark and light band occurs in the plug core in response to the internal physiological rhythm of whale body. In the course of study on this subject, it was necessary that the glove-finger and the ear plug were examined in detail morphologically and histologically. In this paper the several supplemental informations for the previous works are obtained from the external observation of the glove-finger and the ear plug. With regard to the formation mechanism of ear plug, new findings are given from the histological study. Any conclusive comment is not given in this paper to the reason why the alternation of bands occurs in the ear plug. Such a reason should be explained in the future research.

I am indebted to Dr. Hideo Omura, the Director of our Institute, for his encouragement throughout this work. My sincere thanks are due to Dr. Hiroshi Hosokawa and Mr. Toshitomo Shida, the Department of Anatomy, Faculty of Medicine, University of Tokyo, for their kind helps and valuable suggestions in the histological study. I am also indebted to

the inspectors and the staffs of the whaling companies, too numerous to name here, who collected many materials for the Whales Research Institute.

MATERIAL AND METHOD

Numerous ear plugs have been collected on the deck of the Japanese floating factory ships in the Antarctic Ocean and the northern part of the North Pacific since 1956. Fin whale plugs occupied the most part of these specimens which were preserved in 10% formalin solution soon after collection. The ear plugs from the blue, humpback and sei whale were preserved in the similar way. The humpback whale plugs off Okinawa Island were collected from January to April in 1959. A few specimen from the Bryde's whale and the minke whale also have obtained from the Japanese coastal land stations, with the fin whale plugs from the East China Sea.

Although the laminations of all plugs were counted, the morphological study in this paper mainly dues to 662 fin whale plugs from the northern part of the North Pacific in 1957 and 1958. Under the imperative necessity of explanation, the numbers were complemented by the plugs from the fin whale in the other waters and from the other species.

With these ear plugs, the glove-fingers were collected from the various whales of different localities but they are in less numbers than the ear plugs. 165 glove-fingers were used for the present purpose. In the present histological study, the blocks of specimens from the various species were embedded in paraffin in the first trial, however, this method was not suitable for the preparation of section. Therefore, the blocks of specimens were prepared in the celloidin and frozen section in the second step. Finally the celloidin section suited for the hard materials like the glove-finger and the frozen section did for the soft materials like the ear plug. In such ways, the various parts from the specimens were sectioned in the thickness from 10 to 15 μ.

After sectioning the specimens, the several staining methods were tried; haematoxylin eosin, Heidenhain's iron haematoxylin, Azan, Sudan III etc. In particular, haematoxylin eosin and Sudan III staining were applied for the study on the formation mechanism of ear plug. Photomicrographs were taken from the numerous sections and some of them are illustrated in plates.

SIZE AND TYPE OF GLOVE-FINGER

Penetrating the thick blubber, the external auditory meatus of the baleen whales goes along the squamosal region of the skull, ending at the glove-finger structure connecting the tympanic bulla with the triangular ligament. Glove-finger had been believed by many whale biologists as the tympanic membrane until Fraser & Purves (1954) have suggested that in the course of study on the conductivity of sound, the triangular ligament mentioned above corresponds to the tympanic membrane. In baleen whales, the glove-finger projects outerwards into the external auditory meatus, having the slightly flattened shape in vertical direction and the elongated, hollow conical structure in general. At its outer convex end it is capped by the ear plug. Its position and its relation to the ear plug were illustrated concretely in text-figure 1 in Purves' paper (1955). Since the glove-finger is closely associated with the formation of ear plug in the auditory meatus, it is necessary to note glove-finger first of all remarks on the shape of ear plug.

In the course of taking the ear plug from the whale head, it is often detached from the outer surface of glove-finger. This detachment, being usually seen more frequently in the young whale than in the old one, sometimes depends on the plug shape coating the curved extremity of glove-finger and sometimes to the shape of papillary layer existing in the corium of glove-finger. The numerous papillaries often project from the outer surface of glove-finger to enter the column of tissue of the ear plug. Detailed description on this connection appears later in this paper. The thick membrane-like glove-finger shows usually the white, yellowish white colour and sometimes the slightly smoke-stained white colour. In the longitudinally bisected specimen many capillaries are seen embossed on the internal surface of the glove-finger. This observation implies presumably the abundant blood vessels exist in the glove-finger.

On the size of glove-finger several descriptions have seen until now. Kellogg (1928) has stated that the glove-finger of humpback whale is 3 ½ inches long and it is flexible in the fresh material. It has been described by Hinoura (1938, '41, '43) that the thickness and size of the membrane-like glove-finger is a little different from species to species, however, it is from 2.0 mm to 5.0 mm thick in the various baleen whales. He has furthermore concluded comparing the sizes of glove-fingers from 5 species in baleen whales that the minke whale and sei whale possess the glove-finger of about the same size, 5.0 cm in length, and the fin and blue whale have a little more large ones and at any rate the humpback whale possesses the most large one of 8.0 cm in length and 3.0 cm in the greatest breadth. Yamada (1948) has shown the glove-finger projects outerwards about 6 cm into the external auditory meatus in the Antarctic fin whale. In Burne's cetacean dissection (1952) it has been suggested the glove-finger in large baleen whale some 2 $^1/_2$–3 inches long in the protruding part.

Fig. 1 indicates a close relationship between the length of projected glove-finger from the tympanic bulla and its greatest breadth. Most of examined specimens consist of 53 fin whales from various localities and their mean values are indicated in the left side, suggesting the linear relationship is suitable in two kinds of measurements. Records from one northern blue whale, one humpback whale from Okinawa waters and one Bryde's whale from the coast of Japan also are plotted, being situated near the straight line. Furthermore to the right side in Fig. 1 mean glove-finger weights at different greatest breadth are plotted on a double logarithmic scale for the fin whale. Records from blue, humpback and Bryde's whale are added near the assumed straight line. Although the small numbers of records give a great variation in the lower range, the linear relationship between the weight of glove-finger and its greatest breadth is assumed. In the examined specimen, the maximum length of glove-finger is 84.8 mm and its minimum length is 51.0 mm. The range of weight covers 31.4 gr from 7.5 gr, four times increase as compared with a less than twice increase in the greatest breadth (22.4 mm to 42.4 mm). The mean thickness of membraneous glove-finger is 3.17 mm for 21 fin whales, being 3.16 mm for 5 blue whales and it is 3.50 mm for 8 humpback whales, however, these values do not seem to be so accurate since the measurement is difficult in the

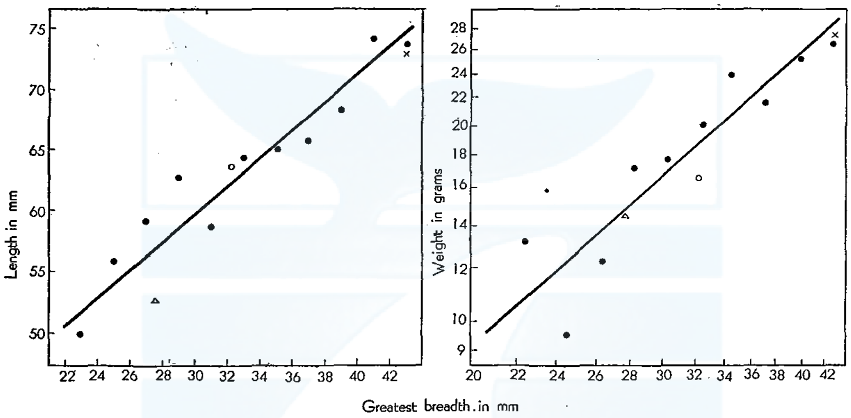

Fig. 1. Relation of length and weight to greatest breadth of glove-finger. Length indicates the projected part from the tympanic bulla. Fin whale, mean values; other species, single records. ● Fin whale, × Blue whale, ○ Humpback whale, △ Bryde's whale.

specimens of markedly projected pappilae. The thickness varies from one specimen to another and its range is from 2.0 mm to 5.0 mm.

In general my finding for the size of glove-finger is compatible with the previous works mentioned above, however, it must be emphasized that all findings in the previous paper are due to the small numbers of glove-finger. Hinoura is the first person who has compared the sizes of glove-finger from various baleen whales as far as I know. His finding should be corrected in respect of the ranking of size. I disagree with his interpretation on the minke whale examined, judging from the external character of that whale.

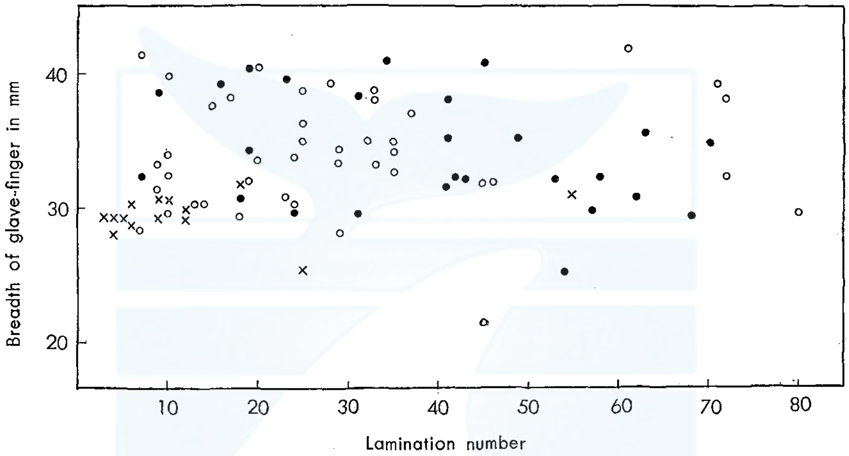

Fig. 2. Relation between greatest breadth of glove-finger and age of fin whale in three localities. × East China Sea, ○ Northern Pacific, ● Antarctic.

In relation to the life-history of whale, Purves (1955) has suggested that in view of its association with the tympanic annulus and its importance in regulating the tension of the tympanic ligament, it may be assumed that the glove-finger also remains constant in size throughout the life of the animal. Certainly Purves' suggestion must be taken up here and confirmed, because there is a close association between the size of outer part of the glove-finger and the size of core of the ear plug. In this connection, the study is started from whether the size of glove-finger changes or not at the increasing age of whale. Since the glove-finger shows the curious form, it is so difficult to express its size as dimensions. So far as the breadth of core of ear plug concerns, the greatest breadth of glove-finger becomes the best expression in dimensions. With regard to the age of whale, there is no justification to reject the lamination number seen in the plug core is an excellent age character according to Nishiwaki, Ichihara & Ohsumi

(1958), Purves & Mountford (1959), even if no method has yet been standardised on the annual increment of lamination as Chittleborough & Godfrey (1957) and Symons & Weston (1958) have pointed out.

In Fig. 2 the greatest breadth of glove-finger is plotted against the lamination number. The specimens used here are collected from the fin whales in three localities—the East China Sea in 1958, the northern part of the North Pacific in 1957 and the Antarctic Ocean between 1956 and 1958. In the range from 3 to 80 of lamination, the greatest breadth of glove-finger does not show the increasing character with age, varying from one specimen to another. This fact implies the glove-finger remains constant for one species from the birth to the end of whale life, confirming Purves' suggestion. It is of interest to note the fin whale of the East China Sea possesses smaller glove-finger than those of the North Pacific and the Antarctic. It is interesting incidentally that the breadth of glove-finger does not show the significant difference between the male and the female fin whale in one locality, and it is found conclusively in the other baleen whales.

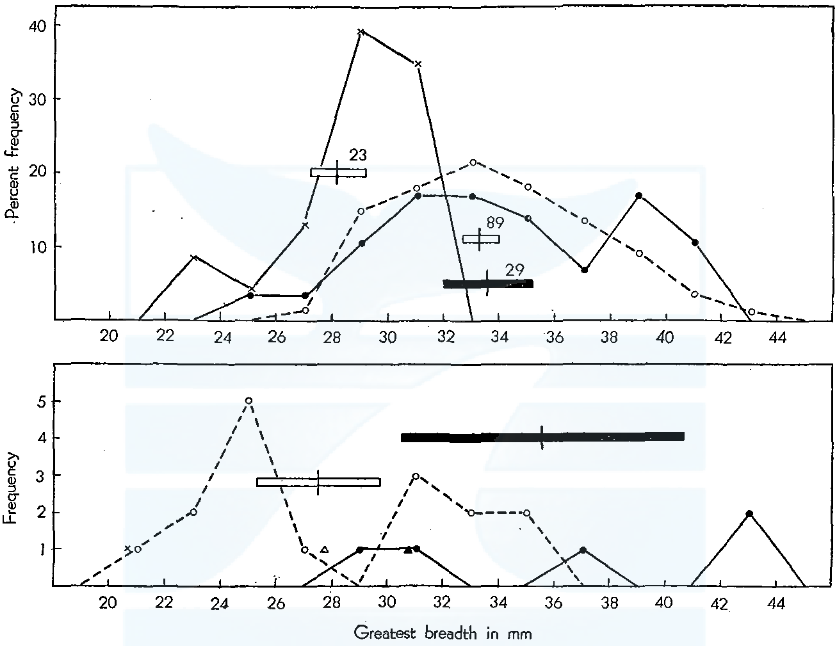

Fig. 3. Frequency distribution of greatest breadth of glove-finger. The means and two standard errors are indicated. Above: On the fin whale in three localities, ×——× East China Sea, ○---○ Northern Pacific, ●——● Antarctic. Below: On the other baleen whales, ○---○ Okinawa humpback whale, ●——● Northern Pacific blue whale, ▲ Northern Pacific sei whale, △ Bryde's whale, × Minke whale.

Since a morphological character of constant size, in no relation to the increasing age, often becomes a clue to the study of subpopulation, I collected the glove-finger from the various baleen whales to measure its greatest breadth. The frequency distributions of the greatest breadth are found in Fig. 3 in which the means and two standard errors are indicated for each group of whale. Since the data contain the glove-finger from of which ear plug is detached and missed, the numbers of specimens become a little larger as shown in Fig. 3 than in Fig. 2. On the fin whales as explained in the figure, the breadth from the North Pacific group is in almost the same range as that from the Antarctic group. In this group the breadth is 33.7±1.54 mm (means and two standard errors) and in that group it is 33.3±0.74 mm. It is evident no significant difference is found between both group. While, in the East China Sea group the breadth is as small as seen in the figure and 28.2±0.99 mm, being different significantly from the other two groups. It has been pointed out by Mizue (1956) that the fin whale of the East China Sea matures sexually at the smaller size than that of the northern part of the North Pacific by about 2 feet. Besides Mizue & Fujino (1957) have suggested the shape of baleen plate is different between both areas. Furthermore Ichihara (1957) have concluded that the external shapes of the whales from both areas are significantly different and suggested that the fin whales are divided from the external proportion into two areas with mathematical foundation. Occurrence of smaller glove-finger in the East China Sea may be taken as the other explanation on the locality of the fin whales there in addition to findings mentioned above, and on this subject further studies of subpopulation are needed as pointed out by Omura, Fujino, Ichihara, Kimura (1958).

Since the collections of glove-fingers from the other baleen whale are not so large, their distributions are seen as the frequency number in the lower part of Fig. 3, in which the means and two standard errors are indicated for the northern Pacific blue whale and for the humpback whales near Okinawa Island where the whaling has been operated in the winter season since 1958. In the group from 5 blue whales, the greatest breadth of glove-finger is 35.6±5.12 mm and in the group from 16 humpback whales it is 27.5±2.24 mm. It is suggestible from these means and two standard errors that the breadth differs significantly between these two groups, although the indicated specimen is small in number and the overlapping area is seen between two frequency distributions. Kawakami & Ichihara (1958) has made clear from the evidence of whale marking that the humpback whales off Okinawa Island migrate as far as Alaskan waters in the north-eastern part of

North Pacific. Accepting this clearness the glove-finger of the humpback whale living in the northern part of the North Pacific is inferred to be the same in its greatest breadth as that of the Okinawa humpback whale.

The frequency distribution of glove-finger of the humpback whale shows seemingly the bimodal curve, which is based on the small numbers of materials collected. As regards the sei whale and Bryde's whale, the only one glove-finger is obtained from the adjacent waters to Japan and its breadth is as medium as 30.7 and 27.7 mm respectively. One specimen from the minke whale captured in the Okhotsk Sea is as small as 20.9 mm in its breadth. The glove-finger of blue whale seems to be a little larger than that of the fin whale.

In relation to the shapes of laminae seen in the ear plug, the type of glove-finger must be noticed. The present type of glove-finger is dependent upon the shape of papillae seen in its corium. In the course of study on the glove-finger of blue whale, the great numbers of papillae are observed in naked eyes to project remarkably outerwards from its surface. All examined specimens from the blue whales have the protruding papillae of which parts are as long as about 5 mm and marked at the curved extremity of glove-finger. These papillae go into the tissue of ear plug covering them, therefore, the ear plug being compacted between one papilla and the neighbouring one. It was described previously in this paper the detachment of ear plug from the glove-finger partly depended on the shape of papillae layer. This statement are supported here by the fact that the collected glove-fingers sticking to the ear plugs usually make the papillae projecting into the plug.

With regards to the glove-finger of fin whale, its type may be divided into three groups. In the first group, the papillae project conspicuously outerwards from the surface of glove-finger like the blue whale. In the second, they project moderately and are not so many in numbers as in the first group. In the third group, they are not so protrudent that the surface of glove-finger looks smooth. These three types of glove-fingers from the fin whales are shown in Plate I, Fig. 1 with the glove-finger from the other baleen whale. The curvature of the distal end of glove-finger effects on that of the laminae of ear plug, varying from one specimen to another, however, it is effectless on the type of glove-finger. According to the grouping method into three types the percentage of the first group is as low as 13.4 and that of the second group is as medium as 32.8, that of the third group being as high as 53.8, in 89 glove-fingers from the northern Pacific fin whales. These percentages show the papillae of the fin whale glove-finger usually are not so protrudent as those of the blue whale. This finding may be supported from the view of the proximal end of ear plug as indicated in Fig. 4.

In the most case of ear plug collection, ear plugs detach from the outer surfaces of glove-fingers but the borders between both materials are kept well in the formalin preservation. From the detailed observation it is confirmed that the epithelium of glove-finger remains at the proximal end of ear plug, where the type of papillae of glove-finger are observed indirectly. Supplying the small numbers of the glove-fingers, 662 ear plugs from the North Pacific expeditions in 1957 and 1958 are used for this survey and the percentage frequencies of three types are plotted against the lamination numbers in Fig. 4. The second type occupies about 30 percentages in all specimens and the comparatively constant level from the young to the old. While the first type of the remarkably projected papillae shows the percentage below 20 in the young and characteristically indicates increasing percentage from the young to the old. With regard to the third type, its percentage falls with the increasing age to the contrary of the increasing percentage in the first group. Over 50 laminations, the first and third group approach to the second group in their percentage. This interesting finding suggests the projection of papillae of glove-finger grows higher and higher from the young to the old and finally three types occur in almost the same frequencies in old whales. It is supported by the shapes of laminae seen in the core of ear plug as described later, how-

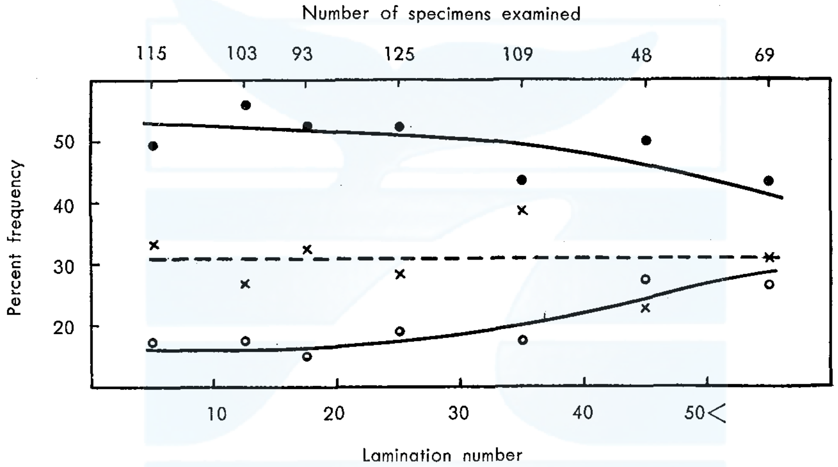

Fig. 4. Percentage frequency of three types of fin whale glove-finger observed indirectly from ear plug, at increasing lamination number. ●——● papillae not projected, ×---× medium type, ○——○ papillae projected markedly.

ever, the occurrence of the first type in the very young whale should be noted.

In the one specimen from the sei, Bryde's and minke whale respectively, the papillae are not protrudent, belonging to the third group. Three types appear in the glove-fingers of humpback whale like those of the fin whales. In all specimens examined from the blue whale, the fin whale and the humpback whale, the occurrences of papillary types are almost similar in the two sexes.

RELATIONSHIP BETWEEN CORE LENGTH AND SKULL WIDTH

It has been suggested by Purves (1955) " the characteristically great lateral growth of the posterior region of the skull in the Mysticeti is apparently almost wholly associated with the lateral extension of the zygomatic process of the squamosal, the paroccipital process and the mastoid process of the tympano-periotic and during the lateral extension of these bones which are concerned in the formation of the bony external meatus, the wax plug would tend to be drawn away from its contact with the glove-finger." Later Laws & Purves (1956) have explained " the dark band found in the fin whale plug marks an abrupt interruption which implie almost complete cessation in the growth of the entire skull and presumably in that of the skeleton and such an interruption, therefore, would have occurred during the migratory period when the excessive physiological demands of active swimming were coincident with complete absence of food." Apart from whether the dark band of core is formed or not coincidentally with the migratory period, between these two suggestions mentioned above it is a common maintenance that the formation of ear plug is dependent on the various stages of the lateral growth of skull. If so, these important suggestions must be confirmed through the relation between the core length and the skull width.

In the northern Pacific expedition of 1957, I measured the several parts of skull of the fin whale and simultaneously collected the ear plug from the measured whale. Two purposes have lain in these skull measurements, in which one purpose is to contribute through the craniometry to the study on subpopulations of fin whales and the other is to confirm the relationship between the formation of ear plug and the lateral growth of skull. For the latter purpose two dimensions of skull took place before sawing the bone. One dimension is the greatest width of skull and the other is the distance between both postglenoid processes of squamosal. The greatest width of skull means the distance between both zygomatic process of squamosal which is situated in the adult fin whale at a little anterior part than the tymanic bulla and the external auditory meatus. The external auditory meatus proximally lies in a deep groove between squamosal and paroccipital process and therefore the distance between both postglenoid processes of squamosal will become better expression of the width of skull near the external auditory meatus.

With regard to the relationship between the lamination number and the core length of fin whale plug, Nishiwaki, Ichihara & Ohsumi (1958) have concluded that the total length of the core per one lamination varies very greatly from one specimen to another. This conclusion was also affirmed later by Purves & Mountford (1959) using many ear plugs from the Antarctic fin whales. If this great individual variation of the total length of core is depend on the ratio of lateral growth of individual skull, the close relation should be found between the total length of core and the width of skull. To confirm this relationship two parts from 69 skulls of female fin whales are plotted corresponding to the total length of core in Figs. 5 and 6, in which the total length of core per the skull width varies greatly from one specimen to another, however, the hypothesis of a linear relationship between the total length of core and the skull width provides a fit to the data in the range of skull width indicated. The linear regression of the total length of core to the greatest width of skull is

$$Y=0.21-9.67X$$

and to another width of skull it is

$$Y=0.29-15.10X$$

where Y and X are the total length of core in mm and each skull width

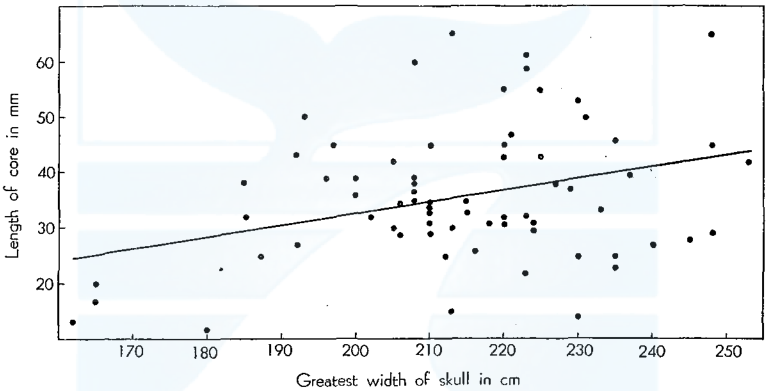

Fig. 5. Relation of length of plug core to greatest width of the skull in female fin whale. Individual value is indicated.

in cm respectively. From this result it can not be emphasized that there is a close association between the increasing total length of core and that of the skull width. The similar result is obtained when the correlation coefficients are considered for 51 measured male fin whales reserved from Figs. 5 and 6. In male fin whales, the greatest width of skull ranges from 170 to 230 cm and another width of skull ranges from 130 to 190 cm respectively.

The correlation coefficient between the total length of core and the greatest skull width is as little as 0.43 and that between the total length of core and another skull width is as little as 0.40 in male fin whales. Then the coefficients are as little as 0.33 and 0.36 for each skull width of the female fin whale. Using *t*-test, these correlation coefficients are significant at the level between 1% and 0.1% respectively, however, it will be beside the mark to emphasize the close correlation between the increasing total length of core and the growing skull width. Because these significancies derived from the mathmatical treatment do not become justifiable reasons to conclude that there is a close causality between two variates although the interrelationship should not be neglected.

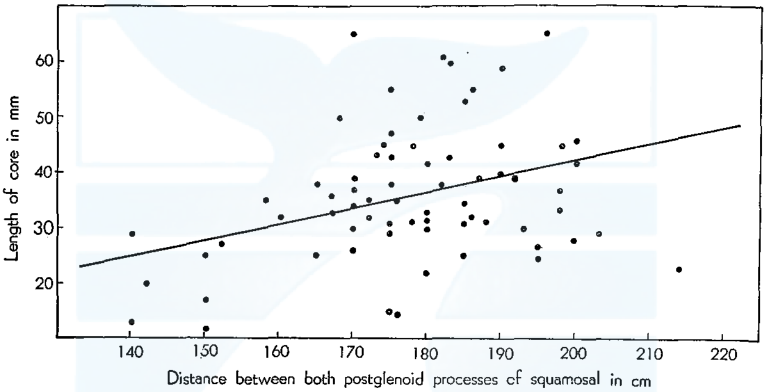

Fig. 6. Relation of length of plug core to distance between both postglenoid process of squamosal of the skull in female fin whale. Individual value is indicated.

Recently Purves & Mountford (1959) have inferred that the total length of ear plug has no close relationship to the skull length. It is assumed that their inferrence does not come from the direct research for the relation between the plug length and the skull width but it is based on the combination of the next two findings: firstly, there is a close linear relationship between the body length of whale body and the skull width, secondly, between the body length and the core length is there a relationship which is perceived between the lines in their paper. That is, my finding may be taken as a definite illustration of their inferrence. The increasing length of core should be positively based on the internal progressing metabolism of whale body as stated by Purves & Mountford (1959), and this finding will be explained later in this paper.

It is of incidental interest to note that the increasing rates of the total length of core on two parts of skull width for female and male fin whales are not significantly different. Furthermore the distance between both postglenoid processes of squamosal is not deemed to effect more positively on the increasing length of core than the greatest with of skull.

GENERAL NOTE ON PLUG CORE

Since the laminae in the conical ear plug are deposited from the epithelium of glove-finger in the progressive stage of the life of baleen whale, the total length of core seems to be stretched regularly from the young to the old age. Purves (1955) has indicated the thickness of the laminations decreases exponentially over the greater part of the series, although there is a certain degree of irregularity. With regard to this irregularity Laws & Purves (1956) have suggested in their preliminary report the alternation in the thickness of the fin whale lamina may be thought to cast some doubt on the validity of assesing a regular six monthly period for the formation of each lamination and the inter lamina areas of the ear plug would occur at six monthly intervals in the blue whale and approximately four and eight monthly periods in the fin whale, considering the migration periods exist regularly in the blue whale and irregularly in the fin whale. However, it must be emphasized that the alternation in the thickness of lamina often occurs irregularly in the blue whale ear plugs I examined.

It is of interest to note the finding in their paper the first lamination, being always a small, conical, unstratified body rich in calcium, is deemed to be that part of the plug which is present in the ear before birth. The prenatal lamina is always present in all ear plugs I examined, its structure and thickness varying from one specimen to another. In the young ear plug its presence is confirmed more easily than in the old one. This phenomenon is explained from the fact that the epithelium of glove-finger is fully keratinized in the distal end of the old ear plug and the conical form of the first lamination is compressed between the growing core and the interfering outer covering derived from the external auditory meatus. The presence of core before birth is suggested by the evidence that a full grown foetus of the humpback whale caught off Okinawa Island in the winter season of 1959 has the thin ear plug in the outer surface of the glove-finger. This male foetus is 12 feet and 10 inches long, it being considered to be near the length of parturition (Nishiwaki, 1959). In this connection it is interesting to draw attention to the occurrence of the ceruminous glands in the human foetus. Iwata (1933) have reported the ceruminous glands of human foetus in 6 months of pregnancy begin to secrete as the apocrine glands, however, there are controversies on the embryological studies of the ceruminous glands according to Nagashima (1934), Hirota (1939), Nagasawa (1941) and Ito (1942, '49). Purves (1955) has proposed that the many ceruminous glands exist in the curved extremity of glove-finger, but, for reasons stated later in the histological study of ear plug, I disagree with this interpretation. Apart from the presence of ceruminous glands in the glove-finger of the baleen whale, the embryological study of ear plug remains a further important one.

There has been no description with regard to the breadth of core of the ear plug in relation to the constant size of glove-finger throughout the life span of whale. In the course of the ear plug study, I noticed the young plug was different in its shape from the old plug. The difference is more evident in the specimen of which ear plug sticks on the glove finger and it is shown in two diagrams of Fig. 7. Although the all ear plugs cover the distal part of the curved glove-finger, the young plug characteristically caps the curved extremity of the glove-finger, while the old plug usually covers the almost all curvature of glove-finger. The first lamina of the humpback whale foetus mentioned above caps only the curved extremity of its glove-finger. The fringe of old ear plug existing along the lateral side of glove-finger is really composed of both

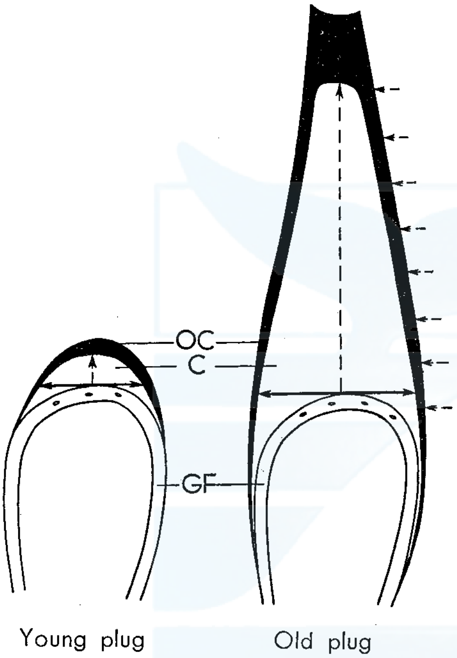

Fig. 7. Diagram showing the increasing length and breadth of ear plug core from the young to the old age with the directions of pressures. OC: outer covering of the ear plug, C: core of ear plug, GF: glove-finger, Silid arrows show the breadth of core and pressure in its part. Broken arrows show the longitudinal and lateral pressures.

the core part and the outer covering part.

The breadths of large numbers of ear plugs from the North Pacific fin whale are measured in such a right-angled direction to the length of core as indicated in Fig. 7. These breadths of cores are plotted against the lamination numbers in Fig. 8 in which each plot shows the mean breadth per 2 laminations. For this purpose, 437 specimens from the fin whale are used and the numbers of specimens per 10 lamination numbers are described in Fig. 8. The breadth of core varies from one specimen to another, growing from the young to the old, however, over about 40 laminations it does not grow more. It is of interest that the mean breadth of core a remarkably similar in the two sexes, concequently the specimens from both sexes are applied in Fig. 8. Nishiwaki, Ichihara & Ohsumi (1958) and Purves & Mountford (1959) have concluded the increasing rate of the core length is not different between the male and female fin whale. The size of core finally is resemble in the two sexes of the fin whale and this finding presumable is extended to all baleen whales.

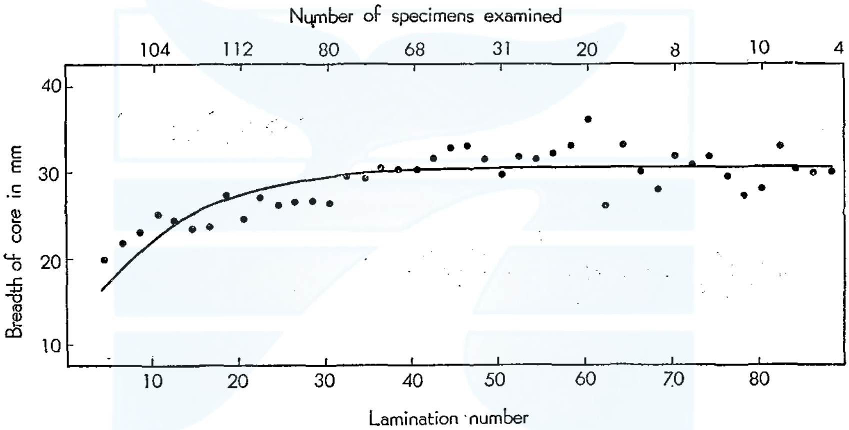

Fig. 8. Change in the breadth of plug core at increasing lamination numbers in the northern Pacific fin whale.

The presence of longitudinal light bands running in the core are the most evident macroscopically in its centre portion and the distance between one longitudinal light band and the neighbouring is the most wide there in all areas of core. It should be noticed further more that the breadth between two bands spread a little and the numbers of longitudinal light bands are increasing little by little from the distal to the proximal end of plug core. The latter finding suggests in the old individual the ear plug are not only formed from the curved extremity but also from the lateral side of glove-finger. It is suggested that the outer covering derived from the lining of the meatus presses little by little the lateral side of the growing plug core from the young to the old.

After all, the conical form of the plug core is deemed to be dependent upon the balance of the next three pressures, which are indicated in Fig. 7. The two pressures of them are due to the keratinized epithelium of the glove-finger, in which the most effective one on the conical form of core operates in the outward direction from the glove-finger, the other being in the laterally outward direction from it. The last pressure is due to the compacted keratinized epithelium of the meatus and operates in the laterally inward direction from it. The various conical form of the ear plug results from the three pressures mentioned above, which operate in different intensities from individual to individual. Among the baleen whale I examined, the longitudinal pressure is more intensive in the plugs of the blue, fin and humpback whales than in that of the sei whale. In the sei whale the distance between two laminations regarded as the age character is usually narrower. Plate I, Fig. 2 indicates the bisected ear plugs from the different 5 baleen whales.

It has been concluded by Nishiwaki, Ichihara & Ohsumi (1958) that the colour of the plug core in the young fin whale is discriminated from that in the old fin whale, and that the colour of core from the sexually immature whale is rather whitish yellow while that from the old whale changes from a dull ochre to blackish brown. This finding in the fin whale is extended to the plug core of the other baleen whale and it is supplemented by the next explanation. The change of colour appears even in one specimen. The dark band of core is rather lighter in the proximal end than in the distal end, and this suggests that the keratinizing progresses further more in the distal end of core than in the proximal end, following the period elasped since the epithelium is detached from the glove-finger. It must be noted that in the parts of core surrounded by the outer covering the darker colour appears macroscopically than in the center of core. Lastly in the supplemental note on the core colour, it is necessary to describe the abnormal ear plug appears in very few frequency. In this abnormality there are various cases to be studies further as seen in Plate II, Fig. 1. In the extremely abnormal ear plug, which looks like a black coal, the lamination number is not counted. In the other case, the alternate occurrences of the dark and light band are interrupted abruptly in the series by the blackish brown substances and successively appear the normal laminae. In some cases the alternate laminae are not seen until the core is sectioned longitudinally.

HISTOLOGY

Morphological characters on the glove-finger and on the ear plug have been described and suggestive to some extent on the mechanism of ear plug formation, which should be explained in the histological study. In this connection the glove-finger is examined firstly since it plays a important part in the formation of ear plug.

Glove-finger. Specimens have been preserved in 10% formalin solution shortly after they are collected on the factory ships and from the land station. Most of all specimens examined are composed of the glove-fingers from the fin whale and blue whale and small numbers of them are occupied by the glove-fingers of the other baleen whales. The specimens for the histological preparation are obtained in the rectangular block of about 5×5×10 mm from the curved extremity of the glove-finger, partially from its lateral side. These blocks are embedded in the celloidin solutions and sectioned in the thickness of 10 μ after the interval from two to three months, and followed by haematoxylin eosin, Heidenhain's iron haematoxylin and AZAN staining. In relation to the formation of ear plug, the epitherial and connective tissues of the glove-finger are studies for the present problem.

The epidermis covering the most outward part of the glove-finger is the stratified flattened epithelium, which the germinal and horny layer constitute. The germinal layer is composed of the many cells in which the basal cylindrical cell layer shows especially the aspect of progressive cell division. Between the germinal layer and the horny layer there are not the confirmatory aspects of the granular layer or clear layer as seen usually in the thick epidermis. In the corium below the epidermis, there are characteristically many papillary layers, of which shapes effect on the shapes of the laminae seen in the ear plug. The sectioned specimen, Plate II, Fig. 2, suggests the collagen fibers occupy the most part of the connective tissue and the elastic fibers exist between them. The papillary layer project many papillae into the epidermis and the projection is remarkably in the papillae of the blue whale. Plate I, Fig. 1, shows the papillae of the blue whale and the different types of those of the fin whale. The papillae are about 5 mm so long in the projected extremity in the blue whale, that they can be observed macroscopically. These papillae are not arranged regularly and it is observed microscopically that there are many small papillae both two large papillae. In the corium of the blue whale the small papillae characteristically distribute irregularly and they show the something like a hive in the section as seen in Plate III, Fig. 2. This suggests the intervening papillae are laterally pressed so intensively between two developed long papillae that they form the curious constructure as if the basal layer of the germinal layer subsides deeply into the corium.

In a papilla and below the papillary layer, there are many blood vessels composed of blood capillaries, arterioles and venules. Although the contents of the capillaries are often disolved out in the section, they are sometimes occupied by the red blood corpuscles as shown in Plate III, Figs. 1 & 2 and Plate IV, Fig. 1 in which the distal end of papilla of the blue whale and the papillary layer of the fin whale are indicated. Any excretory ducts opening on the surface of epidermis are observed nowhere in the specimens examined in which the cavities exist a little apart from the basal layer of germinal layer. I disagree with the presence of the ceruminous glands in the glove-finger, for the reason which Purves (1955) has interpreted. In Plate XVII, Fig. 3 of his paper, the abundant blood-capillaries are indicated as the ceruminous glands, however, that section shows the presence of erythrocytes in the cavities which the endotherial cells surround, even if it is obtain from the old specimen.

With relation to the formation of laminae seen in the core of ear plug, the shapes of papillae should be noticed. The structures like bands are divided into three parts macroscopically. One of them is the light yellowish band arranged as fairly regular structures of concentric circles from the proximal to the distal end of core, and the band of the similar light yellowish colour runs longitudinally in the core. Lastly it is be noted that the dark coloured band exists between two light concentric circles. These light concentric and longitudinal bands are stained well by SUDAN III and looks the yellowish red or red colours in the sections. In the microscopically examination, the macroscopical concentric light bands are really curved along the shapes of the projected papillae. With regard to this finding Plate V, Figs. 1 & 2 are referred in which the proximal part of core of the blue whale and fin whale plug are indicated. Especially in the proximal end of the blue whale specimen, a part of germinal layer remains and enables us to know relation between the shapes of papillae and those of the light curved bands. Since the papillae project irregularly into the ear plug and a large papilla sometimes is more protrudent than another small papilla, the lamination numbers are different from one column of tissue to another within the constant range from the outside curvature of glove-finger. Here, the colume of tissue is defined as the tissue between two longitudidal light bands in the plug core.

In this connection, the lamination counting must be noticed particularly in the ear plug with the remarkably projected papillae in its glove-finger. It is furthermore desirable that the laminations are counted along the one longitudinal light band which is present in the middle part of core. On the contrary the light curved bands become to distribute concentrically in the ear plug without so much projected papillae in its glove-finger. It has been stated previously about a half of the glove-finger of the fin whale has no markedly protrudent papillae and so its surface is fairly smooth.

The germinal layer of the epidermis of glove-finger remains usually in the most proximal end of the ear plug collected. Since the germinal layer covers the papillary layer of corium, the most proximal end of the ear plug collected sinks corresponding in position which the papillae project. It is of interest to note that Malpighi's Ret is apparently present there.

In the course of the study on the mechanism of ear plug formation, the histological examinations are practised in the next two parts of core; the first part of them concerns the curved light yellow band and the dark band between two light yellow bands. These bands are important for the age determination of the baleen whale. The second part involves the longitudinal light yellow band.

Concentrically curved light and dark bands. Specimens preserved in 10% formalin solution shortly after they are collected from the whale body are partially embedded in the celloidin solutions, however, most of them are prepared in the effectual frozen section since the paraffin embedding is not available for such a deposited material as the ear plug. Numerous specimens sectioned in thickness from 10 to 15 μ are stained by haematoxylin eosin and Sudan III.

Before the sectioned materials are produced, I measured the distance between two curved light yellowish bands under a dissecting microscope. Nextly, the ear plugs of the frozen section were observed under the dissecting microscope to measure the distance between two light bands. After these preliminary processes, the position of the light band were presumed from the distance between two bands in the section stained by Sudan III. Although the various fatty substances are observed to distribute in the whole area of the stained section, the curved light yellow band is confirmed as the parts stained darkly by Sudan III. These shapes of darkly stained bands, of course, are different from one species to another, corresponding to the shapes of laminae. The stained sections are shown in Plate V, Figs. 1 & 2. The curved dark band between the two light yellowish bands is not stained well by Sudan III but by eosin. In the course of the examination on the numerous sections from the proximal end of well fixed ear plugs, it has been fortunate the light band and dark band are found under the formation, and it facilitates to explain the process of formation.

In the stratified flattened epithelium, the cells of germinal layer are generally elevated outerwards according to the increasing numbers of cells in the basal layer. The epidermis of glove-finger belong to the same categoly, however, the cells of germinal layer characteristically remain the degenerated forms in the ear plug throughout the life span of whale. Plate VI, Figs. 1 & 2 indicate the various transforming cells of the germinal layer according to their distances from the basal layer. These two photomicrographs are obtained from the fin whale plug sticking to the outer surface of glove-finger. Plate VI, Fig. 2 shows the various kinds of cell forms near the basal layer and Plate VI, Fig. 1 indicates the transformation of cell in the more distal part. It is indicated in this plate that the size of cell becomes not only larger and larger but also its shape is deformed by and by soon after it is apart from the basal layer. Lastly, it is flattened and becomes a fusiform cell of which cytoplasm is stained well by eosin. Since the primitive stage of keratinized epithelium appears in these two figures, it must be illustrated subsequently how to already keratinized epithelium is deposited in the core of ear plug. In Plate VII, Fig. 1 and enlarged Plate VII, Fig. 2, there are many layers of accumulated keratinized epithelium. The fusiform cells are destroyed in response to the passing of time, therefore, they disappear in the distal end of the section from the old whale, forming the developed keratinized uniform tissue stained by eosin. The germinal layer of epidermis of glove-finger remains in the lower parts of these two figures and many nuclei are stained by haematoxylin.

It may be, therefore, safely said that the appearance of fusiform cell corresponds to the beginning of conification, that is, to the first stage of the formation of curved dark band in the ear plug. In the course of the keratinized degeneration of the germinal cell of glove-finger, the nuclei are deformed in the various stages. The deformation of nuclei appear even in the cells near the basal layer of epidermis and the forms of nuclei vary greatly from one cell to another, for example, from the ellipse to the circle, indicating sometimes the curious projection and notch, as shown in Plate IV, Fig. 2 and Plate VI. The complicated forms of nuclei may suggest the degenerated epithelial cells function abnormally. These nuclei disappear soon after the fusiform cells occur.

Another case in which the light yellowish band is occurring is different greatly from the case of forming dark band mentioned above. From the frozen section from other specimens of fin whale, I can obtain the Plate VIII, Figs. 1 & 2, one of which is enlarged from the other figure to facilitate the explanation. The germinal layer in epidermis of glove-finger remains in the lower part of Plate VIII, Fig. 1, besides the band stained darkly by SUDAN III appears in the middle and the keratinized fusiform cells are present in the upper part. This figure indicates the light yellowish band has been just formed. In this connection see the enlarged photomicrograph, Plate VIII, Fig. 2 in which the fatty degeneration of the cells in the germinal layer is illustrated.

In the first stage the fatty granules begin to appear sporadically in the cystplasms of degenerated cells and they occupy the most part of the cystplasm in the second stage when the nuclei remain yet in the compressed deformation. In the last stage, the fatty granules flow out destroying the cell of developed degeneration and they forms the band filled with the various fatty substances. The nuclei remain in the last stage as compressed forms among the fatty substances and stained by haematoxylin, however, they disappear after all. In this connection it is interesting to draw attention the sebaceous gland in which the degenerated cells filled with the fatty substances send out simultaneously the involving fatty substance when they are destroyed. If the presence of the gland must be stated persistently in the glove-finger, such glands do not belong to the category of the eccrine and apocrine gland but to that of the holocrine gland. As far as the fatty degeneration concerns, the epithelial cells function rather like sebaceous glands. When the dark band is formed, the keratinized epithelial cells show the shapes like the fairly obese fusiforms, however, in the case of the fatty degeneration they form usually the shapes of a little obese rounds. In the latter case the deformed nuclei remain even when the cells filled with fatty substances are destroyed at last. These differences muse be emphasized particularly in respect that the epithelial cells of glove-finger result so alternately in the fatty and the keratinized degeneration that the light yellowish band and the dark band appear macroscopically in the regular concentric circles in the plug core.

In Plate VII, the fatty substances are observed to encircle the keratinized fusiform cells. This is explained from the next two findings. Firstly in the course of keratinized degeneration, most of all epithelial cells grow into fusiforms and they are stained well by eosin, however, a few of them remains rather roundly degenerated cells and the fatty substances appear in their cystplasms. Secondly, into some parts of the layer of keratinized epithelium, especially into the neighbouring parts to the longitudinal light band, the fatty substances flow from the longitudinal light band through spaces of stratified fusiform cells. The structure of the encircling fatty substances is compared to the sewing the pieces of keratinized fusiforms cells together with the fatty substances and it may not keep the ear plug a very fragile material. The keratinized fusiform cells appear sometimes in few frequencies in the course of the fatty degenerations. The intervention of these substances of different character brings forth the difficulity in case of the lamination counting. Abnormal ear plug showing coarse and fine laminations which is indicated in Plate 6 by Purves & Mountford (1959) seems to be an example of such a case. With regard to the second findings mentioned above, the longitudinal light bands are described in the next part.

Longitudinal light band. The longitudinal bands are observed as the light yellowish structure homologous to the concentric light band in all ear plugs from the various baleen whales and their positions are illustrated in Plates V & IX. It is noticed that the projections of papillae of glove-finger exist between two longitudinal light bands and the protrudent shapes of papillae bear closely on the formations of these bands. The longitudinal yellow bands are stained by SUDAN III and shows homologous structure to the curved light bands composed of various fatty substances. The proximal end of ear plug is sectioned and stained by SUDAN III, which is illustrated in Plate IX, Fig. 1 in this connection. It should be noted firstly the shapes of degenerated cell is different from those of the other bands.

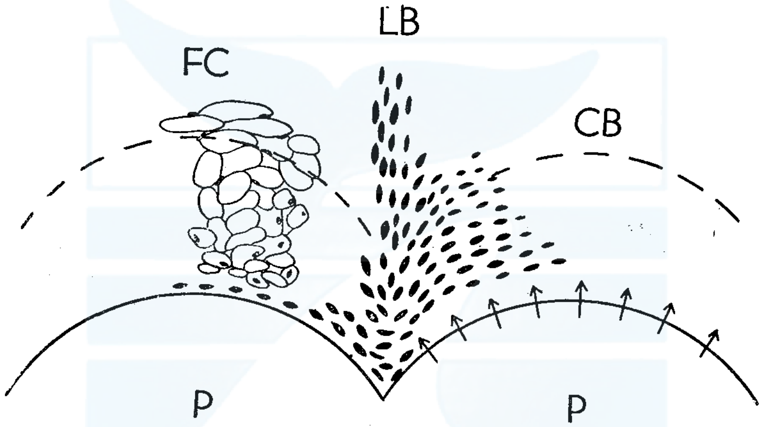

Fig. 9. Diagram showing the relationship between the arrangements of nuclei and the direction of pressure from the basal layer of epidermis of glove-finger. Arrows indicate the direction of pressure. LB: longitudinal band, CB: concentric band, FC: fusiform cell, P: papilla.

The cells are so elongated in the longitudinal direction that the extremely proximal end of the longitudinal band looks like fine roots of tree. In the sectioned materials stained by SUDAN III, the orange colour of the structure like fine roots is more apparent against the violet colour of the nuclei of the germinal cell stained by haemotoxylin. The fatty degeneration of epithelial cell in the longitudinal band begin in the earlier stage than the curved light band. In the longitudinal band, the compressed nuclei, their shapes corresponding to the elongated epithelial cell, remain in the fatty substances which flow from the destroyed cells. It is endorsed by Plate IX, Fig. 2 of the section from the young plug that the nuclei remain for the long period in the plug core. In this section stained by haemotoxylin and eosin, the papillae of glove-finger are not so projected and it is shown in the lower part of that figure, however, the nuclei are not absorbed and remain in the longitudinal band. Here it is pointed out that there is the similarity of fatty degeneration between the curved and longitudinal light band, that is, the sizes of epithelial cells are not so enlarged in the fatty degeneration as in the keratinized degeneration, and the deformed nuclei appear in the cells filled with the fatty substances and remain yet longer after the cell destroyed.

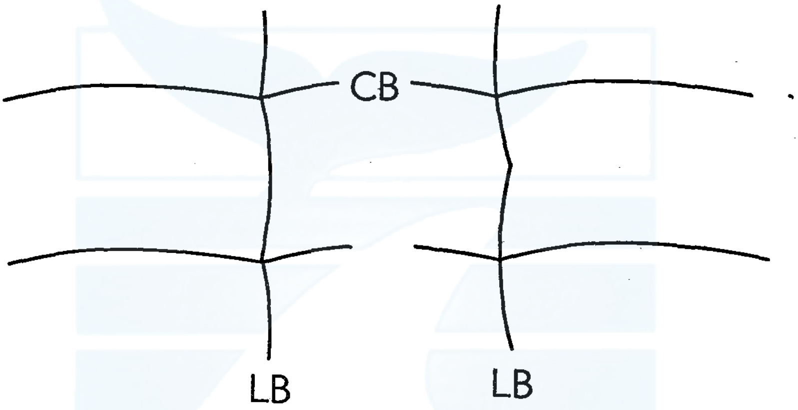

Fig. 10. Diagrams showing the relation between the direction of the curvature in longitudinal light band and that in concentric light band. LB: longitudinal light band, CB: concentric light band.

It is assumable that there is a close interrelationship among the deformed shapes of nuclei, the form of their arrangements and the directions of pressures dependent on the shapes of papillae. The photomicrograph is given in Plate IV, Fig. 2 to explain this relationship. This photomicrograph is taken from the section with the projected papillae and so enlarged in the germinal layer between two large papillae that the extremely proximal end of longitudinal band are surveyed. The nuclei begin to be deformed in any part of the germinal layer soon after the cells are apart from the basal layer. Characteristically between two large papillae, the nuclei are much flattened than the other part of germinal layer. This suggests the cells are flattened similarly there. In the other part of the germinal layer the nuclei are arranged along the curvatures of projected papillae. From Fig. 9 showing the relation between the arrangements of nuclei and the directions of pressure, the reason which the cells and nuclei are compressed laterally in the longitudinal band is illustrated. The diagram indicates furthermore the projection of papilla is effective on the formation of longitudinal band and on the shape of lamina formed upon it.

The longitudinal bands seem to run spirally from the proximal end to the distal end of the plug core. It may be explained, however, from Fig. 9 that there is no close relation between the longitudinal band and the curved light yellowish band. Numerous frozen sections do not suggest me that the curved light yellowish band is in general derived from the longitudinal band as Purves (1955) has pointed out. He has stated the structure like the longitudinal light band corresponds to the ceruminous duct and the lipoids are secreted from the ceruminous gland in the corium of glove-finger in the resting period and the active formation of the squamous epithelium is seen in other period. If the curved light band dues to the lipoid secretion from the ceruminous gland of glove-finger, the left diagram in Fig. 10 always should be applied to the formation process of ear plug, however, there are various relationships between the direction of the longitudinal band and that of the curved light band and the right diagram in Fig. 10 is often applied. Furthermore I can not observe always the second lamina is formed reversely in its curvature to the first lamina, on the contrary, the second lamina curves similarly to the first lamina in the most of examined specimens.

Based on the reasons referred above, I disagree with Purves' interpretation on the formation mechanism of ear plug. Yamada (1953) has suggested the plug of ear wax seems to be produced by the meatal epithelial and not the products of glands, however, he has not referred to the core part of ear wax of Mysticeti. It was endorsed before in this paper that the alternation of the dark and light band considered as the valid index of the age determination appears in the process of degeneration of the epithelial cells in glove-finger. Assuming the rhythmic growth in the passage of time, I would like to conclude that such a degeneration is practiced in response to many factors related to the metabolism of whale body. Particularly the effect of hormone and enzyme on the metabolism are regarded initially, and with the intractable problem of the inherent physiological rhythm set aside, the external environment may effect on such a periodicity. On this subject further research remains a fascinating one.

The incidental statements in the histological study are as follows.

The granules stained darkly by haematoxylin appear often in the longitudinal section of ear plug, and distribute irregularly in the degenerated tissue. In the young specimens they appear more often than in the old specimens. Their abundance in the distal end of core characteristically may indicate the metabolism of the whale body in the very young stage. It is, furthermore, of interest to note that many capillary crystals, not stained by SUDAN III, are observed in the formalin preserved specimens. They distribute frequently in the longitudinal light and concentric light band but sometimes in the layer of keratinized epithelium, concentric dark band. These crystals are indicated in Plate VIII, Fig. 1.

SUMMARY

Glove-fingers and ear plugs from baleen whales were studied morphologically and histologically. The examined numerous specimens consist of 6 species, the blue, fin, humpback, sei, Bryde's and minke whale, being collected from the Antarctic Ocean, the northern part of the North Pacific and from the adjacent waters to Japan from 1956 to 1959. My findings are summarized as follows.

1. The size of glove-finger is constant throughout the life of whale.
2. The size of glove-finger varies from one species to another and it gives a clue on the study of subpopulations located in the various areas. In the northern hemisphere, the glove-finger of fin whale from the East China Sea is significantly smaller in size than that from the northern part of the North Pacific.
3. The glove-finger are divided into three types from the shape of papillae, which is effective on the shape of laminae seen in the core of ear plug. The papillae of glove-finger from the blue whale are protrudent remarkably from the outer surface of glove-finger. Moderately projected and macroscopically not projected papillae occur in the glove-fingers of fin and humpback whale. Papillae seem to be protrudent litte by little at the increasing age of whale.
4. The core of ear plug seems to be formed in the prenatal stage of the baleen whales.
5. In the longitudinally bisected specimen, the breadth of plug core grows in its the proximal end at the increasing age of whale. This finding suggests the plug core is formed from the lateral side of glove-finger in the old whale. The increases of breadth and length of core gives the ear plug the conical form. The similarity in the size of core is recognized in the two sexes.
6. There is no ceruminous gland in the corium of glove-finger. The

numerous small cavities observed in the corium are the blood capillaries.

7. The concentrically curved light band and longitudinal light band in the plug core are composed of the various fatty substances. The keratinized epithelium of glove-finger constitutes the most part of the dark band between two curved light bands. These bands are derived from the degeneration of epithelial cells of glove-finger. In particular the periodical occurrence of the fatty and the keratinized degeneration gives the ear plug the validity of age determination.

8. It is not able to emphasize there is a close relationship between the length of plug core and the lateral growth of skull. Based on the histological examination the increasing length of core is rather dependent on the internal progressing metabolism of the whale body. Since the alternation of light and dark band appear rhythmically in the plug core, the effects of hormone and enzyme on the degenerations of epithelial cells of glove-finger are regarded initially. Besides, the effect of the external environmental factors are presumed indirectly. Further studies are needed on this subject.

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EXPLANATION OF PLATES

PLATE I

Fig. 1. Glove-fingers of the various baleen whales with indicating the three types of glove-finger from the fin whale (×1/2).

Upper: Fin whale, left to right; papillae are not projected, papillae are projected a little, papillae are projected markedly, papillae are projected at the one side on the curved extremity of glove-finger.

Lower: Left to right; minke whale, Bryde's whale, sei whale and blue whale.

Fig. 2. Bisected ear plugs of the various baleen whales with the scale in cm.

Left to right: minke whale, 9 laminations; sei whale, 40 laminations; humpback whale, 24 laminations; fin whale, 29 laminations; blue whale, 41 laminations.

PLATE II

Fig. 1. Bisected abnormal ear plugs of the fin whale with the scale in cm.
Black substances interrupt the regular occurrence of laminae.

Fig. 2. Longitudinal sections of the curved extremity of glove-finger, from the baleen whales, staining by haematoxylin eosin.
Left: Glove-finger of the fin whale (×15).
Right: Glove-finger of the blue whale (×7).
P: papilla, EP: ear plug, CT: connective tissue.

PLATE III

Fig. 1. Longitudinal section of the distal end of one papilla (×100), from the glove-finger of blue whale, staining by haematoxylin eosin. This photomicrograph indicates the ear plug is formed from the distal end of papilla and red corpuscles exist in the blood capillaries of the corium.
GL: germinal layer of epidermis, BC: blood capillary.

Fig. 2. Longitudinal section of the many small papillae which are present between the two large papillae (×100), from the glove-finger of blue whale, staining by haematoxylin eosin. This photomicrograph shows that the sectioned small papillae form the structure like a hive and that there are the blood capillaries in corium.
LP: the proximal end of large papilla, SP: small papilla, BC: blood corpuscles.

PLATE IV

Fig. 1. Longitudinal section near the basal layer of epidermis (×100), from the glove-finger of fin whale, staining by haematoxylin eosin. In this section, the proximal end of ear plug sticks on the glove-finger. There are the blood capillaries in the corium.
EP: ear plug, BL: basal layer of epidermis, C: corium of glove-finger, V: venules.

Fig. 2. Longitudinal section of germinal layer of epidermis (×400), from the glove-finger of fin whale, staining by haematoxylin eosin. This photomicrograph indicates the occurrence of flattened nuclei in the proximal part of longitudinal band.
LB: the space corresponding to the longitudinal band, FN: flattened nuclei, BL: basal layer of epidermis of glove-finger.

PLATE V

Fig. 1. Longitudinal section of the proximal part of ear plug (×20), from the fin whale, staining by SUDAN III. In this photomicrograph the concentric light band and the longitudinal light band are stained darkly by SUDAN III.
CLB: concentric light band, LLB: longitudinal light band, GL: germinal layer of glove-finger.

Fig. 2. Longitudinal section of the proximal part of ear plug (×15), from the blue whale, staining by SUDAN III. This photomicrograph indicates the shape of curved light band resembles to that of papilla.
CLB: curved light band, LLC: longitudinal light band, GL: germinal layer of glove-finger.

PLATE VI

Fig. 1. Longitudinal section of the extremely proximal end of ear plug (×400), from the ear plug of fin whale, staining by haematoxylin eosin.

Fig. 2. Longitudinal section of the germinal layer near the basal layer of glove-finger (×400), from the glove-finger of fin whale, staining by haematoxylin eosin.

These photomicrographs are obtained from the same specimen. They indicate the various stages in the deformations of epithelial cells and nuclei, corresponding to the distance from the basal layer of epidermis of the glove-finger. The conification of epithelial cell progresses further and it is stained more darkly by eosin in the upper part of Fig. 1 than in Fig. 2.

FC: fusiform cell, DEC: deforme depithelial cell, BL: basal layer of epidermis of glove-finger.

PLATE VII

Fig. 1. Longitudinal section of the proximal end of ear plug (×75), from the fin whale, staining by SUDAN III. The specimen is forming the concentric dark band which is not stained very by SUDAN III. The fusiform cells appear above the germinal layer of glove-finger.

Fig. 2. Longitudinal section of the proximal part in which the keratinized fusiform cells begin to be formed. (×400), from the same specimen as indicated in Fig. 1, staining by SUDAN III.

FS: fatty substances occupying the space among the fusiform cells, FC: keratinized fusiform cell, GL: cell of germinal layer under deformation.

PLATE VIII

Fig. 1. Longitudinal section of the proximal end of ear plug (×75), from the fin whale, staining by SUDAN III. The specimen is forming the concentric light band which is stained well by SUDAN III. The keratinized fusiform cell appear above the part stained darkly.

FC: keratinized fusiform cell, CC: capillary crystal, GL: germinal layer of the epidermis of glove-finger.

Fig. 2. Longitudinal section of the proximal part of ear plug, in which the fatty degeneration in the epithelial cell of glove-finger begin to occur (×400), from the same specimen as indicated in Fig. 1, staining by SUDAN III. The fatty granules are stained in the cystoplasm of the deformed cell.

PLATE IX

Fig. 1. Longitudinal section of the proximal end of ear plug (×200), from the fin whale staining by SUDAN III. This photomicrograph indicates that the proximal part of the longitudinal light band forms the structure like the fine roots of the tree. The germinal cells are compressed laterally in the longitudinal light band, which is stained darkly.

LLB: longitudinal light band, GL: cell of germinal layer under deformation, P: the space at which the papilla is situated.

Fig. 2. Longitudinal section of the ear plug and glove-finger (×40), from the young fin whale, staining by haematoxylin eosin. Nuclei remain at the longitudinal light band in the ear plug.

LLB: longitudinal light band, G: granules stained darkly by haematoxylin, CG: corium of glove-finger.


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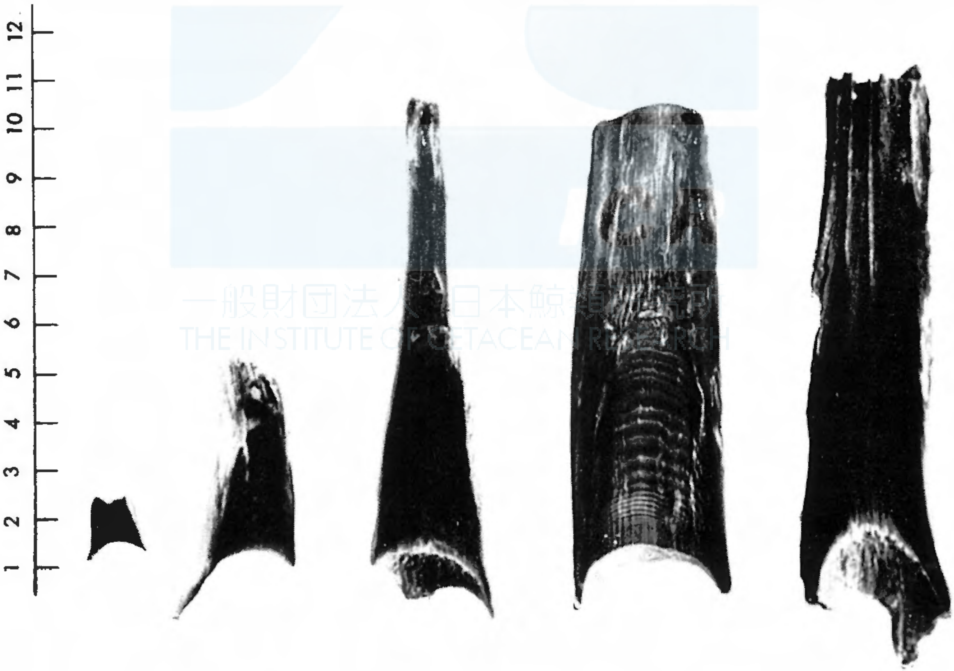
Fig. 1



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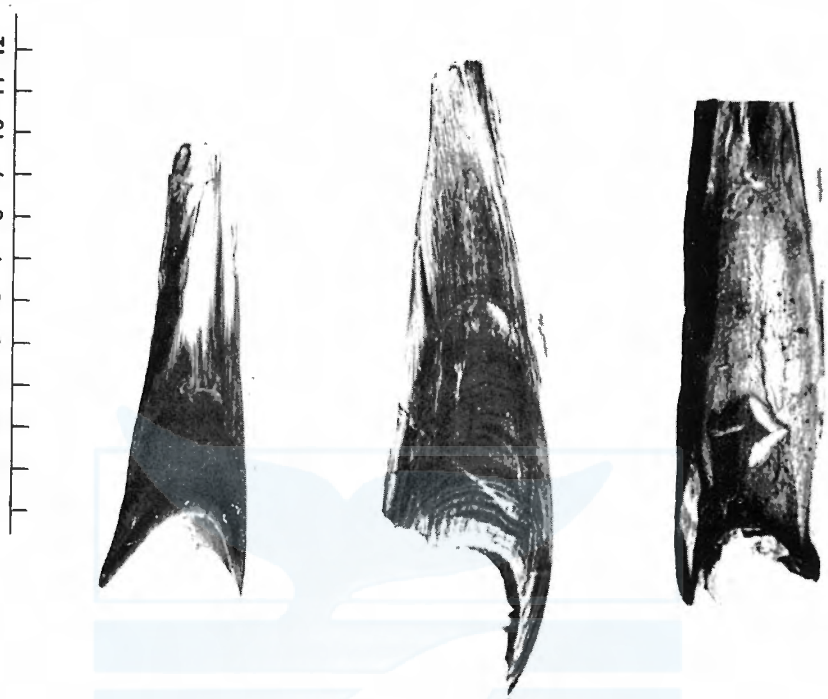

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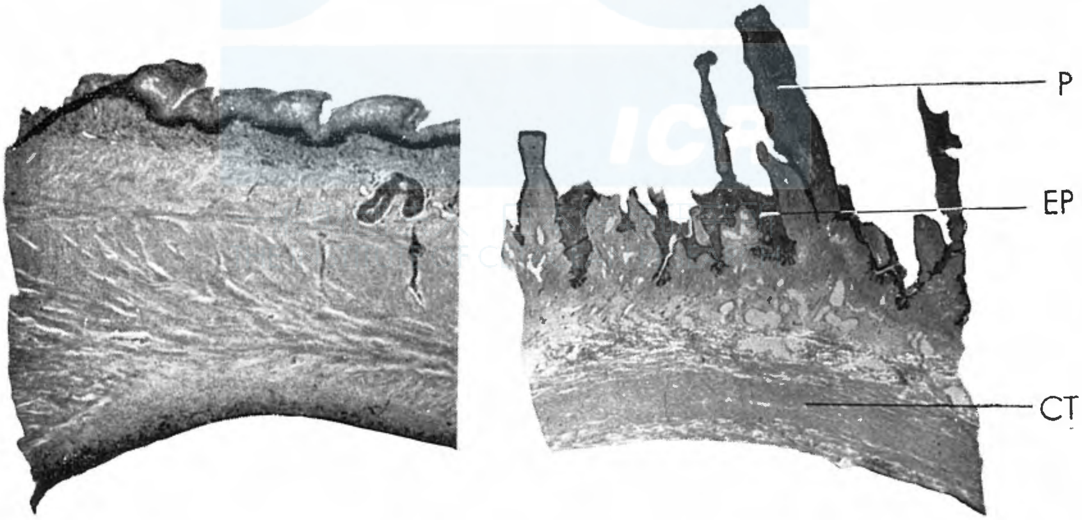

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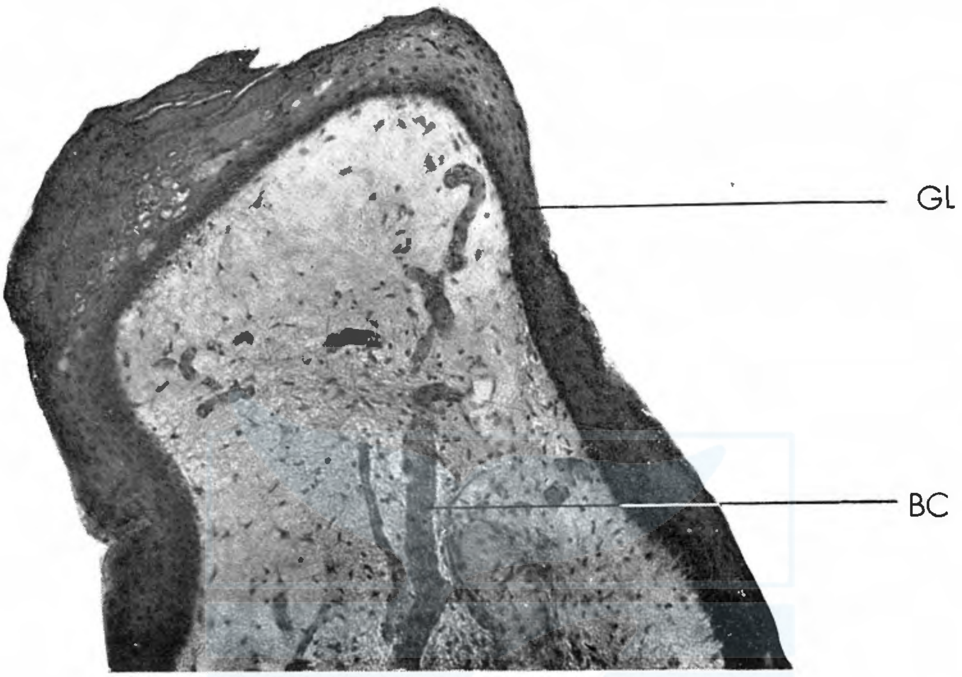

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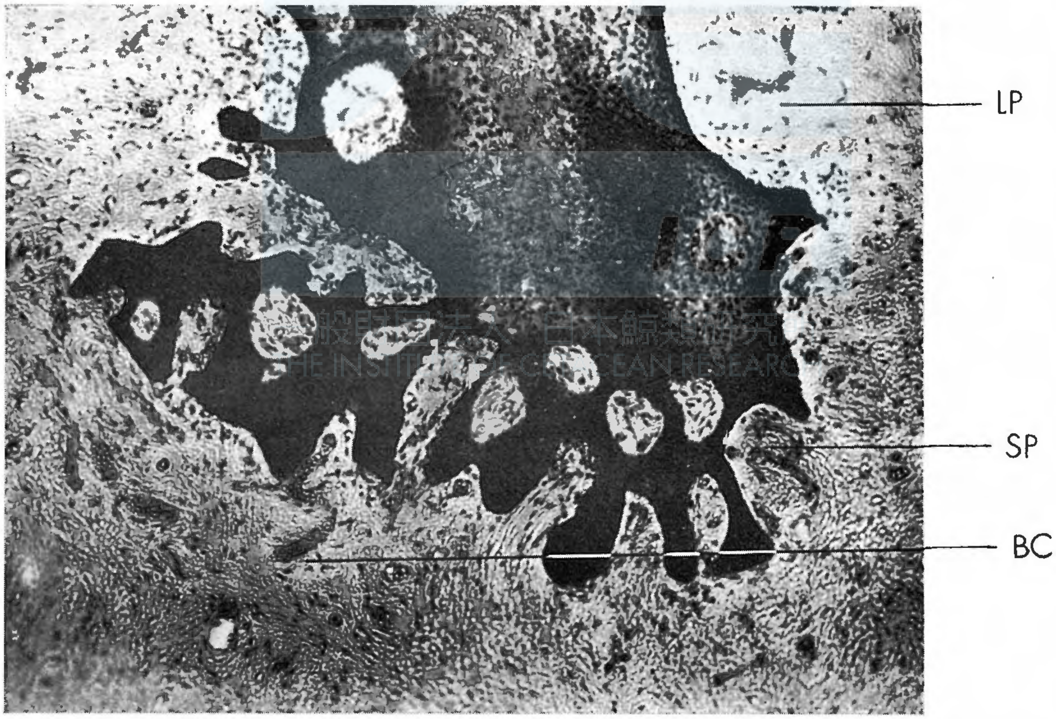

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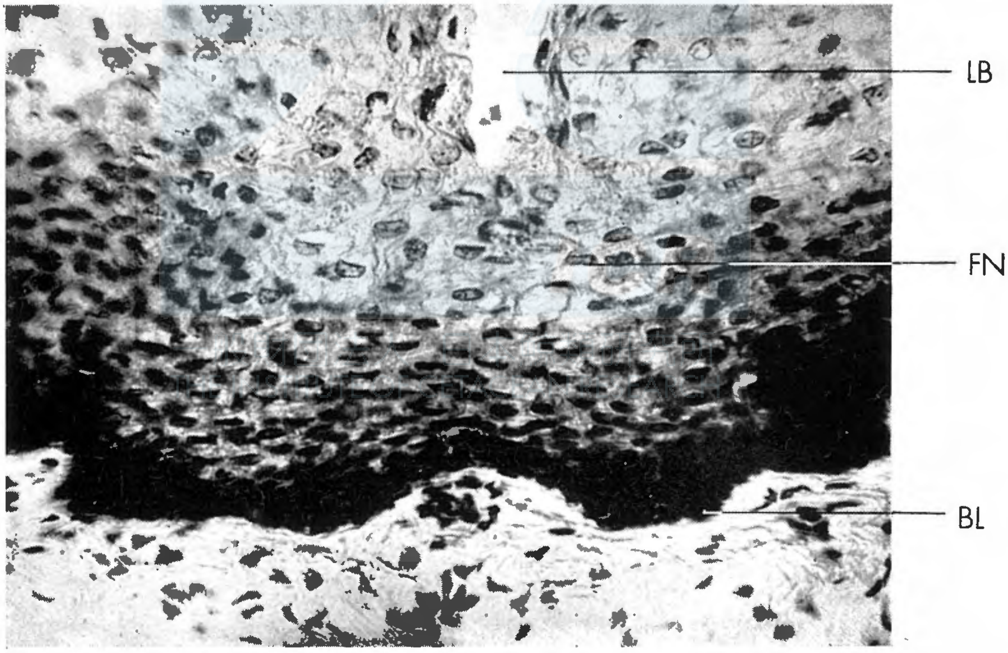

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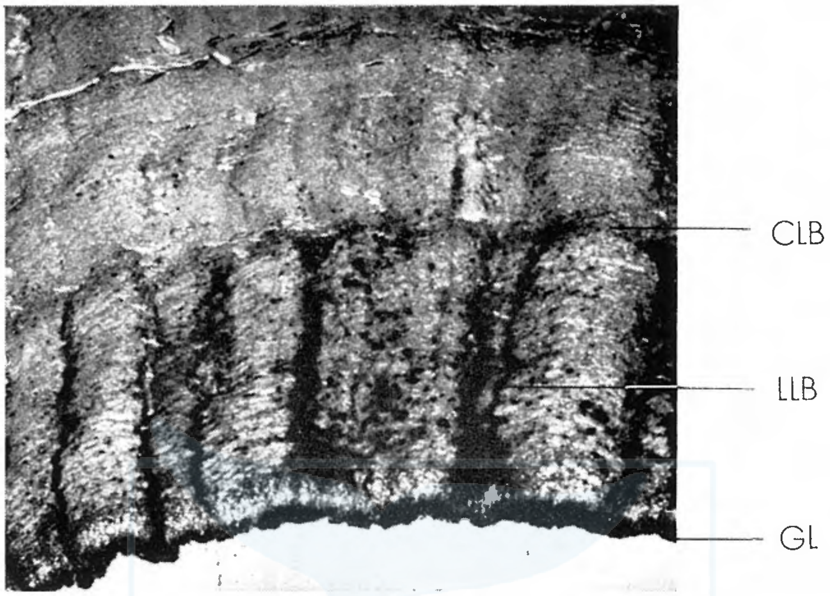

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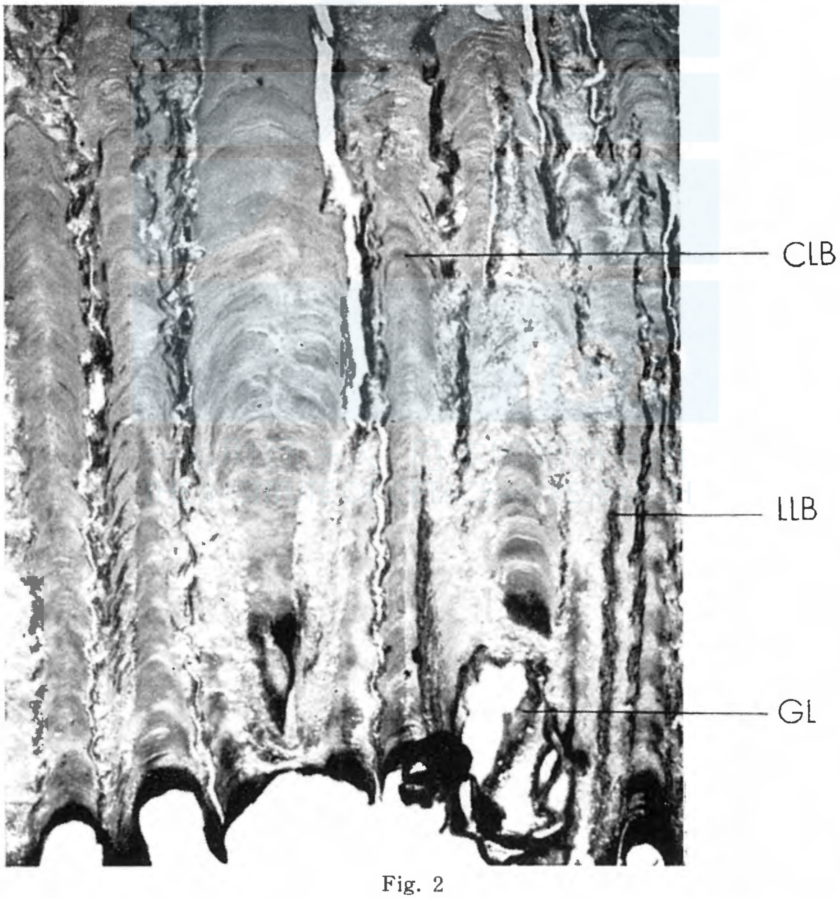

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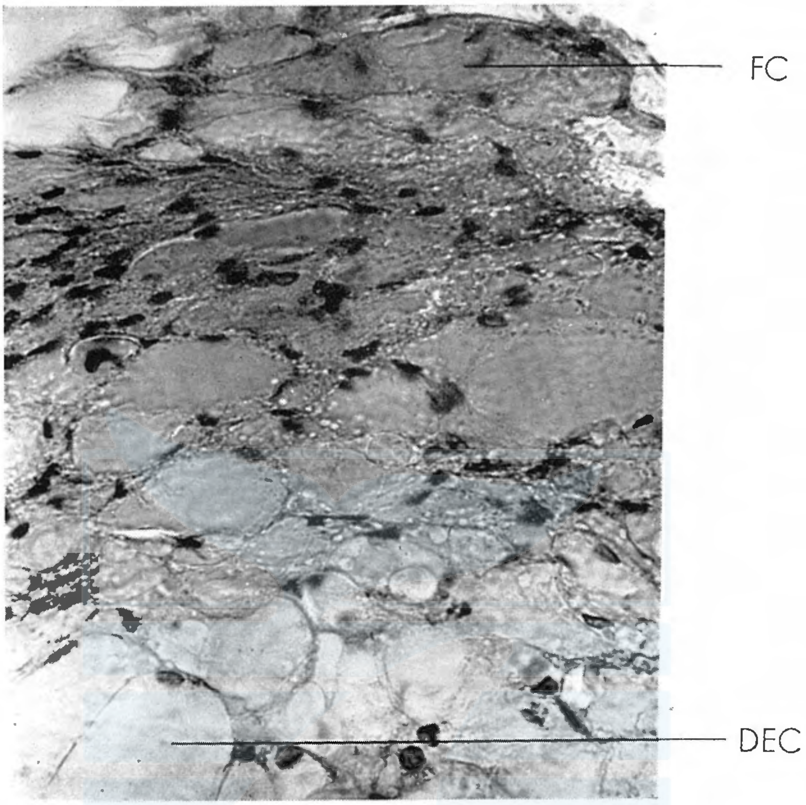

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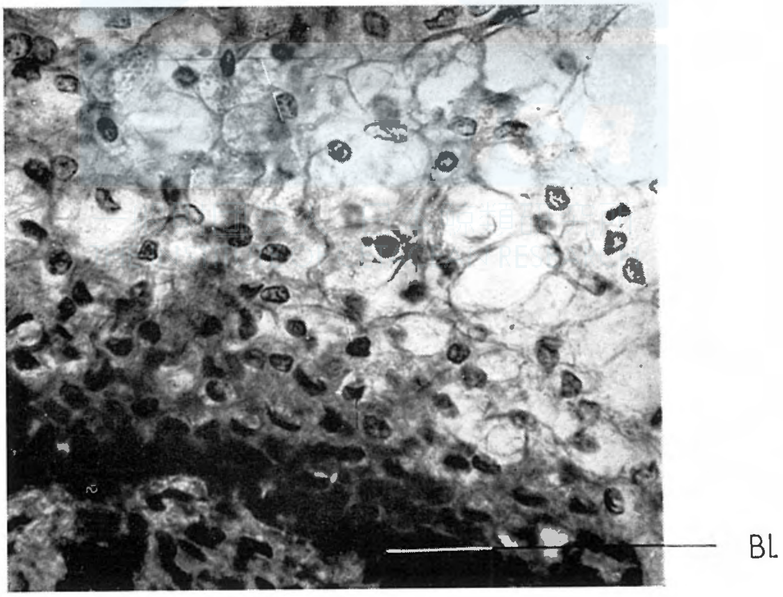

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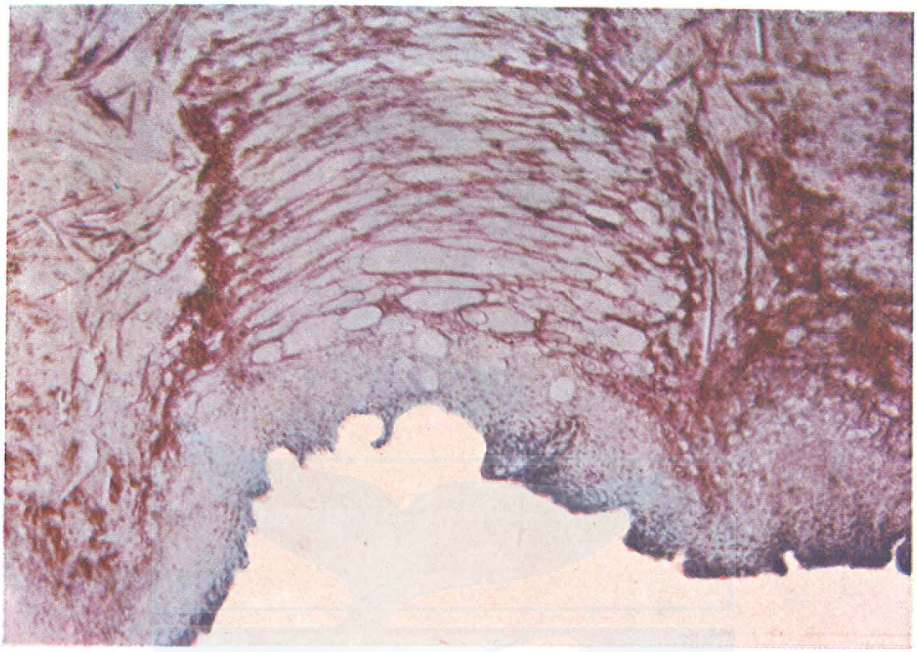

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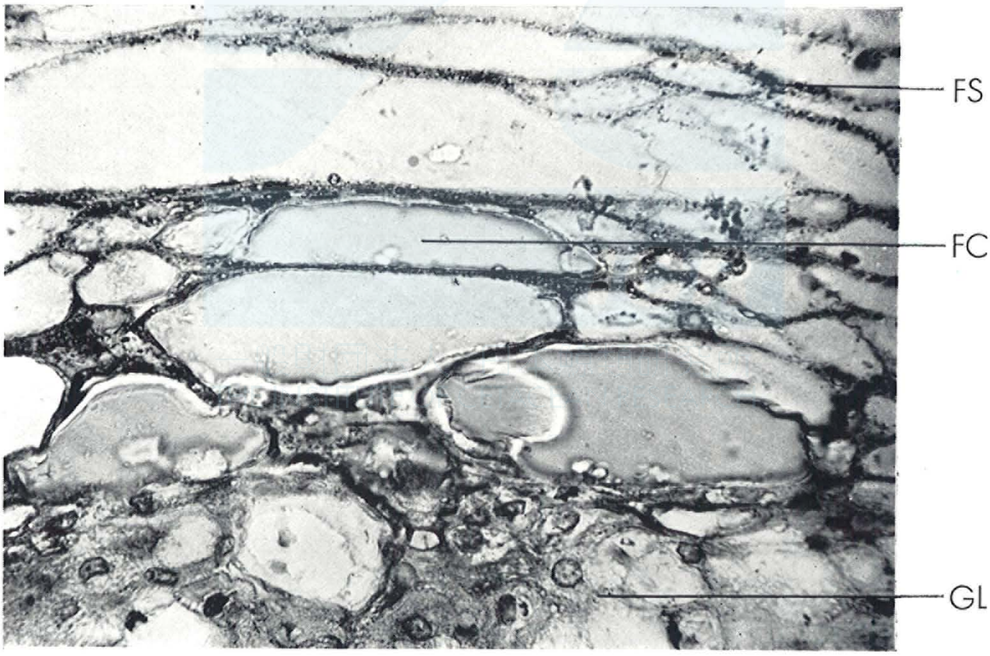

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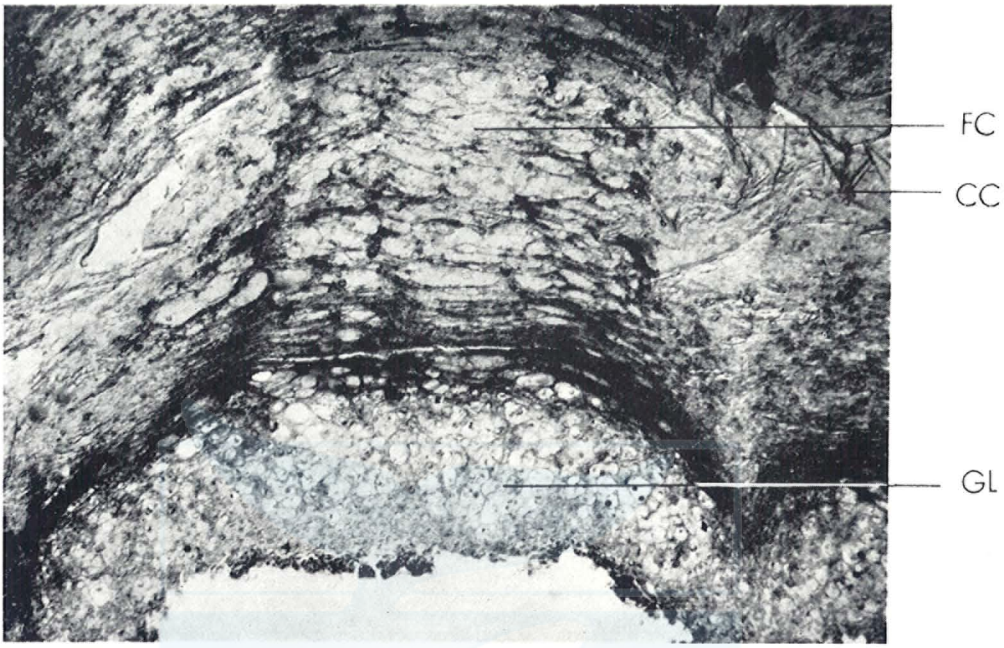

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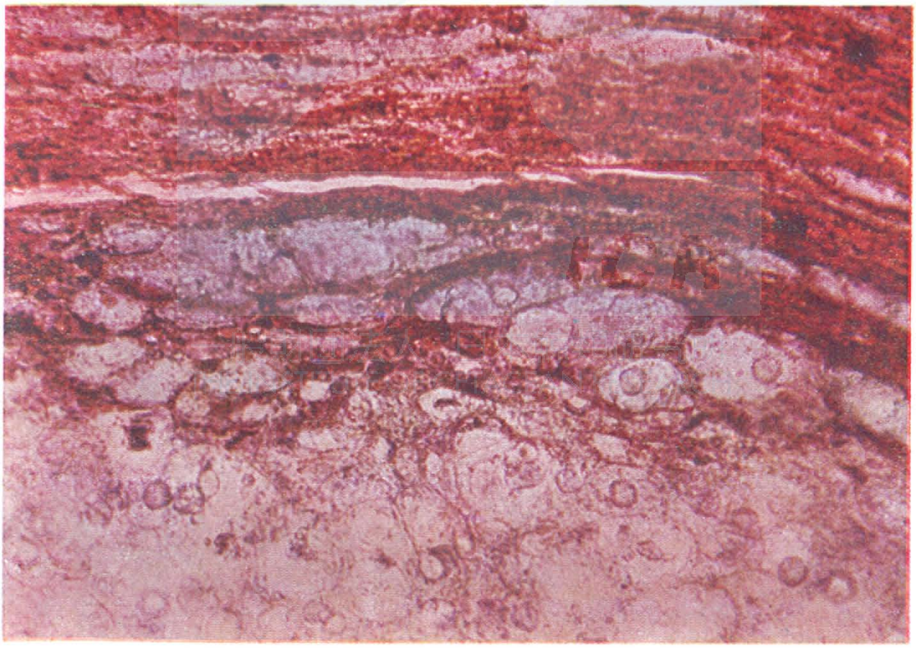

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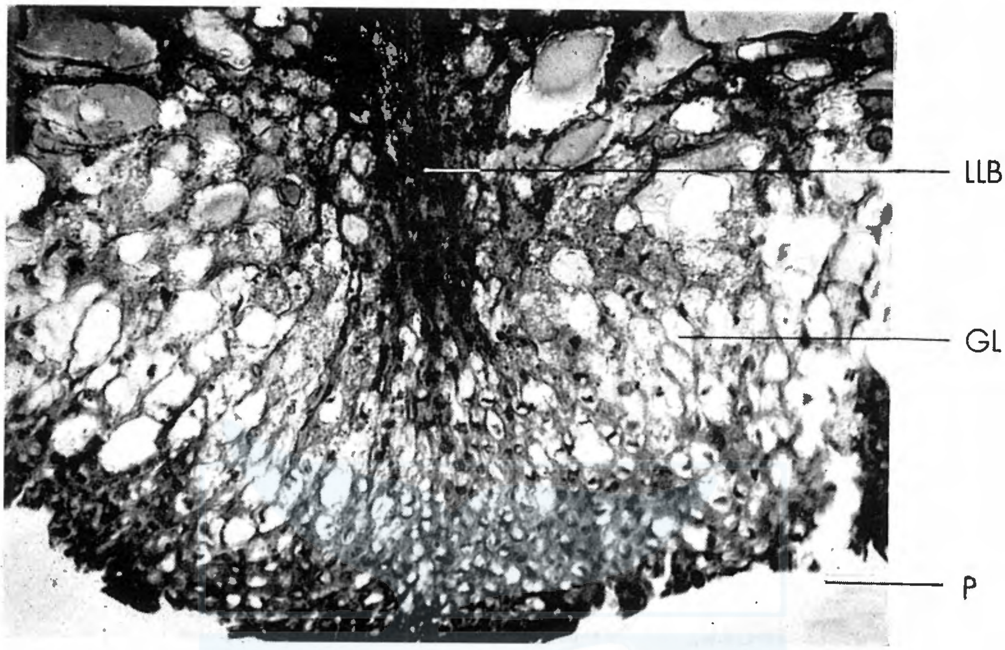

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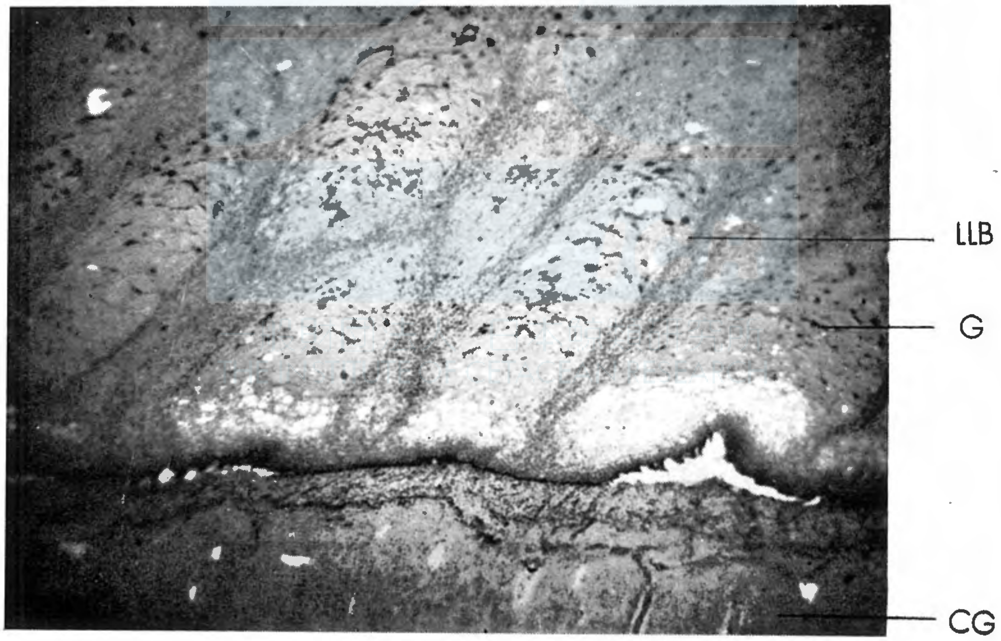

Fig. 2


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SURFACE WATER CONDITION IN THE ANTARCTIC WHALING PACIFIC AREA IN 1956-57

KEIJI NASU

INTRODUCTION

In this paper the surface water conditions in the Antarctic whaling grounds are discussed by use of the oceanographical data obtained by our investigations 1956-57, on the board of whaling factory ship "Nisshin-maru" and the whale marking research boat "Fumi-maru No. 17" belong to the Taiyo Fisheries Co., Ltd.

Our observation area is mainly covered by the region within the foremore whaling sanctuary area, from 70°W to 150°W. The oceanographical materials treated in this paper are the terms of surface temperature and salinity of sea water. The observations concerning these materials were made at interval of 4 hours on the board of "Nisshin-maru" and on the board of "Fumi-maru No. 17" at interval of one hour, during the whale marking research before the opening baleen whaling.

WHALING GROUNDS IN THE FOREMORE SANCTUARY AREA

Considering from twice catch operations carried out by the Japanese Whaling Expeditions, the whaling grounds within the foremore sanctuary area can be roughly separated into three parts.

Namely, these whaling grounds are located along the meridians of 90°, 120° and 150°W. The operations in the ground along the 90°W were mainly carried out in the beginning season (January) and afterwards shifted towards the west sea areas with the pass of the whaling season. Moreover, the latitudinal area of these whaling grounds corresponds to the domain from about 60°S to 71°S.

The positions of northern-most and southern-most parts of these grounds exist near the 140°W. And, generally speaking, as for the latitudinal width of the whaling grounds, it appears to become narrow from west towards east.

HORIZONTAL DISTRIBUTION OF SURFACE TEMPERATURE AND SALINITY

December. The −1.5°C-isotherm is situated in the east of the Peter I

Island, in the neighbourhood of 68°S, 83°W. And, in this region it is extended in a tongue shape towards the NE direction. In the vicinity of the tongue area, the temperature changes abruptly.

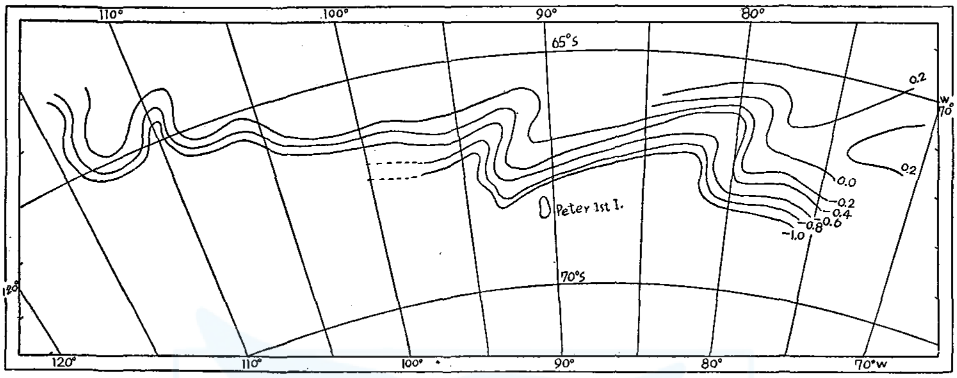

Fig. 1. The horizontal distribution of temperature at surface. December 1956.

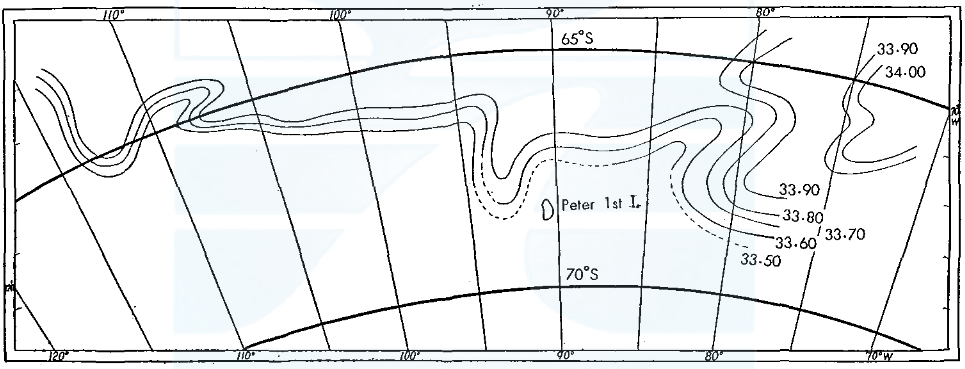

Fig. 2. The horizontal distribution of salinity at surface. December 1956.

The 33.50‰-isohaline is distributed in the same pattern as the temperature isoline, and in this region the low temperature and salinity water mass, which is formed by the melting ice and moves northward, is apparently found. The salinity seems to reduce gradually with the pass of month, as already described by Sugiura (1949). The sea water in this region is well known as the Antarctic surface water (Midttun and Natvig, 1957).

At the position of 66°–30′S, 73°–00′W, the tongue shape distribution of the high temperature and salinity water mass (more than 0.5°C and 34.00‰) is projected towards the west. Near 74°W, the meandering discontinuous lines of temperature and salinity are found. At the position of 64°S, 83°W, the water mass having the high temperature and salinity more than 1.0°C and 33.90‰ is situated towards the south-west.

And, in the region of south-west direction of the above water mass (about 68°S, 93°W), there exists a tongue shape region which extends towards the southern direction.

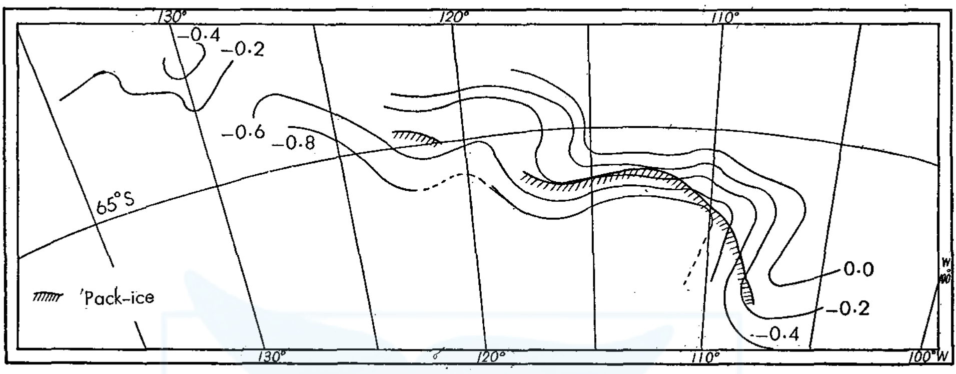

Fig. 3. The horizontal distribution of temperature at surface. January 1957.

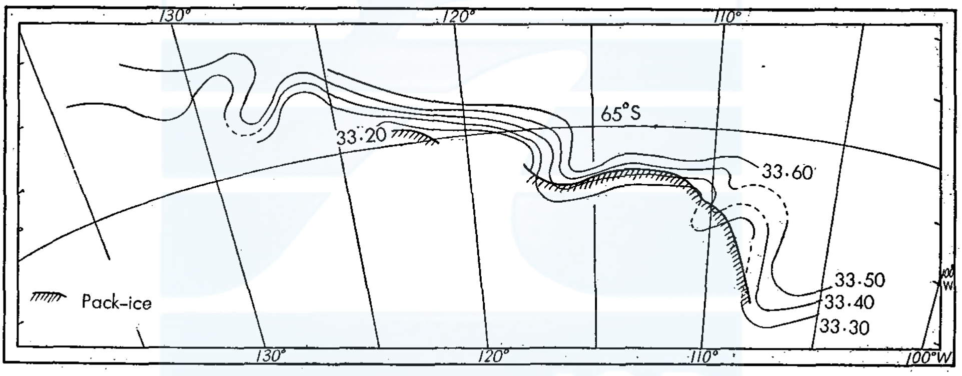

Fig. 4. The horizontal distribution of salinity at surface. January 1957.

In the vicinity of the about 65°S, 110°W, the low temperature and salinity water mass which are formed by −0.5°C and 33.50‰ run northerly in a tongue shape. In the western part of the above tongue shape region, the comparative high temperature and salinity water mass (more than −0.2°C and 33.70‰) is projected southerly. The isotherm and isohaline of this region are laterally meandered and it seems that their patterns form the cyclonic.

January. Observation area covered from about 105°W to 130°W. The surface temperature in this area varies from 0.5°C to −0.9°C. The distribution of pack-ice at January is extended towards the east from the vicinity of the position 66°, 117°W and it is directed southerly very sharp from the position of 66°S and 110°W. To the east area of the pack-ice, the tongue shape of the isolines of relative high temperature and salinity with values more than 0.0°C and 33.60‰ is penetrated towards the south-west. To the west side of the south-westerly tongue region, the low temperature and salinity water mass is projected towards the north-east. This fact would have been probably caused by the condition of distribution of pack-ice. In the sea region between the northern and southern currents evaluated by referring the isoline map are formed the intricate sea conditions, and the distribution of temperature in this area varies abruptly.

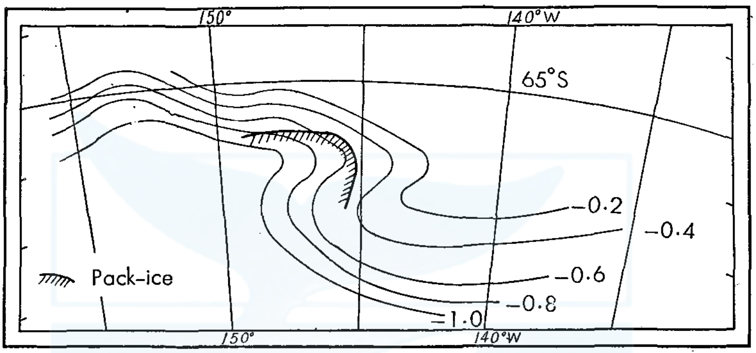

Fig. 5. The horizontal distribution of temperature at surface. February 1957.

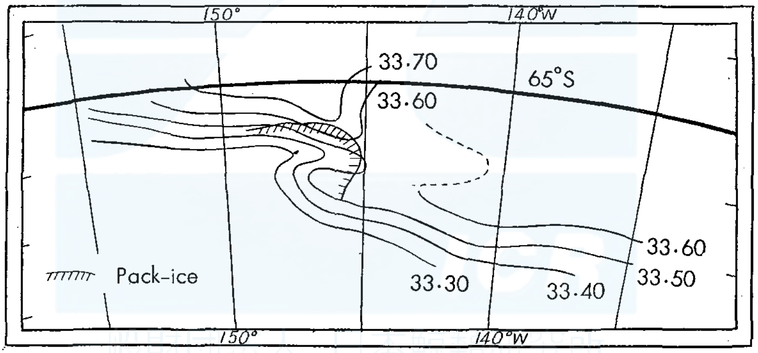

Fig. 6. The horizontal distribution of salinity at surface. February 1957.

The condition of pack-ice at the western part of the 117°W is not clear, but it will be evaluated that the pack-ice is distributed towards southern direction from about 117°W.

At the vicinity of 117°W, the high temperature and salinity water mass is found, and at the west part of it, near the 128°W, the considerable emphatic tongue shape running toward the south-west direction is recognized.

February. Observation area made in this month is covered from 160°W to 120°W. And, the minimum temperature in this region was −1.4°C in the edge of pack-ice and also there exists the tongue-shaped low temperature zone extending towards the east direction along the pack-ice zone. Moreover, the low isohaline of 33.30‰ runs in the same pattern as the low isotherm along the pack-ice line. In the vicinity of the pack-ice zone the low temperature and salinity water mass is found, and the hydrographical conditions of water mass vary extremely. This fact is clearly influenced by the melting of ice, as described by Sverdrup et al (1946), and it is assumed that before the occurrence of its melting, the distribution of ice was extended towards the east.

On the other hand, the high temperature and salinity water mass is extended towards the west part, and in this part there exists the meandering convergence. Generally, the temperature and salinity in December, January, and February are distributed to the tendency to have high value in the east and low in the west. The isoplethes of temperature and salinity are analogous each other.

SEA CONDITION IN THE VICINITY OF THE PACK-ICE

It is clear from the facts already stated that the water temperature and salinity are low in the vicinity of the pack-ice. But we cannot

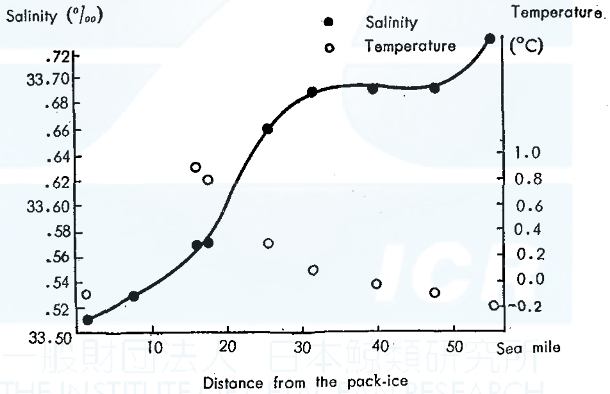

Fig. 7. Temperature and salinity in the vicinity of pack-ice.

assert the generality of this character. Because, the above result did not be deducted from an average treatment of the data obtained by many observations. But, it is recognized that the salinity becomes abruptly lower within the domain of distance 30 sea miles from the pack-ice zone. Besides, Tsuchida (1952) has pointed out that the distribution of salinity changes suddenly within the domain of distance 100 sea miles from the pack-ice.

Referring from Fig. 7, it seems that water temperature is ascent with approaching to the pack-ice and is descent at the nearest vicinity of the pack-ice. But, we will consider that this phenomenon is unreasonable under our physical analysis. Because, in our treatment concerning the distribution of water temperature, we did not take into account the effect of the time dependent deviation of water temperature caused by the variation of the various kinds of meteorological factors with the phase shift of the time of observation in the respective positions.

RELATION BETWEEN THE SURFACE WATER CONDITION AND THE WHALING GROUNDS

In January, the main whaling grounds are situated near the regions of 65°S–115°W and 67°S–107°W, and in the neighbourhood of these two regions the southerly warm currents are found.

In February, the area of whaling grounds are narrower than that in January, and the center of ground area in this month are located near the position of 67°S–145°W, in where the relative high temperature and salinity water mass are projected towards the west. The most of whale caught in this area are fin whales, and the blue whales which are very few in the same ground are caught in the relatively lower temperature region, especially in the region near the pack-ice water.

It will be considered that the center of whaling grounds were situated in the tops of the tongue shape of isotherms and isohalines, as already reported by Shimomura (1950). Generally, it can be assumed that the southerly warm currents play a very important role for the formation of the Antarctic whaling grounds, especially baleen whale's ground.

ACKNOWLEDGEMENT

The author is obliged to Dr. Michitake Uda, Prof. of the Tokyo University of Fisheries, and Mr. Takahisa Nemoto, a member of the Whales Research Institute, for their instruction and helpful suggestions. Dr. Yasukazu Saito and Mr. Makoto Ishino, the Tokyo University of Fisheries, read this manuscript and gave him the valuable suggestions.

Last of all, the author would like to express his hearty thanks to Mr. Yuji Tobita and Mr. Kazuo Haga, member of Fisheries Agency who co-operated this research on the board of "Nisshin-maru".

SUMMARY

1. Generally, the water temperature and salinity at the former sanctuary area have a tendency to be high in the east and low in the west.

2. The salinity around the pack-ice have varied in the vicinity of 30 sea miles apart from the pack-ice.
3. It can be assumed that the southerly warm currents play a very important role for the Antarctic baleen whale's ground.

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A DEFORMED FIN WHALE FETUS

SEIJI (KIMURA) OHSUMI

On January 21, 1959, a deformed fetus was found when a female fin whale was flensed on the deck of the factory ship Tonan-maru in the Antarctic. Then the ship was operating in 61°26′S, 99°58′E.

The mother of the deformed fetus was seventy one feet long, and had one corpus luteum and seven corpora albicantia in her ovaries. I did not notice any abnormality in her body.

I observed that the deformed fetus was living in her mother's uterus when the latter was killed.

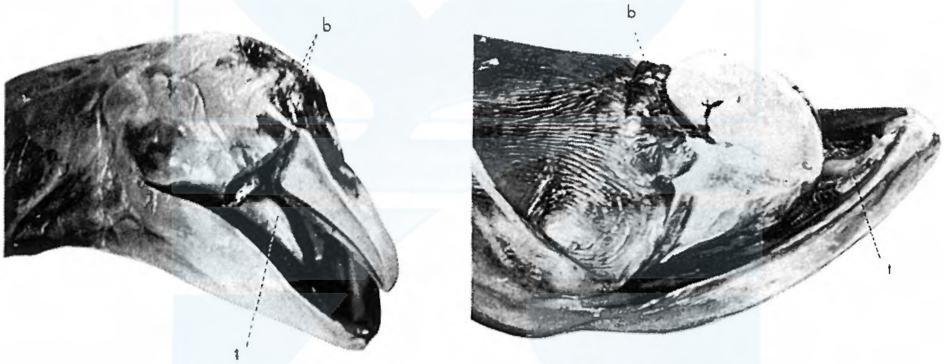


Fig. 1. Heads of a normal and a deformed fetus.
A: Normal fin whale fetus (♀ 73 cm long). B: Deformed fetus.
b: Blowhole. t: Tongue.

The fetus is female and 148 cm long, when I measure from the tip of lower jaw to the notch of flukes along her body axis. Her body weight is 45.4 Kg.

The fetus is very deformed structure in many parts of her body as shown in Plate I. Her upper jaw rolls up and covers her blowholes (Fig. 1b).

Abnormality appears also on her tongue, that is to say, the tip of the tongue fuses to the inner margin of the lower jaw. Furthermore the margin of the tongue is tucked. The throat grooves are complete and normal.

From her body proportion, the tail of the deformed fetus is short in comparison to the normal fetuses as shown in Table 1. And then the tail winds rightward and I could not straighten the body before the fetus was fixed in the formalin solution.

The dorsal fin of the fin whale fetus usually appears when the fetus grows to 15 cm in length. At first the middle of the dorsal fin grows upward, then the top of the fin turns backward at about 50 cm in body length, and becomes near completion. However the dorsal fin of this abnormal fetus is isosceles triangular as shown in Fig. 2.

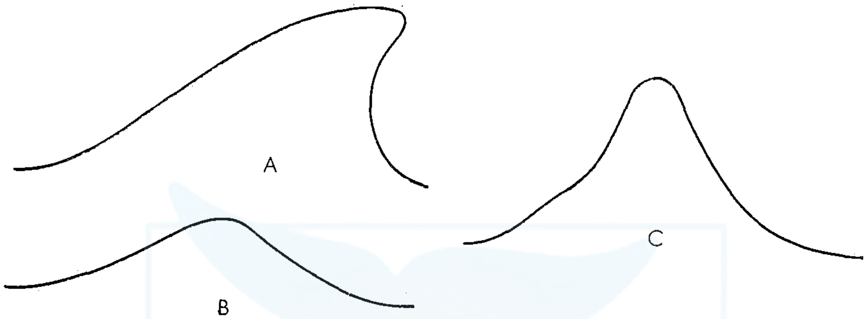


Fig. 2. Dorsal fins of a deformed fetus and two normal fetuses.
A: Normal fetus (♀ 170 cm) (×1). B: Normal fetus (♂ 27.6 cm) (×5).
C: A deformed fetus (×1).

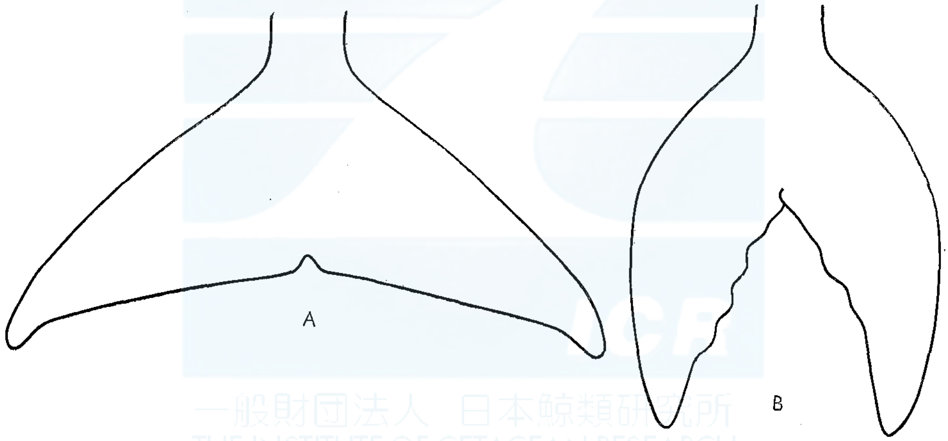


Fig. 3. Flukes of a normal fetus and a deformed fetus.
A: Normal fetus (♀ 214 cm). B: Deformed fetus.

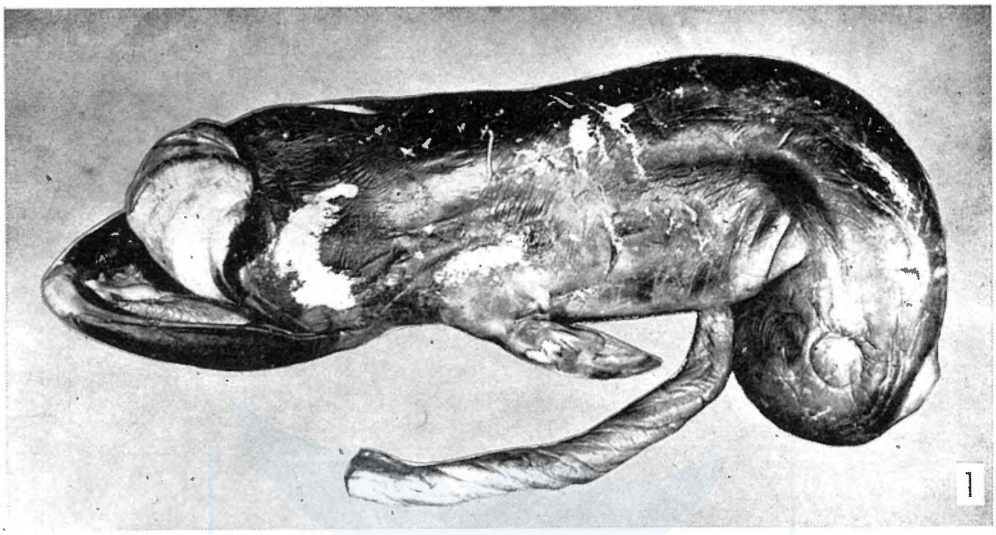
The tail flukes of the fetus (70 cm and over) are usually doubled at the insertion, and when we spread the flukes, the shape of them is nearly the same as that shown in Fig. 3a, although the shape varies with the stage of the fetus. But the flukes of the deformed fetus are not doubled and the tips of them retrocede and approach.

The close examination would be needed further, but I did not dissect and examine this deformed fetus, for this is used as a specimen of our Institute.

TABLE 1. BODY PROPORTION OF FIN WHALE FETUSES

	Deformed fetus[a)]		Normal fetuses (150~250 cm)
	Actual length (cm)	%	Range of percent to total length[b)]
Tip of lower jaw to notch of flukes	148	100.0	—
Tip of lower jaw to angle of gape	L 31.0 R 33.0	20.9 22.3	—
Tip of lower jaw to center of eye	L 27.0 R 31.0	18.2 20.9	16.0~20.0
Tip of lower jaw to tip of flipper	L 65.0 R 65.0	43.9 43.9	40.5~45.5
Center of eye to center of ear	L 9.4 R 10.5	6.4 7.1	6.0~ 7.5
Notch of flukes to posterior margination of dorsal fin	36.5	24.7	23.0~28.0
Notch of flukes to center of anus	35.0	23.6	27.0~33.0
Center of anus to reproductive aperture	2.5	1.7	1.5~ 3.5
Center of anus to umbilicus	17.5	11.8	13.0~19.0
Center of anus to posterior margin of ventral grooves	20.5	13.9	14.0~17.0
Height of dorsal fin	4.6	3.1	1.8~ 3.5
Length of base of dorsal fin	9.7	6.6	3.5~ 6.5
Flipper, tip to anterior and of lower border	L 22.0 R 20.0	14.9 13.9	11.0~16.5
Greatest width of flipper	L 6.3 R 6.0	4.3 4.1	3.0~ 4.0
Width of tail flukes at insertion	8.0	5.4	6.5~ 4.0
Tail flukes, tip to notch	L 15.5 R 15.5	10.5 10.5	10 ~14
Total spread of tail flukes	13.5	9.1	—

a) Fixed by formalin solution.
b) Tip of upper jaw to notch of flukes.



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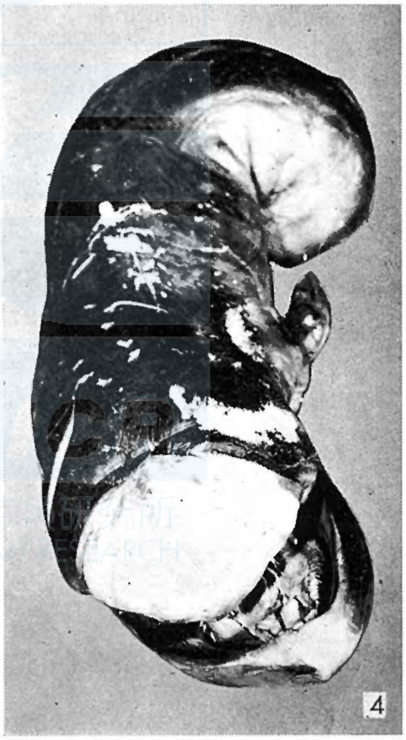

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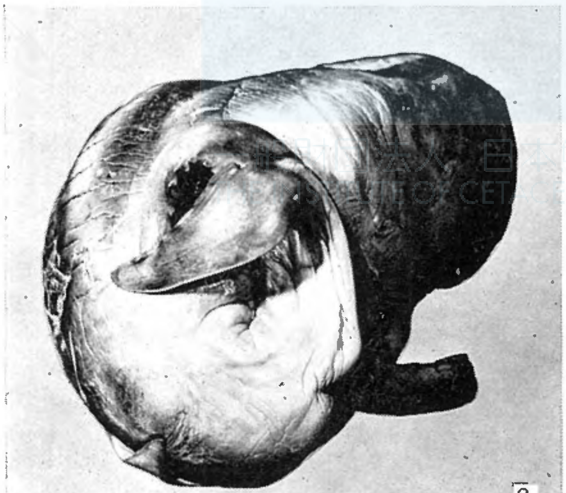

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FOOD OF BALEEN WHALES WITH REFERENCE TO WHALE MOVEMENTS

TAKAHISA NEMOTO

The close relationship between foods and whales has long been recognized and many works on the role of foods in the interrelationship between foods and whales have been undertaken in many parts of the world open sea. In the previous report (Nemoto, 1957), I described the short summarized historical reviews on the problem and tried to discuss the foods of baleen whales in the northern part of the North Pacific. In the paper, the main foods of the northern Pacific baleen whales caught by Japanese pelagic expeditions are described. But after the year 1956, Japanese expeditions have covered broader areas in the northern Pacific, and insufficient data in the paper have been complemented by the successive researches. The previous paper of mine, at it was, should be regarded as a preliminary report on this problem, and I would add the more detailed discussions here but some discussion described in my previous paper may be omitted for the convenience for the preparation of the paper.

Japanese investigation of foods of baleen whales are also carried out in the waters adjacent to Japan as well as in the northern part of the North Pacific. Only a few works has been made on the subject, however, the works are not always quite satisfactory. Especially on the taxonomy of food planktons in the adjacent waters to Japan, those works were not so correct still in the very recent investigation, and I point it in the previous paper that the insufficient taxonomy of food planktons has made some confusions among the studies of foods of whales. I have been trying to correct these mistaken species as well as possible except some species still remained to be corrected owing to the lack of materials. As to the Antarctic waters, Japanese investigations on whales have operated in some 14 years after the year 1945. These accumulation of researches have proved the results done by *Discovery Committee* are quite satisfactory, and there are some other reliable informations of the whales in Antarctic that they feed on other euphausiids and planktons than *Euphausia superba*, the famous main food of baleen whales in the water.

Whales Research Institute's investigation on the biology of euphausiids is in process now, but interesting results have been obtained through the course. Unfortunately, Japanese investigations only cover the summer seasons of both high latitudes, and I could not examine the winter samples of both areas at all. So I would like to refer to the *Discovery* works (Bargmann, 1945; Fraser, 1937 etc.) about the biology of euphausiids in the Antarctic in some points, but I would state some new consideration on the problems of the relation between foods and whales in order to add something to the recent knowledge of baleen whales. The distribution of euphausiids is also studied in view of feeding condition for whales in the ocean and local characteristics of euphausiids in growth and morphological points.

With regard to the migration and movement of whales, vast number of researches should be done before the definite conclusion is obtained. But I would try here, to comment the particular tendencies of whale movements related to the food of whales mainly consulting with marking results, catch statistics and oceanographical conditions.

Oceanographical studies on whaling ground do not show so rapid accumulation of materials that I can't fully discuss the migration of whales only from the oceanographical conditions of view. But some baleen whales show clear distribution in accordance with the water temperature of the sea, the shape, the topography of the sea and the abundance of the foods.

For comprehension of the relation between foods and whales, it is desirable to study body characters of whales. I examined these particulars as feeding apparatus in order to add the appropriate consideration to the foods of whales in this paper. Body structure examination of baleen whales show interesting fact that the preference of whales for food are affected by the body structure, external apparatus for feeding. Some ecological classification of whales is given by Eschricht (1846 in Tomilin, 1945) and Kükenthal (1892 in Tomilin, 1945), and Tomilin (1954) states further discussions on the classifications based on morphological and biological characteristics. In this report I also try to classify baleen whales into typical types according to said features of whale bodies and feeding.

This paper is by no means a conclusive information on the foods of whales, because there are many unsolved question of foods of whales remained. And these question will be discussed again after many examination and collection of materials are obtained.

Finally, I think it is of use to summarize the species of foods of whales in many sea regions from many previous works on the problem here in this paper to suffice the present inquiry of knowledge of foods of baleen whales.

ACKNOWLEDGEMENT

I wish to express my sincere thanks to Dr. Hideo Omura, the Director

of the Whales Research Institute in Tokyo for suggesting this investigation as well as for constant guidance in the course of the work. Dr. Masaharu Nishiwaki of the Institute has kindly given me valuable comments on my draft of illustrations of the whales' body characters and kind suggestions. The present work could not have been written without the materials supplied and facilities by my colleague Mr. Kazuo Fujino, Mr. Seiji Ohsumi, Mr. Keiji Nasu and Mr. Tadayoshi Ichihara. They have kindly collected my stomach samples and net collections in their expeditions on board both in the Antarctic and in the North Pacific.

Sincere thanks are also due to Dr. Yoshiyuki Matsue, Professor of the University of Tokyo, for his kind and constant guidance throughout the course especially on the plankton study.

On the whale marking problems, I am much indebted to Mr. Takehiko Kawakami of the Fisheries Agency of the Japanese Government. He also furnishes me some valuable informations which have not been published by himself.

Dr. Yoshio Hiyama, Professor of the University of Tokyo, has kindly suggested me methods for analyzing the feeding apparatus and quantities of stomach contents and gives me constant encouragement.

I would appreciate very much the helpful discussions on euphausiids with Mr. Yasuhiro Honjo of the Tokai Regional Fisheries Laboratory and Mr. Yuzo Komaki of the University of Tokyo.

I am also indebted Dr. Michitaka Uda, Professor of the Tokyo University of Fisheries for his helpful comment on the oceanographic problems.

To many member of the whaling companies, I am much indebted for many facilities on board and at the landstations in Japan throughout my examination of whales.

Finally, I thank with very best regards Mr. Jinjiro Nakai, the chief biologist of the Tokai Regional Fisheries Laboratory for his constant guidance in the plankton study from my school days at the University of Tokyo.

MATERIALS

The following materials are available for the present study throughout the course. These data and samples are collected by biologists and inspectors on board in the North Pacific and in the Antarctic waters.

In the northern part of the North Pacific, Japanese pelagic expeditions have caught following baleen whales which have been examined.

Periods covered	Blue	Fine	Sei	Humpback
1952–1958	569	7505	804	392

Methods of the examination on these baleen whales is already stated in the previous report (Nemoto, 1957). Rough classification on species quantity and freshness are determined on boards, and a part of each stomach contents have been preserved in formalin sea water and brought back to our Institute.

In adjacent waters to Japan, following investigations have made collections of materials, however, those materials and observations are not so sufficient. They are all partial collections of whales caught in the waters adjacent to Japan. These are as follows.

Okhotsk Sea, in 1952, 1953, 1957 and 1958. Stomach samples and observations by T. Nemoto and T. Ichihara.

North east area of Japanese coast, Sanriku and Hokkaido in 1952, 1953, 1956 and 1957. Stomach samples and observations by all staffs of the Whales Research Institute.

South west area of Japan proper, Oshima, Wakayama in 1958. Stomach samples and observation by T. Nemoto.

West Kyushu area or East China sea, in 1955, 1956 and 1957. Stomach samples and observations by K. Mizue, K. Fujino and T. Koga.

Bonin Islands waters, in 1948, 1949, 1950 and 1951. Stomach samples and observations by inspectors and biologists on board.

The Whales Research Institute data on the baleen whales in the Antarctic available up to date are made of following whales.

Period covered	Blue	Fin	Sei	Humpback
1946–1958	5449	28395	1502	975

These observations include the works on the stomach contents, species, quantity, freshness and size of the foods of whales.

The following statistics are also used in this paper so as to get the informations on the catch and seasons of whaling.

International whaling statistics

Japanese shore whaling statistics, seasons in 1910, 1911, 1914, 1919, 1921, 1922, 1926, 1932, 1934, 1940, 1941, 1942, 1943, 1944, 1945, and those after the year 1945.

Japanese whale marking investigations have been carried out from 1949 in the North Pacific and data of discovery of marks are all provided by courtesy of the Fisheries Agency of Japanese Government. A full list of these marks returned from baleen whales from 1949 to 1958 is given in the Appendix. Some interesting informations on the Antractic whale marking carried out by co-operations of International whale marking program are also very useful for the consideration of movements of whales. The note of those prepared by Brown in the Norwegian Whaling Gazette is helpful for consideration of the movement of whales in recent years too.

The materials of body proportion and body characters obtained through the northern Pacific, Bonin Islands and Antarctic waters expeditions and results at the stations are referred to make the illustrations of whales. The skeletons and baleen plates preserved in Japanese museums are measured in needs in order to get the comprehension of feeding mechanisms of baleen whales and body characteristics.

FEEDING APPARATUS

As already well known, all of the baleen whales take their foods with their baleen plates or whalebone. The baleen plates of whales and some other special features about mouth part of whales differ among each species of whales considerably. It is considered that feeding habits and their preference for foods are much affected by the character of baleen plates and other features. Here, I would state the summarized discussion on feeding apparatus of baleen whales. However, the difference among internal organs of baleen whales is omitted in following.

BALEEN

Number of baleen plates. Number of baleen plates of whales is illustrated in Table 1, mainly based on the data by *Discovery* investigations and Japanese expeditions. There is no significant difference between the Antarctic and North Pacific whales except Bryde's whales. The data of the North Pacific Bryde's whales are obtained in the Bonin waters (Omura, Nishimoto & Fujino 1952), and those of southern hemisphere may be gotten in Saldana Bay, though it is not certain. Bryde's whales in these two localities are considered really the same species, *Balaenoptera edeni* (Omura, 1959 p. 24), but I have no further information on the number of Baleen plates of Bryde's whales in the southern hemisphere.

TABLE 1. AVERAGE NUMBER OF BALEEN PLATES OF BALEEN WHALES IN ONE SIDE IN THE NORTHERN PACIFIC AND THE ANTARCTIC WATERS

	Blue	Fin	Bryde's	Little piked	Sei	Hump-back	Right	Grey
North Pacific								
Range	300–400	300–400	260–370	260–300	320–380	300–370	230–260	130–180
Approximate mean	360	355	300	280	340	330	245	160
Antarctic and Southern hemisphere								
Range	260–400*	260–480*	250–280	—	300–410*	300–370*	220–240*	—
Approximate mean	320	360	—	—	345	—	—	—

* After the data by *Discovery* research since 1929.

Generally speaking, the large whales have more numerous number of baleens, but the number of baleen plates does not bear such a great efficiency for the selection of their food as the morphological characteristics of mouth part or the features of baleen plates and fringes. It is noted, however, that the whales belong to BALAENOPTERIDAE have many baleen plates ranging from 250 to 400, but whales belong to BALAENIDAE from 220 to 260, and whales belong to RHACHIANECTIDAE from 130 to 180. Above results may be due to the fact that whales belong to BALAENIDAE and RHACHIANECTIDAE lack the baleen plates rows at the top of palates in the mouth. Grey whales have the smallest baleen plates in number, which is the half of the number of baleens of BALAENOPTERIDAE whales. Another reason for the fact may be the heavy thickness of baleen plates of grey whales.

Right whales lack the plates row at the top position of palate and the number of baleen plates are comparatively small in number comparing with other whales. Right whales have, however, the longer plates which may enable the whales to filt the micro-planktons successfully by the broad baleen filter. This morphological feature is very important for the feeding habits of right whales which I discuss later.

Shape of baleen plates. The shape of baleen plates also differ very much according to the whale species. It may be classified into following three groups.

Balaena (*Eubalaena*) type
Balaenoptera type
Rachianectus type

Whales belong to BALAENIDAE (*Balaena* and *Eubalaena*) have long elastic baleen plates with fine fringes. On the other hand, BALAENOPTERIDAE whales have comparatively short and less elastic plates. Above distinctions give us very interesting suggestions. Tomilin (1954) considers in his short but very excellent paper, the adaptive type of baleen whales are classified according to the thickness of bristles and flexibilities of the plates. The latter point flexibilities of baleen plates may be very useful for successive filteration in the sea. Generally speaking, the long elastic baleen plates mean convenience to skim the foods in the sea water. Because the baleen plates are filtering foods on the surface of the inner plane consists of fine baleen fringes, and long inner edge of baleen plates is very effective in the successive filtering. Short and wide based plate is on the other hand very useful for filtering their foods in a very short time, with strong stress of flesh tongue to make the water run off through the plates remaining the mass of food in the mouth.

Baleen plates of fin whales belong to *Balaenoptera* type show some ocal difference. Baleen plates of fin whales caught in the northern part of the North Pacific have a strong resemblance to those of the Antarctic waters but those of fin whales caught in the East China Sea are shorter and of more coarse texture. The difference closely related to the one between the baleen plates of sei whales and Bryde's whales. I would also consider this difference means some local stock existence of fin whales in the Pacific Ocean as considered by Omura, Fujino, Ichihara and Kimura (1958) and Ichihara (1957) as well as some different condition of feeding environment in the waters.

Grey whales have very characteristic baleen plates. Tomilin (1954) describes it in following way, semi-elastic thick, short and coarse. The baleen plate of a grey whale sent by courtesy of Mr. G. C. Pike (Canada) bears such distinctions. But to my regret, the plate may be collected in the anterior portion of baleen plates row, so that I can't imagin the shape of the plates exactly but it is short. Tomilin (1954) considers further that grey whales can dig up and probable even to plow up the silty benthic ground with these short and thick plates. The above function can only be made by such a characteristic baleen plates of grey whales.

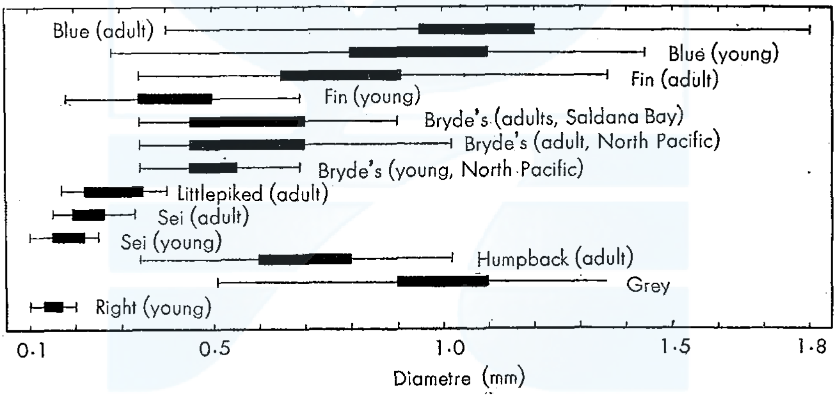

Fig. 1. Diameters of baleen fringes of baleen whales measured at the center position of baleen plates. Black belts show the ranges of dominant sizes of baleen fringes. Adult—whales after the sexual maturity, young—sexual immature and baleen plates are not chipped.

Fringes of baleen plates. I would consider that the baleen fringes of baleen plates have comparatively importance for the selection of their food or feeding habits, though I state in the previous report (Nemoto, 1957) that the degree of luxuriancy or thickness of baleen fringes are considered not to be so important to decide food species of whales. The diameters of baleen fringes of each baleen whales are illustrated in Fig. 1. As clearly shown in Fig. 1, fringes of right whales are the finest one ranging from 0.1 to 0.2 mm in diameter, the same result as

Tomilin (1954). My data are, however, based on two young specimens caught in adjacent waters to Japan, and they are all immature adolescent whales, fringes of which may be far finer than old whales. Usually, the baleen fringes of the older whales are more coarse than those of the younger whales. It is very interesting that the baleen fringes of Bryde's whales caught in the adjacent waters to Japan show the same value as those caught in Saldana Bay, South Africa, and Bryde's whales are famous for their selection of fish as their food (Ruud in Peters 1938). As to the species of whales in Bonin water before 1950, it is not certain if all sei whales caught are Bryde's whales, but Bryde's whales caught along the coast of Japan take fish mainly with some occasional occurrence of euphausiids with rough baleen fringes.

Fin and blue whales have comparatively coarse baleen fringes. Of course the younger fin and blue whales have much fine fringes when they are sucking the milk of mother whales. The smallest baleen whale, little piked whale has still more course baleen fringes than sei whales. Sei whales prefer small copepods to euphausiids in the northern Pacific (Nemoto, 1957), and there is no indication that sei whales take small euphausiids or furcilia stage of euphausiids, which is as small as copepods. This fact suggests something to the selection of food by sei whales. Tomilin (1954) simply considers sei whales, by reason of its fine baleen bristles, may also be classified as 'Microplanktonphagi'. But I would consider further the patch of planktons also bears characteristic distinctions, and the selection of food by whales is also much influenced by them because there are many circumstances that can't be explained by simple diagnose of baleen fringes.

Humpback whales have coarse fringes too, but not so coarse as adult blue and fin whales. As to the baleen plates of grey whales, I have only one example of the North Pacific. The baleen is not suitable for my study as it is collected from the anterior position of the baleen plates row. However, it may be concluded by works of some scientists (Andrews, 1914; Tomilin, 1954), that the baleen fringes of grey whales is very coarse when we consider the moderate body size of grey whales. Tomilin (1954) states in the whales feed on benthic and near-benthic organisms (chiefly amphipods), the straining apparatus develops as a very coarse structure consisting of relatively few semi-elastic, thick, short and coarse plates with spine-like bristles. The plate and fringes are quite different from those of BALAENIDAE, but in the feeding method there is a little resembrance considered.

From the Fig. 1, it may be concluded whales having baleen plates with fine fringes ranging 0.1 to 0.3 mm in diameter can take even small copepods of 0.5 mm or less in cephalothorax length in the scattered condition in the sea. Whales having baleen plates with coarse fringes from 0.4 to 1.8 mm can take euphausiids or other macroplanktons favourably. Of course there are some other evidence and observations that whales with coarse fringes take small copepods. The fact is considered to be due to feeding habits of whales and condition of food planktons, on which I should discuss in the latter part of this paper.

Number of baleen fringes along the edge of plates. The luxuriance of baleen fringes also should be investigated. At the center part of inner edge of baleen plates, the number of baleen fringes are counted for 1 cm. Fig. 2 shows the results. It is clear, from Fig. 2, that blue, fin, Bryde's, little piked and humpback whales are classified into the same group. Sei and right whales into another one group, and grey whales is third group. With comparing the diameter of baleen fringes, the number of baleen fringes also shows interesting fact. Little piked whales have baleen plates with fine fringes, but number of baleen fringes are small in number owing to their thin plates. Usually baleen fringes are found in double or more in some part of inner the edge of baleen plates in other whales. Baleen fringes of little piked whales are rarely doubled, thus making a small number of fringes. Little piked whales often take fish in many parts of the world (Omura & Sakiura, 1956). It must be due to the small number of baleen fringes along the inner edge of baleen plates enabling to take fish or larger macroplanktons more often than they feed on smaller copepods. Sei and right whales have many baleen fringes of the finest tissue. This character is very useful for slow filteration for the scattered small planktons. The heavy luxuriance of fine baleen fringes is considered not so effective the instantaneous filteration for big organisms in the sea water.

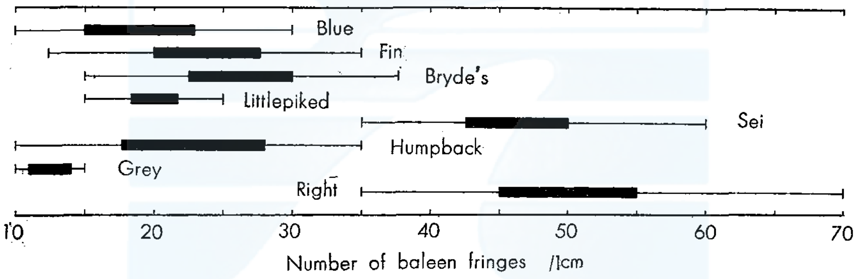

Fig. 2. Number of baleen fringes along the edge of plates of baleen whales caught in the north Pacific. Black belts show the ranges of main range of number. All specimens are collected from sexually mature whale except grey and right whales.

Gray whale has the fewest number of baleen fringes. The baleen fringe of grey whales also the most coarse one. This mechanism must be very effective for rather rapid and successive filteration of food among mud in the bottom of the sea as considered up to these days (Tomilin, 1954).

Baleen plates row. The baleen plates row of baleen whales on the plates has special peculialities too. As already stated, right and grey whales lack the baleen plates or horny spines at the top of the plates, inner rostrum, that is left and right rows of baleen do not coalesce. So, when they open their mouth in swimming the sea water run into the mouth and is then filtered by baleen plates. Right whales have rather broader space between the tip of the plates rows because of the rows projecting in a certain angle. If we see the head of right whales in front, it's shape resembles to triangle form, each side of which is baleen rows. Among BALAENOPTERIDAE whales, the left and right rows are jointed by means of numerous horny spines located near the tip of the plates (Tomilin, 1954). This type of baleen plates row is observed also in *Megaptera* humpback whales. The projecting angle of baleen plates in these whales are nearly the same, but sei whales' baleen plates are considered projecting in a little like right whales.

As to the spacing of the baleen plates row, Matthews discusses the problem in his paper on sei whales (Matthews, 1938). He compares the space between baleen plates of sei whales with those of blue and fin whales and concludes that the spacing of sei whales are not much less than in fin whales. I also notice as the baleen fringes of all whales are long enough to cover the space between baleen plates, the spacing does not mean the significant difference among the feeding types of whales. There is another evidence that the spacing of young whale are extremly narrow comparing with the older whales, and the baleen fringes of the former are also comparatively shorter than the latter

The filtering area in a right whale formed by baleen plates row is much greater than in the other whales belong to BALAENOPTERIDAE. These shapes of the filtering area exactly show the feeding type of whales. Blue whales represent spindle shape filtering areas, and grey whales too. But as grey whales have arched rostrum, they may be able to use this narrow filtering area also in successive skimming. Right whales have, of course, broadest filtering area as shown in Fig. 3. From this illustration, the more available position is located in about two-third of all rows from the tip of the plates in blue and grey whales, and about half to two-third in right whales.

HEAD, MOUTH AND TONGUE

The head parts of whales are also divided into three types in first stage of investigation according to their structure. Blue whale type, grey whale type and right whale type are them.

Those whales belong to *Balaenoptera* and *Megaptera* have related structures of mouth parts. The head is less than one-fourth of the total body length. The rostrum is pointed, but it is not so narrow as right whales, when the mouth is closed, the rostrum fits in between the two lower jaws. The rostrum of sei whales is pointed as in the blue whales, but from lateral view, the rostrum is slightly curved. Fraser (1949) describes this distinction that it recalls the acurate form of BALAENIDAE, but of course in a much less degree, and other *Balaenoptera* whales are closely related to each other. The distinction of sei whales must bear the meaning of the feeding method, which has a little resemblance to that of right whales. The beak of humpback whales is comparatively short and broad. But mouth part is apparently *Balaenoptera* type and feeding method is also considered more related to blue and fin whales.

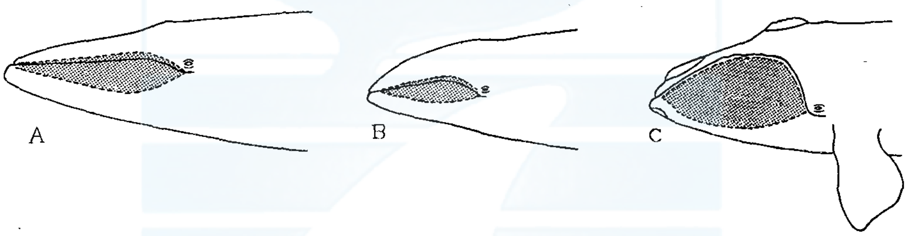

Fig. 3. Heads of baleen whales, A—Blue whale, B—Grey whale, C—Right whale. Shading areas show baleen plates and filtering area of each whale.

The head of right whales is triangular in shape in front of view. The lower edge of the triangle is made of space between two lower jaws, and top of the triangle is the arched head bone. The fore part of the skull is arched. The arching of the skull is not so pronounced as in the Greenland whales, and when the mouth is opend, the water may rush into the mouth because the top of the inner rostrum lack completely whale bones. The lower jaws and sides projected above form an efficient scope for gathering foods as stated in Fraser (1949).

Andrews (1914) states the full description on the body characters of grey whales. The head of *Rachianectes* is very characteristic. Its shape, in some respects, is the intermediate form between that of the BALAENIDAE and the BALAENOPTERIDAE. The rostrum is convex dorsally, narrow and very deep, but it is neither as narrow or curved as in the former, but is much narrower and deeper than in the latter. From the form of skull *Rhachianectes* is the intermediate between of skulls of the *Eubalaena* and *Balaenoptera*.

The lateral section of mouth parts of right and Bryde's whales are illustrated in Fig. 4. Left illustration of Fig. 4 shows the right whale mouth part in scheematic condition. When the mouth is opened, the water rush into the mouth along the tongue and filtered in successive motion. The rather tough tongue may keep the water spread on the inner surface of filterning area of baleen plates row. The narrower base and long extension of baleen plates is very available for running out of waters from cavity of mouth in the slow swimming. As clearly shown in the illustration, to make a successful filteration of foods in swimming, the mouth cavity is widened by opening the mouth, because the sides become U shaped boards from the triangle shape in a closed mouth.

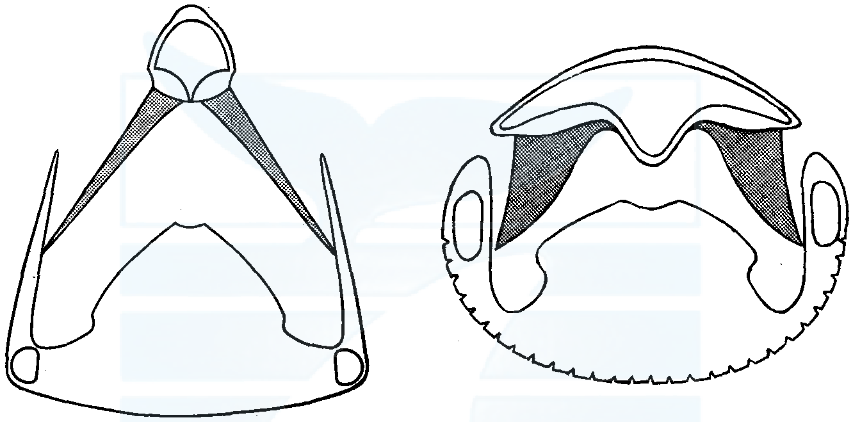

Fig. 4. The lateral sections of mouth parts of baleen whales at the center position of baleen plates rows, Left—Right whale, Right—Bryde's whale.

The section of a Bryde's whale, typical *Balaenoptera* type is shown in the right of Fig 4, the fleshy tongue and ventral grooves expansion make a large cavity to take large volume of water containing the swarms of foods. After the swallowing, the water come out through the space of baleen plates. The left shows the condition of this filtering. The baleen plates in the base keep the baleen very effective in a stong filteration with pressure in a short period. Fleshly tongue is able to scrap all the remaining of food on the surface of coarse baleen fringes successively.

VENTRAL GROOVES

The number of ventral grooves also differ among baleen whale species, and some of baleen whales lack absolutely these ventral grooves. Greenland and right whales have no ventral grooves. Right whales have none of these ventral furrows like grey whales (Omura, 1958). Along the throat and belly part of the body, whales belong to BALAENIDAE have none of throat furrows but grey whales have some thoroat furrows. These throat furrows are comparatively deep and usually two of them are longer than others. And as Andrews (1914) described, the most of grey whales have only two furrows. The function of these furrows is considered to bear some significants to increase the throat capacity in also grey whales, it bears a close connection to take foods or the air (Andrews, 1914).

Humpback whales have fewer ventral grooves than other whales of BALAENOPTERIDAE. And the width of each ventral grooves is wider than the other whales, but the extension of grooves reach the position of 58 percent of the body length from the head in average, and there is no difference from other BALAENOPTERIDAE whales. As shown in Table 2, the number of ventral grooves is the most numerous in blue whales and fin whales come next. According to the data by Omura, Nishimoto & Fujino (1952) there is little difference in number between Bryde's and sei whales in the north Pacific. The number of ventral grooves has been considered as a taxonomic distinction of Bryde's whales from sei whales, so it needs more examination on the point. I would consider the number of ventral grooves of Bryde's whales is more numerous than those of sei whales according to my recent observation.

TABLE 2. NUMBER AND EXTENSION OF VENTRAL GROOVES OF BALEEN WHALES IN THE NORTHERN PACIFIC

	Balaenoptera whales					*Megaptera*
	Blue	Fin	Bryde's	Little piked	Sei	Humpback
Ventral groove extension	58%	55%	58%	47%	45%	58%
Approximate no. of ventral grooves	80	64	53	62	52	22
Range of number	64–94	50–86	40–69	—	40–69	18–24

The extension of ventral grooves also differ among the each whale species. Table 2 shows these values, and blue and Bryde's whales are considered to have the most long extension of ventral grooves in general. On the other hand, sei and little piked whales have comparatively shorter extension of ventral grooves among whales of *Balaenoptera*. The ventral grooves of sei whales do not reach umbilicus, and sei whales have only such a character in Balaenopterids. The shorter extension of ventral grooves suggests something about the feeding of sei whales. Sei whales which have the shorter extensions of ventral grooves may have less convenience to gulp the water, or less throat and mouth capacity when they are feeding. Sei whales often skim their foods in the surface of the water is partly due to above reason, but I have never noticed if the little piked whales usually take their foods by skimming of the water containing the foods scattered condition.

Above stated discussions are all indicating the 'type' of whales in feeding from the point of view of body structures. I would summarize following the each subject. The Table shows four type of body structures for feeding. Those are, Blue whale, Sei whale, Grey whale and Right whale types.

The most important point may be the type of sei whales. Sei whales are considered a little different from other Blue whale type whales, which I describe before. These feeding apparatus type should be examined again by many stand points, feeding method, selection of food etc.

Whale species	Baleen plates			Head, mouth and tongue	Ventral grooves	Apparatus type
	Shape	Fringe	Row			
Blue	Blue	Blue	Blue	Blue	Blue	Blue
Fin	〃	〃	〃	〃	〃	〃
Bryde's	〃	〃	〃	〃	〃	〃
Little piked	〃	〃	〃	〃	〃	〃
Sei	〃	Sei (Right)	〃	Sei (Blue)	Sei	Sei (Blue)
Humpback	〃	Blue	〃	Blue	Hump.	Blue
Grey	Grey	Grey	Grey	Grey	Grey	Grey
Right	Right	Right	Right	Right	Right	Right

I have no exact information on the body characters of Greenland whales, however, they are apparently considered to belong to Right whale type.

FOOD OF THE BALEEN WHALES IN THE ANTARCTIC WATERS

SPECIES OF FOODS

The reason why so many baleen whales swarm in the Antractic waters in summer of the southern hemisphere is up to now attributed to the vast propagation of *Euphausia superba*, which is the main food for them. Many works of foreign and our own Japanese scientists prove that the almost all baleen whales feed on those krill *E. superba* (Mackintosh & Wheeler, 1929; Mizue & Murata, 1951 etc.). In my first cruise to the Antarctic waters from 1954 to 1955, I found none but *E. superba* in the stomachs of baleen whales in the Antarctic area IV. Recent investigations, however, have collected some other very interesting examples of stomach contents though I lack samples of stomach contents in November and December owing to the whaling regulations. One of those food, *Thysanoëssa macrura* is already described in a previous report (Nemoto & Nasu, 1958). In the Antarctic whaling grounds VI and I, which has been sanctuaries before 1955 whaling operation, *Thysanoëssa macrura*, another kind of euphausiids, is considered to bear significans as a foods of baleen whales (Nemoto & Nasu, 1958).

Besides above two euphausiids, the plankton amphipod, *Parathemisto* *gaudichaudi* is found as a food of sei whales in the Antarctic. There are still other planktons which probably become foods of baleen whales. Peters (1955) describes these planktons.

The recent Japanese collections of stomach samples show following occurrences of *Euphausia superba*, *Thysanoëssa macrura* and *Parathemisto gaudichaudi* in the each Antarctic whaling area. As described in the remark of Table 4, the observations and collection of *P. gaudichaudi* are not sufficient, but it has mainly been found in areas V and IV.

TABLE 3. OCCURRENCE* OF *EUPHAUSIA SUPERBA*, *THYSANOËSSA MACRURA* AND *PARATHEMISTO GAUDICHAUDI* IN THE COLLECTED SAMPLES OF THE ANTARCTIC BALEEN WHALES CAUGHT BY JAPANESE EXPEDITIONS IN 1955, 1956, 1957 AND 1958

Species of foods	Area				
	I	III	IV	V	VI
Euphausia superba	69	11	311	402	318
Thysanoëssa macrura	15	2	—	2	20
Parathemisto gaudichaudi	—	—	—	14	—

* Samples containing *T. macrura* besides *E. superba* are included in the column of *T. macrura*, and sampling for *P. gaudichaudi* is not sufficient.

TABLE 4. OCCURRENCES OF ONE AND TWO YEARS' GROUPS OF *EUPHAUSIA SUPERBA* IN THE STOMACH OF BLUE, FIN, SEI AND HUMPBACK WHALES CAUGHT BY JAPANESE WHALING EXPEDITION, CHIEFLY IN AREA V AND IV IN 1958

Euphausiids group	January			February			March	
	1st	2nd	3rd	1st	2nd	3rd	1st	2nd
2 years group								
after copulation	29	58	52	7	4	2	29	11
before copulation	—	—	2	—	—	1	7	—
1 year group	—	8	25	26	36	27	3	—
Mixture	—	2*	16*	7	2	4	2*	—

* *Euphausia superba* of two years group not copulated.

From said results and description by Marr (1956), Peters (1955), I may describe following planktons of the foods of Antarctic baleen whales.

Euphausia superba
Thysanoëssa macrura
Calanus propinquus
Parathemisto gaudichaudi
Euphausia crystarollophyas
Thysanoëssa vicina
Calanus acutus

According to Japanese observation, the Antarctic *Calanus* has never been observed in the stomachs of whales in dominant quantity. But these copepods may play some part of a food for sei whales, because sei whales can skim the scattered food like plankton amphipods in the sea (Nemoto, 1957). *Euphausia crystarollophias* is considered Antarctic species, on which Marr (1956) describes that it becomes a food for blue and little piked whales in the high Antarctic such as Ross Sea. *Thysanoëssa vicina* has not be confidently known as a food of baleen whales in the Antarctic but in the whaling area I, the occurrence in the far off waters from the pack ice is probable from the distribution.

Euphausia superba is the most important food for the Antarctic baleen whales as considered up to the present. *E. superba* is a by-ennial euphausiid, and the investigation usually finds 1 year or 2 years groups in the stomachs of whales. I would use here the term, 0 year group, 1 year group and 2 years group, after the classification by Ruud (1932). In this case, 0 year group means the *E. superba* from egg to adolescent within a year living, 1 year group after 1 year making comparatively rapid growth and 2 years living, 2 years group after 2 years living. I find *E. superba* of 1 year or 2 years group in the stomachs of baleen whales in general, and 0 year group has never been noticed by my investigation. Recent observations of above classifications are shown in Table 4.

TABLE 5. OCCURRENCES OF ONE AND TWO YEARS' GROUP OF *EUPHAUSIA SUPERBA* IN THE COLLECTED SAMPLES OF WHALES' STOMACH IN 1957

Euphausiids group	January			February			March	
	1st	2nd	3rd	1st	2nd	3rd	1st	2nd
2 years group								
after copulation	5	10	14	36	16	25	17	7
before copulation	—	1	—	—	1	—	—	—
1 year group	3	12	6	15	34	57	21	16
Mixture	—	4	4	3	4	5	3	3

I get these observations in whaling area IV and V mainly, but the samples in 1957 had been collected from the whaling area I and VI. It is clear from these Table 4 and 5, that 2 years group is comparatively dominant in the earlier decades and 1 year group in the later decades. Of course as shown in Table 4, I observed many occurrences of 2 years group in the late decades of March in the whaling ground V in 1953, which is also illustrated in the next figure of Fig. 5. Generally speaking, *E. superba* of 2 years group is the better food for baleen whales than 1 year group of euphausiids. This has fewer oil contents than that, and further there are another reasons such as the behavior of the dirnnal migration. The adult 2 years group *E. superba* swarms heavyly in the surface waters to take their foods and copulate. The swarms of these *E. superba* are mainly restricted in the surface waters within the 10 meter depth (Marr, 1957). This condition is very favourable for baleen whales to feed. It is also very interesting that the most of 2 years group of *E. superba* has copuleted. There are, on the other hand, some occurrences of 2 years group *E. superba* in 3rd decade of January in 1958. These 2 years group *E. superba* swarms are, however, found along the pack ice where the growth and spawning of euphausiids are comparatively slower or later than those in the off waters. A example of distribution of 1 year and 2 years group is given in Fig. 5, which is drawn after the observation in 1958. This figure gives exact distribution of the two groups. The detailed explanation should be referred to the explanation, but in short it may summarized as follows. At first in the earlier whaling operation, fin whales feed on the 2 years group *E. superba*, which is copulating, distribute in the off waters 200 miles from the pack ice as shown in Fig. 5. The feeding ground consists of 2 years group of *E. superba* falls down in February which is due to the subsiding of gravid females of *E. superba* to spawn in deeper waters, as Bergmann (1945) discussed in her paper. But the feeding grounds of

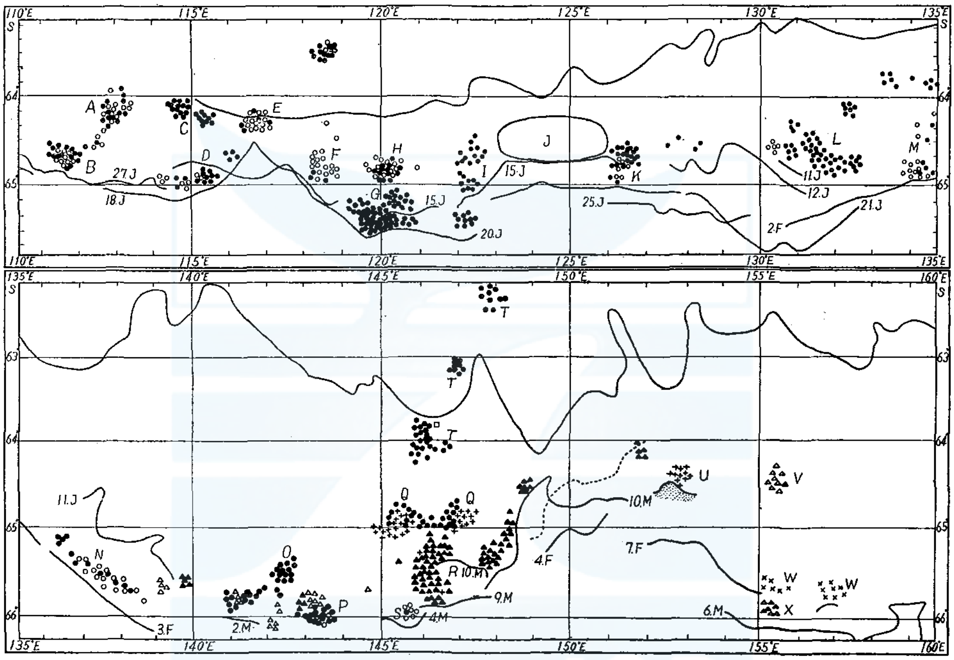

Fig. 5. A example of the distributions of pack ice line and foods of baleen whales in the stomachs of whales caught by Japanese operations in the Antractic in 1958. Open circles—1 year group of *Euphausia superba*. Solid circle—2 years group in January and February. Open triangle—1 year group of *E. superba* in March. Solid triangle—2 years group of *E. superba* in March. Cross—*Parathemisto gaudichaudi*. Open square *Thysanoëssa macrura*. Alphabet show the whaling grounds and number and alphabet show the pack ice line of the date. J—waters where no swarm of *E. superba* is obsered and no whale caught.

1 year group flowerish still in the late of the summer season of the Antarctic. This fact does not deny the another evidence that the 2 years groups of *E. superba* are found throughout the season. But in this case successive appearance of 2 years group of *E. superba* is not due to the same group of *E. superba* occurrence. Different *E. superba* may come up successively into the surface waters with the retreat of the pack ice.

According to Ruud (1932), the Nowegian whalers well know 'Blue whale krill' and 'Fin whale krill' meaning 1 year and 2 years groups of *E. superba* respectively. Peters (1955) states, these early stages of the smaller *E. superba* occur dominantly at the beginning of the whaling season from November to December. But my collections do not show such tendencies. I am not sure which is right, because my collection only started from 1954, before which no available observation and collections of systematic research had been made on the stomach contents. So I lack completely these earlier season samples. But the explanation may be given by local characters of the Antarctic ocean. Except some waters along the Ross sea, Japanese whaling has covered usually the ground along the pack ice. On the other hand, the foreign Antarctic operations sometimes have been conducting in the far off waters from the pack ice, where the drift of the euphausiids from the southern waters is observed. The circulation of Weddle sea current may bring these younger stage euphausiids to the ground, or 2 years group of small size appears in the earlier seasons along the pack ice before retreating to the south. Thus the foreign scientists found the small size euphausiids. According to the Peters (1955, Fig. 3–6), the size of *E. superba* in the off waters are comparatively larger than that in the waters along the ice, or the small size groups, that is 20 to 30 mm in length, are more abundant in the latter areas than the former said waters. On the other hand, he considers the small *E. superba* is dominant in the earlier season. Blue whales, the earlier comer to the Antarctic waters than fin whales, take their foods along the pack ice where the euphausiids of 20 to 30 mm in length are mostly abundant. Fin whales feed, on the other hand, *E. superba* of 30–40 mm in length favorably. In my collections of 1957 and 1958, the dominant size groups belong to the larger body length groups as shown in Fig. 6. From 15 mm to 40 or 45 mm length group is considered to be 1 year group in 1957 and from 45 to 50 mm groups is 2 years group. As above measuring is given by the value from the tip of telson, these value may be a little different from the figures given by Peters (1955). Anyway, the occurrences of 1 year group and 2 years group are about half and half of the total in my collections.

Bargmann (1945) measured the diameter of eggs of gravid female, and get the average of 0.55 mm, and my work also coinside with the result. The heavy gravid female (stage 7 by Bargmann, 1945 p. 115 or Ruud stage 3–4) is found in the collections of stomach samples in January and February. These stage of maturities of *E. superba* also show the half in total in consideration of swarms of euphausiids. Whether the swarms of *E. superba* in the stomach of whales copulated or not is already given in the Tables 4 and 5, and the copulation date is late one or not is shown by the condition of spermatophores in thelycum (Bargmann, 1945). The half of copulated swarms of *E. superba* out of 15 samples show the fact because there still remains the sparm-mass. This discrimination is very interesting in order to examine the condition of swarms of euphausiids as stated above. From the 14 years observations, the copulated females are dominant from January to February suggesting that the pairing of *E. superba* occur mostly in this season of a year. Bargmann (1945) already refers to the point and describes the peak season of pairing comes in February when the greatest number is found, and the gravid females become scarce in the surface waters to spawn in the deeper waters. So before subsiding, the gravid *E. superba* must be the most fovorable food for baleen whales, the peak season of which is the same as the peak of the migration of baleen whales in the Antractic waters. I have also noticed the swarms of *E. superba* consisted of mostly dominant males in 2 stomachs of whales and females with vacant ovary. One may think they are swarms of euphausiids after spawning.

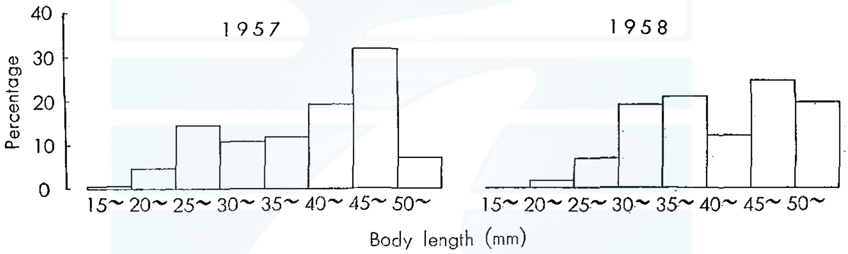

Fig. 6. The size distribution of dominant group of *Euphausia superba* observed and collected by Japanese whaling expeditions is 1957 and 1958 in the Antarctic waters in the whaling area IV, V. VI. and I.

The egg and the younger larva, from nauphi to furcilia, have never been observed in the stomachs of baleen whales. The smallest *E. superba* is about 20 mm adolescent, which is nearly the same length as previous paper on the *E. superba* in the Antarctic (Marr, 1956).

The sex ratio of *E. superba* differs from those of the North Pacific euphausiids. As described in a previous report (Nemoto, 1957), males are less in number among the Northern Pacific *Thysanoëssa*. On the contrary to this fact, male *E. superba* is not less dominant in the swarm collected from the stomach of whales. As to the body length of *E. superba*, males are a little larger than females in general. This fact is also different from that of the North Pacific *Thysanoëssa* euphausiids (Nemoto, 1957, Fig. 20). The female of *Thysanoëssa* euphausiids exceeds the males in body length in the northern Pacific and in the Antarctic.

Thysanoëssa macrura. Next to *Euphausia superba T. macrura* is mostly common in the Antarctic waters. It is also described as a staple food of baleen whales in the Antarctic waters (Nemoto & Nasu, 1958). *T. macrura* distributes more abundantly in the whaling area VI and I, only few samples of which are observed in the whaling areas IV and V. In 1958 whaling season, I examined euphausiids in the stomachs of whales chiefly on the samples of whaling areas IV and V, but only 2 samples of *T. macrura* are found in the area V and none in the area IV. From three years investigations from 1955, I get a percentage occurrence of *T. macrura* in the Antarctic whaling area from 40° east to 80° west longitudes. As clearly given in Fig. 7, *T. macrura* shows dominant appearance in the waters from 140° west to 80° west longitudes. Another dominant occurrence is observed in the west waters from 40° east to 60° east longitudes, but it must be due to the insufficiency of collections. *T. macrura* swarms in the warmer waters than *E. superba* and in off waters from the pack ice (Nemoto & Nasu, 1958), their main occurrences are observed in the last decade of January and the first decade of February, and baleen whales are considered to concentrate

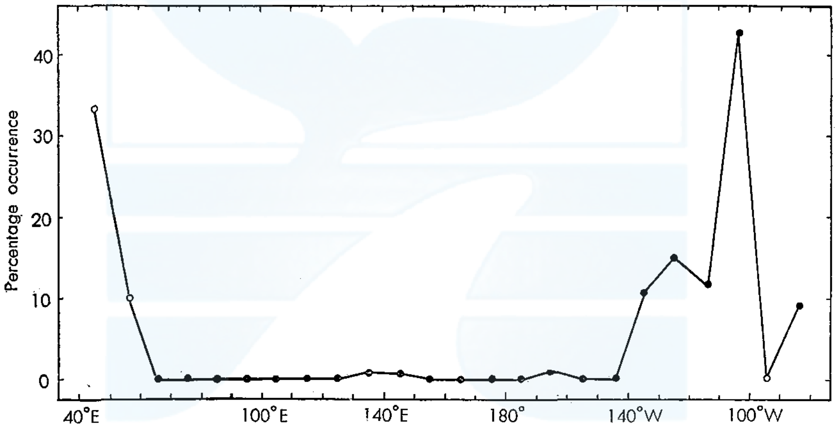

Fig. 7. Occurrences of *Thysanoëssa macrura* in the stomachs of Antarctic baleen whales in 1956, 1957 and 1958. Open circles shows insufficient observations in number.

to take *T. macrura* in the off waters at these periods of the season in the said waters.

T. macrura, showing the dominant appearance in the stomachs of whales, must make large swarms in the sea. In my collections, however, no copulated females appear. It is very difficult to explain if the pairing season of *T. macrura* is earlier or later than that of *E. superba*, because I lack the complete series of *T. macrura* throughout the whaling season. From their distributional occurrences in the whales' stomachs, it is considered that the spawning time and grounds differ a little from those of *E. superba*. Ruud (1931) discusses, however, spawning of *T. macrura* may begun October and continue to February. Rustadt (1930) also finds that the youngest stage of *T. macrura* are more common among or near the ice. Rustadt (1930) and Ruud (1932) suppose from above observations *T. macrura* has the same spawning ground and season as *E. superba*. *T. macrura* is considered to distribute in waters with temperature about 0°C (Ruud, 1932, Nemoto & Nasu, 1958), and the temperature distributes a little apart from the pack ice. So I would consider the distribution and spawning season differ from those of *E. superba* according to above Japanese observation.

As it is pointed by Rustadt (1930) and Baker (1954), in the younger stages, it is difficult to separate *T. macrura* from *T. vicina*. Still collected samples at my hand are considered all *T. macrura* by external characters. But in the far off waters especially in the whaling area I, it is probable that *T. vicina* may be a food for whales.

Besides the dominant appearances of *T. macrura*, the mixed occurrence of *T. macrura* with *E. superba* should be examined. Because the stomach samples of the Antarctic baleen whales have been classified according to the size of euphausiids in the *Discovery* method. 'X' in the classification of stomach contents means the mixture of the larger and smaller sized euphausiids. It may sound strange, I have a evidence that some routine observations might cause mistaken description as to the species of euphausiids. It is probable the small *T. macrura* has not been noticed by routine workers only describing sizes of euphausiids. In this point, to my regret, I can't refer to any former works especially carried out in Japanese investigations.

Euphausia crystallorophias. The Antarctic neritic species, *E. crystallorophias* has not been collected by Japanese investigations. However, Marr (1956, 1957) notes that in the high Antarctic, Ross sea, some blue and little piked whales may take *E. crystallorophias* as their food, and blue and fin whales fed on *E. crystallorophias* in the high Antactic caught by A. Larsen expedition in 1923–24 season because along the Ross sea barrier, the patch of *E. crystallorophias* were observed very often (John, 1936).

Parathemisto gaudichaudi. *P. gaudichaudi* has only been described as a local plankton in the Antarctic waters, and it bears no significance for the baleen whales as their foods (Mackintosh & Wheeler, 1929). Also by Japanese investigations, the dominant occurrence has never been noticed up to recent time. (Mizue & Murate, 1951 etc.). *P. gaudichaudi* has only been found among the euphausiids in the whales' stomach in few number. It has been considered insignificant diet for whales (Mackintosh, 1942). But in 1958, Japanese whaling expeditions have taken considerable number of sei whales in the Pacific sector of the Antarctic, when I was aboard on a factory ship to examine the whales as my second cruise to the Antarctic ocean. Some 1500 sei whales are caught in the late season of March, which is a very interesting phenomena since the Antarctic pelagic whaling opened. Other blue and fin whales become comparatively scarce at that time and sei whales feeding on *P. gaudichaudi* besides *E. superba* are found in the off waters from the pack ice. *P. gaudichaudi* is exclusively found in stomachs of 14 sei whales. Many sei whales with vacant stomachs also have darker excrement in their gut, showing that they had fed on *P. gaudichaudi* before their being shot. Because the excrements of *E. superba* origin and *P. gaudichandi* have different colour and remaines respectively. At the sametime, fin whales caught in these areas have no trace of *P. gaudichaudi* but the stomach contents of *E. superba*. This is the first description of *P. gaudichaudi* as a staple food of sei whales in the Antarctic, suggests sei whales skim the water to take scattered patch of *P. gaudichaudi*. Table 8 gives us the same data of feeding condition of whales in a certain period in March in 1958. Only sei whales take *P. gaudichaudi*, and all fin whales feed on *E. superba*. In other time of the season, the occurrence of the amphipoda has not been observed. But I would consider that from the abundance of sei whales it is abundant in the warmer waters of the Antractic. In the near waters of the Antarctic convergence, sei whales must have been feeding on the amphipods or some other organisms scattered in the sea. Foxton (1956) well describes

TABLE 6. OCCURRENCE AND QUANTITY OF *E. SUPERBA* AND *PARATHEMISTO GAUDICHAUDI* IN A CERTAIN AREA OF ANTARCTIC AREA V, MARCH IN 1958

Whale species	*E. superba*				*P. gaudichaudi*				None
	R	rrr	rr	r	R	rrr	rr	r	
Blue	—	—	—	—	—	—	—	—	2
Fin	1	5	14	6	—	—	—	—	88
Sei	—	2	1	1	—	5	4	5	24

the total volume of zooplanktons from the north to the south crossing the Antarctic convergence. The zooplankton concentration is observed in a region 0-200 miles south of the convergence. Of course, this value is calculated without *E. superba* near the pack line, the former waters must be one of the probable feeding grounds of sei whales consisting of scattered plankton such as *P. gaudichaudi*.

The concentration of Japanese catch of sei whales is located in the waters of 140° east longitude and 140° west to 160° west longitudes. In the former area, the peak of the occurrence of *P. gaudichaudi* is described by Baker (1954).

Fish. Fish in the stomachs of baleen whales in the Antarctic waters are appearently considered incident occurrences. There is no finding of fish in the stomach of baleen whales dominantly but a few specimens along with euphausiids. They bear no significant meaning for whales feeding, only being swallowed by whales with other food planktons. Those fishes also often swallow *E. superba* of ten or more individuals in their stomachs. Only the slender fish *Notolepi coatsi* Dollo has often been observed. Those fish persure krills in the surface of the water, and one can see the fish chasing *E. superba*. The fish is called as 'icy long nose fish' by Japanese whalers. Another fish belonging *Myctophidae* are sometimes observed in the stomachs of baleen whales.

In 1955, I found a curious fish from the stomach of a fin whale in the whaling area IV, which afterwards is named *Xenocyttus nemotoi* by Abe (Abe, 1957). This fish was found along with numerous *E. superba*, but the fish fed exclusively on the copepods, contrary to the expectation.

As a conclusion from 14 years observation, it is safe to say there is no important fish for baleen whales as their food in the Antarctic.

QUANTITY OF STOMACH CONTENTS

As a routine work, the stomach contents are classified into four groups according to their quantities (Nemoto, 1957). It is, however, made by the naked eyes and exact weighing has not been obtained. So it gives us only a comprehension of the feeding condition. Figures 8 and 9 show the stomach quantity of each species. Generally speaking, blue whales show higher feeding percentage than fin and sei whales, and there is no difference between sei and fin whales. Humpback whales take their food usually in their stomach, thus the percentage of vacant stomachs is less in number, or show higher percentage of feeding than blue and fin whales. In other localities, humpback whales also show higher percentage of feeding food. Mackintosh (1942) already describes full stomachs are found in 80% of blue whales, 50–60% of fin whales and 90% of humpback whales according to the observations by Major Spencer. When I compare above figures with Japanese result, the latter shows lower value than the former by Mackintosh. I have some probable explanation to this difference. To begin with, in the modern whaling, the prolong chasing of whales may cause vacant whale's stomachs, because the longer the chasing is done, the more the vacant stomachs of whales caught we find (Nemoto, 1957). Really the diesel motor equipped catcher boat chases whales in higher speed for longer hours in the recent operations. In second, the abundance of euphausiids may differ in each localities of the Antarctic waters or owing to the fluctuations in each year. Japanese investigations carried out in 1940 and 1941 give also higher percentage than recent results.

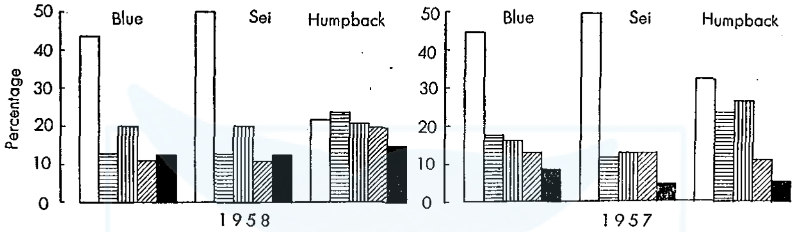

Fig. 8. Quantity of stomach contents of blue, sei and humpback whales in the Antarctic waters in 1957 and 1958. White—vacant, Lateral—few, Straight—moderate, Oblique—rich, Black—full.

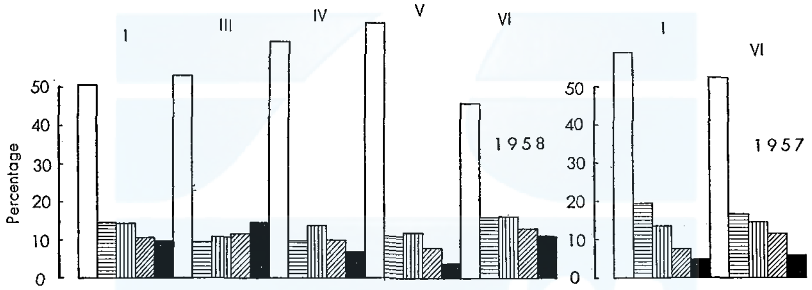

Fig. 9. Quantity of stomach contents of fin whales in the Antarctic waters in 1957 and 1958. Roman numeric shows Antarctic whaling secters. White—vacant, Lateral—few, Straight—moderate, Oblique—rich, Black—full.

Based on the results of 1957 and 1958, the feeding percentage of fin whales show the local differences among the whaling sectors of the Antarctic waters. Comparatively many fin whales take their food in the whaling ground VI. On the other hand, over 60% of the stomachs of fin whales are empty in the whaling grounds IV and V. Although no evidence is obtained as to the exact abundance of food in the sea from above figures, the result may be an indication that there are different abundance of euphausiids in each Antarctic area. Peters (1955) also describes that pelagically caught whales had more empty stomachs, as compared with the whales off South Georgia. Mackintosh states (1942), there was some indication that empty stomachs may be found a little more often in the early and late part of the season. I also think it is probable if a certain area is confined to examine, because whales follow the waters where their foods are abundant, but it is rather difficult to get the exact feeding percentage in seasonal comparison. Still, it is evident that the peak of *Euphausia* occurrence is observed in the mid-summer of the Antarctic when the feeding percentage must show the higher value throughout the season.

THE GROWTH OF *EUPHAUSIA SUPERBA*

Ruud (1939) and Bargmann (1945) state full discussions of growth of *E. superba*. By their discussions, *E. superba* attains the sexual maturity stage after two years. It makes comparatively rapid progress in earlier and slower progress in later stages in general. The growth of *E. superba* is considered to be different among each locality of the areas of the Antarctic. Bargmann (1954) already describe the very heterogenous population of *E. superba* owing to the prolonged spawning seasons. Generally speaking, *E. superba* in the off waters where the pack ice melt in the earlier date of the Antarctic summer makes more rapid growth at the same season of a year. As shown in Fig. 10, 1 year group of *E. superba* in 155° west longitude area shows an advance of growth

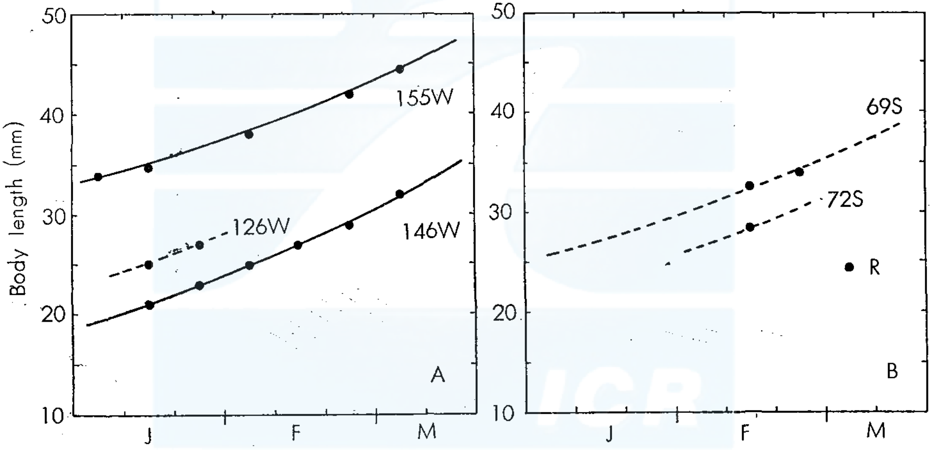

Fig. 10. Growth of *Euphausia superba* of 1 year group along the pack line of the Antarctic. A—The latitudes are nearly the same but the longitudes are different. B—longitudes are the same but latitudes are different. R—see R of Fig. 5.

in 20 mm, or the group of *E. superba* in 146° west longitude shows smaller body length at the same time of the Antarctic summer. Going more east waters, *E. superba* again recovers its body length in the waters of 126° west longitude. Among the every group of *E. superba,* exact division lines are considered, which is directly considered to be due to the different spawning time in a year.

On the other hand, this fact is partly due to the melting time of pack ice when the rapid propagation of foods of *E. superba* diatoms and some other zoo organisms have begun. The foods of *E. superba* are described by Barkley (1940). According to his work the main food is a diatom *Fragilariopsis antarctica* and my recent investigation supports

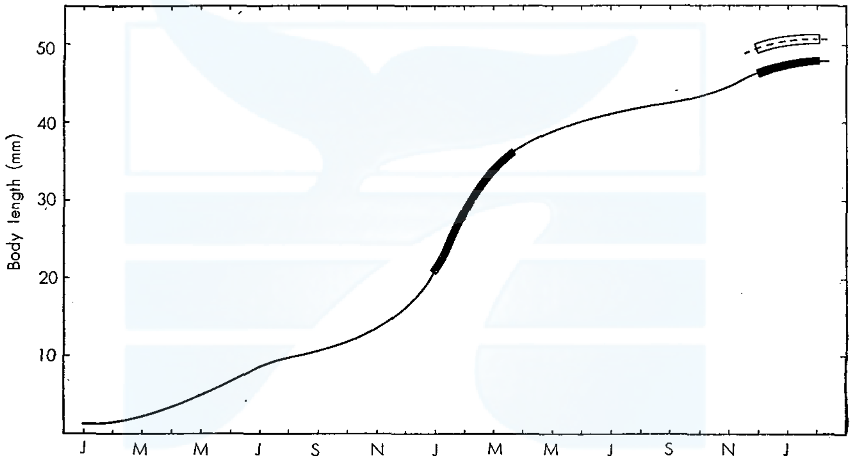

Fig. 11. Growth curve of *Euphausia superba* along the pack ice of the Antarctic waters, Solid line—female, Broken line—male, Shading area shows main Japanese collections.

the fact. And in a favorable condition diatom will propagate so rapidly as to support the vast growth of *E. superba* of 1 year group. From the body length of 20 mm to 45 mm, the body weight of *E. superba* becomes three times as big as the smaller stage of 20 mm. So the different spawning time of each group should be considered as one stable reason of different growth of *E. superba* in each locality. In 1958, I get two groups of *E. superba* which are swallowed by whales at the same longitude but the latitudes of the positions are 69° and 72° south latitude at 151° west longitude.

The pack ice at 69° south latitude melted away in the middle of January, but the pack ice at 72° south latitude melt in 30th of January. There exists 15 days delay in melting of the ice. The body length of

E. superba in the former waters shows about 10 mm advance, the difference of which may be too big for the lapse of 15 days. But the figure gives us evidence of difference in growth of *E. superba* in each locality. If I consider the rather rapid growth curve of *E. superba,* as shown in A of Fig. 10, it is probable that *E. superba* makes 10 mm growth in 15 days. Thus the difference in growth according to the food supply is also evident.

The marked decrease during the winter months (Fraser, 1936) is attributed to scarcity of materials by Bargmann (1945). But I would consider from the growth of 0 and 1 year group of *E. superba,* the winter growth should show more decrease than that by Bargmann, because along the pack ice the growth of *E. superba* is very rapid after the melting of ice covering the surface of swarming area as shown in Fig. 10. As the maximum length of female *E. superba* is about 55 mm, and if they do not stop the rapid growth in the winter season, it goes too far. With considering above points, I draw the growth curve of *E. superba* along the pack ice in Fig. 11, which may have some resemblance to that of Bargmann (1945).

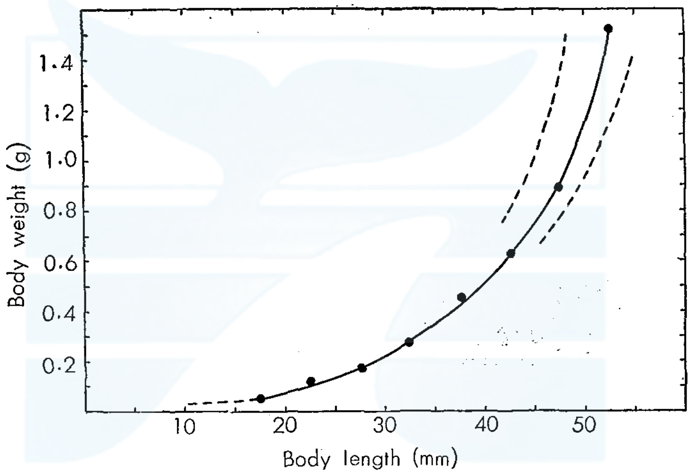

Fig. 12. Body weight and body length relation of *Euphausia superba* in the Antarctic waters along the pack ice, the sudden increase from 45 mm in body weight show a illustration of expansion and growth of ovary of euphausiids.

The relation between body length and body weight of *E. superba* is illustrated in Fig. 12. This figure clearly shows the tremendous growth of *E. superba* in the weight in the latter part of its life. Especially after copulating, the ovary of *E. superba* which contains more fat expand remarkably, thus the increasing growth curve is obtained. Peters (1955) also considers the larger whale shrimps (2 years group of *E. superba*) are the better food resource for the baleen whales than the small stage of *E. superba* owing to their fat content. The smallest copulated *E. superba* is about 35 mm in length, which is, however, not real signal of coming maturity. The weight of it is not so heavy that it is considered to be only a external phenomena, because maturity of a female euphausiid can be measured by the body weight of it. The increase of weight in the later stage of *E. superba* is well given by the development of the egg in ovary.

The relation between body length and weight of euphausiids in the different localities in the North Pacific is given by Ponomareva (1954), but with regard to *E. superba* in the Antarctic waters, there is no significant difference among the relation in each locality.

FOOD OF THE BALEEN WHALES IN THE NORTH PACIFIC

NORTHERN PART OF THE NORTH PACIFIC

Stomach contents of whales

The foods of baleen whales in the northern part of the North Pacific based on the observations by the year 1956 are summarized in the previous report (Nemoto, 1957). The successive whaling operations have covered broader areas than the former operations. In 1957 and 1958, the expeditions have covered the off waters of Anadyr gulf, the most northern part of Bering sea, Navarin cape, Anadyr gulf and Olutorskiy

TABLE 7. STOMACH CONTENTS OF BALEEN WHALES CAUGHT BY JAPANESE WHALING FLEETS FROM 1952 TO 1958 IN THE NORTHERN PART OF THE NORTH PACIFIC

Kinds of stomach contents	Whale species			
	Blue	Fin	Sei	Humpback
Euphausiids	266	2222	10	203
Eu. & Copepods	2	137	1	2
Eu. & Squids	—	6	—	1
Eu. & Fish	—	8	—	11
Eu., Fish & Squids	—	1	—	—
Eu., Fish & Co.	—	7	—	—
Copepods	—	965	286	1
Co., & Squids	—	3	5	—
Fish	—	247	8	53
Fish & Squids	—	—	1	—
Squids	—	22	15	1
Empty	298	3868	473	120
No. of Stomachs examined	566	7486	799	392
Not examined	3	19	5	—

Bay. From the two years' operations, I can get more detailed features of food of baleen whales and distribution of whales. Stomach contents of baleen whales caught during 1952 to 1958 are illustrated in Table 7. It is clear from the Table 7, that blue whales feed on only euphausiids, but 2 occasions. Some 140 blue whales caught in 1957 and 1958 take nothing but euphausiids like the previous report. Fin whales caught in the both years also feed on mainly euphausiids and copepods as previous year. Still considerably many fin whales feed on fish swarms in the years. Some 244 fin whales take fish in the North part of Bering sea, and fish is important as a food of fin whales. In the previous report, I consider that fish is only a makeshift food for fin whales. But I would think here fish is a main food for fin whales in the north waters of Bering sea above 58° north latitudes where the whaling operation had not operated before 1957. Sei whales show the same tendency as previous investigations. Calanoid copepods are the favourite foods of sei whales with other occurrences of euphausiids, fish and squids. The main food of humpback whales are euphausiids and fish, which is also the same result as the previous investigations.

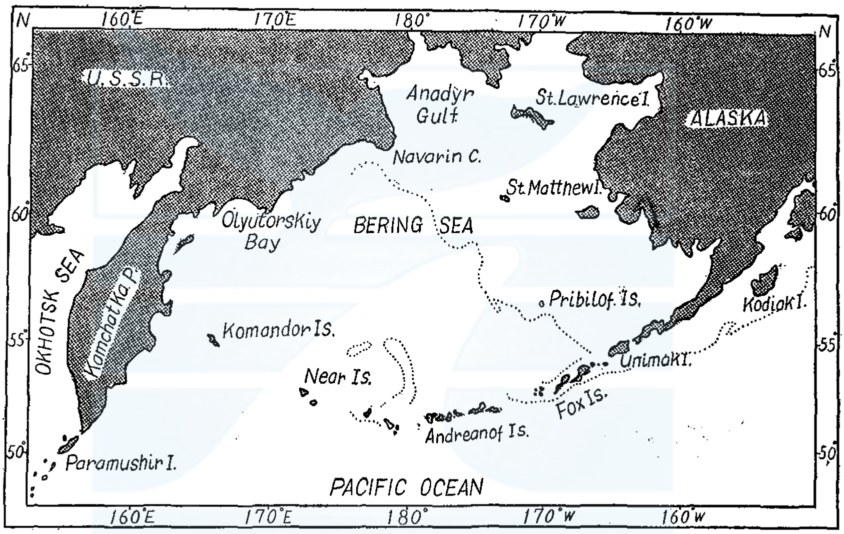

Fig. 13. Whaling ground in the northern part of the North Pacific.

Thus the foods of baleen whales in the northern part of the North Pacific, adjacent waters to Aleutian Islands and Bering sea are described as follows.

Blue whale	euphausiids
Fin whale	euphausiids, copepods, and swarming fish
Sei whale	copepods

Humpback whale euphausiids, and swarming fish

Besides above listed foods, squids are considered a makeshift food for fin and sei whales. From 1952, 22 fin whales and 15 sei whales have fed on squids and 7 fin whales and 6 sei whales have taken the mixture of squid and other organisms. There is a evidence that one main food of sei whales in the adjacent waters to Japan is squids, but it is not so important in the northern part of the North Pacific.

Species of food

Euphausiids. The previous studies on euphausiids are summarized in the report (Nemoto, 1957, p. 44–52), and I add here further knowledge on the problem. Following 5 species belonging to EUPHAUSIACEA have been collected through the investigation. Among them, *Thysanoëssa raschii* is found in 1957 as a first record in the northern part of the Bering sea, and the successive collection in 1958 proves this.

One *Euphausia* and four *Thysanoëssa* observed are follows.

Euphausia pacifica Hansen, *Thysanoëssa inermis* (Krφyer)
Thysanoëssa longipes Brandt, *Thysanoëssa spinifera* Holmes
Thysanoëssa raschii Sars,

The distribution and occurrence of above species in the northern part of the North Pacific are already stated to some extent in the previous paper (Nemoto, 1957).

TABLE 8. OCCURRENCES OF PLANKTONS IN THE COLLECTED SAMPLES OF STOMACH CONTENTS OF WHALES IN THE NORTHERN PART OF THE NORTH PACIFIC SINCE 1954

Species of plankton	Whale species									
	Blue		Fin		Sei		Humpback		Total	
Euphausiids										
E. pacifica	3	(3)*	12	(25)	—	—	1	(1)	16	(29)
T. inermis	8	(8)	95	(123)	9	(9)	8	(10)	114	(150)
T. longipes	5	(7)	86	(121)	1	(3)	1	(3)	93	(134)
T. spinifera	—	(1)	2	(17)	—	—	—	(3)	2	(21)
T. raschii	—	—	7	(7)	—	—	—	—	7	(7)
Copepods										
C. cristatus	—	—	116	(140)	9	(9)	—	—	125	(149)
C. plumchrus	—	(1)	11	(20)	2	(3)	—	(2)	13	(26)
M. lucens	—	—	1	(1)	—	—	—	—	—	(1)

* Number in bracket shows the subordinate and dominant occurrences in the stomachs of whales.

Still, recent investigation reveals very interesting distribution of euphausiids in the northern part of the North Pacific. Since the year 1954, distributions and occurrences of euphausiids and copepods are obtained as shown in Table 8. From the Table 8, it is clear *Thysanoëssa inermis* and *T. longipes* are the most important euphausiids in the waters.

When I compare the Table 8 with the data before 1957, it is evident that *Thysanoëssa longipes* become dominant in the collected sample of 1957 and 1958. One of the reason for the fact is due to the fact that Japanese whaling operation have caught considerably many whales in the

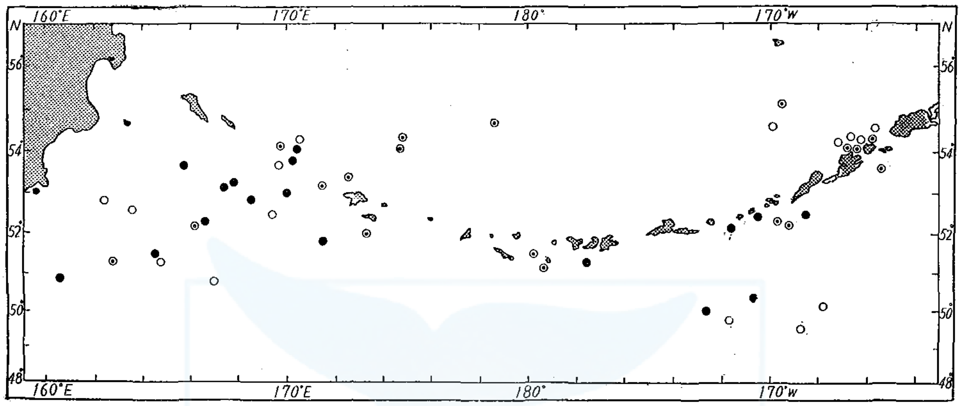

Fig. 14. Occurrences and distributions of *Euphausia pacifica* in the northern part of the North Pacific since 1952. ●—Dominant occurrences in the stomach contents, ○—Subordinate occurrences in the stomach contents, ⊙—Occurrences by net collections.

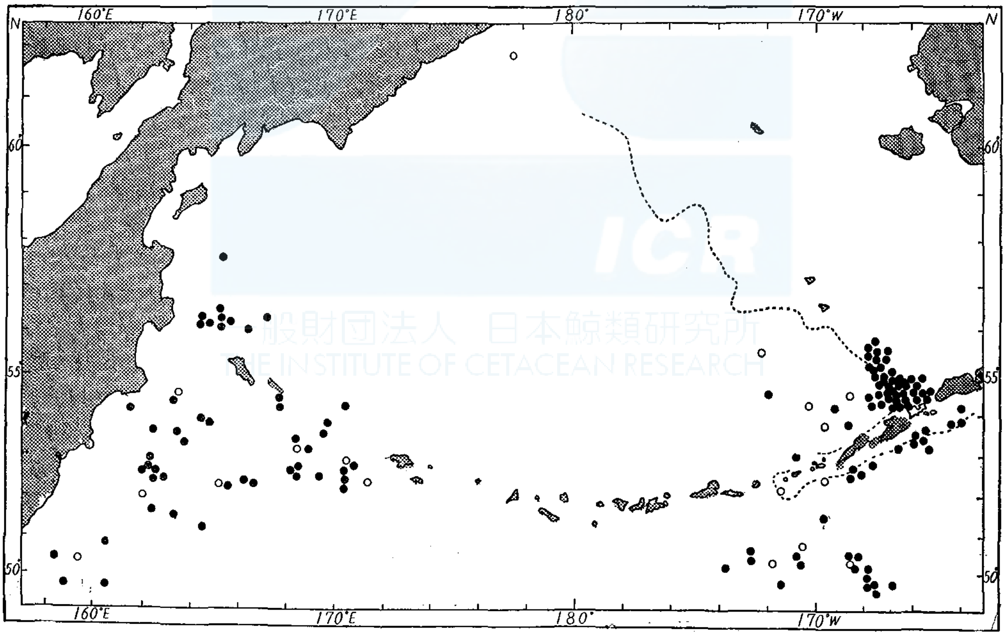

Fig. 15. Occurrences and distributions of *Thysanoëssa inermis* in the northern part of the North Pacific since 1952. ●—Dominant occurrences in the stomachs of whales, ○—Subordinate occurrences in the stomachs of whales.

south water of the eastern Aleutian Islands, Andreanof Islands and Fox Islands where the swarms of *T. longipes* have been mostly observed. Besides above two species *Euphausia pacifica* and *Thysanoëssa spinifera* have been observed and the more detailed knowledge is obtained on the characteristic of distributions.

Euphausia pacifica has been observed comparatively warmer waters in the northern part of the North Pacific. I describe as to the distribution of *E. pacifica* that it vanishes as a dominant food of whales in the north waters of Aleutian Islands (Nemoto, 1957). The recent collections add many occurrences of *E. pacifica* as illustrated in Fig. 14. None of specimen is found in the collected stomach contents of baleen whales north waters of 56° north latitude. The net hall collections also show the same tendency, as no specimen of *E. pacifica* is collected in the north waters. From above result, it is evident that *E. pacifica* plays little role of foods of whales in the north waters of Aleutian Islands and significance of *E. pacifica* is not so heavy as in the southern waters, adjacent waters to Japan (Nemoto 1957).

Thysanoëssa inermis is described one of the dominant foods in the Aleutian waters. Japanese investigation clearly reveals the concentration of *T. inermis* is observed in the north waters of eastern Aleutian Islands, Fox Islands. There are also scattered occurrences in the western part of the North Pacific. In the southern waters of Fox Islands, some occurrences of *T. inermis* are observed. But the number is far smaller if the comparing with the occurrences of *T. longipes* is made. On the contrary to the distribution of *T. inermis, T. longipes* is mostly found in the off waters of eastern Aleutian Islands. Few *T. longipes* distributes along the continental shelf of the eastern Aleutian Islands, but the dominant occurrences are observed in the off pelagic waters from the continental shelf. The relative abundance of *T. longipes* in each side of the North Pacific has not been given yet, however, the data by the year 1958 furnish us that the most dominant area of *T. longipes* is in the south waters of the eastern Aleutian Islands. Before reaching the definite conclusion, the alternation among the euphausiids should be considered. For example in 1954, *T. inermis* was very abundant along the continental shelf of the north waters of the eastern Aleutian Islands. The next year in 1955, *T. longipes* was comparatively abundant in the off waters of the same area along with the dominant patches of *Calanus cristatus*. Along the south edge of continental shelf of the eastern Aleutian Islands, swarms of *T. inermis* was very numerous in 1954, when the considerable number of blue and humpback whales had been caught in the waters. In 1957 and 1958, on the other hand, *T. longipes* has been very abundant in the far south waters from the shelf, and few whales distributed along the shelf. Above alternate occurrences of euphausiids give us the very illustration of annual variation among the euphausiids abundance. This must partly be due to some oceanographical conditions in the sea water which I discuss in the latter part of the paper. *Thysanoëssa spinifera* distributes along the Alaskan continental shelf and is neritic species (Nemoto, 1957). Japanese recent collections add few samples of *T. spinifera* to the Fig. 4 of my previous paper, but all occurrences are found along or within the Alaskan continental shelf. As discussed in the previous report, no swarm of *T. spinifera* is observed in the western part of the North Pacific. As shown in Fig. 18, and Table 8. *Thysanoëssa raschii* is observed in the stomachs of fin whales in the off waters of Anadyr gulf. I am very pleased to have the specimens of *T. raschii* in the waters because I have little expectation that *T. raschii* plays the role of food of baleen whales in the Bering sea. The distribution of *T. raschii* is restricted to the shallow and neritic waters within 50 metre in depth as illustrated in Fig. 18. The water of Anadyr gulf contains less salinity affected by the flesh water by the Anadyr river, and temperature and salinity are lower than that of the southern waters. *T. raschii* can live in such shallow waters so that fin

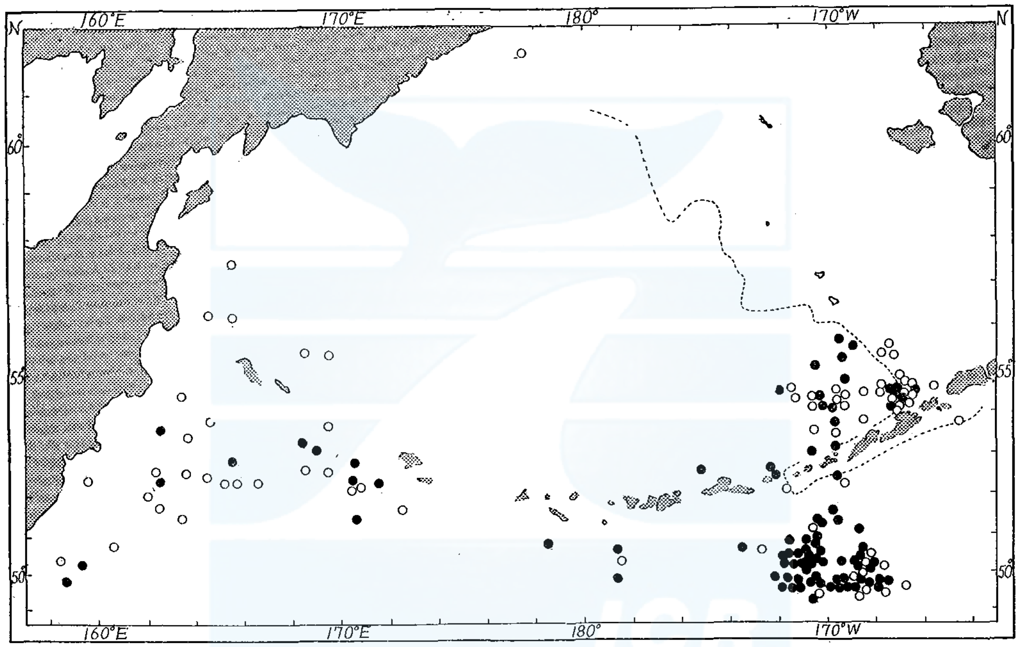

Fig. 16. Occurrences and distributions of *Thysanoëssa longipes* in the northern part of the North Pacific since 1952. ●—Dominant occurrences in the stomach contents. ○—Subordinate occurrences in the stomachs of whales.

whales in the waters successfully take the euphausiids in the day time, though it may go down to the near bottom depth as it is observed on the another euphausiids *Euphausia pacifica* (Saito & Mishima, 1953). Besides above food euphausiids, a young specimen of deep water living *Gnathophausia gigas* is found in a fin whale in the north waters of the eastern Aleutian Island among the swarm of *Thysanoëssa inermis*. I consider the fact is not due to the deep diving of the fin whale but to the coming up of the *Gnathophausia gigas* to the near surface waters.

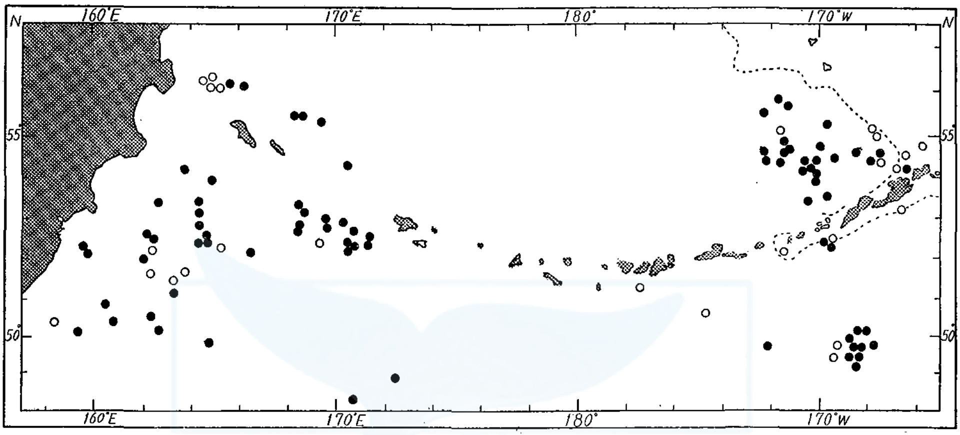

Fig. 17. Occurrences and distribution of *Calanus cristatus* in the collected samples of stomachs of baleen whales since the year 1952. ●—Dominant occurrences in the stomachs of whales, ○—Subordinate occurrences in the stomachs of whales.

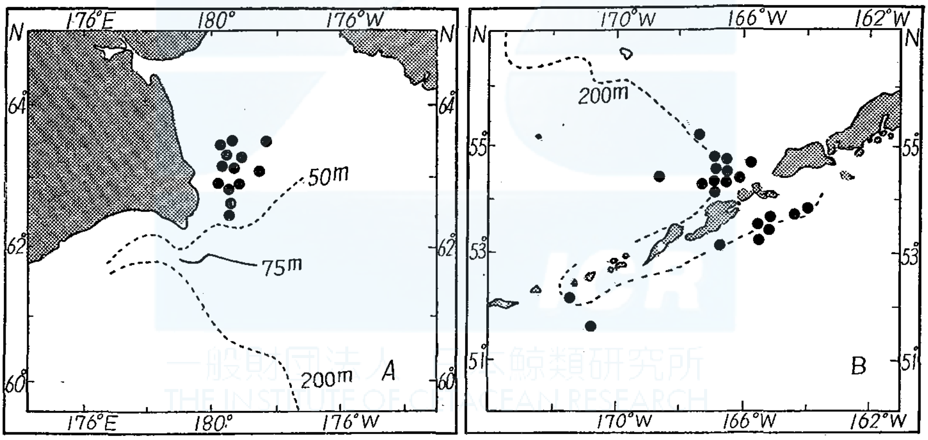

Fig. 18. Occurrences and distribution of euphausiids in the stomach of baleen whales in the northern part of the North Pacific. A—*Thysanoëssa raschii* in the north part of the Bering Sea off Navarin Cape. B—*Thysanoëssa spinifera* in the eastern Aleutian Islands.

Copepods. Two important copepods are observed in the previous researches in the northern part of the North Pacific.

Calanus cristatus and *Calanus plumchrus* are the main copepods consisting the food of baleen whales. In my collections *C. cristatus* is more abundant than *C. plumchrus*. But as stated in my former report *C. plumchrus* is very important for right and sei whales. In Japanese routine observations, inspectors do not classify copepods into above two species. Only biologists on board have some chance to do so. According to their reports, *C. cristatus* is dominant in three areas. As shown in Fig. 17, in the western part of the Near Islands, *Calanus cristatus* is usually found in the stomachs of baleen whales swarming there from May. The next whaling ground of *C. cristatus* is the north waters of Fox Islands. I already stated this distribution of *C. cristatus* in the previous report (Nemoto, 1957) that *T. inermis* is dominant along the shelf and *C. cristatus* is in the off water of about 3000 meters depth. As plankton survey shows the adult *C. cristatus* is found in the deeper waters than 500 metres (Nakai, 1954) in the waters adjacent to Aleutian Islands, it is reasonable that *C. cristatus* swarms in the off waters where the sea depth is more than 500 metres.

The third place is the south waters of the eastern Aleutian Islands, where also considerable fin whales feed on *C. cristatus*. According to Japanese collections, the most northern collections are obtained in the waters north of Komandorskiy Islands at about 56° North latitudes. On the other hand, I already cited the work by Brodsky that the main food of fin whales in Olyutorsky Bay, which situated at about 60° North latitude, is *Calanus cristatus* (Brodsky 1955). It seems reasonable to say, further, that *Calanus cristatus* plays a role of food for fin whales in the waters around the Aleutian Islands and Olyutorsky Bay. Along the Alaskan continental shelf, *Calanus cristatus* has not appeared as a dominant food but few cases and of course it vanishes within the shelf. With regard to the quantity of *C. cristatus*, it needs more collections before definite conclusion is obtained. But as illustrate in Tables 7 and 8, *Calanus cristatus* bears the very important part of foods of fin whales in the Aleutian waters.

Another macro copepods *Calanus plumchrus* distributes dominantly in the south waters of the chain of Aleutian Islands and Komandorskiy Islands. The most common occurrences are observed in the south waters of the eastern Aleutian Islands and south waters of Komandorskiy where considerable number of sei whales have been feeding on *Calanus plumchrus*. In the Table 8, only 3 samples of sei whales take *C. plumchrus* in samples owing to the insufficiency of collections. There are evidences, however, that sei whales are mainly feeding on *Calanus plumchrus* by the observations of biologists on board.

Calanus finmarchicus and *Metridia lucens* are described in my former report (Nemoto, 1957, p. 53, 54), but the successive investigations in 1957 and 1958 add no occurrence of these copepods to the previous results.

Fish. As shown in Table 7, swarming fish is considered to be very important in the northern part of the North Pacific, the north part of the Bering sea. Before the year 1957, baleen whales feeding on fish are comparatively small in number (see the table 2 in the previous report, Nemoto, 1957). Only 7 fin whales and 5 sei whales take fish or mixture of fish and plankton, though considerable number of humpback whales take fish. The successive operations, however, find many fin whales feeding on the swarming fish. Table 9, shows the occurrences of fish in these waters. There are some differences among the fish species according to whale species suggesting the difference of feeding habits. Fin whales take mainely herrings and capelin and Alaska pollack, and on the other hand sei whales take only saury. Humpback whales have a particular favourite for Atka mackerel as given in the Table 9. The distribution of the swarming fish also shows interesting tendencies. Generally speaking, capelin, Alaska pollack and herring distribute in the high latitude of 58° north, and capelin is found from the Olutorskiy Bay to Andyr gulf along the Kamchatka Peninsula coast but two occasions. The latter samples are observed in the north waters of Fox Islands of the eastern Aleutian Islands. Main occurrences go as far as the near waters of St Lawerences Is., but the most congregated area in the two years is the waters off Nawarin cape. The water depth there is about within 100 meter and as I described the neritic euphausiid *Thysanoëssa raschii* is the main food for fin whales in the water. Fin whales took sometimes *T. raschii* with capelin, the stomachs of which were often satiated with the former *T. raschii*. The size of capelin is about 15 cm and females are dominant usually in the swarms and stomachs of fin whales. Herrings demonstrate the same distribution as capelin. They are observed along Kamchatka Peninsula, mostly in the waters around Olutorskiy cape and south waters of Nawarin cape. Zenkovich (1934) states considerably many fin whales took herrings and often chase the swarms of herring in the Bering sea. Those occurrence of herring is the

TABLE 9. FISH FOUND IN THE STOMACH CONTENTS OF BALEEN WHALE CAUGHT BY JAPANESE WHALING EXPEDITIONS IN THE NORTHERN PACIFIC FROM 1952 TO 1958

Whale species	Fish species						Unknown
	Herring	Capelin	Saury	Alaska pollack	Sand lance	Atka mackerel	
Fin whale	16	172	1	70	—	4	—
Sei whale	—	—	9	—	—	—	—
Humpback whale	—	3	—	2	2	54	3

next one to the Zenkovich's description in the North Pacific. The largest size of herring is about 25 centimeter. At this stage of growth, herring must migrate in a very congregated swarm which attracts fin whales.

Alaska pollack shows the dominant occurrences among these fish. It is observed those fin whales fed it appear along the Alaskan continental shelf from 58° North to 61° North especially in 1957. The size of Alaska pollack never exceed 30 centimeter in length. This small size Alaska pollack swarms in the shallower waters than the adult Alaska pollack. The larger size Alaska pollack is found in the stomach of humpback whales in two occations (Nemoto, 1957). In this case, it is clear that two whales have different preference of feeding. From 1952 to 1956, few fin whale was caught in the northern part of the Bering Sea, and Japanese whaling expeditions have mainly covered the southern waters where many euphausiids are abundant. In recent years, however, the transition of the food from euphausiids to fish must be considered. In 1956 and preceding seasons, the scouting boats for whales seek the school of whales in the northern part of Bering sea. But not so many fin whales have been observed and the locality is unfavourable for whaling operation.

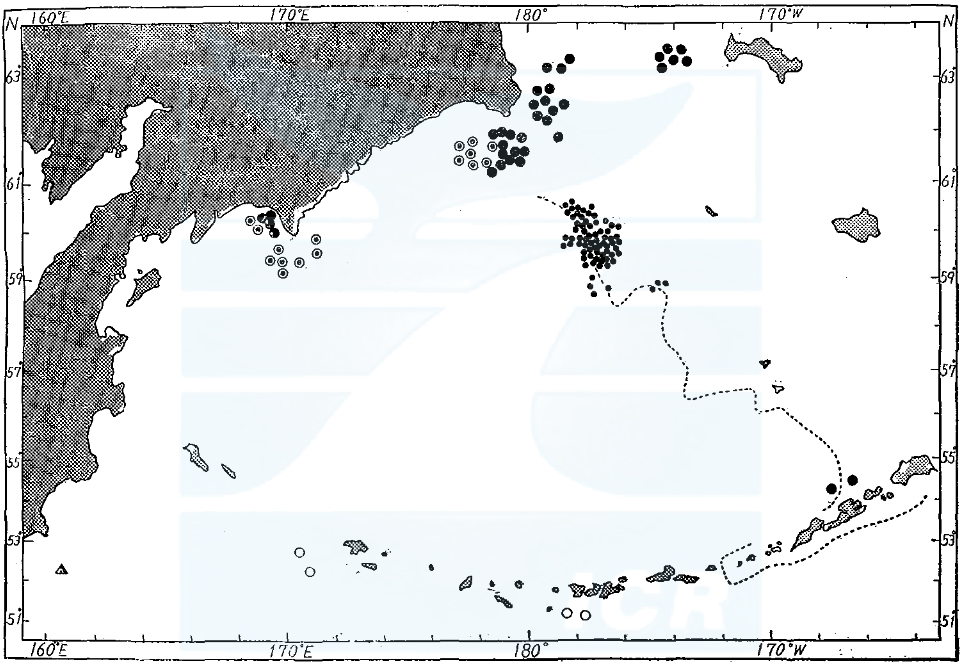

Fig. 19. Occurrences and distributions of fish in the stomachs of fin whales caught from 1952 to 1958 in the northern part of the North Pacific. ●—Capelin, ⊙—Herring, •—Alaska pollack, ○—Atka mackerel, ▲—Saury.

In 1957, fin whales swarming in the north waters of the eastern Aleutian water swim further to the north waters of the eastern Aleutian water and swim further to the north part of Bering sea along the continental shelf and feed on Alaska pollack. The relative abundance of euphausiids there is considered not so sufficient as in the preceding seasons. The whaling ground where Alaska pollack is fed shows no single occurrence of euphausiids in the stomachs of whales. In some years, *T. inermis* which is very abundant along the Alaskan continental shelf may propagate to the northern water along the shelf. But I have no specimen of *T. inermis* in 1957. Alaskan pollack fed by fin whales take, in its turn, mainly food of *Calanus plumchrus*. Small pelagic amphipods are also observed in its stomachs in smaller quantities. *Calanus plumchrus* distributes in the northern part of the North Pacific widely. But according to Johnson (1958), *C. plumchrus* (*C. tonsus*) is not so common in the Bering strait and Arctic sea. So, it is considered the main occurrences of *C. plumchrus* are within 61° or 62° North latitudes. The patch of *Calanus plumchrus* may be a food for fin whales sometimes, but fin whales never take favourably *Calanus plumchrus*. On the other hand, to the larval and adolescent form of Alaska pollack, Atka mackerel and adult saury, *Calanus plumchrus* is the most favourable food especially because the usual living depth of *C. plumchrus* is the same as that of the swarming fish.

The swarm of herrings found in the stomachs of fin whales caught in the Olutorskiy cape feed mainly on *Thysanoëssa inermis* and small appearances of *Calanus cristatus* and *C. plumchrus*. As already stated in the part of *Thysanoëssa inermis, T. inermis* is found in the north part of the Komandorskiy Islands as far as 58° north latitude and the dominant occurrences are observed 57° north latitudes as shown in Fig. 16. Because within the continental shelf, *T. inermis* is usually found in far smaller number and only herrings from Olutorskiy to Nawarin cape take *T. inermis* as their food.

Humpback whales are famous for their fish feeding. I describe humpback whales are very fond of Atka mackerel, as comparatively many humpback whales take Atka mackerel in the waters near Near Islands and Andreanof Islands. As shown in Table 9, the most favourite food for humpback whales is Atka mackerel of 15 to 30 centimetre. Fin whales never take, the Atka mackerel of the latter body length, 30 centimetre. But humpback whales sometimes take Atka mackerel of 30 centimetre or adult. In the same way, humpback whales feed on adult Alaska pollack in two occasions, and none of fin whale take it. Small Alaska pollack fed by fin whales and Atka mackerel fed by humpback whales contained many specimens of *Thessarabrachion oculatus* besides

Calanus cristatus and *Euphausia pacifica* in their stomachs in the waters of Near Islands. It is a very interesting fact that *T. oculatus* never swarms in so close patches as *Thysanoëssa* euphausiids, and fin and humpback whales of 'swallowing type' whales cannot take them. On the other hand, for the migrating swarm of fish, *T. oculatus* become a food for them.

Sei whales are surface feeders and feed on saury only according to Japanese collections from 1952 to 1958. Of course, other swarming fish may be a food for sei whales in some occasions. In the adjacent waters to Japan, many kinds of fish are favourite food for sei whales. But the limitting facter of foods of sei whales is due to their vertical living layer, that is, the surface swimmer is only considered as a food of sei whales. Sauries distribute largely in the North Pacific (Kasahara & Otsuru, 1956), and by observations on foods of whales, saury is mainly found in the western part of the Aleutian Islands, where the northern limit of the distribution of saury is considered. The stomachs of saury are often satiated with copepods *Calanus plumchrus*, and the dominant occurrence of saury coincides with the dominant season and place of *Calanus plumchrus* occurrence.

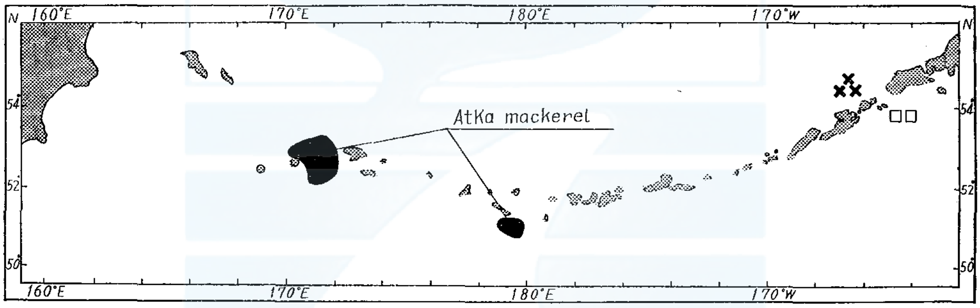

Fig. 20. Occurrences and distributions of fish in the stomach contents of humpback whales in the northern part of the North Pacific. Black shading—Atka mackeral. Open circle—Cod. Cross—Probably Capelin. Square—Capelin.

I find no addition to the occurrence of sand lance and capelin in the south waters along the Aleutian Islands since I wrote the previous paper. So it is considered the important fish for baleen whales are followings.

Fin whale	Herring (*Clupea pallasi*)
	Capelin (*Mallotus catervarius*)
	Alaska Pollack (*Theragra chalcogranma*)
Sie whale	Saury (*Cololabis saira*)
Humpback whale	Atka mackerel (*Pleurogrammus monopterygius*)

Besides above species, Cod, whiting, rockfish and sea lamprey are noticed through the observations (Matsura & Maeda, 1942 etc.). Their occurrences are considered to be very incident one, though there is still a possibility that those fish, swarming so heavily, attract whales in some cases. Rock fish (*Sebastodes polyspinis*) and sea lamprey (*Entosphenus tridentatus*) are apparently swallowed with other planktons or incidently because above rock fish take planktons of the same kind as foods of whales and sea lamprey attacks whales (Pike, 1952; Nemoto, 1954).

These swarming fish show some fluctuation of abundance, which affect the distribution and migration of whales very much in the northern part of the North Pacific.

Squids. Squids have been considered not so important as a food for fin whales, because only 0.5 percent of total fin whales have taken them. Sei whales have taken them in 3 percent of all. Humpback whales have never fed on squids before 1956, but 1 humpback whale take squids dominantly in 1956. Of course, no blue whale has taken squids.

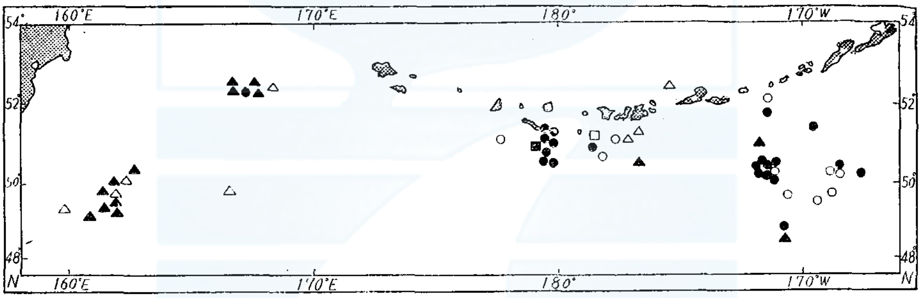

Fig. 21. Occurrences and distributions of squids in the stomachs of baleen whales in the northern part of the North Pacific. ▲—Squids fed by sei whales, △—Squids & others fed by sei whales, ●—Squids fed by fin whales, ○—Squids & others fed by fin whales, ■—Squids fed by humpback whales, □—Squids & others fed by humpback whales.

Ommastrephes sloani pacificus is dominant through the survey. Small squids (*Watasenia scintillans*) and opalescent squid (*Loligo opalescens*) are observed too in less occasions. Especially sei whales often take *Ommastrephes sloani pacificus* in the western part of the Aleutian Islands. Squids come up to the surface waters in dark time of a day, and sei whales fed on squids are mostly found in the night, twilight times and heavey clouded days like fin whales.

Foods of fin whales in each locality and year

As described in the former part, blue whales feed only on euphausiids, humpback whales on euphausiids and fish and sei whales on copepods mainly. These three species show no typical change among their foods in the northern part of the North Pacific. But foods of fin whales bear some local characteristics as partly considered from the illustrations of Tables 10 to 12. In the south waters of Komandorskiy Islands, east of Kamtchatka and west of Near Islands, the foods of fin whales from 1952 to 1958 are illustrated in Table 10. From the Table 10, the main foods are euphausiids and copepods. The former consists of *Euphausia pacifica*, *Thysanoëssa longipes* and *T. inermis*, and the latter of *Calanus cristatus* mainly and a few occurrence of *C. plumchrus*. The annual change among foods is also observed, suggesting there are '*Calanus* year' and '*Euphausiid* year' (Nemoto, 1957), which I describe in next part. Euphausiids are a little more important in this waters as a conclusion. In the south waters of the eastern Aleutian Islands euphausiids

TABLE 10. STOMACH CONTENTS OF FIN WHALES CAUGHT IN THE OFF WATERS OF KAMTCHATKA PENINSULA, THE SOUTH WATERS OFF KOMANDOR ISLANDS AND THE WEST OF NEAR ISLANDS

Contents	Year						
	1952	1953	1954	1955	1956	1957	1958
Euphausiids	79	83	182	32	149	57	64
Eu. & Copepods	4	15	18	1	17	8	1
Eu. & Squids	—	—	—	—	1	—	—
Eu. & Fish	—	1	—	—	—	—	—
Calanoid	19	105	92	48	47	69	37
Ca. & Squids	—	—	—	—	1	3	—
Fish	—	1	—	—	1	—	—
Squids	1	—	—	—	7	—	—
Empty	110	252	272	67	114	143	166
Total	213	457	564	148	337	280	268
Not examined	—	13	—	—	—	—	1

TABLE 11. STOMACH CONTENTS OF FIN WHALES CAUGHT IN THE ADJACENT WATERS TO THE EASTERN ALEUTIAN ISLANDS FROM 1954 TO 1958

Contents	South waters					North waters				
	1954	1955	1956	1957	1958	1954	1955	1956	1957	1958
Euphausiids	66	7	8	171	75	306	421	264	45	70
Eu. & Copepods	4	—	—	13	2	—	22	13	2	9
Eu., Co. & Squids	—	—	—	3	—	—	—	—	1	—
Eu. & Fish	—	—	—	—	—	2	—	—	—	—
Eu. & Squids	1	—	—	—	4	—	—	—	—	—
Co. & Squids	—	—	—	—	2	—	—	—	—	—
Fish	1	—	—	—	—	—	—	—	—	—
Fish & Squids	1	—	—	—	—	—	—	—	—	—
Squids	—	—	1	2	12	—	—	—	—	—
Copepods	23	1	—	26	56	4	137	172	42	63
Unknown	—	—	—	—	—	3	—	1	—	1
Empty	71	27	37	285	290	269	597	323	196	155

also play considerable part of the foods of fin whales. In 1954, the most of the euphausiids are *Thysanoëssa inermis* along the continental shelf along the Islands. Fin whales swarm on *T. inermis* exclusively in the areas. On the other hand, *Thysanoëssa longipes* take the position of *T. inermis* among the food euphausiids in 1957 and 1958 as I describe in the part of foods in the north Pacific. In 1957, *Thysanoëssa longipes* was very dominant and numbers of fin whales taking *Calanus cristatus* were comparatively less in number. But *T. longipes* becomes rather less than the preceding season, and number of copepods are more dominant in 1958. From the above number of euphausiids occurrences and empty stomachs of fin whales, the feeding condition in 1958 is considered not so favourable for fin whales as in 1957. As other occurrences of stomach contents, 56 fin whales feed on copepods mainly *Calanus cristatus* and 12 fin whales on squids, also suggesting the above scarcity of euphausiids in 1958.

TABLE 12. STOMACH CONTENTS OF FIN WHALES CAUGHT IN THE NORTHERN PART OF THE NORTH PACIFIC IN 1957 AND 1958

Locality		Stomach content					
		Capelin	Alaskan pollack	Herring	*Thysanoëssa raschii*	Copepod	Empty
Alaskan continental shelf 58°–61°N	1957	—	70	—	—	2	86
Anadyr gulf & Navarin Cape	1957	6	—	8	47	—	113
	1958	141	—	—	11	—	120
Off Olutorskiy cape	1957	—	—	5	—	—	1
	1958	23	—	3	—	—	21

In 1954, almost all fin whales take euphausiids (mainly *Thysanoëssa inermis*) along the Alaskan continental shelf. But successive operations show the considerable occurrences of copepods in the off waters. Especially copepods are important for fin whales in 1956. Fish and Squids are rather scarce in the waters north of the eastern Aleutian Islands. In 1956, Japanese pelagic whaling covered the north waters of Komandorskiy Islands. Fin whales caught in the waters were feeding on euphausiids mainly and on *Calanus cristatus* resembling to the constitution of the south waters of the Islands.

In successive operations in 1957 and 1958, the waters north of 58°N latitudes have been covered, where many fin whales were feeding on fish, Alaska pollack, capelin and herring. In 1957, along the Alaskan continental shelf from 58° to 61° North latitudes, some 158 fin whales were caught by the Japanese operation. These whales were feeding on Alaska pollack (*Theragra chalcogramma*) exclusively but 2 whales on copepods. Fin whales caught a little northern waters of Anadyr gulf and off Navarin cape waters, mainly take a euphausiid *Thysanoëssa raschii*, and the rest of about 20 percent of the total feed on capelin and herrings. The 6 fin whales caught in the off waters of Olutorskiy feed on herring only. The aspect of feeding in 1958 is a little defferent from above preceding year. In 1958, capelin (*Mollotus catervarius*) is so dominant that almost all fin whales take it in the waters off Navarin cape, and no fin whales feed on Alaska pollack. This fact apparently suggests that there are annual fluctuations of swarming fish, and the feeding condition of fin whales is very much influenced by the fluctuation. In the preceding season before 1957, the swarming fish, capelin and Aaska pollak were not so abundant that fin whales did not migrate to the northern water of the Bering sea. It was probable almost all fin whales remained in the southern waters of the adjacent waters to Aleutian Islands in those years.

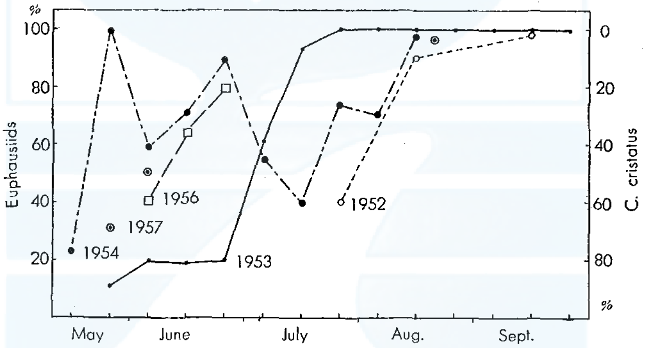

Fig. 22. Occurrences of euphausiids and *Calanus cristatus* in the west part off waters of the Kamtchatka Peninsula from 1952 to 1957.

Euphausiid year and calanus year

I describe in the former report there are ' *Calanus* year ' when copepods (mainly *Calanus cristatus*) is abundant and ' euphausiid year ' when euphausiids are abundant (Nemoto, 1957). As a example, I would refer again to the stomach contents of fin whales in the west part of the northern Pacific from 1952 to 1958. In 1952, the occurrence of *Calanus cristatus* is not so many as compared with the number of euphausiids, and the year 1952 is considered euphausiid year. In 1953, 1955 and 1957, the number of fin whales fed on copepods are dominant in number. These years are considered to be *Calanus* year. Especially in 1953, fin whales took *Calanus cristatus* mainly or 80 percent of total catch fed on *C. cristatus* at the beginning of the operation. To discuss the problem more clearly, the seasonal change between euphausiids and copepods should be considered. Generally speaking, Copepods are dominant at the beginning of the season in May and June, and euphausiids become dominat from July to September as it is seen in 1953. This is the typical change which '*Calanus* year' demonstrates. In euphausiid year in 1954, both euphausiids and *Calanus* are observed in stomachs of whales, and there is no typical change from May to July. In the latter part in July, however, euphausiids become dominant and copepods are vanished. The latter part of this curve is rather related to the curve of 1952 as shown in Fig. 22. It may be safe to say in some euphausiid year, though the complete transition from *Calanus* to euphausiids is finished in August, from May to August euphausiids are abundant through the seasons. Anyway, in the late decade of August and September, almost all whales feed on euphausiids or *Calanus cristatus* disappear from the surface waters of the area in August and September (Nemoto, 1957). This affects the migration of blue whales, euphausiids feeder, very clearly. In '*Calanus* year' the migration of blue whales to the waters becomes later, and earlier in 'euphausiid year' (Nemoto, 1957, p. 77).

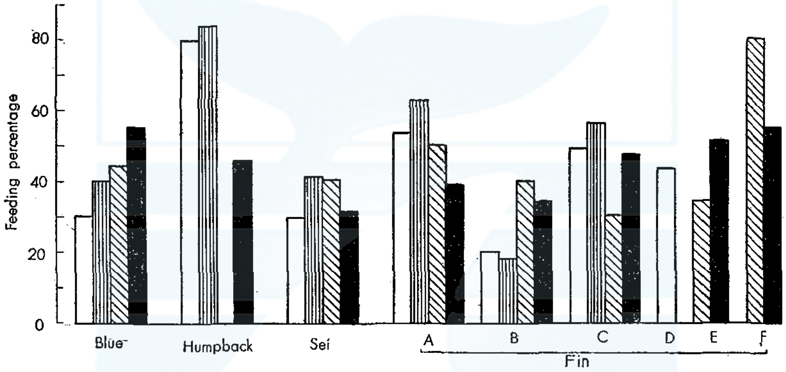

Fig. 23. Feeding percentage of baleen whales in the northern part of the North Pacific waters from 1955 to 1958. White—1955, Straight—1956, Oblique—1957, Black—1958. A—West waters of North Pacific, B—South waters of the eastern Aleutian Islands, C—North waters of the eastern Aleutian Islands, D—North waters of Komandorskiy Islands, E—Waters along the Alaskan continental shelf, F—North waters of the Bering sea.

From the Table, the years 1952, 1954 and 1956 are considered euphausiid years, and the year 1953 *Calanus* year. The both years come alternately about every 4 years by rough examinations on the net samples of planktons.

This phenomena must have some relations to the variation of strength of 'Kuroshiwo' current, but the present data are so scarce that I would wait further investigation and refrain from the conclusion.

Quantity of stomach contents

The quantity of stomach contents of baleen whales also has been examined in the North Pacific. The recent result of the routine works is illustrated in Fig. 23. As a general tendency humpback whales take more foods than other whales like those in the Antarctic. But blue whales indicate comparatively low feeding percentage in the northern part of the North Pacific. The feeding percentages of above two species show yearly changes as illustrated in Fig. 23. These yearly changes may suggest the feeding condition of each year to some extent which I describe in the later part.

The feeding percentage of fin whales domonstrates local differences as well as the yearly changes. In the whaling grounds, in the off waters of Kamtchatka (A in Fig. 23), it indicates the higher value than that of the south waters of the eastern Aleutian Islands (B in Fig. 23). As fin whales in these two waters mainly feed on planktons of euphausiids and copepods of the nearly same species, the difference of feeding percentage is considered to be due to some reason of whaling season or abundance of foods. In 1955 and 1956, the number of fin whales caught in the south waters of the east Aleutian Islands were comparatively small in number suggesting the scarcity of the foods with the low percentage of feeding. But the successive operation in 1957 and 1958, many fin whales have been caught in the same waters but a little more southern position and the feeding percentage in both years increase. Still, they are lower than those of western waters (A in Fig. 23). One explanation for this is the season of whaling. Japanese whaling usually begins its operation from the western waters when the dark hour of a day is longer which may cause the higher feeding percentage as this make the less diurnal migration of food planktons of whales.

Fin whales in the northern part of the Bering sea (F. Fig. 23) show the highest feeding percentage, which is apparently due to partly the sea depth and food species in the waters. Fish and a euphausiid, *Thysanoëssa raschii* are eaten by fin whales in also daytime in the shallow waters of the northern part of Bering sea, and this makes that high feeding percentage of fin whales.

Sei whales only show 30 to 40 percent feeding percentage of all whales, and there is no significant yearly change. The fact will suggest that the favourite food of sei whale, the crop of *Calanus plumchrus*, has been constant in the described years.

KURIL ISLANDS

In the pre-war seasons, Japanese shore whaling from the landstations of Kuril Islands had caught many baleen whales, but only few observation on foods of whales in the waters is remained. 'Krill' and fish were described as their foods.

Recent investigations by a Russian scientist (Betesheva, 1954, 1955) gives us the fairly good comprehension on the problem. Two *Thysanoëssa* species, *T. longipes* and *T. raschii* are the main euphausiids in the waters according to his description in 1954. Besides above euphausiids, *Calanus cristatus* and *C. plumchrus* (*tonsus*) are described from the copepods as food planktons. Squid, *Ommastrephes sloani pacificus*, anchovy, *Engraulis japonica*, Alaska pollack, *Theragra chalcogramma* are also found in the stomachs of fin whales. The 42 percent of fin whales of the total, take euphausiids and 20 percent is occupied by copepods (Betesheva, 1954). Though examined number is few, sei whales feed on mainly squid, *Ommastrephes sloani pacificus* and a copepod *Calanus plumchrus* (*tonsus*). Only one case, they feed on the mixture of *Calanus* and a euphausiid, *Thysanoëssa raschii*.

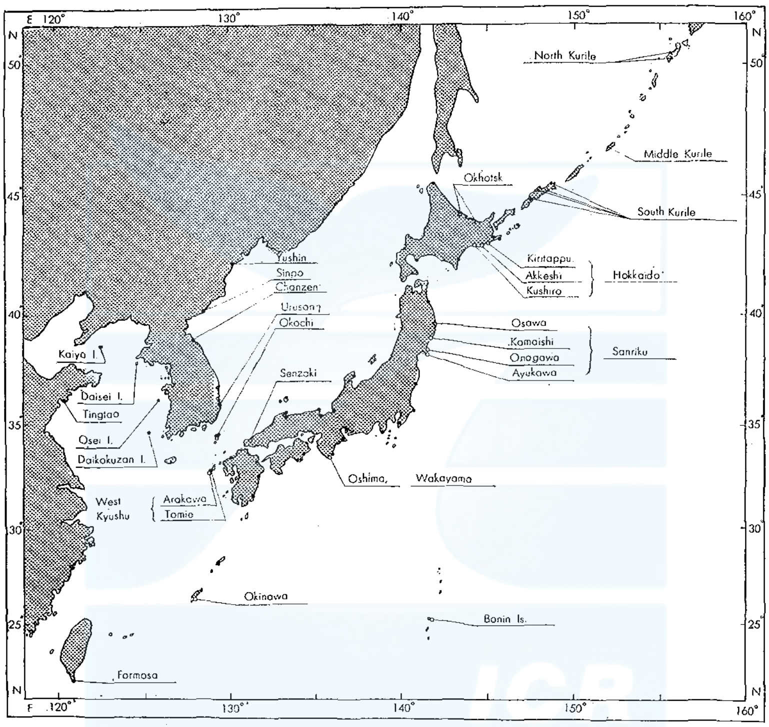

Fig. 24. Whaling centres around the Japan proper. Solid circles—whaling landstations only before 1945. Open circles—whaling landstations which have been operated after the year 1945 too. The name of the landstation before 1945 is referred to the old Japanese name.

The results on little piked whale obtained in Kuril waters in 1951 is very interesting (Betesheva, 1954). Little piked whales are feeding on fish, Alaska pollack. And euphausiid species is all *Thysanoëssa raschii*. This neritic species has not been observed in the stomachs of baleen whales in the off waters of Kamtchatka Islands. As *T. raschii* play a subordinate food of fin whales in the shallow Okhotsk sea, it must also distribute in the very coastal waters to Kuril Islands where the coastal form little piked whales are feeding. The following data in 1953 give somewhat different data on foods of baleen whales caught in the adjacent waters to Kuril Islands (Betesheva, 1955). *Thysanoëssa inermis* is also observed in the investigation. Fish *Cololabis saira* and *Podonema* *longipes* are added to the list of previous season in 1951. Fin whales also feed on euphausiids, *Euphausia pacifica*, but no *Thysanoëssa raschii* is described. With other occurrences of fish, *Podonema longipes* and *Cololalis saira*, some annual changes among the foods may be considered. Though sei whales show no typical change of constitutions among the foods between 1951 and 1953, little piked whales feed only Alaska pollack in 1953. It is desiable that the further accumulation of observations on stomach contents will be obtained to explain above annual changes and feeding habits of baleen whales in the waters adjacent to Kuril Islands.

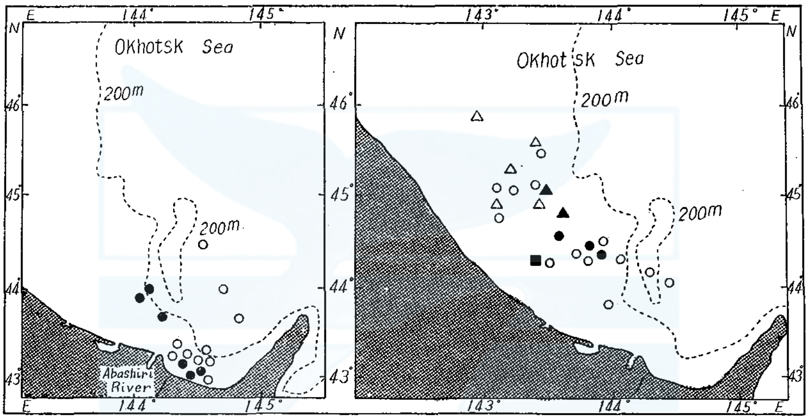

Fig. 25. Occurrences and distributions of foods of fin and little piked whales in the northern part of the North Pacific. △—*Euphausiids*, ▲—*Thysanoëssa inermis*, ●—*Euphausia pacifica*, ○—Vacant stomachs, ■—*Thysanoëssa longipes* and *T. raschii*. Left—little piked whales, Right—fin whales.

OKHOTSK SEA

In the Okhotsk sea, fin whales have been caught mostly, and a few catch of sei and humpback whales are observed. Baleen whales in the area mainly feed on euphausiids. From 1946–48, the biological observations had been carried out, summary of which was already described by Mizue (1951).

According to his descriptions, the main food for baleen whales is Krill and no other food is described. In recent operations, the number of whales caught has been decreasing considerably. Owing to those small number of the catch, examinations on the stomach contents have been carried out are not so satisfactory. I have 13 samples of stomach contents from fin and little piked whales from the Okhotsk sea. *Euphausia pacifica* and *Thysanoëssa inermis* have been observed as a dominant food and *Thysanoëssa longipes* and *T. raschii* are also found among above two species. The distribution of food euphausiids are not certain owing to the scarcity of collections yet. But I would think that ' Krill ' contains in this case only euphausiids though I can't insist on the staple food is only euphausiids in the Okhotsk sea.

TABLE 13. STOMACH CONTENTS OF FIN WHALES CAUGHT IN THE OKHOTSK SEA IN 1955 AND 1956

		1955			1956			
		Euphausiids	None	Unknown	Euphausiids	Squids	None	Unknown
June	1st	10	5	—	—	—	—	3
〃	2nd	9	4	4	1	—	1	6
〃	3rd	6	3	4	6	1	2	—
Aug.	1st	—	—	—	2	—	2	—

TABLE 14. FOOD EUPHAUSIIDS OF BALEEN WHALES CAUGHT IN THE OKHOTSK SEA COLLECTED FROM 1953 TO 1956

Occurrences		Euphausiids			
		E. pacifica	*T. inermis*	*T. longipes*	*T. raschii*
Fin whale	dominant	3	4	—	—
	subordinate	—	—	2	2
Little piked whale	dominant	7	—	—	—
Humpback whale	subordinate*	—	1	1	1

* Dominant species is unknown, because the whale is flensed the day before my arrival at the landstation.

Euphausia pacifica distributes in shore waters and *Thysanoëssa inermis* in off waters. Fig. 25 shows little piked whales take mainly *Euphausia pacifica* in the shore waters. There is the Abashiri river running into the sea. The shore waters along the coast has less salinity than the off waters. *Euphausia pacifica* is more neritic species in the Okhotsk sea than *Thysanoëssa inermis* or *E. pacifica* may be more tolerable in the less salinity waters. On the other hand, the main currents in this part of the Okhotsk sea may be divided into two origins. One of the warm current from Tsushima current, and the other is the cold current of Sahalin current. From the distribution of water temperatures, *E. pacifica* appear in the warmer waters, and *T. inermis* in the colder waters. *Thysanoëssa raschii* is also observed with *T. longipes* and *T. inermis* in the colder waters. As it has been considered as a arctic neritic species I have found none of *T. raschii* in the oceanic whaling ground of the North Pacific but the waters of Anadyr gulf (see p. 181). The fact that *T. raschii* is found in the stomach of fin whales is apparently due to the shallow waters of the Okhotsk sea. As in the neritic waters along the Kuril Island, *T. raschii* is already noticed by Russian scientists, as a food of baleen whales (Betesheva, 1954, 1955). *T. raschii* and *T. longipes* are not so abundant as *E. pacifica* or *T. inermis* in the Okhotsk sea, considering the occurrence in the stomachs of baleen whales. Above occurrences and distributions are quite the same as some previous paper on the subject (Iizuka, Kurohagi, Ikuta & Imai, 1954). These euphausiids must play the role of food for fish too. Squid (may be *Ommastrephes sloani pacificus*) is found once in 1956 as a food.

As to humpback whales in this waters, I have no exact information on about their food. But I have a chance to examine the scattered euphausiids on a flensing deck of the landstation. The whale is considered feeding on *Thysanoëssa* species, *T. longipes, T. raschii* and *T. inermis*. There is a evidence that baleen whales in the Okhotsk sea are sometimes feeding on swarming fish. From 1943 to 1945, 3 occurrences of fish in the stomachs of fin whales, and in 1945, 9 little piked whales are observed as fish feeding occurrences. The species of fish is following.

Fin whales	Sand lance (*Ammodytes personatus*)
	Herring (*Clupea pallasi*)
	Cod (*Gadus macrocephaus*)
Little piked whales	Sand lance (*Ammodytes personatus*)
	Alaska pollack (*Theragra chalcogramma*)

Regarding to the foods of little piked whales, Omura (1956) summarized them. In his report, plankton organisms are described as 'Krill' containing copepods. But it is certain to consider 'Krill' means usually euphausiids only in the Okhotsk sea owing to the shallow sea and the warm current habitats. According to his report, saury and sardin like fish are described besides above species as foods of little piked whales. It is probable that saury is found in the stomachs of whales in the Okhotsk water along the coast, but I am not sure the sardin occurrence in the Okhotsk sea.

SANRIKU AND HOKKAIDO

Along the Pacific coast of north east part of the Japan proper, many baleen whales have been caught and examined until now. Omura (1950) and Mizue (1950) state the summarized consideration on the foods of whales in those waters. Their descriptions, however, are not so satisfactory, because the identifications of foods comprise many mistakes as I discussed in a previous report (Nemoto, 1957, p. 45). To my great

TABLE 15. STOMACH CONTENTS OF SEI WHALES IN THE ADJACENT WATERS TO JAPAN IN THE NORTH EAST AREA FROM 1955 TO 1957

Stomach Contents	May		June		July		Aug.		Sept.		Oct.	
	S*	N**	S	N	S	N	S	N	S	N	S	N
Euphausiids	13	1	14	3	13	24	3	7	—	6	1	10
(Anchory)	—	—	21	2	6	11	2	6	8	9	3	7
Anchory	10	—	7	—	—	4	—	6	—	5	7	2
Mackerel	1	—	—	1	1	3	—	1	—	11	—	1
Mackerel & Anchory	—	—	—	—	1	—	—	—	—	—	—	—
Saury	—	—	—	—	—	3	—	—	—	25	—	9
Saury & Anchory	—	—	—	—	—	1	—	—	—	—	—	1
Saury & Mackerel	—	—	—	—	—	—	—	—	—	1	—	—
Horse mackerel	—	—	1	—	—	—	—	—	—	—	—	—
Squids	6	—	11	—	1	27	—	4	—	21	—	38
Squids & Saury	—	—	—	—	—	1	—	—	—	4	—	3
Squids & Anchory	—	—	1	—	—	—	—	—	—	—	—	—
Squids & Euphausiids	—	—	—	—	—	2	—	—	—	—	—	—
Fish sp.	—	—	—	—	1	—	—	—	—	—	—	—
None	36	5	103	7	25	164	15	34	3	92	13	23
Unknown	65	1	104	8	16	122	21	20	6	106	3	89

* S—Southern waters of 40°N latitude. ** N—Northern waters of 40°N latitude.

TABLE 16. FOODS OF WHALEBONE WHALES IN THE ADJACENT WATERS TO JAPAN OF SANRIKU AND HOKKAIDO AREAS COMPILED AFTER THE DATA BY MIZUE (1951)

	Blue		Fin		Sei*		Humpback	
	S	H	S	H	S	H	S	H
Krill	16	34	43	90	253	103	2	—
Sardin	1	—	1	1	103	32	—	1
Saury	—	—	—	1	25	16	—	—
Mackerel	—	—	1	—	1	10	—	—
Rock fish	—	—	—	—	2	—	—	—
Squids	—	1	—	2	10	135	—	—
Octopus	—	—	—	—	1	1	—	—
Empty	11	23	41	34	547	145	4	6

* Apparently include Bryde's whales in Sanriku waters.

regret, the recent investigations have added few observation and collections of the stomach contents owing to the cutting of whales' body to preserve the meat fresh. Especially very little knowledge has been obtained after the paper by Mizue on the stomach contents of blue, fin and humpback whales which have been caught also in few number in recent operations. With regard to sei whales, comparatively many results show the same tendencies as that illustrated by Mizue (1951), though there are many unknown and empty (considerable part is considered broken stomachs) stomachs.

Sei whales in the Sanriku and Hokkaido areas feed mainly on euphausiids, anchovy saury and squids. Euphausiids consist of *Euphausia pacifica, Thysanoëssa longipes* and *T. inermis* in the northern region of the water off Hokkaido. But latter two species are observed in only a few occasion. In the southern waters from 35° to 40° north of the off waters of Sanriku, *Euphausia pacifica* play a role of foods of baleen whales. *E. pacifica* is considered rather abundant from spring to the summer season in the southern waters and little piked whales migrating to those areas from May to June also feed on *Euphausia pacifica* too. Sei and little piked whales also feed on it, and fin, blue and humpback whales caught in pre-war seasons must have fed on *E. pacifica* along the coast of these areas. Among the fish, anchovy (*Engraulis japonica*) sardin (*Sadinops melanosticta*) and saury (*Colorabis saira*) are the most important species. As shown in Table 15, anchovy occurrs throughout the season, but saury becomes dominant in the later part in September and October. It coincides with the height of saury in these areas. Besides above two species, mackerel (*Scomber japonicus*) is found in a considerable number in September. The size of mackerel is not so large, ranging about 7 to 20 cm in length.

Squids is also important for sei whales, especially in the northern area. Mizue describes further that all the species of whales eat, besides " Krill ", squids, the proper food for sperm whales in this sea area (Mizue, 1951, p. 88). But his consideration should be corrected. Because the species of squids on which sperm and sei whales feed are quite different. Sperm whales feed on mainly *Onychoteuthis* squid, *Onychoteuthis banksii*, and sei whales seldom or never feed on it. Sei whales on the other hand feed on large squids, *Ommastrephes sloani pacificus* which is very abundant in the Sanriku and Hokkaido waters. There is some reliable evidence that the former squids distributes in so deeper sea waters that sei whales, shallow water divers, can't take it.

As to the food of blue, fin and humpback whales, I would refer to the results by Mizue (1951) as summarized in Table 16. These three species mainly feed on ' Krill '. Though the species contain two kinds of planktons, *Calanus* copepods and euphausiids, it must be *Euphausia pacifica* from its abundance in these waters. The 10 stomach samples of planktons collected from these areas are all *E. pacifica, Thysanoëssa inermis* and *T. longipes*. Although the main food plankton is *Euphausia pacifica*, there are another evidence that sei whales are feeding on micro-copepods *Calanus helgolandicus* too. I have 3 occurrences of it in 1953 and also 3 occurrences in 1956 in the northern area of Hokkaido region. Other copepods, *Calanus cristatus* and *C. plumchrus* have not been observed definitly, but it is probable that the whalebone whales take above two copepods in the northern Hokkaido waters where the cold current planktons dominate abundantly. Food of Bryde's whales in the Sanriku waters are mainly euphausiids and anchovy (*Engraulis japonica*), and some Bryde's whales also take the larva of anchovy (Shirasu in Japanese) squids and mackerel.

TABLE 17. FOODS OF BRYDE'S WHALES IN THE OFF WATERS OF OSHIMA, WAKAYAMA PREFECTURE IN 1955 AND 1958

	Stomach contents	May			June		
		1st	2nd	3rd	1st	2nd	3rd
1955	Euphausiids	1	—	14	3	—	—
	Anchory	—	—	—	—	3	—
	Empty	—	—	1	2	—	2

	Stomach contents	May	June			July	
		3rd	1st	2nd	3rd	1st	2nd
1958	Euphausiids	1	2	—	—	—	—
	Anchory	1	—	8	—	6	3
	Post larva of fish	—	—	1	7	—	—
	Unknown & Empty	—	1	18	23	3	—

Two right whales caught in the adjacent waters of Sanriku and Hokkaido in 1956 show the trace of the feeding *Calanus plumchrus* mainly as the scraps collected from the stomachs are mostly of remains of *C. plumchrus* (Omura, 1958). A little fragments of *Calanus cristatus, C. finmarchicus* and *Euphausia pacifica* are mixed in *C. plumchrus*. The size of *Euphausia pacifica* is considered only 10 mm or less and these *Euphausia pacifica* must have not swarmed so mackedly but in the scattered in the sea along with copepods. The quantity of foods for baleen whales in Sanriku and Hokkaido waters was considered very abundant. The feeding percentage given by Mizue (1951) shows very high value, and in the pre-war season many baleen whales with full stomachs had been caught along the coast of Sanriku and Hokkaido. As I said, recent operation prove no such tendency owing to the lack of the complete remaining of stomachs and internal organs.

WAKAYAMA, OSHIMA

At the Oshima landstation in the Wakayama prefecture, comparatively many Bryde's whales have been caught by recent operations. Of course, sei and other baleen whales had been described (Andrews, 1916; Omura, 1950 etc.) in the seasons before 1945 and earlier season after 1945, very little is known about the foods of whales in the waters.

Bryde's whales in the waters feed on euphausiids and anchovy (*Engraulis japonica*). A euphausiid *Euphausia similis* is considered as a role in the earlier season of May, and anchovy play a greater part in the later season of June and July. Bryde's whales also feed on anchovy (*Engraulis australis*) in the south western waters of Australia (Chitterborough, 1959). These facts prove the feeding ground of Bryde's whales lies in the warmer waters as considered up to this time (Rund, 1952; Omura & Nemoto, 1955), because anchovy generally distribute within the warm current in the northern and southern hemisphere.

BONIN ISLANDS

In the adjacent waters to Bonin Islands, the pelagic whaling had been carried out, and caught comparatively many Sei and Bryde's whales. The investigations on those whales, however, were not sufficient to discuss the problem completely. I am very sad that there has been remaining only few samples of stomach contents of baleen whales in the Bonin waters. They are all incomplete collections. Especially I noticed there are many notes about copepods as foods of Sei whales in the Bonin waters at the earlier date of pelagic whaling (Mizue, 1950). But to my regret, the species is not certain because I have none of the collections owing to the insufficiency of the preserving. I would only expect future chance to study.

Some of euphausiid and fish samples of the stomach samples are found in my laboratory, which are of use for considering the main foods in these waters. The euphausiids examined are *Euphausia similis* and *E. recurva*, both of which distribute from subtropical to warm waters in the north Pacific. Nishimoto, Tozawa & Kawakami (1952) describe the food of sei whales in the adjacent water to Bonin Islands in our scientific report No. 7. In the report, the euphausiids is named *Thysanoëssa gregaria* with the illustration of Fig. 1. I would think it is a serious mistake. The illustration clearly shows the distinctions of *Euphausia similis*. I would consider it is *Euphausia similis* which appears dominantly among the remained collections of Bonin Islands waters. *Thysanoëssa gregaria* is also found in considerable number by net collections in these waters (Nakai & Honjo, 1953). But *Thysanoëssa gre-*

garia never swarms so markedly as *Euphausia similis*, and the relative abundance of *E. similis* is far greater.

Fish swallowed by sei or Bryde's whales are all Myctophyid and Gonostomid fish. *Yarrella* sp described by Nishimoto, Tozawa & Kawakami, (1952), is *Yarrella microcephala* which is commonly found from the subtropical warm waters. *Myctophum asperum* is another fish found mainly in the stomachs of whales but in a smaller number. *Myctophum asperum* is not found alone in the stomachs of whales, it is found among the *Euphausia* occurrences. There is another question as to the species of sei or Bryde's whales in the waters from feeding of view. Because Mizue's data based on the catch from February to early May. On the other hand, the distinct Bryde's whales cited by Omura, Nishimoto & Fujino (1952) were taken from the early May to June. So the catch from February to the early May may contain real sei whales as suggested by Omura & Fujino (1954). So it is probable that some baleen whales described as sei whales in the former investigations from 1946 to 1949 take copepads (Mizue 1950). As sei whales can take the scattered copepods in the sea with fine fringes and in skimming feeding, Mizue's description should be examined again with regard to above suggestions.

TABLE 18. STOMACH CONTENTS OF SEI AND BRYDE'S WHALES CAUGHT IN THE ADJACENT WATERS TO BONIN ISLANDS IN 1947, 1948 AND 1949

		Feb.	March			April			May		Total
		3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	
1947	Plankton	1	1	42	16	20	24	7	10	7	128
	Fish	—	—	—	5	5	4	—	—	1	15
	empty	—	—	3	—	—	1	—	—	3	7
1948	Plankton	3	13	1	3	1	15	3	10	—	49
	Fish	—	—	3	5	6	1	4	1	—	20
	empty	1	2	5	7	2	10	8	—	—	35
1949	Plankton	—	—	—	7	2	5	2	5	4	25
	Fish	—	1	3	3	5	14	9	16	6	57
	Decapoda	—	—	—	1	—	—	—	—	—	1
	empty	2	2	2	1	6	4	2	6	7	32

As I stated in the former part, copepods are found in the stomachs of sei whales (Mizue, 1950) in the earlier seasons. According to his description, 13 whales take euphausiids, 34 *Calanus* and 17 young serdines. The last species, young sardines should be corrected as *Yarrella microchephala*. These species show single occurrences of each species in the stomach of whale. From 1947 to 1949, the rough classification of stomach contents of sei whale including some Bryde's whale are illustrated in Table 18. The most dominant occurrences are observed in planktons' part containing different two species, euphausiids and copepods, but in 1949. Fish is twice as many as planktons in 1951 according to the data by Nishimoto, Tozawa & Kawakami (1952), and the whales species at the whaling periods are considered to be Bryde whales considered from the season. Thus no *Calanus* copepods are found in those whales. Generally speaking whales with vacant stomach show comparatively few number when we consider the locality of Bonin Islands waters in 25° to 28° North latitudes, the southern unreproductive area. The fact that so many whales fed, on the other hand, clearly suggests that the waters around Bonin Islands is very productive though it located in the south waters. Subtropical convergence run through laterally the Bonin Islands waters and especially in the seasons between winter and spring (Uda, 1954). I find out many small pelagic Copepods in the stomachs of *Yarrella microchephala* which has generally the small month part. The most dominant species are *Candacia* species living in the subtropical to boreal warm waters. None of euphausiids has been found in the stomachs of *Yarrella microchephala*. On the contrary to this, *Myctophum asperum*, which have comparatively large mouth part, take euphausiids. Each of *Myctophum asperum* feeds on *Euphausia similis* of about 10 specimens. *Candacia* species are not so congregated into swarms of plankton, and they will not become a food for baleen whales in themselves. But if it is fed by *Yarrella* species as a favourite food, *Yarrella* species may become food of Bryde's whales in the waters.

EAST CHINA SEA AND WEST KYUSHU AREA

In the seasons before 1945, Japanese whaling had covered broad area of the Yellow sea and adjacent waters to Korea. These whaling grounds had not been operated after the war as we lost the landstation of all. In 1955, Japanese whaling have commenced the operation in the East China sea from the landstation of a little southern waters of the Yellow sea and adjacent waters to Korea. The baleen whales caught in this area are mainly fin and Bryde's whales. The latter species are, however, descriminated only after the year 1955. Before 1955 and pre-war seasons, comparatively many sei whales (may be Bryde's whales) had been caught along the western coast of Kyushu. The main grounds for sei whales (Bryde's whales) in these area is described in Fig. 26, and season of pre-war seasons before 1945 are between June to September. The whaling ground of Bryde's whales in recent years is also the same as the preceding seasons.

Fin whales, the main object in these waters have been caught in the off waters from the landstations, where no whaling operation had been carried out. The whaling grounds range from 30° to 32°50′ North latitudes and 125°30′ to 128°56′ East longitudes. The water temperature in the area is comparatively high ranging from 21°C to 29°C and differs much from other whaling grounds of the feeding type (Nemoto, 1957) in the North Pacific. Fin whales in this area feed on euphausiids mainly except two occasion of fish and 1956. The quantity of euphausiids in these waters is not so abundant as in the northern part of the North Pacific. Illustrated tables show, that the whales with vacant stomachs are found more. Owing to the long draging from the whaling grounds to the land

TABLE 19. STOMACH CONTENTS OF FIN WHALES CAUGHT FROM THE LAND STATIONS OF WEST KYUSHU, GOTO ISLANDS IN THE EAST CHINA SEA IN 1955 AND 1956

		July		Aug.			Sept.			Oct.	
		2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd
1955	Euphausiids	—	6	3	3	16	7	10	1	—	—
	Empty	—	4	20	26	19	24	35	17	6	1
	Unknown	—	—	2	—	1	2	2	6	9	5
1956	Euphausiids	—	2	12	5	3	5	—	—	—	—
	Flying fish*	—	—	1	—	—	—	—	—	—	—
	Blind eel*	—	—	—	—	—	—	—	1	—	—
	Empty	—	3	7	2	17	14	10	1	—	—
	Unknown	2	47	25	38	16	10	16	21	17	2

The quantity is not so large

TABLE 20. QUANTITY OF EUPHAUSIIDS IN THE STOMACHS OF FIN WHALES CAUGHT IN THE EAST CHINA SEA IN 1955 BASING ON THE DATA OF REMAINED STOMACH

Quantity	July	Aug.			Sept.			Total
	3rd	1st	2nd	3rd	1st	2nd	3rd	
Full	1	—	—	1	—	—	—	2
Rich	1	—	1	1	—	3	—	6
Moderate	1	1	—	2	2	3	1	10
Few	3	2	2	12	5	4	—	28

TABLE 21. STOMACH CONTENTS OF BRYDE'S WHALES CAUGHT IN THE WEST KYUSHU AREA IN 1957 AND 1958

		July	Aug.	Sept.			Oct.	
		3rd	3rd	1st	2nd	3rd	1st	2nd
1957	Anchory	1	2	—	—	—	—	—
	Horse mackerel	—	1	—	—	—	—	—
1958	Anchory	—	—	4	1	—	—	—
	Horse mackerel	—	—	3	—	—	—	—
	Empty	—	—	4	2	1	—	1
	Unknown	—	5	11	9	2	—	4

stations, whales are cut at the belly portion of the body to preserve the meats flesh. As the result, stomachs are often damaged or swollen and contents are washed away by the sea water. Thus the unknown stomachs, thus amount to a considerably number. It is difficult to decide the quantities of euphausiids exactly because of said reason, but as described in Table 20, the euphausiids' occurrences are clearly less than the quantities of the North Pacific whaling areas.

I have got some 20 stomach samples of fin whales caught in the area from 1955. These euphausiid are all *Euphausia pacifica* which is considered dominant in the East China sea and the Yellow sea. *Euphausia pacifica* is commonly found in the waters from adjacent waters to

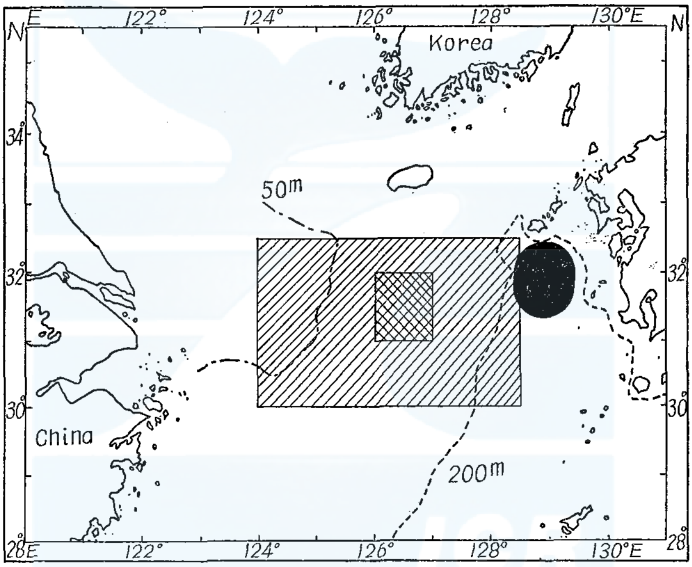

Fig. 26. Whaling grounds showing sea depth in the east China sea. Shading area—whaling ground of fin whales. Double shading—main ground of fin whales. Black area—whaling ground of Bryde's whales.

Japan, but I think this is the first description that *E. pacifica* play the role of foods of fin whales in these waters. Of course, *E. pacifica* is already a famous food for mackerel in the Yellow sea up to these days (Nakai, 1942). The relative abundance of euphausiids is not certain, but the fed fin whales are exceedingly small in number comparing with the northern Pacific water regarding the long pulling and lost stomachs by waves. There are still some fin whales fed abundand euphausiids, however, *Euphausia pacifica* is not so abundant considering the occurrences of fin whales with few stomach contents. Besides *Euphausia pacifica,* blind eel (*Eptatretus burgeri*) and flying fish (definite species name is unknown) are observed in the stomachs of fin whales. They are considered not so important as the foods of fin whales because only one occasion of each species is observed. The blind eel lives coastal and neritic shallow waters of south part of Japan. It is also found in the south waters of Korea (Matsubara, 1955). The name of flying fish is not certain, but some flying fish swim in swarms in the surface of the warm sea, it may be probable that they attract the fin whales in the warm waters.

Another occurrence of very particular organism has been observed in the stomachs of fin whales in the East China sea. So many MONOSTOMATRIDAE parasitic worm are found that one may consider them as a food of fin whales. This worm is determined as *Ogmogaster plicata* Crepl. or the related form by courtesy of Dr. J. Senoo of the Tokyo University of Fisheries. This is found in the caecum of *Balaenoptera* whales by Jagerskiold (Senoo, 1958), but I have never noticed in the stomachs of fin and other whales in other part of the sea. Further information on the parasitic worm is desirable to get the definite cycle of the parasitic worm. Bryde's whales in the adjacent waters to Kyushu are confirmed since the year 1955. These Bryde's whales have been caught in the coastal waters as illustrated in Fig. 26. They are mainly feeding on fish. In 1955, 2 Bryde's whales fed on small sardins (*Sadinops melanosticta*) which distribute widely and abundantly in the summer season in these waters. In next year's operation, 3 Bryde's whales with vacant stomach content are caught. In 1957 and 1958, 3 and 47 Bryde's whales have been caught respectively, foods of which are summarized in Table 21. These Bryde's whales are feeding on anchovy (*Engraulis japonica* (Houttuyn)) and horse mackerels. Horse mackerels in these waters are classified into three species, *Trachurus japonicus* (Temminck et Schlegel) *T. argenteus* Wakiya and *T. declivis* (Jenyno), and it is not certain that how horse mackerels found in the stomachs of Bryde's whales belong to above each species, but *T. japonicus* and *T. declivis* are considered mostly common in the waters. From the observations in 1958, 5 whales take anchovy abundantly and 3 whales take horse mackerels moderately, suggesting that the swarming fish such as anchovy and horse mackerels are abundant in the waters and the waters are very favourable for Bryde's whales. In 1944, the provisional investigation has operated on the stomachs of whales, that is 25 sei* (Bryde's) whales feed on big sardin, 37 whales feed on sardins (may consist of sardin and anchovy) and 38 whales with vacant stomachs in the same whaling grounds as the recent seasons. Big sardins were

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* In 1944, Bryde's whales had not been discriminated from sei whales.

mostly found in July, but I am not sure if the observations were satisfactory in taxonomy.

ADJACENT WATERS TO KOREA

In the pre-war seasons, Japanese whaling had operated from the land-station of the both sides of Korea, in the Yellow sea and the Japan sea. The rough observations on the fin whales caught in the areas were made from 1940 to 1945. The food found in the fin whales stomachs are all 'Krill' but one occurrence of squids. Above two categories of foods are not identified to belong to any species. There is a evidence, however, that *Euphausia pacifica* is very abundant in the Yellow sea and the Japan sea (Nakai, 1942), Especially it plays the role of foods for serdin and mackerels adjacent waters to Korea. He also found that fin whales and little piked whales in the off waters of south Korea mainly took *Euphausia pacifica* as their foods. Considering the dominance of *Euphausia pacifica* in these waters by previous works, above stated 'Krill' is on the whole considered to be *Euphausia pacifica*. The fact that fin whales in these water feed on 'Krill' in winter and in summer, suggests *Euphausia pacifica* is occurring throughout the year, though the cycle of *Euphausia pacifica* in the waters is not certain yet. According to Nakai (1942), a copepod *Calanus plumchrus* is the most dominant plankton in the surface water of the Japan sea. As it is found in the stomachs of fin whales in the northern part of the North Pacific, it may also bear a little significance for fin whales in the Japan sea.

TABLE 22. FOODS OF FIN WHALES CAUGHT IN THE OFF WATERS OF CHANZEN IN KOREA BY AVAILABLE DATA FROM 1940 TO 1945

	Jan.	Feb.	Mar.	April	May	Nov.	Dec.
Krill	10	9	5	17	4	14	6
Squids	—	—	—	1	—	—	—
Empty	—	2	13	7	1	—	—

A swarming fish *Clupanodon punctatus* is once found in a stomachs of fin whales in the Yellow sea at about 38°N latitudes and 124°E longitudes. This is only occurrence of fish in the stomach of a fin whales described in the pre-war investigations in the waters adjacent to Korea.

OKINAWA (RYUKYU)

Many humpback whales have been caught by recent whaling operation in 1958 and 1959. These humpback whales take nothing in their stomach

(Nishiwaki, 1959). A humpback whale take few fragment of *Euphausia similis* in its stomach, but none of humpback whale takes the bulk of euphausiids according to the observations carried in 1959. There is another observation on a occurrence of euphausiids in 1958, the size of which suggests that the euphausiids may be *Pseudoeuphausia latifrons* distributing in the neritic subtropical waters (Nishiwaki, 1959). Other foods such as bentholiving sea slug are considered to be fed by whales according to whalers. But it has been not certain if humpback whales are feeding actively in the warm waters of reproduction and rearing.

JAPAN SEA

Very few observation has been obtained as to the food of baleen whales in the sea of Japan. Only data on little piked whales are followings. Little piked whales in Wakasa Bay (whaling ground II in Omura & Sakiura, 1956, Fig. 17) take *Calanus finmarchicus* and fish, sand lance, The whales in the Hokkaido of the Japan sea side also take sand lance mainly with other occurrences of Alaska pollack and euphausiids (probably *Thysanoëssa inermis*).

BRITISH COLUMBIA

Pike (1952) describes the foods of baleen whales in the off waters of British Columbia in his progress report. *Thysanoëssa spinifera* and *Euphausia pacifica* are observed in the stomachs of fin, blue and humpback whales. To my regret, the name of copepods is not suggested by his descriptions, but one occurrence of it is described in a fin whale stomach.

CALIFORNIA

The foods of humpback and grey whales in the waters of California are given by Howell & Huey (1930). Humpback whales take shrimps (*Euphausia pacifica*) and sardins. *Euphausia pacifica* also play some part of foods of grey, fin and humpback whales in these waters.

NOTE ON THE FOOD IN OTHER WATERS

AUSTRALIAN WATERS

In some Australian waters, humpback whales feed on euphausiids or other shrimps though the food quantity is extremly few. Dawbin (1954) says in his letter, the whaler sometimes observes semi-transparent "shrimps" smaller than *Munida gregaria* in the stomach of humpback whales in the Australian and New Zealand seas. Generally speaking, the foods in the Australian and New Zealand waters are considered to be not so abundant as in the adjacent waters to Japan. He notes further, there has been also a few fragments macerated fish bone too far digested for identification, and very finely digested crustacean materials. The latter remains mean certain euphausiids may play parts of humpback whales. Dall and

Dunstan (1957) describe the fragmental occurrence of *E. superba* in the stomach of a humpback whale treated at Tangalooma whaling station. They describe this is the first record of the food in the stomachs of 2,000 humpback whales examined at the station during 1952 to 1955 seasons. This observation causes some enthusiasm discussion by Jonsgård (1957) and Marr (1957). They consider the occurrence must have been due to the remaining of digested *E. superba* from the Antarctic waters. On the other hand Dall & Dunstan think it is probable that *E. superba* is not confined to Antarctic regions, and that it may be found as a bathypelagic inhabitant of Antarctic waters in lower latitudes. I would also consider the explanation of Jonsgård (1957) and Marr (1957) is the most probable case.

Besides the incident occurrence of *E. superba*, *Euphausia hemigibba* and *Pseudoeuphausia latifrons* were identified from a whale caught in September at Point Cloates of western Australia (Dall & Dunstan, 1957). Sheard and Chittleborough report *Euphausia spinifera* from a whale at Albany (unpublished report cited Dall & Dunstan, 1957). Above many tropical and sub-tropical species of euphausiids, as they are, are comparatively little in quantity in the adjacent waters to Australia, and their swarmmings are not sufficient for humpback whales feeding.

Grimothea stage of crustacean has also been considered in the warmer waters in the southern hemisphere. Mathews (1932) compiled (1932) the previous knowledge on *Grimothea* larva of *Munida gregaria* and he stresses on its importance bearing the migration of the humpback whale in the New Zealand seas. Around the New Zealand coast, Ommanney (1933) describes the south bound whales have a greater or lesser quantity of food in the stomach, while the stomachs of the north bound whales are nearly always empty. But satisfactory expalanation for the fact has not been obtained.

Recently, Chittleborough (1959) reports the food of Bryde's whales that they were feeding on anchovy (*Engraulis australis* Shaw) along with young mackerels.

NORTH ATLANTIC

With regard to the food of baleen whales in the North Atlantic, many previous works referred to the problem as I described in the former report and Mackintosh (1946) states well summarized comment on then. Blue whales feed on euphausiids exclusively as in the North Pacific (Einarsson, 1945). *Thysanoëssa inermis* and *Meganyctiphanes norwegica* have great importance for blue whales in Norwegian and Irish waters. Fin whales feed on mainly planktons and occasionaly on swarming fish too. In the winter seasons from January to April, fin whales feed on *Thysanoëssa inermis* and herrings, and in 'Summer fishing' from the middle of May to the end of seasons fin whales live on the large Krill *Meganyctiphanes norwegica* (Hjort & Ruud, 1929). Between above two winter and summer seasons *Calanus* copepods are observed in April after the figures illustrated by Hjort & Ruud (1929). The whaling grounds of both two periods stand on the different geographical areas. During winter season, fin whales are caught and inside of bank, on the other hand, they are taken on the slope of the continental shelf and slope of the bank in summer.

Sei whales feed on *Calanus* copepods exclusively along the Norwegian coasts (Hjort & Ruud, 1929), but in the waters off Finmark *T. inermis* play a role of food for sei whales (Collett, 1886). Euphausiid, *Thysanoëssa inermis* is also important for right whales and humpback whales in the North Atlantic as summarized by Einarsson (1945).

These observations and investigations are rather old, and I would consider, the study on foods of whales in the Northern Hemisphere of Atlantic requires further investigation. Still, there is another important result that distinct parallel between the catch of sei whales and abundance of *Calanus finmarchicus* is obtained by Hjort & Ruud (1929, p. 51, Fig. 31). The preceding of *Calanus finmarchicus* by a short time (about 10 days after the illustration) should be noted as a general character showing the relation between food and baleen whales. Japanese investigations also endorse the fact but preceding is considered by 7 days or a week.

SOUTH AFRICA

Mackintosh & Wheeler (1929) describe some comments on the food of whales caught to the adjacent waters to South Africa. These species of euphausiids *Euphausia recurva*, *E. lucens* and *Nyctiphnes africans* were included in the stomach contents according to their descriptions. And it seems reasonable that they consider all species of *Euphausian* occurring in the locality are consumed without discrimination when they are congregated into swarms. Besides above euphausiids, fish are found in the stomachs of some humpback and fin whales examined at Saldanha Bay, however, the names of which are not described. In general, the quantities of stomach contents appear to be empty or contain a very small quantity of food. This apparently means, as well published by Mackintosh (1942), baleen whales in warmer regions in winter are feeding little organism but a very meagre diet of certain small euphausiid, some lobster krill and perhaps an occasional meal of fish (Mackintosh, 1942, p. 212). Many species of euphausiids in the warmer waters are considered not so congregated into swarms as in the North Pacific but scattered in the sea. This condition is unfavourable for the swallowing type of baleen whales.

SOUTH AMERICA AND MEXICO

Matthews (1932) states *Munida gregaria* and its Grimothea stage form the food of the sei whale according to Captain Fagerli. Many sei whales were feeding *M. gregaria* or its larva at the surface or near the surface waters. In 1926 at Magdalena Bay on the Pacific coast of Mexico, sei, humpback and Pacific grey whales were found to be feeding on these crustacea shoals, *Pleuroncodes planipes* (Matthews, 1932).

FEEDING HABITS

METHODS

The skrilful collecter of plankton and some other organisms in the sea, baleen whales have two kinds of method to take their foods. Ingebrigtsen (1929) and I (Nemoto, 1957, p. 57) described Skimming and swallowing (gulping) as methods of their feeding. The swallowing by fin and humpback whales is described by Andrews (1909). When feeding, fin whales turn on the side, the water spouting from between the baleen plates as the mouth is closed, and they often turn of rolling their body at the surface of the water, Humpback whales also show the roll on the side (Andrews, 1909, p. 221), and Ingebrigtsen (1929) describe the skimming of sei whales. From the feeding apparatus and food of whales, baleen whales are classified into the above two groups as follows.

Swallowing (gulping) type
- Blue whale
- Fin whale
- Bryde's whale
- Little piked whale
- Humpback whale

Skimming type	Right whale Greenland whale
Swallowing and Skimming type	Sei whale

As discussed in the former part of feeding apparatus, baleen whales belong to blue whale type whales take their foods by swallowing. The main food for swallowing type of whales is euphausiids as discussed in the former part on Antarctic and North Pacific whales. But in some cases, swallowing type whales feed on swarming fish and copepods as fin, whales Bryde's whales, little piked whales and humpback whales do sometimes. Swallowing type whales have generally thick and coarse baleen fringes, and are fitted to take macro-planktons and fish. Tomilin (1954) simply considers those whales belong to the family BALAENOPTERIDAE are classified into macro-planktonophagi, with short and less elastic plates, thick setous bristles and other peculiarities described in the previous section. Tomilin also refers to the fine baleen fringes of sei whales, and states sei whales may also be classified as "microplanktonophagi". Rearlly they feed mainly on copepods, *Calanus finmachicus* (Hjort & Ruud, 1929) in the Atlantic and *C. plumchrus* in the northern part of the North Pacific (Nemoto, 1957). Of course, those *Calanus* copepods are smaller than the euphausiids in general, but there is a important result which should be examined. I would point out that Tomilin has never considered the pecurialities of patch or swarms of planktons. It is evident that baleen whales with fine baleen fringes can take the small planktons, and the smaller *Calanus* copepods may escape the capture by some species of whalebone whales (Marshall & Orr, 1955). On the other hand, there are considerably many illustrations that fin whales sometimes take small copepods *Calanus plumchrus* with rough baleen fringes, and blue whales feed on the small euphausiids smaller than *Calanus* copepods in volume, weight and size. Accordingly, I would discuss the size and volume of each food planktons to understand the relative volume for the baleen fringes of plates. These values are nearly the same as those by Nakai (1942) on the materials collected in the Japan sea. As illustrated in Table 23, *Calanus finmarchicus* is considered to be the most small size, and it seems reasonable only those baleen whales with fine fringes can take them. *Calanus plumchrus* comes next position to *C. finmarchicus* and may be fed by sei and right whales most favourably. *Thysanoëssa longipes* of 6 mm size is, however, smaller than *C. plumchrus* both in size and volume. This stage should be classified as 'microplankton' according to its size and volume, but blue whales sometimes feed on it. A blue whale caught in 1954 in the south waters of the eastern Aleution Island fed on *Thysanoëssa longipes* of this size which is far smaller than *Calanus plumchrus*.

The next indication is the case of *Parathemisto gaudichandi* in the Antarctic waters. I found *P. gaudichaudi* in the stomachs of sei whales and no occurrence is given in the stomachs of blue and fin whales as discussed in the part of the Antarctic food. The stretched length of *P. gaudichaudi* is about 16 mm and from 8 to 15 specimens may be contained in 1 cc. As these values are higher than the *Calanus finmarchicus* and small copepods, *P. gaudichaudi* should be considered as a macroplankton in the sense. To make clear the above two cases, the swarming condition of planktons in the sea must be examined. The special water noise caused by planktons (Cushing & Richardson, 1956) also should be considered as a factor to attract the baleen whales in the sea water.

TABLE 23. SIZE, VOLUME AND WEIGHT OF FOOD PLANKTONS OF BALEEN WHALES IN THE NORTH PACIFIC AND IN THE ANTARCTIC

Species of plankton	No. of individuals contained 1 cc	Approximate average length
*Calanus finmarchicus**	300–500	3 mm
*Calanus plumchrus**	50–110	5 〃
*Calanus cristatus**	8–25	9 〃
Thysanoëssa longipes	180–220	6 〃
〃	13–18	12 〃
Thysanoëssa inermis	3–6	28 〃
Euphausia pacifica	10–15	15 〃
Parathemisto gaudichaudi	8–15	16 〃

* All copepodite V stage.

I consider those swallowing type baleen whales feed on euphausiids or copepods according to the state of congregated swarms of them. If the swarms of planktons are not so heavy, swallowing type of baleen whales pay little attention to the patch. On the other hand, skimming type whales take sparse patch of planktons. In my previous report (Nemoto, 1957, p. 53), I discussed the case of *Calanus plumchrus* in the northern part of the North Pacific. With consideration on the point it seems reasonable that if the patch of *Calanus* copepods congregated so heavily, fin whales can take the patch such as *Calanus cristatus*.

Swallowing type whales prefer euphausiids, swarming fish and swarming copepods *Calanus cristatus* to scattered foods in the sea. Among them, fin, Bryde's and little piked whales are rather polyphagous animals. (I would not consider 'polyphagous' is suitable for the whales in a strict sence as I described in my former report p. 56. Here I use the term only in comparing meaning). But blue and humpback whales are considered to be monophagous and biphagous whales. As described in Table 7, blue whale feed on only euphausiids. The two cases of blue whale feeding on the mixture of euphausiids and copepods suggest that the patch of the mixture bear both characteristics of euphausiids and copepods, and blue whales take them as a euphausiids' swarm (Nemoto, 1957). Humpback whales are also euphausiid feeder and fish feeder, and only very few of them take squids and copepods in their stomach in the North Pacific. Of course the fact that humpback whales congregate to the shore waters and copepods *Calanus cristatus* and *C. plumchrus* distribute mainly in the off waters may cause such tendency. But as a whole, humpback whales never prefer squids and copepods as their food, they can't take scattered planktons in the sea. Fin, Bryde's and little piked whales are rather polyphagous animals according to the recent investigations. They take euphausiids favourably if there is a sufficient swarm for whales in the sea. In the case of wanting euphausiids, they take fish, squids and copepods too, but they never feed on single swimming fish or scattered copepods in the sea. In the northern part of the North Pacific, a fin whale take *Metridia lucens* in one occasion (Nemoto, 1957, p. 54). *Metridia lucens*, as it is very abundant in the surface waters in the North Pacific, swarms not so heavily as *Calanus cristatus*, and usually is considered unfavourable for fin whales of swallowing type as a food. So above case means the very rare occasion that *Metridia lucens* swarms heavily so that fin whales feed on it. Right and Greenland whales take their food by skimming the water with the foods. This method enables whales to take scattered micro planktons in the sea, but fine baleen fringes and long elastic baleen plates may not be effective for swallowing the foods in a short time with the gulp of water mass containing foods.

In the North Pacific, Greenland and right whales had been caught in the shallow waters of the Okhotsk sea and the Bering strait within the Alaskan continental shelf where the swarming euphausiids and copepod such as *Calanus cristatus* are comparatively scarce (Townsend, 1935). Only *Thysanoëssa raschii*, the neritic shallow water species, and scattered copepods such as *Metridia* species are considered as dominant planktons. Right and Greenland whales must have taken there scattered copepods or other planktons by skimming.

It is very difficult to explain the feeding method of grey whales because few investigation has been carried out up to now. I can refer to only one or two foreign observations on the foods of grey whales. First, it should be noted that grey whales feed the bottom living amphipods (Zenkovich, 1937; Tomilin, 1954). In this case, grey whales may skim the amphipods in the the bottom of the sea with rough baleen fringes and tough baleen plates. On the other band, Howell and Huey

(1930) write the evidence that some grey whales feed on *Euphausia pacifica* along the California coasts. Swallowing methods is considered effective for the swarms of euphausiids, however, it is probable *E. pacifica* comes down to the bottom of the sea and is caught by grey whales. From the narrower space of baleen plates row the shape of the plate and structure of skull and shorter baleen plates, it is probable that grey whales also take their foods by swallowing like *Balaenoptera* whales.

When feeding, these swallowing type baleen whales are considered to open the mouth and take in quantities of the foods, then turn on the side (Andrews, 1909; Gunther, 1948). But as to the skimming type whales, they swim with considerable or moderate velocity below the surface of the sea, with their jaws widely open, and the micro-planktons are filtered to remain in the cavity of mouth (Scoresby, 1820; Nemoto, 1957).

FEEDING TYPES

Preceding a paper by Tomilin (1954), Eschricht (1849) and Kükenthal discuss the ecological or feeding classification of CETACEA. By those authors, whales are divided into five groups, " Ichthyophgi ", " Planktophagi ", " Sarcophogi ", " Teuthophagi " and " Phytophagi ". Tomilin (1954) states, however, these classifications are based on foods only, and do not consider the adaptive morphological characteristics of the organs used to obtain the food. According to his conclusion, among whalebone whales, three adaptive types can be distinguished. Those are microplanktophagi, macroplanktophagi and benthophagi. I would consider further his classifications are inadequate in some means. As I state in the former part, the euphausiids smaller than copepods (apparently microplankton) are sometimes fed by blue and fin whales which have coarse baleen plates fringes and classified as " Macroplanktophagi " by Tomilin. I would explain that the case must be due to the swarms of euphausiids which are congregated so heavyly that blue and fin whales pay attention to the patch. Blue whales is considered to have special preference for euphausiids to other planktons in nature as I discuss in many parts, and they are not ' Macroplanktophagi ' in a strict sense but ' euphausiid shrimp feeder ' in general. ' Microplanktophagi ' described by Tomilin (1954) must mean nothing but the skimming type whales, and the latter whales can take scattered planktons which are generally small and do not offer attention to swallowing type whales. As to the food of Greenland whales, one of the skimming type whales or ' Microplanktophagi ', very little is known up to these days. But copepods are also favourite food for right whales, another skimming type whale, and right whales are considered as a copepods feeder in the North Pacific (Nemoto, 1957; Omura, 1958).

Humpback whales are generally euphausiids feeder as well as fish feeder, and they are anything but copepods feeder or squids feeder as discussed in the previous part. These words, euphausiids feeder etc. may sound too common. But the words 'Macroplanktophagi' and 'Microplanktophagi' are not so satisfactory to explain the delicate feeding types of baleen whales. To make summarized comprehension on the problem, the latter detailed classification may be helpful for the purpose.

In the northern part of the North Pacific where the relative abundance of food for whales are dominant, following feeding types are considered.

Euphausiids feeder		Blue whale, fin whale, Bryde's whale, little piked whale and humpback whale
Copepods feeder	macro-copepods feeder	Fin whale
	moderate and micro-copepods feeder	Sei whale and right wnale
Fish feeder	small swarming fish feeder	Fin whale, Bryde's whale and little piked whale
	moderate and small swarming fish feeder	Humpback whale
Squids feeder		Fin whale, sei whale

From above classifications, it is evident that there are selections by whales for their food and if there are sufficient foods above listed found in the sea water, whales follows their food selection orders as follows. Arrows show the order and lines show equivalent order

Blue whale	Euphausiids
Fin whale	Euphausiids—macro-copepods—Swarming fish→micro-copepods→Squids
Bryde's whale	Euphausiids—Swarming fish→Copepods
Little piked whale	Euphausiids—Swarming fish→Copepods
Sei whale	Copepods→Euphausiids—Swarming fish—Squids
Humpback whale	Euphausiids—Swarming fish
Right whale	Micro and macro-copepods→Euphausiids

In the adjacent waters to Japan, the aspects of the feeding types may be a little different from those in the northern part of the North Pacific where the planktons are abundant. Only *Euphausia pacifica* is available for the baleen whales among euphausiids as a dominant food, and only some occurrences of *Calanus finmarchicus* are considered. But anchovy (*Engraulis japonica*) and saury (*Colorabis saira*) are so abundant that comparatively many sei whales feed on above fish as often as on planktons. One may think that sei whales in the adjacent waters to Japan proper are fish feeder. But other blue, fin and humpback whales do not show such difference in their feeding from data of the northern waters. The above difference of sei whales must be due to the feeding of methods, taking fish and squids by swallowing as well as microplanktons by skimming. As illustrated in Table 7, blue and fin whales were feeding on "Krill", but many sei whales were feeding on fish and squids too. Thus, the feeding type of baleen whales in the adjacent waters to Japan may be described as follows.

Euphausiids feeder	blue whale, fin whale
Fish feeder	sei whale
Squids feeder	sei whale

In the Antarctic waters, the large euphausiid, *Euphausia superba* is available for baleen whales, (Mackintosh & Wheeler, 1929). With Japanese recent investigations, the southern baleen whales take also *Thysanoëssa macrura* and *Parathemisto gaudichaudi*. In the warmer waters, *Munida gregaria* and some other euphausiids are described in the previous parts of this paper. Accordingly the feeding method and type of the baleen whales in the southern hemisphere are given as follows by these recent observations.

Swallowing type	blue whale, fin whale, Bryde's whale, and humpback whale
Skimming & Swallowing type	sei whale

Very little is known as to the feeding of right and little piked whales, and their feeding type is also unknown. The swallowing type whales in the southern hemisphere feed mainly on euphausiids, but there is another evidence that Bryde's whales in the adjacent waters to west Australian waters feed on anchovy (Chittleborough, 1959), humpback whales on *Munida gregaria*, and sei whales on *Munida gregaria* too. But as the data on the foods of whales in the southern warm hemisphere is not sufficient except those of the Antarctic, it seems reasonable, therefore, to refrain from any conclusion. Tomilin (1954) proposed food preferences of baleen whales developed in the northern hemisphere and not in the southern hemisphere. His explanation may be reasonable to some extent because the main food of the Antarctic waters is *Euphausia superba*, and right and sei whales also feed on *E. superba* in the Antarctic (Matthews, 1938, a, c). With the compliments to his explanation the feeding type in the southern hemisphere is as follows.

Euphausiid feeder	blue whale, fin whale, humpback whale, sei whale
Fish feeder	Bryde's whale
Amphipods feeder	sei whale

Referring to the possibilities of feeding, right and sei whales may be Copepods feeder as well as Euphausiids and Amphipods feeder, because some copepods are abundant in the southern hemisphere in a scattered condition but they attract the attension of skimming type whales.

FEEDING TIME

I already discussed the details of feeding activity of the baleen whales in a day in a previous report (Nemoto, 1957, p. 56, Fig. 11–14), and successive investigations have proved the same result. These conclusions are followings. In the pelagic whaling grounds (meaning the whaling ground with deep sea bottom), the feeding percentage is higher in the morning and in the evening, and it shows decrease in daytimes. This fact is considered to be due to the feeding activity of whales and partly diurnal migration of zooplanktons, fish and squids (Nemoto, 1957). Another marine mammal, northern fur-seals also show the same feeding activity according to the diurnal migrations of their main food, *Myctophidae* lantern fish (Taylor, Fujinaga & Wilke, 1955).

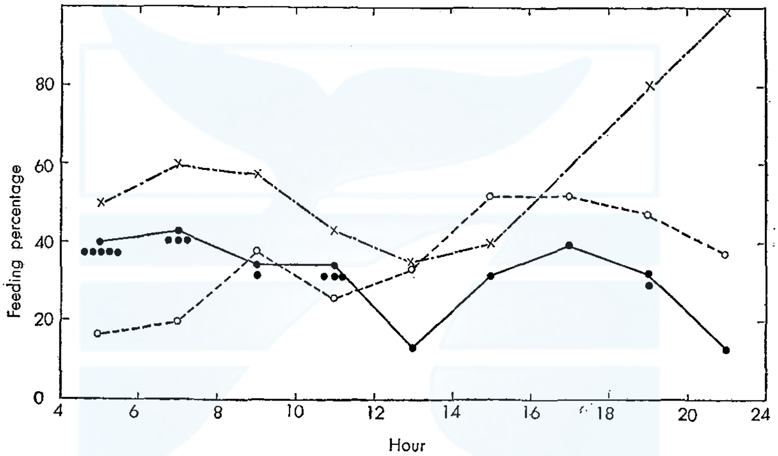

Fig. 27. Feeding percentage of baleen whales in the northern part of the North Pacific in the south waters of the eastern Aleutian Islands in 1958. Solid line—fin whales, Chain line—blue whale, Dotted line—Sei whales. Black dot indicate the occurrences of squids.

There are also some differences of feeding percentage according to the food species and the environment such as sea depth. In the pelagic whaling ground, where the sea depth is over 500 m or more, whales feeding on euphausiid show the said tendency that they feed dominantly in the morning and in the evening. On the other hand, in the coastal or shallow waters such as Andyr gulf in the northern part of the North Pacific where the sea depth is less than 50 m, fin whales take a euphausiid (*Thysanoëssa raschii*) in daytimes. *Thysanoëssa raschii* also follow the general habit of the diurnal migration in the sea, and it is considered to stay in the bottom waters of the shallow waters. The fact suggests the feeding of whales may attain to the bottom layer of the coastal waters of shallow depth less than 50 m. Capelin (*Mollotus catervarius*) is also heavily fed by fin whales in daytimes in the Anadyr waters. These facts give us a comprehension that whales usually feed on their food as much and often as possible to nourish them in their feeding season. If it is possible to take food, they feed also in daytimes and the many vacant stomach directly mean the some unfavorable condition for their feeding in general.

The interesting feeding percentage of baleen whales in the south waters of the eastern Aleutian Islands is illustrated in Fig. 27. Blue and fin whales take their foods mostly in the morning and evening as discussed in the former report (Nemoto, 1957), but the percentage of blue whales is higher than fin whales as a general tendency. As the most favorite food of blue and fin whales is considered to be euphausiids, this difference of feeding percentage between blue and fin whales is partly due to the feeding habit of each whale such as diving depth or the extent of feeding activity. The feeding percentage of sei whales show a little difference of the feeding percentage. The main food of sei whales in the waters is *Calanus plumchrus* which has been considered not to show the more typical diurnal migration. This directly may mean the higher percentage in the daytime as given by the illustration. As to the squids, fin and sei whales take them as a food in the waters. Those squids are fed only in the morning from 6 to 12 by fin whales and no squid has been fed in the afternoon from 12 to 18. Squids are also migrating rapidly according to the diurnal change of light intensity. These squids occurrences in the stomachs of fin whales are described by single marks in the Fig. 27.

WEIGHT OF STOMACH CONTENTS

As the quantity of stomach contents of whales decreases in accordance with the polongation of chasing by catcher boats (Nemoto, 1957, p. 65), and the exact weighing of stomach contents is so difficult that few reliable information has been described. The old description shows that a blue whale take more than 1000 liter of euphausiids in the Atlantic (Collett, 1912), and the full stomach of large rorquals has been considered to contains about 1000 kg of planktons or fish.

The recent investigations by Nishimoto, Tozawa & Kawakami (1952) and Betesheva (1954, 1955) treat the problem, and their data well demonstrate the quantity of stomach contents of whales. The stomach contents of Bryde's whales in the Bonin Islands waters weighed by Nishimoto, Tozawa & Kawakami are ranging from about 100 to 200 kg in the case of full stomach condition. The contents are all considered to be *Euphausia similis*, and its freshness indicates that it is swallowed in the short duration of feeding. Thus the amount of stomach content of 200 kg is directly mean the heaviest food taking of Bryde's whales. The stomach quantity of sei whales has been measured by Betesheva (1954), and he describes the full stomach of a sei whale containes 600 kg of squids (*Ommastrephes sloani pacificus*). Other sei whales in the Kurile waters have also 50 to 370 kg of *Calanus plumchrus* (*tonsus*).

Fin whales take more abundant food usually in their stomachs according to his observation. They take more than 100 kg of foods in 65 percent of all observations. The most abundant volumes are 560 kg of squids, 464 kg of saury and 425 kg of the mixture, *Calanus* copepods and euphausiids.

TABLE 24. WEIGHT OF THE FOODS OF FIN WHALES CONTAINED IN THE FIRST STOMACH OF CAUGHT WHALES IN THE NORTHERN PART OF THE NORTH PACIFIC*

Body length	Sex	Food species	Relative quantity	Weight (kg)
57	Male	Alaska pollack	R	759.0
62	〃	Euphausiids	R	112.5
65	Female	〃	R	100.0
62	Male	*Calanus* copepods	R	81.0
64	Male	*Calanus* copepods	rr	30.0
58	Male	*Calanus* copepods	rr	30.0
60	Male	*Calanus* copepods	rr	26.0
64	Female	Euphausiids	r	10.0

Measured by the courtesy of Mr K. Nasu.

The exact weight of the stomach contents of fin whales are measured in the northern part of the North Pacific on contents of both euphausiids and copepods. The full stomach contains about 100 kg of stomach contents of euphausiids and *Calanus* which is less than those given by Betesheva (1954, 1955) in the Kurile Islands waters. The fact may partly be due to the food species contained in the stomach. These Japanese data are only based on the planktons, euphausiids and *Calanus* copepods, but the heaviest stomachs of fin whales in the Kurile Islands waters containes squids and saury. The one example of a rather small sized fin whale also take vast volume of fish food (Alaska pollack), which show the heaviest weight of the stomach content of fin whales in the northern part of the North Pacific. The fish is generally digested slower than the said planktons and the weight of stomach contents of fish is heavier than plankton contents, and the specific gravity of fish is apparently heavier than that of the plankton. These reason may cause such results. The former whaling ground in the high latitudes of the North Pacific is considered to generally produce more abundant food planktons, so it is strange that fin whales in the northern part of the North Pacific take only 100 kg of planktons at most. It is desirable to weigh more examples in the water to get exact measurements of stomach contents. But it is evident that fin whales take foods from about 100 to 700 kg in weight in their stomach in the Northern part of the North Pacific. The grade of the quantity decided by routine works on whales also shows the typical degree of the quantity as given in the Table 24, which well indicates the relative quantity of stomach contents of the fin whales.

DISTRIBUTION OF FOOD PLANKTON

Euphausiid

As I have described in the previous chapters, vast number of food euphausiids' distributions are examined. Considering from the stomach contents of baleen whales and net collections, each euphausiid has been observed following locality as illustrated in Fig. 28. These euphausiids distribute in relation to the two main facters in general. One is the oceanographical condition which is illustrated by the water temperature, the other is the shape of the sea which is mainly connected with the depth of the sea. I would treat the distribution of euphausiids mainly from the abundance of them in the sea considered by their occurrence in the stomachs of whales and fish with other net collections. So, the zoo-geographical grouping may be a little different from previous works by other scientists mainly according to net collections.

Ruunstrϕm (1927, 1930) and Einarsson (1945) make the three grouping, arctic boreal, boreal and Mediterranean boreal forms. According to Einarsson's excellent discussions, *Thysanoëssa raschii* and *T. inermis* bear the arctic-boreal or rather low-arctic-boreal character. This is the same in the North Pacific waters. By recent years investigations, Ponomareva (1957) writes the account for the distribution of main euphausiids in the north-west Pacific, and she also classifies euphausiids into three distributional groups. Arctic boreal, boreal and tropical groups are her classifications. The latter groups by Ponomareva is apparently following to the works by Ruunstrϕm (1930) and Einarsson (1945). Arctic and Cold boreal group contain, *Thysanoëssa raschii*, *T. inermis* and *T. longipes* by the grouping of Ponomareva (1945). *T. longipes* is somewhat warmer water specimens, and it recalls *Thysanoëssa longicaudata* in the Atlantic in this point. As considered in the paper by Einarsson on *T. longicaudata*, *T. longipes* in the North Pacific belong to the higher temperature group. The next species, *Thysanoëssa raschii* has been found in the stomachs of whales in the most northern part of the Bering sea, adjacent waters to Kuril Islands, and the Okhotsk sea. With other observations, *Thysanoëssa raschii* in the North Pacific distributes in the waters lower than 16°C by the surface water distribution described by Fleming (1955). This value 16°C is the higher limit of surface temperature which is nearly the same value 15°C described by Einarsson (1945). The most northern occurrence in the north Bering sea is covered by ice in winter, and the dominant occurrences are considered to be as south as the middle Kurill waters. The water temperature in the area do not exceed 13°C in August. This value also coincides with 12°C of vigorous spawning area by Einarsson. *T. inermis* inhabits in somewhat higher temperature waters than *T. raschii,* as I find the dominant occurrence of *T. inermis* in the stomach of a fin whale in the waters 42° north latitude and 143° East longitude in the adjacent waters to Japan.

The range of distributional water temperature of *T. inermis* is about the same as *T. raschii*. The former, however, distributes in more colder waters, because I have found no dominant occurrences in the stomachs of whales but a few individuals in the stomachs of capelin in the northern part of the Bering sea. By the fact that, *T. raschii* distributes as far north as the edge of pack ice, it is probable that *T. raschii* is found dominantly in the neritic arctic sea.

With regard to *Thysanoëssa longipes,* the dominant occurrences are considered not to exceed as far as 60° north latitudes. Japanese investigation shows that the most north collection of *T. longipes* are made in the waters north of Komandorskiy Islands. *T. longipes* is also found in the sea of Okhotsk and the south east waters of Hokkaido a little more south than *T. inermis*. In the sea of Japan, Komaki & Matsue (1958) also describe the occurrence of *T. longipes*. The water temperature in the sea of Japan is higher than the waters along the Pacific coast by the 'Tsushima' warm current. Perhaps *T. longipes* in the Japan sea shows the distribution of the most high limit of water temperature. The spineless form of *Thysanoëssa longipes* is considered to distribute in somewhat different way. Namely the spineless form distributes a little more southern waters than the original spined forms (Boden, Johnson & Brinton, 1955). The spineless *T. longipes* is observed in three occasions in the stomach contents of whales dominantly in the western waters of the northern Pacific. Other single or subordinate occurrences are more found in the western part than the east as illustrated in Fig. 29.

According to my collections, and Japanese observations the spineless form has not been observed in Okhotsk sea though the original form is

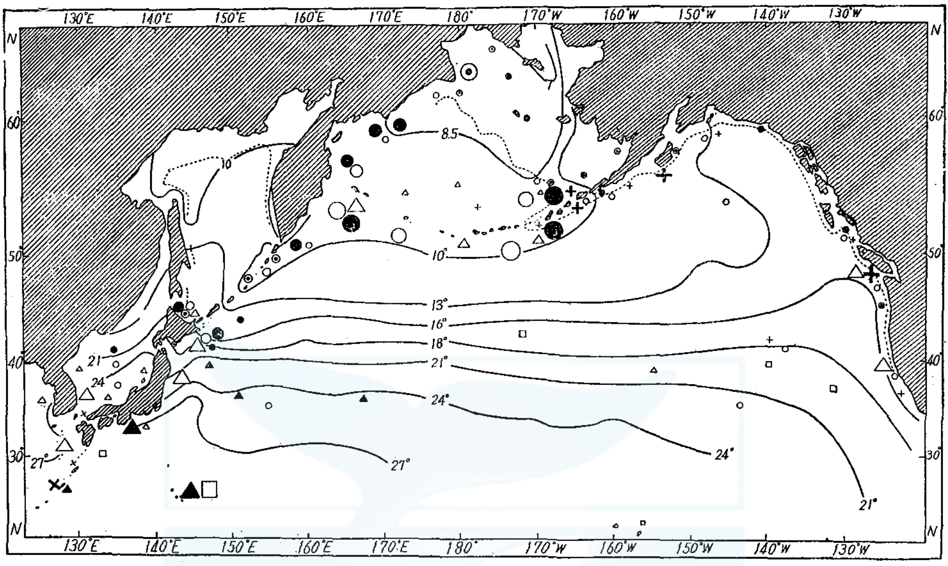

Fig. 28. Schematic illustration of the distribution of euphausiids of foods of whales in the North Pacific. ○—*Thysanoëssa longipes*, ●—*Thysanoëssa inermis*, ⊙—*Thysanoëssa raschii*, +—*Thysanoëssa spinifera*, △—*Euphausia pacifica*, □—*Euphausia recurva*, ▲—*Euphausia similis*, ×—*Pseudoeuphausia latifrons*. The large symbols show the dominant, moderate symbols show usual occurrences and small symbols show the subordinate occurrences as whales' foods.

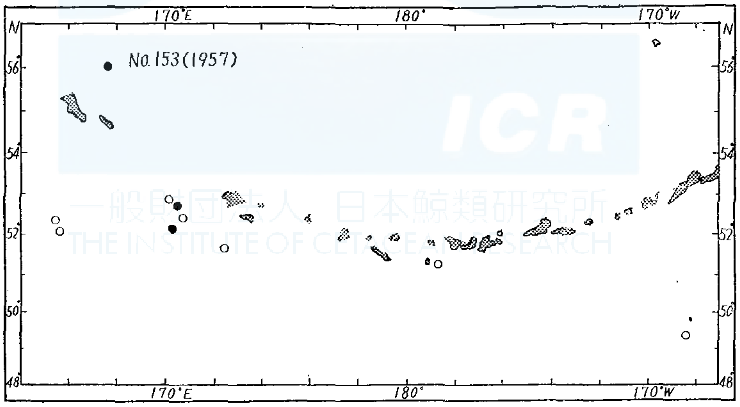

Fig. 29. Occurrence and distribution of spineless form of *Thysanoëssa longipes*. Open circle—subordinate occurrences and net collections, Black circle—Dominant occurrences in the stomachs of whales.

found in the waters by net collections and stomachs of whales. The another different evidence that the spineless forms found in the south waters of the Japan sea is stated by Ponomareva (1957), however, the number of the spineless form of *Thysanoëssa longipes* is considered very scarce or nil by Japanese investigations (Komaki & Matsue, 1958).

Thysanoëssa inermis is considered to show the distribution between *T. raschii* and *T. longipes* from Japanese investigations. It is observed in the stomach of fin whales dominantly in the off waters of Olyutorskiy cape where *T. longipes* is not observed as a dominant occurrence. The most north collection is also obtained from the stomach of capelin found in a fin whale stomach in the water near St. Lourence Islands, but I found none of *T. longipes* in the stomachs of capelin and other fish in the northern waters of the Bering sea. In the Japan sea *T. inermis* also distributes in the more northern waters than *T. longipes* (Komaki & Matsue, 1958). *Thysanoëssa inermis* has two forms according to the classification of the presence of spines at the 6 and 5 abdominal segments (Nemoto, 1957, p. 46). The one spine form is found exclusively in the Atlantic. But the two spines form is dominant in the North Pacific. It distributes mainly in the adjacent waters to Aleutian Islands, but I have found none of the two spine form in the Okhotsk sea. Also in the Japan sea, Komaki & Matsue (1958) illustrate one spine form only, suggesting that one spine form of *Thysanoëssa inermis* preserved in the Okhotsk sea and Japan sea in the North Pacific.

Above three species of *Thysanoëssa* do not distribute in the Yellow sea and mainly inhabit in cold boreal waters. From the consideration of spawning area and its temperature, these *Thysanoëssa* species are classified as Arctic boreal group or low-arctic boreal group as described by Einarsson (1945, p. 130).

The distribution of *Thysanoëssa spinifera* is also very interesting. As I stated in the previous report (Nemoto, 1957), it is mainly found along the west coast of American side, and it plays a role of foods for whales at British Columbia (Pike, 1950). *T. spinifera* has never been found along the Asian side, in the Okhotsk, Japan and Yellow sea, but it distributes as south as La Jolla of California (Boden, Johnson & Brinton, 1955) in American side. This species may be also classified as Arctic boreal group though it is considered a little warm water living species. *Euphausia pacifica* is considered to distribute a little different from above four species. Ponomareva (1957) already states that *Euphausia pacifica* belong to the boreal group in its distribution, a warmer water form than four *Thysanoëssa* group. I would also classify it into the boreal group. Though Einarsson (1945, p. 130) prefers to call the temperate group to the Mediterranean-boreal group described by Ruunstrφm (1927), but this cold temperate group is also the same meaning as the boreal group by Ponomareva (1957, Fig. 1), I would use the term to make contrast to the other *Euphausia*, *Euphausia similis*. *Euphausia similis* mainly distribute in the subtropical waters and it belong to the warm temperate group. Its dominant occurrences are restricted from subtropical waters to the warm temperate zone of 35° North latitude. *Pseudoeuphausia latifrons* is considered to play a role of foods for whales in the tropical and subtropical waters in the North Pacific, a little south waters from the warm temperate group. It belong to the tropical group as it is described by Ponomareva (1957). The excellent schematic illustrations of latitudal distribution of the euphausiids species are given by John (1936) and Einarsson (1945). Here I would repeat it on the North Pacific species. The main food euphausiids in the antarctic are oceanic pelagic forms (Einarsson, 1945, p. 136). On the other hand

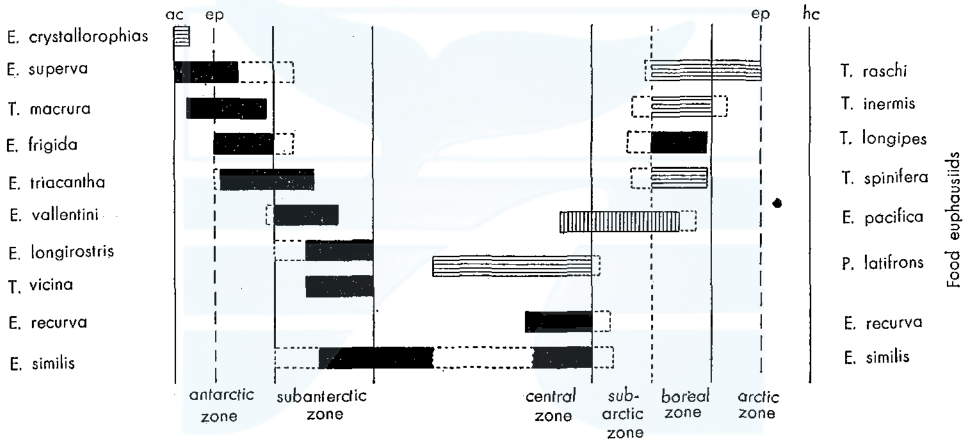

Fig. 30. Schematic illustration of euphausiid fauna of the North Pacific and the Antarctic basing on the data by Einarsson (1945), Johne (1936) and foods of whales. hc—high arctic, ac—Antarctic coast line, ep—edge of pack ice, horizontal shading—neritic species, vertical shading—neritic but some sometimes found in ocean, Black—surface species.

four main food euphausiids are rather neritic coastal species, which is apparently due to the nature of the sea in the North Pacific. Only one, *Thysanoëssa longipes* is considered as a probable pelagic form, because it has been mainly observed in the oceanic water mass and not been confined to the coastal waters. *T. longipes* may take the position of *T. longicaudata* of the Atlantic in the Pacific. *Euphausia pacifica* mainly distributes along the coastal waters, but another *Euphausia similis* and *E. recurva* are considered as the oceanic form. Sometimes *E. pacifica* drifts to the off waters where many baleen whales feed on it especially in Sanriku waters, and it is more oceanic than *Thysanoëssa raschii*, *T. inermis* and *T. spinifera*, Those five main northern species have not been found in the southern hemisphere, but *Euphausia recurva*, *E. similis* and *Pseudoeuphausia latifrons* play some parts of foods also in the southern hemisphere according to the previous investigations (Mackintosh, 1942; Chittleborough, 1959 etc.).

Distribution of food copepods of whales in the north pacific

Four species of copepods have been found dominantly in the stomachs of baleen whales in the North Pacific. *Calanus cristatus*, *C. plumchrus*, *C. finmarchicus* (*helgolandicus*) and *Metridia lucens* are them. There is another occurrence of *Calanus* copepods described by Mizue (1950), but the species is still remained unknown. It is considered to be a subtropical copepod not to belong *Calanus* copepods of boreal waters.

The representatives of Pacific boreal communities of Copepods, *Calanus cristatus*, *C. plumchrus* are considered not to distribute so abundantly in the arctic region, and will not be favorite food of baleen whales. According to the observation on stomach contents of baleen whales, *Calanus plumchrus* and *C. cristatus* have not been described in the northern part of the Bering sea and within the Alaskan continental shelf. As I said in the former report, *Calanus cristatus* need deep waters to be mature, it distributes mostly in the off waters of the adjacent waters to Aleutian Islands and the shelf. Johnson (1956) describes only one specimens of *Calanus cristatus* in the collection of the plankton in the Beaufort and Chucchi sea areas, suggesting that it does not distribute abundantly in the arctic sea. Body length of *C. cristatus* is generally considered to be large in the cold waters. The size of *C. cristatus* in the North waters of Aleutian Islands is larger than that in the south waters. From these size distribution of *C. cristatus*, there are some main local groups in the North Pacific near Aleutian Islands.

Calanus cristatus has not been observed stomachs of whales in the adjacent waters to Japan, and it is also observed in few occasion in the Kurile waters (Betesheva, 1954 & 1955), the bio-mass of *C. cristatus* is considered to be only sufficient in north water from about 45°N latitudes. *Calanus plumchrus* is considered a little warmer water form and the southern range as a food of baleen whales may come down to 40°N latitudes in the western part of the Pacific. *Calanus finmarchicus* (*helgolandicus*) is considered more warmer water form, but the *helgolandicus* form distribute more southern waters. The small Copepoda collected from the stomachs of whales caught in the adjacent waters to Japan of Pacific side are all *Calanus helgolandicus*, and its southern range as a food of whales may attain to 35°N latitude in summer season of the North Pacific.

MOVEMENT AND MIGRATION OF BALEEN WHALES

DISTRIBUTION OF BALEEN WHALES IN THE NORTH PACIFIC

Whaling centers

With regard to migration and distribution of baleen whales, Mackintosh made very important consideration on the problems (Mackintosh, 1942). His summarized Table (p. 229, Tab. 9) gives us clear comprehension on the distribution of baleen whales in the southern hemisphere except some Bryde's whales' occurrences. After the example of Mackintosh's table, the northern Pacific whaling centres and catch may be described as Table 25. Table 25 shows that there are clear distribution of baleen whales in each latitude according to summer and winter seasons of whaling.

TABLE 25. NORTH PACIFIC WHALING CENTERS AND CATCH ACCORDING TO THE SOME AVAILABLE DATA FROM 1910 TO 1945

Whaling centre in Pacific	Approximate latitude N	No. of seasons	Whale species						
			Blue	Fin	Bryde's	Sei	Hump-back	Grey	Right
Arctic pelagic	North of 65°	1	—	74	—	—	101	56	1
Eastern side									
Alaskan coast	53°-60°	7	318	1176	—	2	1115	1	3
British Columbia	50°	7	59	634	—	100	183	—	—
Washington	47°	2	2	53	—	5	246	—	—
California	35°-45°	9	—	145	—	31	1181	7	—
Lower California pelagic	20°-35°	1	239	—	34	—	498	42	—
Maxico Gorgona		1	85	1	—	4#	565	19	—
Western side									
Kamtchatka pelagic	Ca 50°-65°	2	74	591	—	9	13	2	3
North Kurile	50°	3	7	104	—	18	5	—	12
Middle Kurile	45°	12	2	293	—	727	2	—	18
Japan coast	40°-45°	14	70	1683	—	1226	79	1	14
〃	35°-40°	15	186	737	—	2661*	34	—	2
〃	30°-35°	14	429	98	—	480**	89	—	9
Okinawa	28°	5	5	7	—	1**	131	—	1
Bonin Islands	27°	8	9	2	—	180*	288	—	4
Formosa	22°	8	—	—	—	3**	206	—	—

\# Probably Bryde's whale. * Including Bryde's whale.
** Probably almost Bryde's whale.

Arctic sea. As to the Arctic ocean, Japanese pelagic whaling covered Chukchee sea in 1941, and fin, humpback and grey whales were caught along the Siberian coast. No other baleen whales was caught though some Russian scientists consider the migration of blue whales reach to the Arctic sea (Sleptsov, 1955). Another observations made by Nikulin (1946) endorse the Japanese result. According to the data by Nikulin fin, little piked, humpback, grey and Greenland whales had been observed, and no blue and sei whales are described in the adjacent waters to Chukchee Peninsula. From 1937 to 1943, following number of baleen whales, 1051 fin, 1904 grey, 687 humpback, 118 little piked and 12 Greenland whales had been observed. Thus fin, humpback, grey, right and Greenland whales distribute in the Arctic sea as a conclusion. The evidence if Greenland whale exists has not been given and I would not state further comment on Greenland whales' distribution and occurrence here. *Kamchatka pelagic* (*western side*). In the off and adjacent waters to Kamtchatka peninsula in Pacific side, many whales has been caught by Japanese and Russian pelagic whaling. Fin whales are considered to be most dominant in the waters with blue, sei and humpback whales. Among them, blue whales has been caught only in the southern waters of Komandor Islands (about 55° North). Grey whales' occurrences are apparently considered as a illustration that some grey whales may migrate along the coast of Kamtchatka peninsula from north to south in the north waters of Bering sea. Though there is no evidence in the old statistics that Bryde's whales have not appeared, the recent investigation on Bryde's whales affirms that Bryde's whales never migrate to the cold waters of Kamtchatka coasts.

Kurile Island. The catch of Kurile Islands situated between Japan proper and Kamtchatka bears the intermediate character between above two localities. In the Noth Kurile waters, the catch is the same as that of Kamtchatka waters. Fin whales are the main catch of the waters, but number of sei whales are not so dominant. The catch in the middle Kuril water region shows a little difference from the northern Kurile waters. Sei whales become dominant in number and form the main catch of the waters.

Japan coast. Along the Pacific side of Japanese coasts, many baleen whales have been caught both in the pre-war seasons and after the year 1945. From those statistics, the differences among the catch in the each landstations are observed. Fin and sei whales make the main part of the catch in the northern coasts from 40° to 45° North whereas sei whales become more dominant in the south waters from 35° to 40° North. Among the catches of sei whales in the waters, however, some considerable number of Bryde's whales should be considered. As Omura & Fujino (1954) and Omura & Nemoto (1955) state, Bryde's whales have been caught in the summer season in the waters along the Pacific coasts of Japan from 35° to 40° North. Along the southern coasts of Japan from 30° to 35° North, the considerable catch of blue whales had been described from 1910 to 1923 in winter seasons at the Wakayama prefecture landstations. But after 1923, blue whales decreased in number and scarcely caught by recent operations. The recent investigations have proved that sei whales caught in summer season are all Bryde's whales. But among the catches, before 1945 some occurrences of sei whales also should be considered according to the paper by Andrews (1914), but above catches were obtained rather in earlier seasons of the year when the migration of sei whales was probable.

Okinawa. Humpback whales are the main catch in winter seasons. Number of blue and fin whales are extremly scarce in number in the waters, suggesting that these whales do not come down to the subtropical water or do not approach the Islands. Sei whales caught in subtropical waters of Okinawa may apparently be Bryde's whales.

Bonin Islands. Humpback whales had been caught dominantly in the earlier seasons, but Bryde's whales become dominant in recent catches. Few blue and fin whales have been caught as in the Okinawa waters.

TABLE 26. BALEEN WHALE OCCURRENCES IN THE PACIFIC OCEAN AND ADJACENT SEAS

	Blue	Fin	Bryde's	Little piked	Sei	Hump-back	Right	Grey
Arctic sea	−	⧻	−	+	−	⧻	+	⧻
Bering sea	+	⧻	−	+	+	⧻	⧻	⧻
Sea of Okhotsk	+	⧻	−	⧻	+	+	⧻	+
Sea of Japan	+	⧻	−	⧻	−	+	⧻	⧻
Yellow sea	+	⧻	?	⧺	?	+	+	+
East China sea	−	⧻	+	+	−	+	⧺	−
South China sea	−	−	+	?	−	+	+	−
California Bay	−	−	−	−	−	+	−	⧺
Pacific coast	⧻	⧻	⧻	⧻	⧻	⧻	⧻	⧻*

* Only along the American coast of the Pacific ocean. ⧻—whaling operated, ⧺—Considerable occurrences, +—occurrence observed.

Formosa. Only humpback whales are the main catch. Still, there are some captures of blue, fin and sei (Bryde's) whales, but they never consists the important catch of the warmer waters of Formosa.

American side of the pacific. Along the western coasts of American side of the Pacific, the same catch tendencies have been observed as illustrated in Table 25. In the northern waters, fin whales occur in considerable number, and humpback whales in the southern waters. Blue whales were caught in the off waters of Lower California by the winter pelagic operations in a fairly many number with humpback and grey whales. As a general observations, the distribution of baleen whales and the catch in both sides of the Pacific are not different except the local distribution and the migration of some whales which I would discuss in the next part.

THE SHAPE OF THE SEA AND DISTRIBUTION OF BALEEN WHALES

The baleen whales migrate in the sea, following their foods and to complete their reproducting purpose. The catch and observations up to these days give us the general tendencies about the distribution according to the shape of the sea and submarine topography. Krümmel (1907) and Kuenen (1950) describe the seas, and I would summarize the subject following above authors. The seas are distinguished first as *Oceans* and *Adjacent seas*. Adjacent seas (Dependent seas) are also divided into *Marginal seas* (Fringing sea) and *Mediterranean seas*, which are divided into *in-continental* sea and *inter-continental sea*. When above classifications are used, the seas around the North Pacific may be summarized as follows.

Ocean—The Pacific
Marginal sea—Bering sea, Okhotsk sea, Japan sea, East China sea, South China sea, California Bay
Mediterranean sea—Arctic sea.

Baleen whales distribute in each sea locality as illustrated in Table 26. With regard to the distribution of blue whales, they are mostly caught and found along the Pacific coasts (or the Oceanic coasts) of the eastern and western sides. Number of blue whales have been caught in *Marginal seas* or *Mediterranean seas* is extremly limited numbers. As it is shown by the catch statistics, no blue whale has been caught and only few blue whales observed in the Bering sea, and no record of blue whales in the Arctic waters through the Bering strait. In other marginal seas, blue whales have been scarcely caught as described in Table 26. The same tendency is also considered as to sei whales. Sei whales (some occurrences of Bryde's whales must have been included) have never been caught so markedly in the Yellow sea, the Japan sea and the Okhotsk sea. Some 44 sei whales illustrated in the Table 27 were obtained from the catch of the landstations situated near the Kuril Islands, where some visitors of sei whales from the Pacific side through Kurile Islands were probable. Right whales show very little occurrences in Table 27, but it should be considered to be due to the decrease of the stock. By American whaling in 19th century, right whales had been mostly caught in the Okhotsk sea and the sea of Japan (Townsend, 1935). A right whale also occurred in the Mediterranean seas, at Taranto in Italy, (Capellini, 1877) suggesting that right whales occur in the Inter-continental sea. Thus right whales are considered not oceanic denizen only.

The coastal forms, humpback and grey whales are commoner than above BALAENOPTERIDAE whales, however, when the catch of other localities are referred, the former species are not so abundant in the

Marginal seas. Humpback whales usually congregate along the coastal waters of the continent, around islands in the ocean and the archipelago between the *ocean* and the *Marginal seas*. In winter seasons of the North Pacific, they swarm in the waters of Formosa, Marshal Islands, Bonin Islands, and Okinawa Islands in the western side according to the catch statistics. From California to Lower California and Mexico, the winter catch of humpback whales has been demonstrated in the eastern side of the Pacific. Considering the catch in above districts, humpback whales are rather oceanic coastal form and their occurrences in the marginal sea and the mediterranean sea observed are temporary one, though comparatively many humpback whales had been caught in the Arctic sea region by Japanese operations in 1940.

TABLE 27. NUMBER OF BALEEN WHALES CAUGHT IN SOME MARGINAL SEAS OF THE PACIFIC FROM 1916 TO 1949 BY JAPANESE SHORE WHALING OPERATIONS

Seas	Whale species					
	Blue	Fin	Sei	Humpback	Right	Grey
Okhotsk sea	—	1149	44	58	8	2
East coast of Korea	4	1977	2	47	—	606
Yellow sea	13	3137	2	63	2	7

Grey whales have been only observed and caught along the coast of the land, and continents at the oceanic side and in the adjacent seas and the mediterranean sea. Of course, there still remain some questions about the migration routes of grey whales. In some migration course, they may swim in the far off waters from the American continent (Gilmore, 1955), but they are apparently coastal form and never regarded as a oceanic form. The migration course should be examined by further examination. Fin whales have been caught not only in the oceanic sides, but also in the marginal seas and the mediterranean sea. In the Arctic sea, Okhotsk sea, Bering sea, Yellow sea, East China sea, and sea of Japan fin whales demonstrate the highest catch among baleen whales by whaling operations. Bryde's whales, on the other hand, have been caught and observed mainly along the Pacific sides of Japan and California. Recently the sei whales caught along the western side of Kyushu prefecture (the southern main Island of Japan) and in the eastern part of the East China sea in summer seasons are proved to be all Bryde's whales (Omura & Fujino, 1954; Mizue, 1956). And another evidence gives us the occurrences of Bryde's whales in the adjacent waters to Borneo (Harnisson & Jamuh, 1958) and Singapore (Anderson, 1878). These apparently suggest that Bryde's whales migrate to the south waters of the South China sea, the *Marginal sea*. But if the number of whales will be considered, Bryde's whales are rather oceanic form as a conclusion. With regard to little piked whales, they are described as a coastal form by Tomilin (1954). Really the Japanese investigations prove (Omura & Sakiura, 1956) that little piked whales migrate along the coasts of Japan proper in both sides, the Pacific side and Japan sea side. Many little piked whales have been caught in the Okhotsk sea and along the Japan sea coast and Korea (see Fig. 17 by Omura & Sakiura, 1956). Further in the Antarctic and other parts of the seas, they penetrate into the gulf, bay and straits even into the pack ice crevice. From above occurrences, little piked whales are not a oceanic form, and they inhabit also in the *Marginal* and the *Mediterranean seas*.

Besides above baleen whales, Greenland whales had been caught in 19th century in the Okhotsk sea and the northern part of the Bering sea, Bering strait and Arctic sea. Especially in the shallower waters of the Bering sea and the Okhotsk sea, the most dominant catch was observed (Townsend, 1935). Greenland whales are considered shallow *marginal sea* form and not a oceanic form. Thus I would conclude following distributional type of baleen whales in the northern part of the North Pacific.

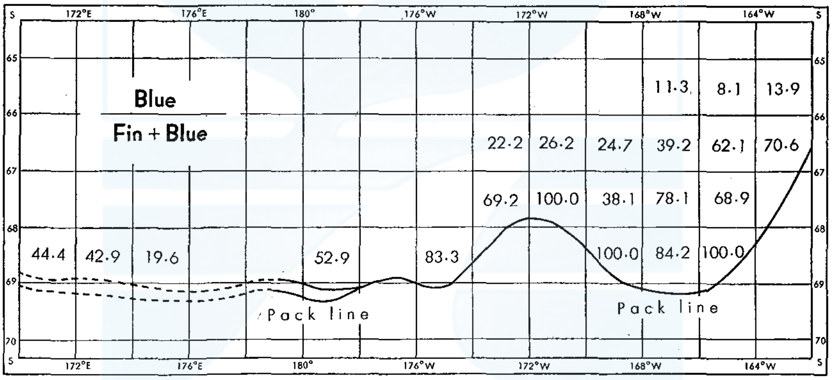

Fig. 31. Catch distribution of blue and fin whales by Japanese pelagic whaling operations along the pack ice line in the Antarctic waters from 1949 to 1950. High value show the domination of blue whales.

Ocean denizen	Blue whale, sei whale, Bryde's whale
Ocean and marginal sea denizen	Pelagic form fin whale, right whale Coastal form little piked whale, grey whale, humpback whale
Marginal sea denizen	Greenland whale

Tomilin (1954) consideres the Antarctic whales are considered to be recent emigrants from the Northern Hemisphere, because the close relationship between structure of the baleen and the nature of the food of whalebone whales is disturbed in the Southern Hemisphere. The distribution of whalebone whales in the Antarctic is also very interesting to study. General aspects of the southern Ocean are rather simple in view of the shape of the sea when the comparing with the North Pacific is made. The Antarctic continent is surrounded by the ocean and only two Ross and Weddle seas make incisions along the coast of the continent. Whalebone whales come to the Antarctic waters generally from September to February and return to the North from March to July (Mackintosh & Brown, 1956), and the height is observed in February in the summer season of the Antarctic. From the observations by whaling operations which cover the adjacent waters to the pack ice edge, blue whales have been mainly observed along the pack ice and fin whales have been observed in the off waters. Whalers usually say, they hunt blue whales in the pack ice and chase fin whales in the off waters. By Japanese whaling operation from 1949 to 1950, Japanese operations have caught blue and fin whales in the Ross sea area as illustrated in Fig. 31. It is clear from the figure that blue whales were caught mainly along the pack ice and fin whales were caught in the off waters. Sometimes whalers have noticed the big herds of fin whales in the off waters more than 200 miles from the pack ice. This fact bears some connection with the distribution of food euphausiids. 'Blue whale krill' distributes mainly along the pack ice, and 'Fin whale Krill' mainly in the off waters, the fact of which suggests their distributions are restricted also by the distribution of euphausiids.

As I stated before, little piked whales are often observed among the pack ice. They penetrate into the high Antarctic such as Ross sea in the neighbouring waters of the Barrier of the Ross sea (see John, p. 223). In this case, little piked whales are considered to show the *Marginal sea type* of the distribution. Taylor (1957) and others also show the evidence that little piked whale are sometimes restricted to pools of sea ice near the land in the Antarctic. With regard to the distribution of humpback whales, I have little data as to the distributional characteristics of them in connection with the shape of the pack ice line, and the concentration of humpback whales in some special sea condition in the Antarctic has not been observed. It is a evident fact, however, they are divided into five more or less self-contained stocks of humpback whales in the Southern Ocean (Mackintosh, 1942). The charts by Omura (1953, p. 1 to 102) and recent recovery of whale marks also furnish us the general comprehension about the distribution of humpback whales in the Antarctic areas in summer season of the southern hemisphere.

OCEANOGRAPHIC CONDITIONS

Surface water temperature

As the first step, the water temperature is often considered as a limiting facter to decide the distribution and the migration of whales. In fact, the distribution of some baleen whales such as Bryde's whales has close relation with the distribution of surface water temperatures (Omura & Nemoto, 1955). Here I would discuss the problem so as to consider the aspects of the whales' distribution according to the oceanographic conditions.

With consideration on the catch and observation of the whalebone whales, the range of temperature in the North Pacific in which each whalebone whale mainly inhabits, may be summarized as follows.

Blue whale	25°C– 8°C	in August from Sanriku to the southern waters of Aleutian Islands
Fin whale	30°C– 5°C	from the east China sea to the Arctic sea
Bryde's whale	30°C–20°C	up to Sanriku waters
Sei whale	25°C– 8°C	from Sanriku to the southern waters of Aleutian Islands*
Humpback whale	25°C– 5°C	from Sanriku to the Arctic sea

Of course, some wanderers call warmer or colder waters, and there must be above remainder in the subtropical or the tropical waters. But it is evident that Bryde's whales inhabit in the warmest waters, and fin whales show the broader range of the distribution as a conclusion. The details will be discussed in the special part of each whalebone whales.

Profile of water temperature

The profile of water temperature is considered to clearly show the whaling grounds. Each whaling ground has peculial profile type, and the profile of the North Pacific differs very much from that of the Antarctic area, about which my colleague Mr. Nasu will discuss in his paper. Here I illustrate the examples in the Sanriku waters. As it is clear from the distribution of surface water, sei whales congregate in the waters a little apart from the sub cold current of 'Oyashio', and sei and Bryde's whales are scanty in the waters where the gradient of the profile of the water temperature is not sharply, or the gradient is very smooth. These profiles of the water temperature also indicate that sei and Bryde's whales congregate into the waters of high plankton production.

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* Japanese whaling expedition in 1958 found some 60 sei whales in the middle part of the Bering sea, but the water temperature was little different from 8°C.

Whaling ground

The whaling grounds of baleen whales are divided into feeding area type whaling ground and breeding area type (Nemoto, 1957). The former grounds consist of many planktons and their patches or swarms of fish and squids, and the latter is generally located in the warm tropical or subtropical waters. The feeding area type whaling grounds have following main oceanographical surroundings.

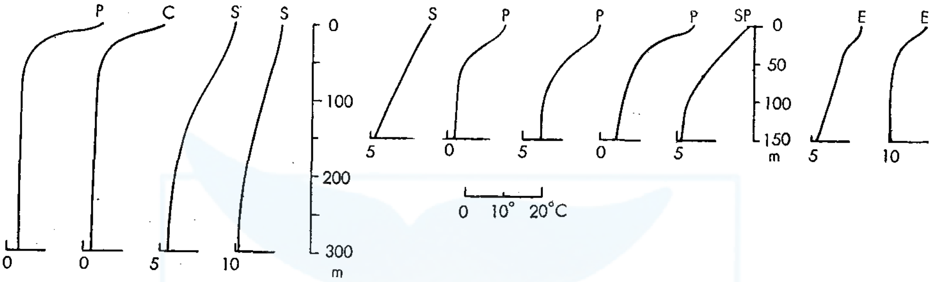

Fig. 32. The profiles of temperature, at stations in the off waters of Sanriku whaling grounds in 1952 and 1955. P—Sei whales congregated and plenty area, C—Above the cold water subcurrent, S—Sei whales scanty, SP—Sperm whales congregated and plenty area, E—East stations of 160°E and 180°E in 1955 through 40°N.

1. *Continental shelf waters and its adjacent waters.* As I described in the previous report (Nemoto, 1957, p. 80, 86), waters along the Alaskan continental shelf produce a large amount of *Thysanoëssa inermis* distributing and form a very favorable condition for whales. *T. inermis* also spawn vigorously above the coastal bank, bottom layer, which is directly suggest the horizontal cycle from the bottom layer to the surface strata where the lavae develop. Einarsson describe the *inermis* type of distribution of euphausiids, and *Thysanoëssa inermis* and *T. raschii* are considered belong to this type. These *inermis* type euphausiids propagate along the continental shelf or within the shelf, and fin whales congregate to feed on them. As I described in the previous report, with the upwelling current and vertical oscillations by wind blowing toward the continental slope, the adjacent waters to the continental shelf become a very productive area. The most typical whaling ground of this type in the North Pacific situated along the continental shelf is the north waters of the eastern Aleutian Islands, and Alaskan continental shelf. I can find further this type of the whaling ground along the shelf, situated the Yamato Bank in the Okhotsk sea and in the East China sea along the China continental shelf.

2. *Boundaries of water-mass and water convergence.* Along the boundary of different water masses, the whales are usually feeding and migrating. In this waters of convergence, the vertical mixing of water and accumulation of food planktons bring very favorable condition for baleen whales. The most typical illustration is observed in the off water of Sanriku in the adjacent waters to Japan (Uda, 1954). The cold current 'Oyashio' meets 'Kuroshio' the warm current in the area. One example of these water convergence in the Sanriku water in summer in 1952 may be illustrated in Fig. 33. The Fig. 33 demonstrates the clear parallel between the water convergence and concentration of whales. There are those heavy water convergences (Fig. 33 middle A, B, C) where many sei or Bryde's whales had been observed. Swarm of birds and bonitoes are also so congregated to the waters that whalers and fisherman can find whales from birds and bonitoes in the waters.

The boundaries of different water masses or currents make the cyclonic water movements, in the center of which the most heavy concentration of foods is observed.

3. *Upwelling and thermal Anticline*. Upwelling occurrs in the high latitude of the earth as well as in the tropical and temperate waters. Upwelling carries nutrient fertilizers into the sulighted zone. Cromwell (1956) describes the mechanism of tuna fishing grounds and that it takes time for biological products to develop after waters has upwelled, so that planktons are found displaced in down stream from the center of upwelling. This caption and his illustration (Fig. 2, a, b) are very important and satisfactory as to the general comprehension of whaling ground consists of the upwelling. Because the whaling ground is also situated a little apart from the center of the upwelling in the sea in general.

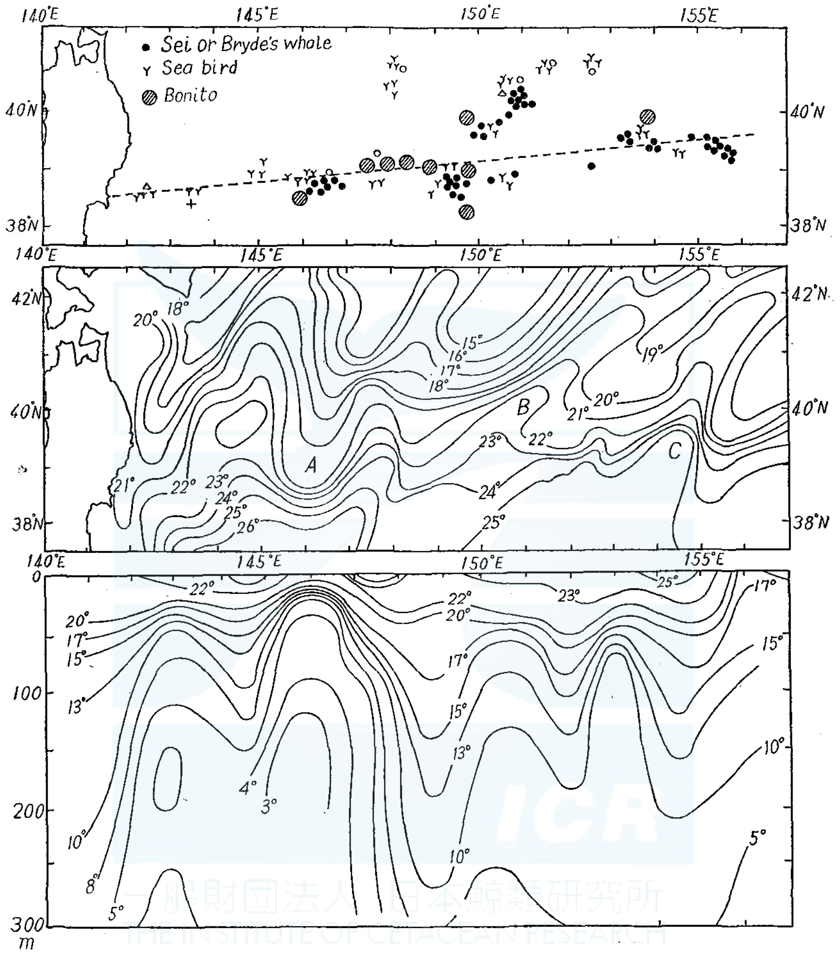

Fig. 33. The distribution of sei and Bryde's whales, surface water temperature and vertical section of whaling grounds in the Sanriku waters in summer in 1952. Upper—Observation of whales, sea birds and fish, Middle—Distribution of surface water temperature distribution, Under—Vertical section along the dotted line in the upper figure from surface to the depth of 300 m. (based on data mainly Miyazaki Otsuru & Watase, 1953).

As the whaling ground due to the upwelling is often made by affection of the shape of sea bottom, and the ridge or Islands situated in the sea current often produce the upwelling such as the waters around South Georgia Islands.

Thermal anticlines also bring the nutrient rich waters to the surface sunlight zone allowing plankton to develop (Cromwell, 1956).

4. *Back waters and the center of the cyclonic movements.* The food plankton, fish and squids are also concentrated by currents into the center of the cyclonic movement or backwaters (Ruud, 1932). These conditions are formed by two causes. One is made by the current and the other is made by the shape of the land, gulf, bank, ridge, islands, and cape etc. The backwaters or the center of the cyclonic movement are found in the off waters as often as in the adjacent waters to the land, but the former whaling ground are not so stable as the grounds made by the shape of land islands etc. in the adjacent waters to the land, and the center of the plankton concentration move or is transported by current strength along the boundary in the off waters.

5. *Whaling ground in the pelagic waters.* Ruud (1932) describes there are large quantity of Krill among the ice far away from land or any known banks like the waters along the slope of the continental shelf and banks. The Antarctic whaling grounds belong to this type of whaling ground, which have the close connection with the ice melting in the summer season. Of course the cyclonic systems round the coasts of the Antarctic continent bear the possible making of whaling ground in some waters (Ruud, 1932), this type of whaling ground is mainly due to the sun shine into the waters in the summer melting of ice and the supply of the nutrient rich waters from the deep by currents. It brings forth the vast propagation of plyto-planktons and successive congregation and growth of *Euphausia superba* in the surface waters.

MOVEMENT AND MIGRATION OF WHALEBONE WHALES

Movement and migration of the whalebone whales are so vast problems that they need many accumulations of investigation and observations before any definite conclusion is obtained. Still there are many evidence for believing that the whales undertake regular annual migrations, or temporary movements and migrations both in northern and southern hemispheres. As to terms ‘migration’ and ‘movement’ in this part, I would refer again to the work by Mackintosh (1942, p. 237). The term ‘migration’ is also used here to imply long annual journeys between the cold feeding grounds and temperate or tropical waters. ‘Movement’ means, I would consider, regular or irregular local movement or journey according to some oceanographical conditions, feeding and breeding conditions. The relationship between foods of the whalebone whales and movement or migration of whales should be discussed to get the reasonable explanation for the subject as a first step. Next, the result of the marking of whales gives us also the direct evidence about the movement and the migration of whales. The marking investigations carried out in the Antarctic waters has been examined by Rayner (1940) and Brown (1955). These works show some clear characteristics as to the migration of the whalebone whales in the Antarctic.

Distribution and migration of Sei and Bryde's whales

Kellogg (1929) well describes the migration and movement of sei whales in his paper, but that Bryde's whales were included in the sei whale in his description. So, I would discuss again it carefully here mainly on the data of the North Pacific by Japanese investigation.

Sei and Bryde's whales have been caught in the adjacent waters to Japan by shore whaling and other sei whales have been caught in the northern part of the North Pacific by Japanese pelagic whaling. About these whales, many investigations and marking examinations are made, and some results are already published (Omura, 1950; Omura, Nishimoto & Fujino, 1952; Omura & Nemoto, 1955 etc.).

Generally speaking water temperature seems to be important in limiting the migrations of the sei whale (Clarke, 1957). Sei whales are considered usually never to call the Antarctic high and cold waters as far as the waters along the pack ice before 1954 seasons by Japanese Antarctic observations. After the year 1955, sei whales have been caught and observed in a considerable number as reported by the International Whaling Statistics. In the 1955 and 1956 season, only 6 sei whales were caught by Japanese whaling operations, while comparatively many schools of sei whales had been observed on these days though these sei whales had not been caught.

In the years 1957 and 1958, 133 and 1466 sei whales have beee caught respectively by Japanese whaling expedition. The higher water temperature in these years than previous seasons, and the abundant crop of *Parathemisto gaudichaudi* (p. 164) might have caused such migrations of sei whales, while the further investigation oceanographically is now under examination by Mr. Nasu of my colleague. The surface water temperature shows a little higher value in the waters where sei whales caught than the waters where other blue and fin whales caught, and sei whales have never been among the pack ice. There is another evidence, however, the surface temperature is going down a little in the late of February to March in the waters of Antarctic convergence, when the almost all sei whales have been captured. This tendency is clearly given by Mackintosh in his figures (Mackintosh, 1946, b, Fig. A–E). The surface water temperature in the waters along the pack ice also declines in March, still it is not so cold as in April. Sei whales have been mostly found along the warm water current from the north, and not in the colder current originated in melting of ice from the pack ice. So, sei whales migrate to the high antarctic waters in the height of the surface water temperature in general.

Sei whales have been caught in a considerable number by recent Japanese pelagic whaling expeditions in the northern part of the North Pacific too, because they produce the high production of whale meats in each blue whale unit. The dominant catch of sei whales in recent years is observed in two areas, south east off waters of Kamtchatka Peninsula and the south waters of the eastern Aleutian Islands. The latter waters range from 49° to 53° North latitudes and 165° to 175° west longitudes. These catches of sei whales are all limited in the south waters of Aleutian Islands. The observation of sei whales in the Bering sea has been few, and directly it is considered that sei whales never migrate in the high latitudes and the Arctic sea like the Antarctic. The most northern record of the reliable observation on sei whales in Bering sea is obtained in 1958. Some 54 sei whales are feeding in the Andyr gulf, off water of Navarin cape on 4th August. Other 3 and 4 sei whales also described in the near waters in the same ranges as described in Fig. 34. I have 8 other single observations in the Bering sea which contain less than 5 sei whales at each position. Above recent reliable informations also endorse the tendency that few sei whale migrates to the marginal sea as I state in the part of distribution of whales according to the shape of the sea. The migrating season of sei whales

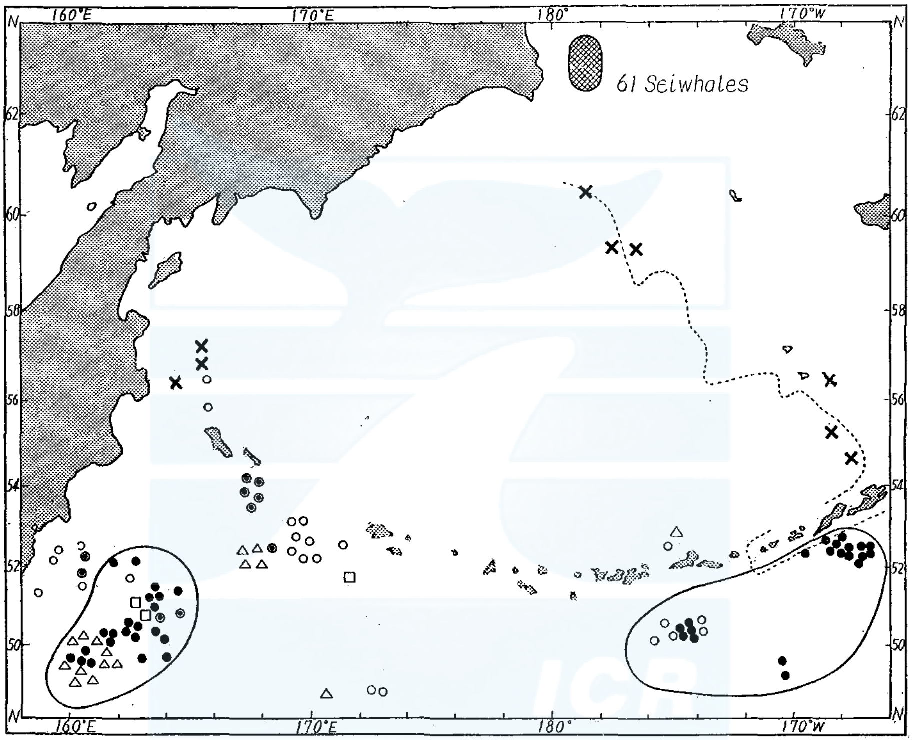

Fig. 34. Distribution of foods of sei whales in the northern part of the North Pacific and the observation of sei whales. × Single observations of sei whale, ● *Calanus plumchrus*, ○ *Calanus cristatus*, ⊙ Saury, △ Squids, □ Euphausiids. The surrounded area shows the waters where *Calanus plumchrus* is dominant.

in the waters is considered a little earlier in the eastern waters than in the western waters. In the former waters of southern waters of the eastern Aleutian Islands, the main sei whales migrate in the middle of June to feed the vast amount of *Calanus plumchrus* and *C. cristatus*.

As the favourite food for fin whales, *Calanus cristatus* also becomes dominant a little earlier than *Calanus plumchrus* and the height of *C. plumchrus* later in general (Vinogradov, 1956), fin whales are considered to migrate to the said area earlier than sei whales. Sei whales also distribute in a little apart from the waters where other fin and blue whales' school are feeding. This suggest the segregation of each species in the feeding grounds, which is partly due to the different distribution of their favourite foods directly. Another explanation for the above fact is ' balance ' or distributional power among the whales.

TABLE 28. CATCH AND STOMACH CONTENTS OF SEI WHALES IN THE WEST WATERS OF THE NORTHERN PART OF THE NORTH PACIFIC IN 1953

Stomach contents	June		July		Aug.			Sept.		
	1st	3rd	1st	3rd	1st	2nd	3rd	1st	2nd	3rd
C. plumchrus	—	—	—	—	2	—	11	—	3	—
C. pl. & Squids	—	—	—	—	—	—	3	—	—	—
Euphausiids	—	—	—	—	—	—	2	—	—	—
Saury	—	—	—	—	—	—	2	—	1	—
Squids	—	—	—	—	—	—	8	—	—	—
Empty	7	1	1	1	1	1	42	1	4	3
Uuknown	—	—	—	—	—	—	2	—	2	—

TABLE 29. CATCH AND STOMACH CONTENTS OF SEI WHALES IN THE EAST AND WEST AREA OF THE NORTHERN PART OF NORTH PACIFIC IN 1954

Stomach contents	West								East			
	May		June		July			Aug.	May	June		
	2nd	3rd	1st	2nd	1st	2nd	3rd	1st	3rd	1st	2nd	3rd
C. cristatus	2	—	—	—	—	—	—	—	—	3	—	2
C. plumchrus	—	—	—	—	—	—	—	—	—	—	—	13
C. cri. & Squids	—	—	—	—	—	—	—	—	—	1	—	—
C. sp.	—	—	2*	1*	9*	10*	20*	2*	—	—	—	—
Euphausiids	—	—	—	—	—	—	—	—	1	—		—
Squids	1	—	—	—	—	—	—	—	—	—	—	—
Empty	3	1	—	1	8	—	—	—	—	1	1	19

* These species are considered *Calanus plumchrus* from some collected samples, but no exact observation on board is available.

Above migrational season is well illustrated in Table 28 and 29. Many sei whales were caught in 3rd decade of August, but few number was caught in preceding decades in 1953 in the west areas, off waters of Kamtchatka peninsula.

In 1954, sei whales were caught from the 2nd decade of May feeding on *Calanus cristatus* and squids, and from the 1st decade of June sei whales are considered feeding on another *Calanus plumchrus*. Sei whales become abundant in July in the west waters, on the other hand, considerable number of sei whales are caught in the 3rd decade of June in the east waters. These sei whales are feeding on *Calanus plumchrus* as I described in previous report (Nemoto, 1957, p. 53).

Sei whales are feeding on squids (*Ommastrephes sloani pacificus*) and saury (*Cololabis seira*) besides copepods. This fed positions are illustrated in Fig. 34. The squid distributes mainly in the Kamtchatka side and saury too. As saury also distributes in the American side (Schaefer & Reintjes, 1950), and sei whales' feeding on saury in the eastern parts is also probable. Squids and saury in their turn feed on *Calanus plumchrus*. The stomachs of squids and saury in the waters are satiated with *Calanus plumchrus*. The following relations are obtained by above discussions.

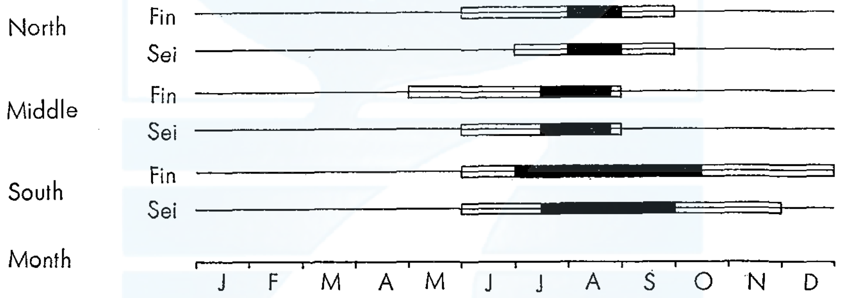

Fig. 35. The whaling seasons of fin and sei whales along the coasts of Kurile Islands by Japanese and Russian operations including the seasons before 1945. Black—main season, White—range of the whaling season.

$$\begin{tikzcd}
\text{Sei whale} \arrow[r, "\text{Close}"] \arrow[dr, "\text{Subordinate}"'] & \text{Calanus plumchrus} \\
& \text{Saury \& Squids} \arrow[u, "\text{Close}"']
\end{tikzcd}$$

The *Calanus year* and *Euphausiid year* make some delay and the early migration of blue and fin whales as I said in the preceding part. But the *Calanus cristatus* and euphausiid are not so favourable for sei whales in the northern part of the North Pacific, sei whales never migrate so early in *Calanus* year.

Sei whales in the northern part of the North Pacific must have close relation to those of Kuril waters, Hokkaido and Sanriku waters. But no mark hit in the adjacent waters to Japan has been recovered in the northern part of the North Pacific and vice versa. The facts that the comparatively many marked sei whales in the adjacent waters to Japan have been caught in the water suggest that they migrate to the waters regularly to feed on foods, and the group may be different from those in the northern part of the North Pacific (the term group is not used in a strict sense).

The catch of sei whales in the Kuril waters which lies between Japan and the northern part of the North Pacific, vary in each localities of the North and South Aleutian waters. In the northern part of the Kurile waters at about 50° North latitude, number of sei whales caught were not so large that the typical migration of the whales to the waters has not been obtained. From the catch of pre-war seasons before 1945 by Japanese and after the war by Russian operations, the height is observed only in August and of short duration, and very few sei whales have been caught in July and September. Along the coast of Middle Kurile Islands, sei whales are also scarce, but they migrate to the waters a little earlier than the north waters of Kurile Islands. Still from July to the middle and the late of August the south Kurile Islands show nearly the same tendency as the Hokkaido waters. Sei whales migrate to the waters from June, and main herds come between the middle of July and the middle of September. Some sei whales also had been taken still in November in the pre-war seasons. Among the sei whales swarming in the South Kurile Islands, some sei whales pass through the straits between Kurile Islands to the Okhotsk sea. Though in the pre-war seasons before 1945, Bryde's whales had not been distinguished from sei whales by Japanese investigations, it is safe to say that all sei whales in the waters are real sei whales (*Balaenoptera borealis*), and they never include Bryde's whales (*Balaenoptera breidei*) or include very few of them. Because Bryde's whales are warm water living whales, and they are considered never to migrate to the north and middle Kurile waters or mainly distribute within the range of surface temperature more than 20°C (Omura & Nemoto, 1955; Omura 1959). Recent Russian investigations also report the occurrence of Bryde's whales in the Kurile waters (Kleinenberg & Makarov, 1955), but it is considered to be restricted to the south waters of Kurile Islands according to recent Japanese investigations.

In the adjacent waters to the north east part of Japan proper Sanriku and Hokkaido waters, Bryde's and sei whales have been examined from the year 1952 at the landstations by the investigation mainly on baleen plates and ventral grooves of whales. The result in 1953 is discussed by Omura & Nemoto (1954), and the fact that considerably many

Bryde's whales are caught in the off waters of Sanriku suggest that the result obtained by the year 1951 were all unreliable to get the comprehension of the migration and the distribution of sei whales in the waters.

In the seasons before 1945 some whale already noticed the occurrence of Bryde's whales, as they called 'Nitarsi' the vague sei whales (apparently Bryde's whales) and 'Triangle sei whale'. The baleen of the whales are coarse and it was never bought so much high price as real sei whales in the Sanriku landstations.

As the catch of baleen whales in the Japanese waters is permitted from May to October, sei and Bryde's whales have been caught by recent operation in the adjacent waters as described in Tables 30 and 31.

TABLE 30. NUMBER OF SEI WHALES CAUGHT IN THE ADJACENT WATERS TO THE SOUTH EAST JAPAN PROPER FROM 1956 TO 1958

		May			June			July			Aug.			Sept.			Oct.		
1956	40 S	5	20	36	70	43	19	3	2	41	13	5	4	7	5	—	1	—	3
	40 N	—	—	6	6	—	5	169	43	13	22	20	23	33	37	32	23	18	28
1957	40 S	—	3	43	51	36	15	1	2	4	6	14	15	4	—	3	7	11	—
	40 N	—	—	—	—	1	1	2	38	18	11	9	13	46	14	18	31	3	11
1958	40 S	2	3	49	42	26	37	20	3	2	4	—	38	21	67	1	4	11	2
	40 N	5	6	6	—	—	—	1	2	1	7	9	31	59	46	12	32	9	22

TABLE 31. NUMBER OF BRYDE'S WHALES CAUGHT IN THE ADJACENT WATERS TO THE SOUTH EAST JAPAN PROPER FROM 1956 TO 1958

		May			June			July			Aug.			Sept.			Oct.		
1956	40 S	—	—	—	3	1	8	2	—	1	—	1	1	2	—	—	1	—	—
	40 N	—	—	—	—	—	—	3	—	—	—	—	—	—	1	—	—	—	—
1957	40 S	—	1	—	—	1	8	6	5	1	—	5	12	2	—	—	—	—	—
1958	40 S	—	—	2	2	—	2	18	19	9	74	48	5	—	—	—	—	—	—

40S means the South waters of 40°N latitude and 40N the North waters of 40°N latitude.

From the Tables, Bryde's whales have been mostly caught in the south waters of 40° north latitude, and sei whales are more abundant in the latter part of the seasons, some sei whales are captured in the first decade of May in the south waters. But generally speaking sei whales become dominant in the late of May to the late of June in the south water, but few Bryde's whales have been caught in May. Only 1 Bryde's whale is caught in 1957 and 2 Bryde's whales are caught in May in 1958 (see Table 31) which show the early migration of Bryde's whales to the Sanriku waters. The main herd of Bryde's whales migrate to the Sanriku waters from the late of June, and the height is observed in July and August though there are some annual variations of migrations among the years (see Omura & Nemoto, 1955, Table 1) as illustrated in Table 32.

Of course, the annual change of the way of whaling operation is probable and the number of Bryde's whales in each local waters also varies annualy. The catch of Bryde's whales in 1955 shows some 85 Bryde's whales which is comparatively high value from 1953 to 1957. The catch of Bryde's whales in 1958 demonstrates the tremendous number of 298 whales, 179 of which are caught in the Sanriku waters. Another catch of Bryde's whales in the adjacent waters is observed in the waters of Oshima, Wakayama prefecture, and the catch of Bryde's whales in each decades in the Oshima waters may be referred to the preceding Tables 17 and 18. Bryde's whales in recent years have been caught mainly from the late decade of May to June. This migration of Bryde's whales bears close relation with the abundance of anchovy (*Engraulis japonica*) in the off waters of Wakayama. In the earlier season, Bryde's whale are feeding on a euphausiid (*Euphausia similis*) which distributes in the off waters of 20 miles from the land in general (Honjo, 1957). Later the main herds of Bryde's whales in the Wakayama waters are feeding anchovy. The relation between the amount of the anchovy captured and the catch of sei whales is illustrated in Fig. 36, which indicates that anchovy has the close bearing on the migration of Bryde's whales. Anchovy is fished in the waters mainly from April to November, and comparatively scarce from December to March. The most abundant catch of anchovy does not always coincide with the

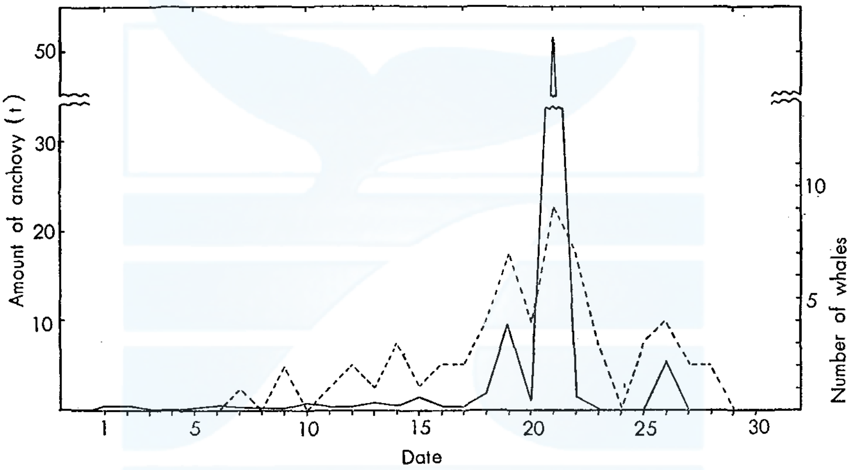

Fig. 36. The relation between the catch of Bryde's whales and the amount of anchovy fished at the landstation of Wakayama prefecture along the Pacific coast in June in 1958.

height of the migration of Bryde's whales, however, the catch of Bryde's whales is increasing with the increase of anchovy. The amount of anchovy fished in April and May in 1958 is very scarce, but the shoals of anchovy come from the early of June and become very abundant in the middle of June considered from the catch of anchovy fishing. Although the amount of anchovy shows only the part of anchovy in the waters, there is a close parallel between the catch of anchovy and Bryde's whales. Anchovy in the waters, in its turn, is feeding on the warm water living copepods, belonging to the *Eucalanus*, *Sapphirina*, *Oncaea*, *Candacia* and *Calanus*. These copepods are considered to distribute in the scattered condition, not to aggregate into swarms or patch in the sea. Bryde's whales are swollowing type whales and can not take the scattered copepods in the natural sea condition. If the copepods are fed by swarming anchovy, the latter make growth and become the favorite foods of Bryde's whales. Especially *Sapphirina* species are very famous as a indicater of 'Kuroshio' current and Japanese fishermen sometimes seek their fishing ground of bonito (*Katsuwonns pelamis* (Linné)) by the water colour containing these *Sapphirina* species. It is reasonable that the whaling ground of Bryde's whales lies in the near waters of bonito fisheries in these Wakayama waters, because Bonito also feed on anchovy very often in the adjacent waters to Japan (Hotta & Ogawa, 1955).

TABLE 32. NUMBER OF BRYDE'S WHALES CAUGHT AND IDENTIFIED ALONG THE ADJACENT WATERS TO THE JAPAN PRORER

Locality	1955	1956	1957	1958
Sanriku & Hokkaido	57	24	41	179
Oshima (Wakayama)	26	—	—	72
Goto (West Kyushu)	2	2	3	47
Total	85	26	44	298

Bryde's whale⟶Anchovy⟶Calanus spp.
↗ Candacia spp.
Sapphirina spp.
Bonito Oncaea spp.
etc.
} Warm water living copepods

Above relation is observed in the off waters of Oshima, Wakayama prefecture, and this tendency will be maintained to Sanriku waters too. At Oshima in 1958, I noticed about 10 new open pits on the surface of body of the whale besides many healed scars. The open pits are not so fresh as they are observed in Bonin waters (see Fig. 6 in Omura, Nishimoto & Fujino, 1952). But the open pits are all more fresh than those observed in the northern Pacific waters of Sanriku waters. This healing stage of the scars is considered to closely resemble to Fig. 7, Plate 36 illustrated in the paper by Mackintosh & Wheeler (1929). This is the very initial stage of healing from the open pits which is usually found in the Bonin and South African waters. The fact clearly indicates the new coming of Bryde's whales to the Wakayama waters from the southern subtropical waters at that time.

From the catch statistics of the seasons before 1945, sei whales (apparently including Bryde's whales in summer seasons) had been caught as illustrated in Fig. 37. Though there are some vague catch in the early spring season and winter the main catch is divided into two heights from winter to spring and from spring to summer. Kasahara (1950) deemes the fact very simply, and summarizes them into one figure, which does not demonstrate the two peaks of the catch.

The former height of the catch is very interest, but the species is not certain, however, it is probable that sei whales (*Balaenoptera borealis*) come to the waters in winter season, and the latter height is undoubtedly the catch of Bryde's whales. One of the explanation for above fact is that sei and Bryde's whales are considered to migrate to the Bonin waters also separately. According to Omura & Fujino (1954) sei whales are taken from November to April in the Bonin Island waters, and the catch is mainly composed of Bryde's whales in May and June. Omura & Fujino (1954) and Omura & Nemoto (1955) already state the occurrences of Bryde's whales only in summer. Their northern migration must be different from sei whales. On the other hand, there is one contradiction to the assumption. Andrews (1916) examined sei whales at the landstation of Oshima in April in 1910, and his descriptions are apparently those of sei whales (*Balaenoptera borealis*). To my regret, there is no explanation as to the ventral grooves of sei whales caught at the Oshima landstation. But he examined carefully the distinguishing points between sei and Bryde's whales in the latter part of his paper, and he further consideres Bryde's whales is distinct from sei whales, so it is probably safe to say that the sei whales described in April at Oshima, Wakayama prefecture, are real sei whales,

TABLE 33. SURFACE WATER TEMPERATURE RANGE OF THE CATCH POSITION OF BRYDE'S WHALES IN THE SANRIKU AND HOKKAIDO WATERS

	Water temperature range, C						
Year	14–16	16–18	18–20	20–22	22–24	24–26	26–28
1953	1	1	6	27	14	7	—
1956	3	1	7	6	5	—	—
1957	—	—	1	5	19	9	7

and the occurrence in 1910 in Fig. 37, also shows the separation of the migration of sei whales in winter seasons. As illustrated in Fig. 37, there are clear two heights of the catch in 1911, 1919 and 1921, which are probably due to the above migrational segregation of sei and Bryde's whales in the off waters of Wakayama.

In 1921, the vague catch of sei whales is described as shown in Fig. 37, but no sei whales had been caught in the winter season from January to March after the year 1926 except some whales caught from October to December. The water temperature still remains 20°C in winter season in the off water of Oshima, so the catch of Bryde's whales in the winter seasons can not be neglected perfectly. As a conclusion, the summer catch of sei whales in the waters are apparently considered

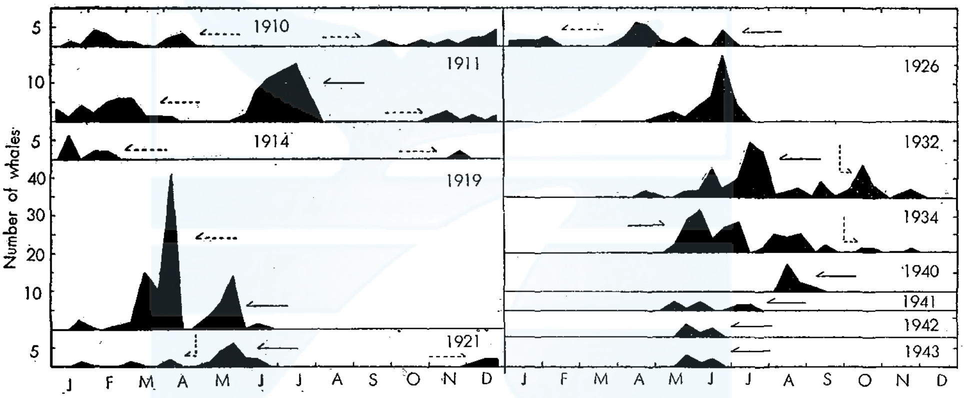

Fig. 37. The catch of sei whales (including Bryde's whales) in the adjacent waters to Oshima, Wakayama prefecture from 1910 to 1943. Solid lines indicate the probable catch of Bryde's whales and dotted lines indicate the probable catch of sei whales. The upper right shows the catch in 1922.

to be Bryde's whales, though the whales were described as sei whales.

In the seasons before 1945, some sei whales had been captured at the landstations of west Kyushu waters from June to September. Also these sei whales have been caught after the year 1945, but recent investigations prove that these whales are all Bryde's whales. Omura & Fujino (1954) state the sei whales measured at Okochi landstation in Tsushima before the year 1945 season are all Bryde's whales considering the extension of ventral grooves on the body. Along the west coast of Kyushu, Bryde's whales are migrating to feed on sardin and anchovy in the summer season, and the northern limit in the west waters of Japan is considered to be 35° North. Bryde's whales are considered never to penetrate into the Japan sea.

In winter, as the west Kyushu waters is still warm by the 'Tsushima' current and their favorite food anchovy is abundant in some waters, some Bryde's whales may pass the winter in the waters though there is no evidence if the sei whale in the winter season is Bryde's whales or not. Some whaler said 'Sendai iwashi' meaning 'Sendai sei whale' had been caught in the west Kyushu areas. This whale may be sei whale (*Balaenoptera borealis*), because Sendai is the city of Sanriku prefecture where many sei whales (*Balaenoptera borealis*) have been caught by whaling operations.

As a conclusion the water temperature range is important for the warm water living Bryde's whales. As I discussed in the previous column, Bryde's whales have been caught mostly in the surface water temperatures more than 20°C. Of course, some yearly change among the dominant occurrences of Bryde's whales in the water temperatures range is observed as illustrated in Table 33. The catch of the year 1956 does not show the typical high water temperature range, but the number of Bryde's whales show the smallest number when the comparison is made with recent other years. It is evident, however, that Bryde's whales are migrating in the water temperature more than 18°C, and never to call the colder waters under 15°C in general.

The whale marking on sei whales began in the spring of 1949 in the Bonin Islands and in the Sanriku and Hokkaido waters, and has been conducted every year in the North Pacific. Recent marking also has covered the northern part of the North Pacific and the recovered marks are listed in the appendix. I would classify these marking data with consideration of marked and captured season, marked and captured whaling grounds and lapse of the year. The whale marking in the Bonin Islands waters had been carried out between 1949 and 1952 and 92 sei Bryde's whales had been marked and 6 of them captured. Three marks were recovered in the same Bonin waters. The two marks were found somewhat west waters of marked position after the lapse of 1 day, and the last mark was recovered from the waters about 20 miles north waters of the marked position after the lapse of 12 days. With the consideration of the swimming direction and the catch of whales in the Bonin Island waters, Bryde's whales stay in the waters from the early of May to July and gradually migrate to the northern waters from the late of May.

Other 3 marks hit in the Bonin Island waters have been recovered from the whales caught in the adjacent waters to Japan Sanriku waters. One mark was recovered in the same year of marking. The whale was marked on 8th May, 1950 at 26°-43′N and 142°-40′E, and captured in the off waters of Sanriku at 37°02′N and 143°02′E after 69 days lapse. The other mark is recovered from a sei whale (The baleen plate is examined, but they say the plate is a sei whale, *Balaenoptera borealis*. The species should be corrected to be Bryde's whale by the recent investigation of a whale of the same school. The baleen plate must be mistaken), and the third is recovered from a Bryde's whale caught at 38°10′N and 145°20′E after the lapse of 8 years. These 3 marks prove directly the migration of Bryde's whales from Bonin Island waters to the Sanriku waters. The Bryde's whales usually call on the Bonin Island waters from the late of April to July and one part of Bryde's whales go north as far as off Sanriku waters, but one part remains longer in the Bonin waters (Omura & Fujino, 1954, p. 101) according to the observation by marking cruises between the late of June and the early of July in 1952 when some 74 sei whales (evidently Bryde's whale) had been observed. The comparatively many Bryde's whales were observed swimming to southern direction suggesting some of them may be feeding around the Bonin waters still in summer. The water temperature was very high showing from 28°C to 29°C in the waters at that time. There is some data of swimming school of Bryde's whales obtained in the Bonin Island waters. The single Bryde's whale predominated and the largest school consisted of 5 Bryde's whales. The single occurrences of whales mean to some extent the migrational special feature that they are due to the initial stage of the migration.

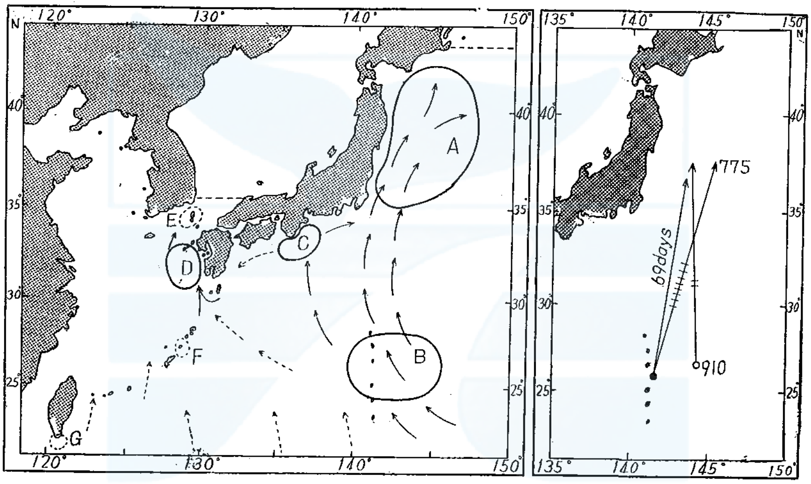

Fig. 38. Left, Schematic illustration of migration course of Bryde's whales in the adjacent waters to Japan. A, B, C, D—Recent whaling grounds of Bryde's whales, E—Catch position of Bryde's whales before 1945, F, G—Probable whaling grounds of Bryde's whales in the seasons before 1945. Dotted lines show the northern range of the distribution of Bryde's whales in the adjacent waters to Japan. Right, The recovery of whale marks bit in the Bonin Island waters and recovered in the Sanriku waters.

In the northern part of the North Pacific, the number of sei whales in a school have been observed in 1954 as shown in Table 35. Though the observations number is not so sufficient, the sei whale school in the earlier time of the season consists of single swimmer, on the other hand the observation in July prove that more schools consist of two sei whales. This fact suggests that some sei whales make rendezvous in the feeding ground and it is probable they return to the south for mating.

The summarized data of whale marking in the Sanriku and Hokkaido are given in Fig. 39. The 0 year group has three individuals, which demonstrates the westward movement from the off waters to the rather coastal waters. The mark (No. 3782) hit on 7th July of 1953 at about 42°N latitude is recovered on 12th September at 39°N latitude, and another mark No. 2675 hit on 2nd September is recovered on 21st October. These two marks show some case that sei whales (in some cases, occurrences of Bryde's whales are probable) are feeding in the off waters in summer, and then go to the coastal waters in autumn. From the 1, 2 and 3 year groups, two sei whales marked in July and August are captured in a little more south waters in the early date July, and two sei whales marked in September are caught also in the more coastal adjacent waters, than the position they were marked. Two sei whales marked in September are also caught in the near waters of the marking position in September. The tendency that whales come back to the same water in the same season of the year is partly demonstrated by these 1 to 3 years groups of sei whales.

TABLE 34. NUMBER OF SEI WHALES* IN EACH SCHOOL IN THE BONIN WATERS IN 1952

No. of whales	1	2	3	4	5
No. of school	12	4	3	1	2

The whales are described as sei whales by lack of observation.

* These sei whales are considered to be Bryde's whales.

TABLE 35. NUMBER OF SEI WHALES IN A SCHOOL OBSERVED BY JAPANESE INVESTIGATION IN THE NORTHERN PART OF THE NORTH PACIFIC IN 1954

	Number of whale in a school					
Month	1	2	3	4	5	6
May	4	1	1	—	—	—
June	12	3	—	1	—	—
July	19	41	14	6	1	1
Aug.	9	6	4	—	—	—

4 years group or more elapsed group also endorse above tendency as shown in C of Fig. 39. Two September groups are recovered in the

near water after the lapse of 5 years. But another three marks marked in September are recovered in the far coastal waters. The marks, No. 2819 and No. 86 marked in July and September respectively are caught in June after 4 and 6 years. Two 5 and 6 years group cross the waters to the west coastal waters too. These marks all prove the general tendency that sei whales are feeding in the boundary of water mass between 'Kuroshio' and 'Oyashio' in the Sanriku and Hokkaido waters. If the heavy 'Siome' (Current rip) moves by some oceanographic surroundings affecting the sea condition of the whaling ground, sei whales also move very rapidly to the next favorable feeding area where the heavy 'Siome' is occurred. A good example is obtained in 1956. From May to June, comparatively many sei whales had been caught in the off waters of Sanriku, but the center of catch goes to the north and few sei whales are caught in the Sanriku waters

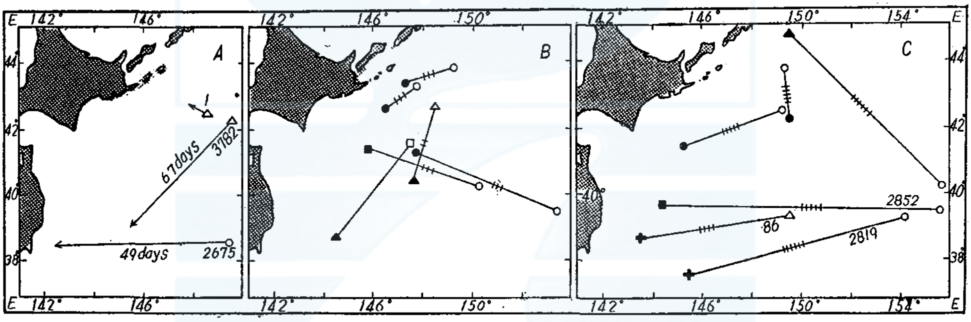

Fig. 39. Marking results of sei whales in the Sanriku and Hokkaido waters by Japanese investigations. Black symbols show the recovered positions. Open symbols show the marked positions. Crosses cutting arrows show the elapsed years. Cross—June, Triangle—July, Square—August, Circle—September, A—0 year group, B—2 and 3 years groups, C—groups more than 3 years.

in July. The typical moving of 'Shiome' is observed between June and July. The catch of sei whales decreases in number in the late of June when the 'Shiome' declines, and sei whales may scatter to feed their food. The sei whales are heavily feeding on *Euphausia pacifica*, *Ommastrephes sloani pacificus* in the 'Shiome' in the Hokkaido waters in the first of July. Again, the developed 'Shiome' down declines in the late of July and the center of the catch of sei whales go to the south in the late of July. These movements of the whaling ground can be explained by the intensity of Oyashio and Kuroshio current and their movements as a conclusion.

In the northern part of the North Pacific, two marks are recovered from sei whales (*Balaenoptera borealis*) after the lapse of 4 years. The sei whales are marked in June along the continental shelf south of

Unimak Islands. When they are marked, they apparently were considered to feeding *Calanus plumchrus* from the observation of other caught sei whales. The sei whales taken in July in 1958 are also feeding on *Calanus plumchrus* but in the more off and western waters. Though there has been no satisfactory explanation for the removal of the whaling ground for sei whales consists of *Calanus plumchrus*, the extention and strength of warm current from the south and the colder shore and northern waters make such a feeding grounds.

There are two evident peculiar features in the catch of sei whales in the Antarctic. That the female is always dominant at the high rate is one, and the catch of mature whales are exceedingly dominant is the other. Among the Japanese catch in the Antarctic in 1957 and 1958, females and mature sei whales are very dominant. In 1957, only 4 immature males and 21 mature males, 5 immature females and 103 mature females of sei whales were captured by Japanese expedition. Matthews (1938a) already noticed the female predominated tendency and thinks one reason for the fact is due to the selection of large sei whales for capture. Kasahara (1950) also subscribes his opinion. But the sexual segregation in the migration course also should be considered to explain the fact successfully, because from the sex ratio of foetus does not show such female predominated tendency. As there is another interesting tendency

TABLE 37. CATCH OF SEI WHALES IN THE NORTHERN PART OF THE NORTH PACIFIC IN THE EAST AND WEST SIDE IN 1957

Decades	West		East	
	Male	Female	Male	Female
May late	5	7	—	—
June early	9	10	—	—
June middle	—	—	16	20
June late	—	—	5	2
July early	—	—	33	26
Aug. middle*	22	10	—	—

* Including 1 male caught in late August.

TABLE 36. CATCH OF SEI WHALES CAUGHT IN THE ANTARCTIC WATERS BY JAPANESE WHALING OPERATIONS IN 1958

	Antarctic area										
	I		IV		V			VI			
Sex	Mature	Immature	Mature	Immature	Mature	Immature	Unknown	Mature	Immature	Unknown	Total
Male	10	1	16	1	114	1	6	234	2	—	385
Female	19	—	50	1	257	9	8	714	18	—	1076

like above segregation in the North Pacific, I would refer to the results in the North Pacific here. Omura (1950) illustrates the sex ratio of sei whales caught in the Kurile and Hokkaido areas in past 18 years. Of course, there must be some trespassers of Bryde's whales in the statistics, but the number is considered very few in above two local waters (Omura & Nemoto, 1955). Males of sei whales are predominated in the Kurile waters, on the other hand, females are more numerous than males in the Hokkaido waters (see Table 36, Omura, 1950). Kasahara (1950) also consideres there is the segregation of migration between male and female of sei whales, and males go to the further northern waters if it is simply considered. In the northern part of the North Pacific, males are always predominated in the western part, off Kamtchatka and south of the Komandorskiy Islands. I would consider these facts are mainly due to the later season of whaling. This illustration is given in Table 37, which show the tendency of male predominating in the latter half season of July and August.

Fin whales

Northern part of the North Pacific. Fin whales have been considered to be a long migratory whale. The recovery of whales' marks in the southern hemisphere proves the long migration between the Antarctic cold waters and subtropical waters of Brazil and South Africa (Brown, 1954). Like the case that the sword of a sword-fish (*Xiphias gladius*) was found in the dorsal flesh of a blue whale in the Antarctic (Ruud, 1952), a sword of a sword-fish was found in the meat of a fin whale caught on 19th July in 1954 in the adjacent waters to Aleutian Island. The fin whale was caught at 54–35N, 165–35W longitude, where the Pacific sword-fish also never inhabit in such cold waters as Aleutian region. This indicates the migration of a fin whale between the northern part of the North Pacific and the subtropical waters of the Pacific.

In the northern part of the North Pacific near Aleutian Islands, fin whales have been caught from May to September by Japanese and Russian expeditions. The catch has been observed along the Aleutian Islands, along the Alaskan continental shelf and Kamtchatka coast. Generally speaking, fin whales come from the southern waters already in May in the west part of the North Pacific. The height of *Calanus cristatus* and euphaussiids, *Thysanoëssa inermis* change their roll in the middle of the season, and the fin whales usually migrate to the north or the east waters to seek the food from July in 'Calanus year' (Nemoto, 1957, p. 79). The catch height in the west waters of off Kamtchatka is considered to be in June (see Fig. 23 Nemoto, 1957) and fin whales become scarce in August owing to the scanty supply of foods in the waters. The height of *Calanus cristatus* shows some local differences according to the latitudal locality in the northern part of the North Pacific as stated in the former part.

In the southern waters of Aleutian Islands, *Calanus cristatus* become dominant already from May, but in the northern waters, it become a little later than May. Fin whales follow the height of their food, and if the food is sufficient they stay there for comparatively long time.

This cause surely the delay of migration (in this case movement is more suitable) of fin whales to the north waters of the Bering sea, especially in the North waters of Kamandorskiy Islands and in the off waters of Anadyr gulf. The temporaly prosperity of swarming fish such as capelin and Alaska pollack also attract many fin whales, the examples of which are observed in 1957 and 1958. The waters where Alaska pollack was abundant in 1957, does not attract fin whales in 1958 owing to the scarcity of Alaska pollack. But comparatively many fin whales go to far north to feed on abundant foods of capelin in 1958. Still, other fin whales feed on planktons in southern waters near Aleutian Islands. This will partly demonstrate that number of fin whales are restricted to the waters according to the abundance of foods in the waters, and excessive number of fin whales may call other waters to feed on their food.

Marking results in the North Pacific. The whale marking research commenced in 1953 in the northern part of the North Pacific, and has been succeeded since then.

With regard to the result of marking investigations on the fin whales in the northern part of the North Pacific, the periodical report and summarized reports (Omura & Kawakami, 1956 ; Kawakami & Ichihara, 1958 etc) discuss the problem to some extent. Here, I would make the discussion mainly considering the seasonal migration and the movement of fin whales.

The recovered marks are classified into year and seasonal groups as illustrated in Fig. 40. In the earlier season, the whaling operation has been conducted mainly in the southern waters, and gradually covered the North waters. As this directly indicates the early finding of marks only in the southern waters, no marks has been recovered in the north waters in the earlier season of whaling when no fin whales has been caught in the north waters. It should be considered that fin whales not always go to the north from the spring season to the summer season because many fin whales have been caught in the southern waters of the Aleutian Islands in the high summer season of the North Pacific.

My preliminary discussion based on the seasonal movement is as follows.

1. From May and June, the general tendency of fin whales migrating north is observed. Fin whales come to the western waters of the south

waters of Aleutian Islands, near waters of Komandorskiy Islands from May. These two marks hit on fin whales in the north waters of the east Aleutian Islands in August and September have been recovered in May, suggesting that these fin whales may migrate to the east and north waters again. The marks connect the east and west groups of fin whales in the northern part of the North Pacific in appearance. Two marks (J. 6042 and J. 6834) are recovered as the May group, but the Mark (3213) hit in May in the middle south waters of the Aleutian Islands is recovered in July in the said waters.

The Mark (J. 6060) in Fig. D. hit in September in the northern waters of Aleutian Islands is found in the western waters of the Near Islands in June, which indicates the same tendency as May group in Fig. A.

2. The marks hit in the north waters of the eastern Alutian Islands in September and August, the rather late season, are recovered in the south waters of the eastern Aleutian Islands. This also indicates the northward movement from the early season to the middle and late season of whaling demonstrated by three marks (J 6799, JS 6987, J 5998) in Fig. D.

3. After the lapse of the time more than 8 months or in the next year after the hit, the same month group show the capture position situating the very near position of marking position. For example, the marks hit in August, rather in the late season, are recovered in September in the near position of markings (Fig. C). The marking and recovering in July and in August respectively also show the same tendency (Fig. B).

Above results endorse the consideration that fin whales migrate to the same waters in the same season of the year as a rough conclusion. The main reason for the tendency is due to the general plankton crop in the same time of every year though there are some yearly change is observed. If there are any changes of oceanographical condition, or amounts of planktons organisms, the different migration of fin whales will be obtained.

4. The ' dispersal ' of the whales also should be considered. The term ' dispersal ' is used to describe the ultimate movement of whales east or west from the position in which they are marked by Brown (1954, p. 358–359). He made very excellent consideration on the problem in the Antractic on the dispersal of whales. Here I would state some different conditions between the Antractic and the North Pacific whaling ground at first as regards the dispersal of whales. The whaling ground in the Antractic is situated along the pack ice surrounding the Antractic continent. Of course, the currents of the Weddle sea, Ross sea and South Shetland sea etc, make the drift of euphausiids into the off waters (Ruud, 1932) or bring forth the constant crop of plankton in the off waters and show the strong latitudal distribution of baleen whales as

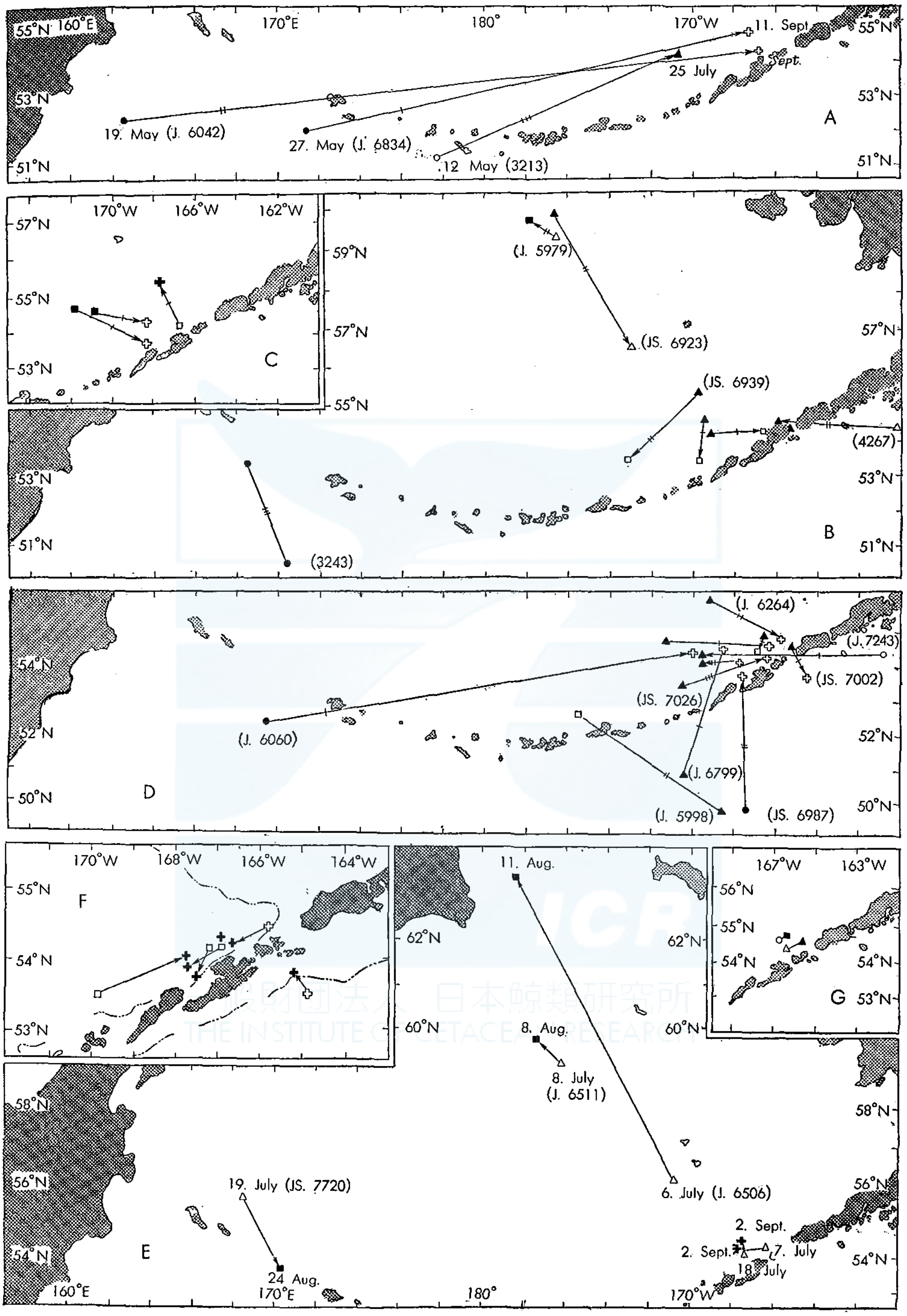

Fig. 40. Marking results by Japanese marking research in the nothern part of the North Pacific: A—May group after the lapse of time more than one year. B & D—June and July group after the lapse of time more than one year. C—August and September group after the lapse of time more than one year. E—July group within the same year of marking, 0 year group. F—August & September group within the same year of marking, 0 year group: Open symbols show the marking position and Solid Symbols show the recovering position. The short crossing lines show the elapsed year. Circle—May & June, Triangle—July, Square—August, Cross—September.

described by Arseniev (1957) in the Weddle sea. But generally speaking in recent times comparatively short whaling periods indicate the following lateral movement more frequently than the longitudinal movement in the whaling grounds of the Antarctic.

Thus the east and west-ward movements are generally observed and typical seasonal movement is not observed in the North Pacific. On the other hand, the typical dispersal of fin whales has not been observed if the seasonal movement is taken into consideration. For example considerably many fin whales hit in August or September in the North waters of Aleutian Islands are caught in the south waters of Aleutian Islands in the earlier season of May and June. As those fin whales might have migrated to the north waters with advance of the season if they had not been captured, fin whales in the course of migration or movement should not be regarded as the dispersive movement. Here I would use the term 'dispersive movement*, to describe the ultimate movement of whales without any relation of seasonal movements.

Up to this time, the real 'dispersive movement' has not been indicated by the recovery of marks on fin whales as illustrate in Fig. 40. But it is probable that fin whales make 'dispersive movement' at some time in the future. The one of the most reasonable explanation may be a change of feeding condition according to the oceanographical surroundings.

5. The most important question about the migration and the movement of fin whales is that fin whales in the east and the west in the North Pacific are separate stock or not. There is already a reliable discussion that fin whales from the waters of western Aleutian Islands and the north waters of the eastern Aleutian Islands belong to the separate breeding populations respectively (Fujino, 1956), however, it is safe to say that fin whales in the northern part of the North Pacific migrate and move eastward and westward to feed on the more profitable condition of their food. And further, there is no barrier between east and west waters because fin whales have the peculiarity migrating to the marginal and the mediterranean sea as well as the ocean. I would consider the evidence that fin whales are separated by blood groups in the northern part of the North Pacific described by Fujino (1956) only support the tendency that fin whales are divided into two or more population in the breeding ground. But the segregation in the whaling ground is not so strong as it is given by the brood type investigations. The satisfactory explanation will be obtained after the many accumulation of data are completed.

6. The northern limit of the migration has not been defined by Japanese

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* The term 'dispersal' is already used by Brown in 1954, and the meaning is different from my term. I would use 'dispersive movement.' here in a different meaning to describe movements of whales.

investigations yet. But considering the distribution and amount of foods of whales the Bering sea is considered the most northern feeding ground in the North Pacific for fin whales. The Japanese whaling in 1940 covered the Chukchee sea though Bering strait and caught 74 fin whales. This phenomenon suggests the herd of fin whales attain to the Arctic sea in their northward migration in considerable number in some years. The food in the waters may consist of bottom living amphipods and one euphausiid (*Thysanoëssa raschii*) is considered only a euphausiid which distributes in the shallow and cold waters. But the condition of feeding for fin whales is not so satisfactory as in the Bering sea.

A mark (J 6506 in Fig. E) hit on a fin whale in the north waters of the eastern Aleutian Islands on 6th July is recovered in the off waters of Anadyr gulf on 11th August after the lapse of about one month as a 0 year group. The mark apparently indicate the summer movement of a fin whale from the north waters of the eastern Aleutian Islands to the most northern part of the Bering sea. This apparently means the northward movement in the Bering sea, and the northern limit is not situated along the Aleutian Islands. The pack ice of the Arctic sea also restricts the feeding ground of whales. As ice is generally prevailing in the Arctic sea and the Bering strait by the early summer (Pilot chart of American navy) fin whales may penetrate the water only in July, August and September. Japanese operation was operating from 5th to 27th August in 1940, when fin whales were feeding in the waters through the Bering strait.

7. The important mark (JS7002) is illustrated in Fig. D. The mark hit on 8th September in the south waters of Aleutian Islands in 1955 was recovered on 12th July in 1956 in north waters of the same eastern Aleutian Islands. Though the moving distance in the figure is short, this movement is considered real 'dispersive movement'. The fin whale might have migrated to the north waters fairly earlier season in the next year or the fin whales was feeding in the south waters through out the season, or came down to the south waters earlier than usual when it was marked.

The movements of fin whales are also considered by the marking results of the lapse of time as well as the seasonal movement. The movement of 0 year group is illustrated in Figs. E, F and G. The marks of 0 year group in August or September and recovered in September indicate the summer feeding in the same waters. Some marks hit in July also recovered in August and September in the very near waters of marking. A mark (JS7720) hit on 19th July in the north of Komandorskiy is recovered from a little south waters on 24th August, which suggests the summer staying in the south west waters to feed on the food. The most exceeding movements is given by the mark (J6506) which connects the south and North Bering sea. The fin whale may migrate along the Alaskan continental shelf, one of the most profitable feeding course for fin whales. The short movement (J6511) of 0 year group of a fin whale indicates also the month long staying in the water. In the year 1957 when the mark (J6511) was hit and recovered, Alaska pollack was the dominant food in the waters in the late of July to the early of August. The shoals of Alaska pollack must have swarmed in the water from July to August, which caused the stay of fin whales. In the next year of 1958, fin whales migrates to the northern water off Andyr gulf and only a few herd has been observed in the waters from 58°N to 60°N along the Alaskan continental shelf. This fact apparently suggest the annual change of abundance and distribution of food cause different distribution and migration of whales. The year groups of fin whales also show the movement, which is given in the figures with the one short crossing the arrows. The definite catch of 1 year group in 1955 and 1958 is given by the next Fig. 41, but one mark (JS7243) which is illustrated Fig. D. In 1954, 209 fin whales are marked in the north waters of the eastern Aleutian Islands, 7 marks of which are recovered within the year, and 7 marks are found in the next year of 1955. The four marks illustrated in Fig. B show the movement to the off waters. The fin whales hit with marks are feeding on *Thysanoëssa inermis* along the continental shelf, and the captured fin whale are considered to feed on *Calanus cristatus*. This change of food condition make 1 year group move to the off waters, and the only consideration of the annual return habit can not explain the problem satisfactory.

The next example, the recovery of marks in 1958 indicates somewhat different movements. The marks were hit in 1957 in the off waters where the fin whales were feeding on *Calanus cristatus* and *Thysanoëssa longipes* which show about two longitudes westward transfer of the *cristatus* and *longipes* areas. Five of these fin whales were caught in the same off waters and they are considered to feed on also *Thysanoëssa longipes* and *Calanus cristatus*. These fin whales were hit in September and are caught in July, the fact of which suggests that fin whales stay from July to September with other data of 0 year group and the result of the year 1955. Two marks (J. 6799 and JS. 7243) hit in 1957 show the comparatively long movement which are illustrated in Fig. 40 D and Fig. 41 C. The former mark is recovered in the same month of hit in the south waters, and the latter hit in June in the east waters is recovered in the west through the Aleutian Islands. The latter mark may be due to the seasonal movement from the east to the west from June to July as I discussed in the former part. A mark (J. 6799) shows the 'dispersive movement' that the fin whale hit in July in the north waters of the eastern Aleutian Islands come to the south waters of Aleutian Islands in July in the next year. The fact also may be due to the feeding in the south waters from the spring, and the whale may not migrate to the north waters in 1958. The south waters whaling ground consists of the large amount of swarms of *Thysanoëssa longipes*, which had not been observed so often from 1954 to 1956.

The 2 year group shows rather long seasonal movement, the first impression of which proves the fin whales dispersing with the progress of years. The 3 year group has been recovered in a few number comparing with the 0, 1 year and 2 year groups, but the movement and 'dispersive movement' do not demonstrate so cxceedingly as 1 and 2 year groups in 3 year group. There has been only one recovery of 4 year group, which was hit on 8th in August at the position 53-24N, 169-55W and is recovered on 11th July at the near position of 54-23N, 169-55W in the north waters of the eastern Aleutian Islands.

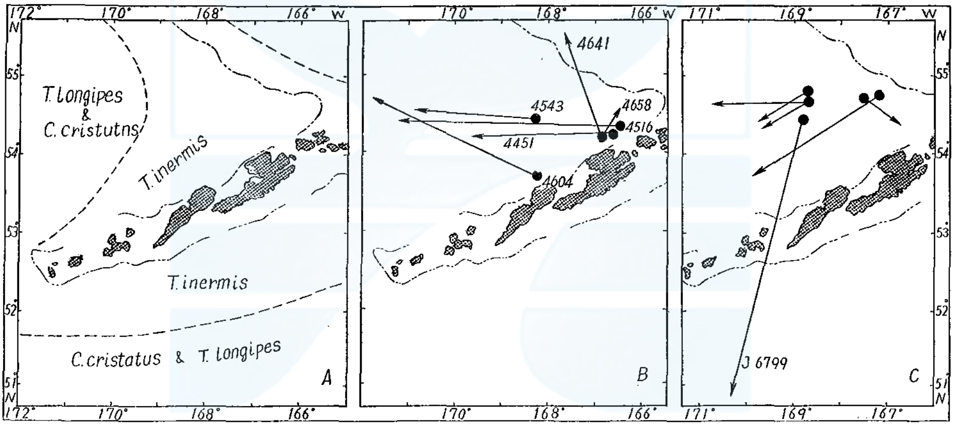

Fig. 41. The distribution of food planktons and recovery of 1 year group in 1955 and 1958. Left—Distribution of *Calanus cristatus* and *Thysanoëssa longipes* in the adjacent waters to the eastern Aleutian Islands. Middle—marking recovery in 1955. Right—marking recovery in 1958.

Swimming direction. About the swimming direction, Kemp & Bennett (1932) describe the swimming direction of fin and blue whales in the waters of South Georgia and South Shetland. Those illustration drawn by them do not demonstrate the clear seasonal tendency of swimming direction but a general tendency of moving. On the other hand, the recent study on the swimming direction of humpback whales in the Australian waters (Chitterborough, 1953), indicates clear seasonal swimming direction along the west coast of Australia. His result well demonstrate the south and north migration along the coast of Australia from May to October, which is directly connected with the migration of humpback whales to and from the Antarctic.

The swimming direction of fin whales also observed by Japanese investigations after 1952. As a example, I describe here the observation in 1953 in the western part of the northern Pacific, the south waters of Komandorkiy Islands. From May to July, the northward movement is the dominant tendency of the fin whales, but the southward movement become dominant from August to September. Besides above tendency, the fin whales feeding in the more northern waters also should be considered because those fin whales will be feeding still in August according to the recent observations in the northern waters. It is reasonable, however, the change of the moving direction is accepted as a general tendency of the migration of fin whales.

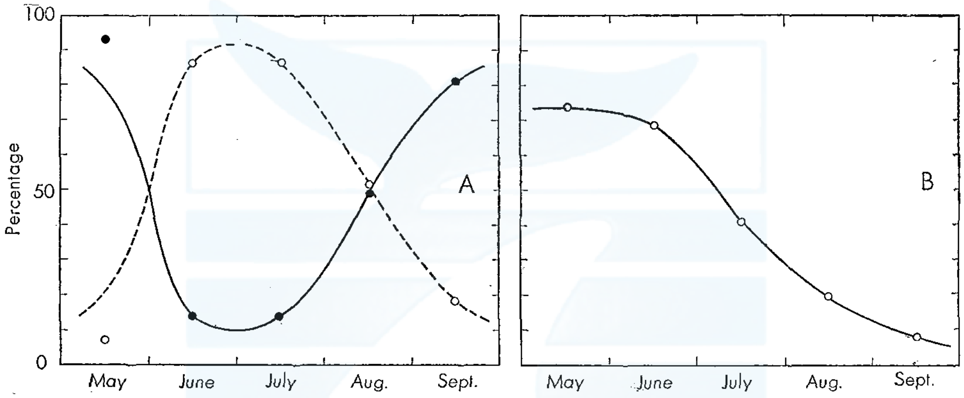

Fig. 42. Swimming direction of fin whales in the west part of the northern part of the North Pacific, south of the Komandorskiy Islands and in the off waters of Kamtchatka Peninsula. A—East and West component, Solid dots—West, Open dot—East component. B—North compornent.

The eastward movement from the earlier to the middle of the whaling season may also be obtained from the Fig. 42 A. But many fin whales move to the west-north, or to the Kamchatka Peninsula from the southeast, the Pacific Ocean in May. This fact suggests partly that the migration from the south waters does not always follow the coastal waters of Kurile Islands to the north. Kasahara (1950) consideres fin whales are coastal form from the catch statistics of the location of capture, but I would consider the fact is only due to the distribution of foods in the adjacent waters to Japan. When fin whales reach the Kamtchatkan coast and Aleutian Islands where the favourite food of *Calanus cristatus* is dominant, fin whales then migrate following two routes, along the coastal waters of Kamtchatka to the north and the Aleutian Island to the east. Zenkovich (1937) describes that fin whales are migrating from the south Kamtchatka in April and distribute in Bering sea and Arctic sea in August and September, and south moving schools of fin whales are observed in October in the south waters of Kamtchatka peninsula. The westward movement in May and the eastward movement in June and July will support the recovery of whale marks as I discussed in the former part. As a probable conclusion, fin whales migrating to the north already pass the waters south of Komandorskiy in July, thus the north moving component decreases in August, the high time of feeding in the northern hemisphere. Fin whales feeding on their food in the northern part of this water are also considered to come down from the late of August as a general tendency. The east and westward movements also endorse the marking results, but if there is any change of feeding condition the movement of fin whales may be much different one.

The result by Chittleborough (1953) indicates the much clear swimming direction, which is apparently due to the fact that humpback whales migrate along the very coast of Australian Islands. Fin whales in the coastal waters of Kamtchatka and Aleutian Islands also migrate and move rather coastal waters, because the food plankton and fish are considered rather scarce in the center to the Bering sea, and fin whales seem not to move through the center of the Bering sea.

The swimming direction of fin whales is also considered to be affected by the feeding of them. If fin whales are absorbed in feeding, they show no indication of definite swimming direction and they are also chased more easily (Gunther, 1948). This is directly connected with the dominant occurrences of swimming undefinitely in the heavy feeding ground especially in the moving when fin whales are mainly feed on their food.

Catch and distribution in the adjacent waters to Japan. Fin whales have been caught in comparatively large number already in the pre-war seasons before 1954 in the Okhotsk sea. The main catch of fin whales concentrate to the summer season from June to September. As shown in the Fig. 39 the height is observed in July and August.

Fin whales caught in the Okhotsk sea may come from both sides of the Pacific side and the Japanese side. Omura (1950) already considers that those whales migrating northwards though the Japan sea in May or June seem to enter into Okhotsk sea through the Soya strait. According to his description (Omura, 1950, p. 53) the thickness of blubber and the diatom infection of fin whales in the Okhotsk sea differ from those of the Pacific side suggesting that there appears to be little likelihood of both groups migrating through the straits between the Kurile

Islands. The latter distinction, however, is rather difficult to be explained as a definate one. Because the whaling grounds in the Okhotsk sea are situated on the shore waters from 10 miles to 60 miles, but those in the Pacific side lie in the off waters. The long pulling of whales from the captured position to the landstation may cause the falling off of diatom covering on the body surface of the fin whales. Thus the latter distinction may not be a reason for separating the groups of fin whales. There is another interesting observation. When I visited the landstation of the Okhotsk sea, the healed oval scars are observed on the surface of fin whales. These oval scars are originated to the open pit formed in the southern waters (Nemoto, 1954, p. 76). As the fin whales caught in the east China sea have only a few oval scars on the surface of the body (Mizue & Fujino, 1957), the fin whales migrating in the Japan sea are considered to bear few scars. Because according to the catch statistics, those two groups of fin whales may not migrate to the subtropical waters of the Pacific Ocean where they may suffer from the open pits. The fin whales with many open pits have migrated from the Pacific side, though there is no evidence of whale marks or some other direct investigations.

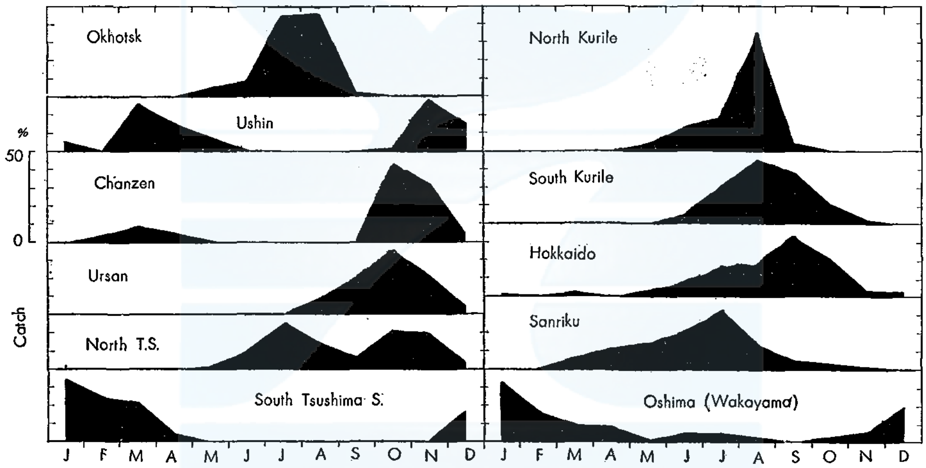

Fig. 43. The catch of fin whales in the adjacent waters to Japan in the seasons before 1954 according to available data by Japanese operations.

Along the Pacific coast of Japan, fin whales have been caught mostly in summer in the waters north of Hokkaido in the seasons before 1945. As the recent operation has not caught the available data of fin whales in the adjacent waters to Japan, I would use only the catch before 1945 on the problem here. The catch percentage is illustrated in Fig. 43. Though only a few fin whales had been caught in the Oshima waters, Wakayama prefecture, but the main catch in Wakayama waters is observed in the January in the winter season. The catch of fin whales in the waters is not so abundant as blue whales in the very opening seasons of whaling. This would indicate that fin whales distributing along the Pacific side of Japan may disperse in the off waters more remarkably in winter season. In the summer season, fin whales had been caught mostly from May to August in Sanriku waters and the height is observed in July. From June to October, fin whales had been caught, and its height is in September in the Hokkaido waters. This difference of prosperous season of whaling for fin whale is considered to be due to the delay of the favorable feeding condition. Foods of fin whales in the waters consist mainly of 'Krill' (Mizue, 1951), which is apparently *Euphausia pacifica* in the coastal waters. Kasahara (1950) states that fin whales are swimming in the coastal waters, but it is difficult to estimate the fin whales migrate to the north along the coast of Japan, because, the fact that the fin whales had been caught from June to August in the off waters of Kamtchatka Okhotsk sea, South Kurile Islands, Hokkaido, Sanriku and South Korea, indicates fin whales which migrate early time to the north feed on their food in the north waters and late comer feed in the southern waters. This habit of migration of the fin whale has not been ascertained by recent investigations owing to the scanty of data. It is probable, however, those fin whales which had been visited the adjacent waters to Japan have decreased in number by the whaling operation or they have changed their migratory course and have gone to the further north waters to feed.

The whaling season of South Kurile waters shows no difference from that of Hokkaido region, but that of the North Kurile waters shows the height only in August suggesting short duration of migration.

The catch of fin whales in the Okhotsk sea is observed also in the short duration of July and August. This will demonstrate the connection of the group of Japan sea. Omura (1950, p. 53) considers fin whales in Japan sea seem to enter in the Okhotsk sea through the Soya strait. The catch along the coast of Korea seem to give the support to this. As shown in Fig. 43, fin whales had been caught in two seasons a year in the North Korean waters which are given by the catch of Ushin and Chanzen. The heights are observed in May, October and November, but the summer catch has not been observed, suggesting that those fin whales go to the north swimming into the Japan sea to the Okhotsk sea as described by Omura (1950). The height of catch in the Urusan waters is observed in October, a little earlier than the northern coast of Korea. If those height mean the northward and southward migration of fin whales as suggested by Omura (1950, p. 52), fin whales migration along the coast of Korea must have gone down in the very winter season, December, January and February or disperse in the off waters.

The catch of South Korea and Tsushima straits are divided into three groups, the South Korean waters, North Tsushima strait and South Tsushima strait along the Kyushu and the most west part of Japan. The north strait catch shows two peaks of heights. This summer catch of fin whales is very interesting, because fin whales have been considered as a migratory animals that they feed in the cold high latitudes in summer. The water temperature in the South Korean waters is ranging from 25°C to 30°C July, August and September which is very high as a feeding ground for fin whales. Kasahara (1950, p. 27) considers that fin whales of the late migratory herd may feed in the southern waters, but I would consider the fact is mainly due to the local segregation of fin whales. The catch of fin whale in the North strait recalls me of the recent catch of comparatively many fin whales in the East China Sea. The catch of fin whales in the east China sea also concentrated in summer from July to August. The whaling ground of the East China Sea is considered to consist of 'the Krill' *Euphausia pacifica*, which is very dominant also in the Yellow sea and Korean water and become a very favorite food for mackerel (Nakai, 1942). This abundant *Euphusia pacifica* and other fish feeding on it, may support the stay of fin whales in the Yellow sea and the East China sea as well as the surroundings of the lands and Islands.

TABLE 38. CATCH OF FIN WHALES IN THE EAST CHINA SEA BY JAPANESE OPERATION FROM THE LANDSTATION OF WEST KYUSHU FROM 1955 TO 1957

	July			Aug.			Sept.			Oct.		
1955	—	—	10	25	29	36	33	47	25	—	—	—
1956	34	2	18	36	45	45	23	26	29	3	3	13
1957	14	20	13	26	12	11	18	27	13	6	11	18

From the body length at the sexual maturity and size composition of fin whales, fin whales in the East China sea are rather related to the catch of the Yellow sea. The Yellow sea landstation before 1945 had distributed along the west coast of Korean Peninsula (see Fig. 24), at which the described number of fin whales had been caught by the available data in the seasons before 1945. At the most southern landstation, Daikokuzan Islands, fin whales had been caught in winter season from November to June, and the height was observed from February to April. This catch seems to have some relation with the catches of North Tsushima Straits and Ursan. If this assumption is true, fin whales migrated to the west along the South coast of Korea in winter may spend winter in the waters, then migrate to the north along the coast of Korea, but this group of fin whales might have never been caught as the summer catch of the North Tsushima Straits from May to the early of September. In the Yellow sea, fin whales had been caught from November to July. It is very interesting that the catch of the most northern part of the Yellow sea, shows its height in May, and considerable catch of fin whales also observed in April and June. These fin whales may come down to the southern waters of the East China sea in summer. Kasahara (1950, p. 29) already noticed that the size distribution of fin whales in the Yellow sea was different from that of the catch in winter season in the South Tsushima strait.

TABLE 39. NUMBER OF FIN WHALES HAD BEEN CAUGHT IN THE ADJACENT WATERS OF WEST COAST OF KOREA AND IN THE YELLOW SEA

Locality	Month											
	J	F	M	A	M	J	J	A	S	O	N	D
Kaiyoto	1	1	5	31	52	31	—	—	—	—	—	2
Daiseito	56	52	20	20	—	—	—	—	—	—	4	50
Tsingtao	—	4	—	—	—	—	—	—	—	—	—	—
Oseito	4	4	4	—	—	—	—	—	—	—	—	—
Daikokuzanto	26	66	96	79	27	4	—	—	—	—	26	2

TABLE 40. CATCH OF BALEEN WHALES IN THE SOUTHERN WATERS OF THE PACIFIC FROM 1920 TO 1954*

	Blue	Fin	Hump.	Sei**	Grey
Formosa	15	—	734	10	—
Bonin Islands	27	7	849	1823	—
Lower California	989	12	1581	119	182

* Figured up from the data by Omura, Nishiwaki, Fujino & Kimura, 1957. ** Including Bryde's whales in the catch.

The latter catch shows the larger size distribution which is considered to have connection with the early migrater of fin whales in the Japan sea. They were different from the former Yellow sea group, which I would consider the same group as fin whales caught in the East China sea by recent operations. Mizue (1956) states fin whales caught in the East China sea may belong to the group of the Yellow sea. As I said in the former part, fin whales caught in the East China sea attain the sexual maturity in the shorter body length (Mizue, 1956), and the body proportion of fin whales in the East China sea differ from those of the nothern part of the North Pacific (Ichihara, 1957). These fin whales in the East China sea are considered as a 'local group' in the North Pacific. The local group of fin whales may be due to the oceanographical separation by lands and islands as well as the abundance of their food throughout the season. The depth of the Yellow sea is very shallow, and water temperature and salinity show the very characteristic values, however, *Euphausia pacifica* and *Pseudoeuphausia latifrons* bear possibility of dominant food for fin whales in the Yellow sea throughout the season.

The whaling ground in recent Japanese operations in the East China sea is found along the boundary of the warm current from the south and the cold current from the north. The boundary between above two current moves as illustrated in Fig. 44, which also indicates the movement of favourable feeding position of whales. This means the movement of the swarms of *Euphausia pacifica* by the current as much as physical condition of *E. pacifica* to come up to the surface waters.

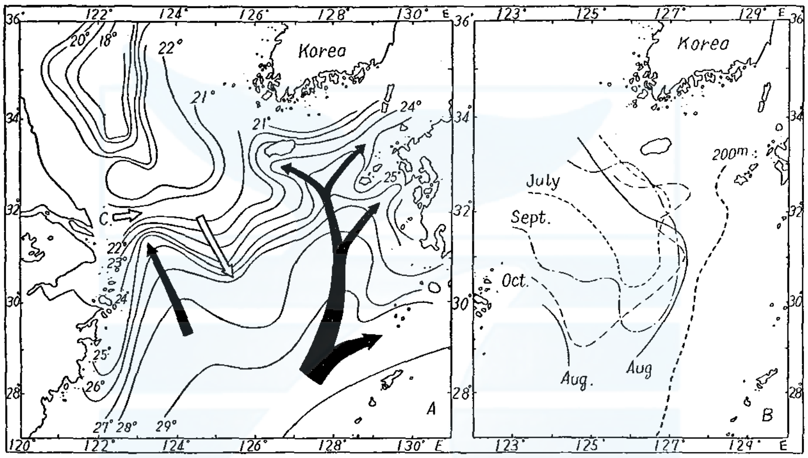

Fig. 44. A example of oceanographical condition and the distribution of the water convergence in the east China sea in summer, A—water currents and distribution of surface water temperature, Black—warm current, White—cold current, C—cold coastal waters. B—the center line of the water convergence in each month.

The summer remainder of baleen whales in the low latitudes is also observed especially among humpback whales in the Indian ocean (Brown, 1957), and in the summer season of the southern hemisphere. Rouqual whales in his report may be warm water living Bryde's whales, but some occurrences of fin whales may be probable like the East China sea.

Winter catch. The winter catch of fin whales in the both side of the Pacific ocean is also should be considered to get the exact distribution of fin whales in Ocean. Up to now, very few fin whales have been caught in the southern Pacific Ocean. Namely only 7 fin whales have been caught in the winter season in the Bonin Island waters, and none in the Formosa waters (Omura, Nishiwaki, Fujino & Kimura 1957) according to

Kasahara, 1950, 1 fin whales was caught). The catch of fin whales in the Lower California along the American coast had been also very scarce in number. These catch results suggest that fin whales in the Pacific seem not to enter the subtropical waters of 25°N latitude and further south waters or perfectly disperse in the subtropical waters not to access the coastal waters of islands and continents.

In the southern hemisphere, however, Moerch (1911) states that the great number of fin back whales congregate on the waters along the Brazil coast between 12° and and 18° south latitudes during the period from May to November. This winter catch of southern hemisphere is observed at the whaling stations of South Africa, but they are situated at about 30° south latitudes.

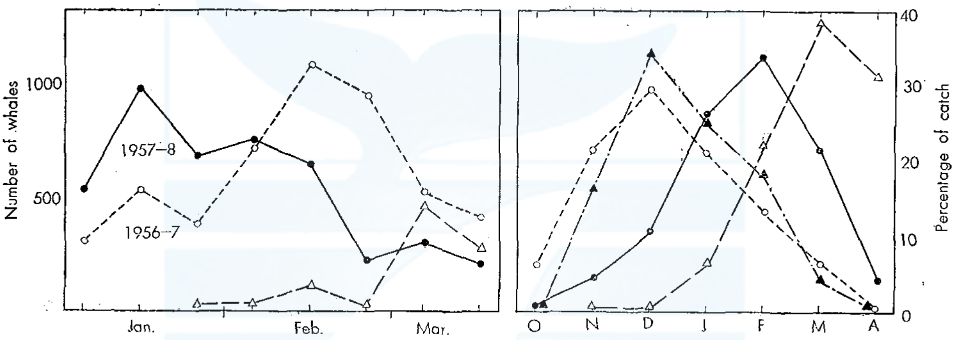

Fig. 45. Monthly catch and monthly percentage of baleen whales in the Antarctic waters. Left—Catch by Japanese operation in the Antractic waters. Solid line and symbol—Fin whales in 1957-8 season in the Antarctic area VI. Dotted line and open symbols—Fin whales in 1956-7 season in the Antarctic area VI. Chain line and triangle symbol—sei whales in 1957-8 season.: Right—monthly catch percentage in the Antarctic waters from 1927-35. Open circle—Blue whale, solid circle—Fin whales, Solid triangle—Humpback whale, Open triangle—Sei whale.

Antarctic waters. In the Antractic waters, the four large baleen whales have been caught by pelagic whaling operations, but fin whales have been the main catch in recent operations. And as the whaling regulation restricts the commencement of the catch of baleen whales, I would consider that the real migration of baleen whales should refer to the catch statistics of old operation in the Antarctic.

Mackintosh discusses (1942, p. 270) the monthly species ratio in the Antarctic as well as in the waters of South Georgia. According to his explanation, it is clear that there are some difference among the arrivals of baleen whales. Blue and humpback whales migrate to the antarctic waters earlier than fin whales, and sei whales come in the late of the summer season. Based on the old seasons' catch between 1927 and '35, the catch percentage of each whales species from October to April shows said clear tendency. Humpback whales seems to migrate to the Antarctic waters a little later than blue whales from the statistics. About the catch of the South Georgia waters, Mackintosh (1942) states the yearly change of migration of blue and fin whales referring Harmers' discussion (1941, South whaling. Proc. Linn. Soc. London, p. 69–83). This oceanographical change bears apparently the influence to migration of whales. Japanese operation in the whaling ground of the former sanctuary, that is the Antarctic area VI, also proves the yearly change. Fin whales have been caught mostly in February like the result in 1956 and 1957 season. But the height of the catch is observed in January in 1957 and 1958 season when the catch of fin whales decrease in the late of the season in March.

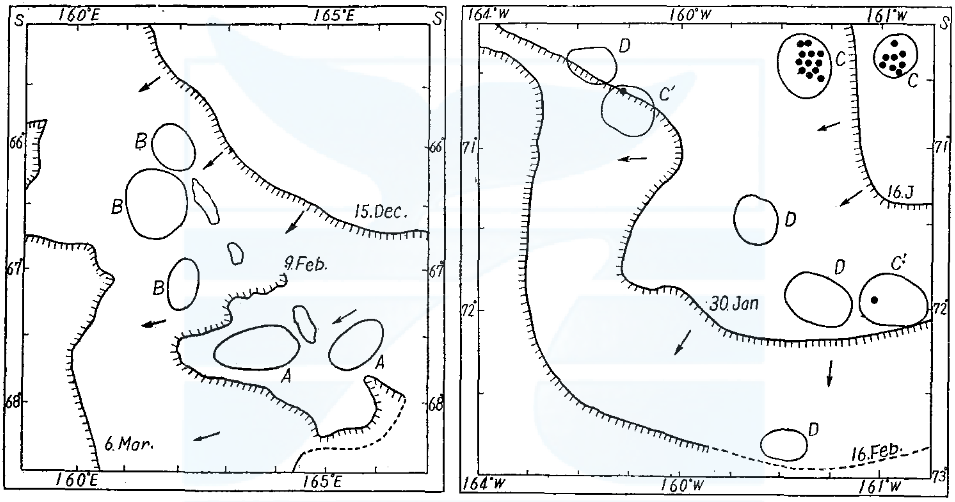

Fig. 46. Two examples of the distribution of pack ice line and food euphausiids. Left—whaling ground near Baleney Islands. A—whaling ground of Blue whales feeding the swarms of 1 year group of *Euphausia superba*. B—whaling ground of fin whales feeding 1 year group of *E. superba*: Right—C—whaling ground of fin whales consists of 1 and 2 year groups of *E. superba*. D—whaling ground of fin whales due to 1 year group of *E. superba*. Arrows show the retreat of the pacle ice lines. Lines and date show the distribution of pack ice lines in the date.

In the latter whaling season, many sei whales were caught in March, but not in the earlier season of January and February, which is the same tendency as the usual year.

The 'balance' among whales should be considered to get the exact distribution of baleen whales. Fin whales come to the Antarctic waters after the height of blue and humpback whales, and sei whales come after the height of fin whales in general. The recent abundant catch of sei whales in the Antarctic partly may be due to the decrease of blue and fin whales by recent whaling operations as well as the oceanographical conditions.

If the waters where the swarm of *Euphausia superba* is abundant are occupied by the early comer of whales. The followers were seem to be obliged to seek their food in other waters. Of course their favorite foods in the North Pacific are so different that the baleen whales may congregate to different waters according to the distribution of food species. But the food of blue and fin whales in the Antarctic is mainly *Euphausia superba* in common, and the segregation of distribution of above two whales in the Antarctic is directly considered to be due to the occupation of favorite waters by the difference of coming and biological strength.

The segregation of fin whales in the Antarctic into some groups is already suggested by Hjort, Lie & Ruud (1933) and Mackintosh (1942, p. 258), and recent interesting results of whale marking compiled by Brown (1954) also subscribe that many fin whales are shown to return from their migrations year after year to somewhere near the place where they were marked. The evidences that the range of dispersal in fin whales appear to be limited to within 50° east or west and the dispersal is not necessary progressive are also considered to show the segregation to some extent. The body length at the sexual maturity is considered to be also somewhat different in the certain Antarctic areas (Purves & Mountfort, 1959).

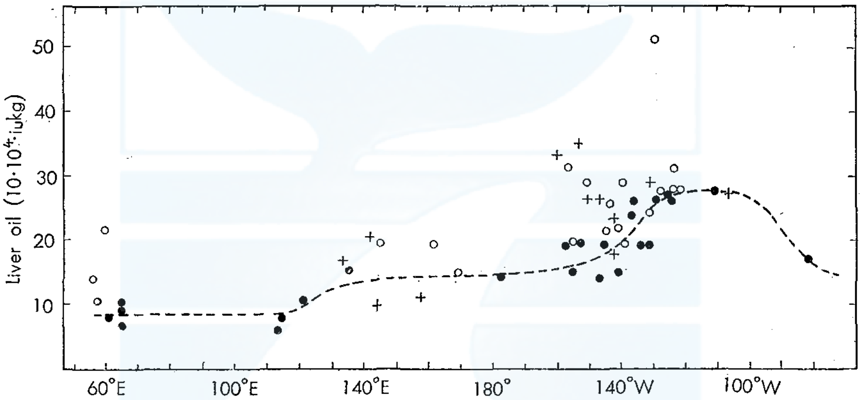

Fig. 47. Vitamin A products from the whales' liver extract by Japanese whaling expedition in the Antarctic waters in 1958. Solid circle—January, Open circle—February, Cross—March. Dotted line shows average curve in January.

Japanese whaling operations usually make vitamin A oil from the liver of baleen and sperm whales. The concentration of vitamin A extracted from the liver differs very much in each Antarctic area and month. In the western waters of Japanese operation in the Antarctic, the value of vitamin A in the liver oil is very low showing about $10 \cdot 10^4$ in 1 kg.

The value is nearly the same in the Antarctic area IV, and considerably higher in the Antarctic area VI and I of former sanctuary, where *Thysanoëssa macrura* has been observed in the stomachs of baleen whales as a staple food. As a simple and bold explanation, the vitamin concentration may be due to the difference of the vitamin concentrations between *Euphausia superba* and *Thysanoëssa macrura*, as the difference among the vitamin A concentration of *euphausiids* is already observed (Fisher, Kon & Thompson 1955). These differences of the vitamin A concentration of whales' liver suggest the local stocks of the fin whales in the Antarctic like the iodin value of whale oil differing in each Antarctic area (Lund, 1952). As the fatty acids of components of whale oil of the northern part of the North Pacific also differs from those of the Antarctic waters (Saiki & Mori 1956 ; Saiki, Shin-chen Fang & Mori 1959), the physical condition affected by food must be considered to suggest the food on which they feed.

A example of the local movement of fin whales in 1958 in the Antarctic waters is following. The whaling ground in the Antarctic waters is much affected by the distribution of pack ice, and baleen whales can feed on euphausiids smarming mainly in the near waters of the pack ice. In the early time of the Antarctic summer, the patch of *Euphausia superba* of 2 years group already appears along the pack ice, and is copulating and feeding in the surface. These patches consisting of 2 years group *Euphausia superba* are left with the advance retreat of the melting of pack ice. The comparatively late commer fin whales feed on the left patches of swarming of *E. superba* in the off waters which is illustrated in Fig. 46. The C whaling grounds in Fig. 46 are found in the waters where the pack ice was prevailing still on 16th January in 1958.

After the lapse of 10 days, the pack ice line retreats to the south west in fairly rapid speed. The patch of *Euphausia superba* has been observed in the C waters in the middle of February, but no fin whale migrates to the waters at that time. After the first observations of Euphausiid patch, fin whales come to the waters in the late of February. The difference in day is about 7 days or one decade. In the late of February, the pack line far draws to the maximum retreat, and fin whales also feeding on the swarms of 1 year group distributing in the waters of the pack ice line of 30th January. In the C'waters both 1 and 2 years groups of *Euphausia superba* are found in the stomachs of whales caught in the waters, but the adjacent whaling ground to C' waters consist of 1 year group of *Euphausia superba* only. The same kind of whaling ground consist of 1 year group of *Euphausia superba* is also observed along the most retreated pack ice line. These waters attract many baleen whales from the middle of February to March, which is apparently one evidence that the swarms of 1 year group *Euphausia superba* make the main food of baleen whales in the latter of the summer. In the C whaling ground, many fin whales come to the waters with the delay of 5 days after the swarms of patch is observed. Arseniev (1957) states the same observations with regard to the distribution of the patch of *Euphausia superba* and whales. Many schools of baleen whales usually congregate to the waters where many patchs of *Euphausia superba* have been observed. And there is a direct relation between the school of baleen whales and the distribution of food patchs. The next illustration is shown also in Fig. 46. In 1958, a Japanese whaling expedition operated in the waters of adjacent to Baleny Islands. The pack ice line in pre-whaling season of 15th December lies still closing the Islands, but on 9th February, the pack ice line retreats making the inlet of pack ice where the abundant of *Euphausia superba* of 1 year group is swarming, many blue whales are observed staying and feeding there for half a week in the early of February. The pack ice line retreats further in a week, and many swarms of *Euphausia superba* observed in the waters between the pack ice and Baleny Islands.

Fin whales have been congregating to the waters for half a month after the melting of ice, and they become a large group consist of many schools of fin whales. These two cases may be a illustration of distributions of whales in the Antarctic in summer. Like the northern Pacific waters, where there is a food, there come many whales. But blue and fin whale do not seem to be mingled so closely with each other as it is shown in the above illustrations.

Seasonal and local changes in compositions of fin whales. Mackintosh (1942, p. 259) discuss the seasonal change in the local composition of the stock of Antarctic baleen whales, and it shows a general comprehension about the mode of the migration of whales. As it is illustrated in Fig. 45, each species ratio shows very particular tendency in the Antarctic waters. But in the northern part of the North Pacific these seasonal change in monthly species ratio has not been observed typically. On the contrary to the fact in the Antarctic waters, fin whales come earlier than blue whales in the western part of the northern part of the Pacific in '*Calanus* year', which is apparently due to the feeding condition. However, fin whales come earlier than sei whales in the feeding area of the northern part of the North Pacific as a general result like the Antarctic.

Up to this time, the difference in the sex ratio with the advance of seasons has not been clearly observed in the North Pacific, but males of fin whales are rather less in number in the early season of May.

The number of male fin whales become gradually dominant in the latter part of the season, and males are dominant in the total sex ratio of fin whales (Ohsumi, Nishiwaki & Hibiya, 1958, Table 1). But such tendency is not observed in some years and localities. For example, males do not become dominant in the latter part of the season in 1953, but the fluctuation of male occurrences were observed throughout the season. In the Antarctic waters, male fin whales also increase from January to February, but decrease again in March in the whaling area VI from 1956 to 1958 (Ohsumi, 1959). This has also been observed in the area I as illustrated in Fig. 48.

As a general tendency in the Antarctic areas, there is a marked change in the summer season in the percentage of adult females which are pregnant (Mackintosh, 1942). Usually pregnant females decrease in number with advance of the season as illustrated in Fig. 48. This tendency has also been obtained in the northern Pacific in some years though it is not so typical as in the Antarctic waters. In the northern part of the North Pacific, near Bering sea, the pregnant female is considered to congregate in the southern waters and the pregnant percentage of female fin whales declines a little in the latter part of the summer season. But the local difference in the occurrence of pregnant female of fin whales shows the very reverse in 1958. Almost female fin whales caught in the waters off Kamtchatka Islands show the pregnant percentage of 77 and those caught in the center of the Bering sea show 44 percent in 1957. The successive operation in 1958 shows the following figures. Pregnant percentage of 70 in the waters off Navarin cape and

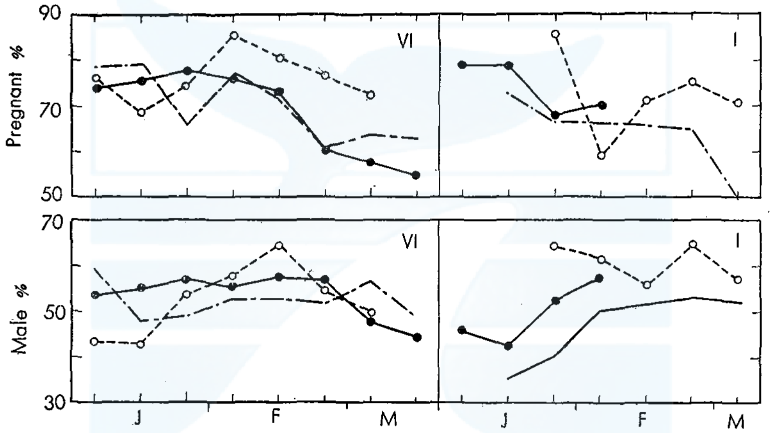

Fig. 48. Catch percentage of pregnant female and male of fin whales caught by Japanese operations in the Antarctic areas of VI and I from 1955 to 1958 seasons. Dotted line and open symbol—1955–6 season, Solid line and black symbol—1956–7 season; Chain and solid line without symbols—1957–8 season.

about 55 percent in the waters off Kamtchatka Peninsula. Above fact will indicate that the migration of pregnant fin whales is rather elastic in the northern part of the North Pacific mainly according to the complicated shape of the sea surrounded by lands and Islands.

Generally speaking, Antarctic feeding grounds are situated high latitudes and colder than those of the northern part of the North Pacific. The decline of the pregnant female in the Antarctic may be due to the start of female fin whales with larger foetuses to the breeding areas for parturition (Laws, 1959). In the northern part of the North Pacific, fin whales still may be able to remain in the waters in the latter part of the seasons, because the water temperature is not so severe as in the Antarctic feeding area.

There is another tendency that the immature whales become comparatively numerous in the latter part of the season in the Antarctic waters (Mackintosh, 1942, p. 274), which is also observed in the recent Japanese operations also in the Antarctic areas of the former sanctuary. In the northern part of the North Pacific, however, the distribution of immature fin whales show the local differences. The sexual immature fin whales congregate most typically in the north waters of the eastern Aleutian Islands. On the other hand the number of immature fin whales is less in the waters off Navarin and Kamtchatka peninsula. Further the age compositions of fin whales in those waters vary through the season, but the mature whales become dominant in the latter part of the season. The south waters of the eastern Aleutian Islands show the lower catch of immature fin whales than the north waters, which indicates that the northern part of the eastern Aleutian Islands is the center of the congregation of immature and younger fin whales in the northern part of the Pacific,

These fragmental informations also demonstrate the general conclusion that the seasonal and local composition of fin whales in the northern part of the North Pacific is rather elastic and it needs further accumulation of materials before any conclusions are obtained. I would treat the problem in the coming report in future.

School of fin whales. The school of fin whales are also examined according to the observation of operations and whale marking cruises. Examples both in the Antarctic and the North Pacific are given in Tables 41 and 42, The single swimming and pair swimming fin whales are dominant in May, and schools consist of more than three fin whales are rather few in number. With the proceeding of the month, single fin whale become scarce and the rate of schools consisting of two and three fin whales become dominant. This fact seems to show fin whales of the early migration make couple or trio in the feeding grounds. There may be another explanation that the school consisting of more than two whales may migrate in the feeding ground later or the single whale comes earlier. I would consider, however, the former explanation is probable according to the other observation by Japanese expeditions. In the Antarctic waters, Japanese whale marking cruises observe the number of fin whales in a school as described in Table 41. As these marking observations have been carried out in advance of the commencement of the catch of baleen whales, the results demonstrate the predominance of a single and couple swimming fin whales alike in the northern Pacific waters.

TABLE 41. NUMBER OF FIN WHALES IN A SCHOOL OBSERVED BY JAPANESE AND NORWEGIAN WHALE MARKING CRUISES IN THE ANTARCTIC WATERS FROM 1955 TO 1958

Cruise	Number of whales in a school									
	1	2	3	4	5	6	7	8	9	10
Konan maru No. 12	25	12	5	1	1	1	1	—	—	—
Seki maru No. 16	27	24	10	4	10	3	1	3	0	2
Fumi maru No. 17	56	4	2	1	1	2	1	—	—	—
Kyo maru No. 5	3	6	2	2	2	—	1	—	—	—
Enern	22	34	19	7	5	2	1	—	—	—

TABLE 42. NUMBER OF FIN WHALES IN A SCHOOL IN THE NORTHERN PART OF THE NORTH PACIFIC, OFF WATERS OF KOMANDORSKII ISLANDS

	Number of whales in a school								
	1	2	3	4	5	6	7	8	9
May	58	64	18	5	7	1	1	—	—
June	135	190	64	14	6	4	—	—	—
July	40	86	49	10	6	—	—	1	—
Aug.	26	78	44	5	4	—	1	1	1

TABLE 43. COMPOSITION OF SCHOOLS OF DIFFERENT SPECIES, BLUE AND FIN WHALES OBSERVED BY JAPANESE WHALE MARKING CRUISES IN THE ANTARCTIC FROM 1957 TO 1958

	Blue	Fin	Blue	Fin	Blue	Fin	Blue	Fin	Blue	Fin
Number of whales	1	1	1	3	1	4	2	4	2	Ca 10
Estimated length of whales in feet	62	71	72	63-65	80	65-67	73	64-65	60	70
Total number of whales in a school	2		4		5		6		Ca 12	

The result by 'Konan-maru No. 12' and 'Seki-maru No. 16' were obtained in 1955 to 1956, which shows the rather related tendency. But that by Fumi-maru No. 17 in 1956-57 clearly shows the excessive predominance of single swimming fin whales. These facts also seem to suggest the coming time of fin whales to the Antarctic waters. In the whaling season 1956–57, the whaling operation observed the late coming of fin whales in the Antarctic area of VI and I. The catch result illustrated in Fig. 43, also endorses the fact. The next season in 1957 and 1958, fin whales come earlier to the Antarctic area I and VI as given by the same Fig. 43. The exact observation on the constitution of fin whales is, however, only given by a catcher boat 'Kyo-maru No. 5' on which I was board. The data are so few that I can not draw any definite conclusion here, but I would consider the single swimming fin whale is dominant in the earlier time of the Antarctic summer according to other observation throughout the season,

The interesting fact that fin whales make a school with other blue whales have also been observed in the Antarctic. I noticed five schools consist of blue and fin whales. The estimated size of whales' body gives us the impression that comparatively small blue whales swim along with the moderate fin whales. The number of blue whales are always the same or less than that of fin whales as described. The smaller size immature blue whales may not have special characteristics of species, and migrate along with the fin whales of different species. The fact will add something to the consideration of 'balance of whales' that the strength of each species will develop especially after the attainment of the sexual maturity.

Diatom infection. Hart (1935), Karcher (1940) and Omura (1950, a) consider that the whales with heavy diatom infection must migrated to the Antarctic waters earlier than those without the infection, and the habit of making school in fin whales is a favorable infectious condition for diatom films. The main parasitic species of diatom infection is *Cocconeis ceticola* Nelson both in the Antarctic and in the North Pacific. As *Cocconeis ceticola* has not been found among planktons and on other things than the skim of whales, *Cocconeis ceticola* is considered the real parasitic diatoms and not holophitic. The variation of *C. ceticola* varies according to the host species of whales (Nemoto, 1958). With regard to the other species of infections diatoms, *Stauroneis*, *Navicula* and *Gomphonema* diatoms are considered to be real parasitic diatoms. But these species will not indicate the migration course or stage of whales in migration so satisfactory as *Cocconeis ceticola* (Nemoto, 1956).

The whales with heavy diatom is considered to migrate to the high latitudes of cold waters earlier than those without the diatom infection or have a chance to be infected. But the chance of being infected by diatoms is not so common for every fin whales. This mean the case that fin whales early migrated to the high latitudes have not been infected by the diatom patches, and the late comer which has the direct chances of infection bears heavy diatom patches.

Examples for these propagation of *Cocconeis ceticola* and the migration of fin whales in the northern part of the North Pacific are summarized as follows.

1, In 1952, the percentage of infection shows the minimum degree in the late and middle of the August when the ratio between body length and thickness of blubber also decreases mostly. This would indicate the migration of lean fin whales of new coming to the waters.

2. In 1953, the same tendency that the number of fin whales with heavy diatom infection vanish in the late of August, and the whales with heavy diatom infection have thick blubbers in general. But in the early season of May and June, fin whales without diatom patches also have rather thick blubbers.

3. In 1954, the whaling operation had covered the broader area. And the result obtained in the year shows that the fin whales caught in the north waters of the eastern Aleutian Islands demonstrate the high percentage of infection, and no decrease in the late of August. In the south waters of the eastern Aleutian Islands, the infection percentage is very low in May and rapidly increase with the advance of seasons in June and July.

After July, the percentage of infection is higher in the eastern waters than in the western waters.

4. The infection percentage in 1955 is comparatively higher from the early season of whaling, and fin whales in the north waters of the eastern Aleutian Islands show no difference from those west waters in the infection percentage. And there is no seasonal change throughout the season.

5. In 1956, the diatom infection percentage is also higher among the whales in the north waters of the eastern Aleutian Islands. The infection percentage of diatoms increase with advance of the whaling season, but the decrease of number of fin whales with heavy diatom infection is also observed in August.

As a probable conclusion, fin whales come to the Aleutian waters from May, and many fin whales migrate to the waters by July. The school of fin whales are feeding on the food planktons and make northward movements. If the food become scarce in sometimes, whales move to other waters at once. The decrease of number of whales with heavy diatom infection in the off water of Kamtchatka Islands in August may be due to the change of migration of whales owing to the scarcity of food planktons as I said in the former part. In the north waters of the eastern Aleutian Islands, the food is comparatively much and fin whales are congregated in the waters throughout the summer season. Thus it is considered that the high percentage of diatom infection is obtained. The school of fin whales with heavy diatom infections will indicate the difference of the stage of movement for feeding from those with few diatom infection.

In the Antarctic waters these observations of diatom infection by Japanese investigations also have been carried out and the results have been published in former reports (Omura, 1950 a, etc.). I found very characteristic tendency that the fin whales which had been feeding for long time in the definite school were infected with heavy diatom films.

The school of fin whales caught at the waters of B whaling ground in the left figure of Fig. 46 in 1958, and those whales were considered to feed on 1 year group of *Euphausia superba* for a long time, as fin whales caught in the near waters were different in the stage of diatom infection. Some of the latter school of fin whales lacked completely the diatom infection. Other biological characters such as the thickness of blubber endorse the above suggestion. So it is very important to treat the diatom infection on whales in the Antarctic separately in each whaling ground. The summarizing of the data may cause very elastic conclusion.

Thus the infection of *Cocconeis ceticola* indicates the stage and condition of migrations of baleen whales to some extent, but the following point should be considered to get the more definite conclusion.

a. As the observation on the diatom is made by the naked eyes infection, it is not so stable that the data of stage of infection may be uncertain in some cases.

b. It is not certain that *Cocconeis ceticola* propagates on the body surface of whales from spore or a cell in what speed. On the point, Hart (1935) considers it takes about a month that the diatom film propagate on the surface of the body of whales by observations of sei whales in the waters of South Georgia. But I would consider that the time is shorter than a month by other observations on the propagation of marine diatoms.

c. The seasonal prosperity and decay may be observed also among the propagations of parasitic diatoms. The height of the propagation of diatoms is considered in spring and autumn in the sub-Arctic and Antarctic waters, but the height is concentrated in the summer in the high latitudes. The fact would indicate the decrease of infection percentage in the middle of the season in the comparatively lower latitudes.

d. The chance for the infection of *Cocconeis ceticola* is not similar for each school of whales. For example some whales without diatom infection have very fat body with heavy thickness of blubber. On the other hand very lean whales with new half healed open pits sometimes bear diatoms infections.

e. The diatom film of dead *Cocconeis ceticola* is also found on the body surface of whales, which is very difficult to be observed. The case show a indication of probable decrease of the infection percentage in the latter part of the propagating season.

f. In the adjacent waters to Japan, the diatom infection is only observed on fin whales in high percentage in the Okhotsk sea, and whales in other waters show very few infection of diatoms. As the towing of whales in the long run cause the coming off of diatom films completely, and above fact is apparently due to the long towing of whales, because the whaling ground in the Okhotsk sea is comparatively near the land-station, but those of other waters is in the off waters.

SUMMARY

The present paper is described mainly on Japanese investigation on whales both in the Antarctic and in the North Pacific after the year 1945. And two subject of food of baleen whales and the movement of whales are discussed, but the biology of food planktons is omitted in this paper. The essential points are described follows.

1. The feeding apparatus of baleen whales and preferences for foods are discussed. Baleen characteristics such as number, shape and fringe of plates are examined according to former published reports and the preserved specimens. These characteristics show the four types. Those are blue whale, sei whale, right whale and gray whale types. The type of sei whales is included in blue whale type in one point, but is also included in right whale type in another point.
2. The summarized description on head, mouth, tongue and ventral grooves of whales body is described in order to get the comprehension of feeding of baleen whales. These body structures are also divided into above four types.
3. The Antarctic large baleen whales feed heavily on *Euphausia superba*. But blue and fin whales also feed on *Thysanoëssa macrura* in the waters of former sanctuary. Sei whales take *Parathemisto gaudichaudi* favorably, but other blue, fin and humpback whales never take it as a main food. Fish and squids are considered to bear no importance for baleen whales in the Antarctic.
4. Feeding percentage of baleen whales is high in the morning and in the evening in general. The percentage is higher in humpback and blue whales than in fin and sei whales.
5. The growth of *Euphausia superba* described according to the locality and distribution of the pack ice. *Euphausia superba* in the low latitudes or in the early ice melting waters grow more rapidly and in advance

of the late ice melting waters. But there is no difference in the relation between body length and weight of *Euphausia superba* in each locality.

6. The main foods of baleen whales in the northern part of the North Pacific are described with successive investigations after 1956. These are as follows:

Blue whale	euphausiids
Fin whale	euphausiids, copepods, swarming fish
Sei whale	copepods
Humpback whale	euphausiids, swarming fish

7. Five species of euphausiids are found in the stomachs of baleen whales in the northern Pacific. *Euphausia pacifica, Thysanoëssa longipes, T. raschii, T. inermis* and *T. spinifera* are those species.

8. Two copepods, *Calanus cristatus* and *Calanus plumchrus* are also described as main foods of baleen whales. *Calanus cristatus* is important for fin whales and *C. plumchrus* is important for sei whales.

9. Swarming fish, herring, Alaska pollack, capelin, Atka mackerel and saury are fed by fin, humpback and sei whales. A squid, *Ommastrephes sloani pacificus* is sometimes fed by sei and fin whales.

10. There are annual changes among the abundances of foods and the distribution and fluctuation of foods which influence the migration and movement of baleen whales in the North Pacific. These problems are discussed to some extent in the paper.

11. There are 'Calanus year' and 'Euphausiid year', in the adjacent waters to Aleutian Islands and the South Bering Sea.

12. The quantity of stomach contents in the northern part of the North Pacific is examined. Humpback whales usually take more abundant food than sei and fin whales like whales in the Antarctic waters.

13. Along the coast of Kurile Islands, baleen whales also feed on planktons, *Thysanoëssa longipes, T. raschii, T. inermis, Calanus cristatus* and *C. plumchrus*. *Thysanoëssa raschii* in the Kurile waters should be noted. Squids and swarming fish are found in the stomachs of baleen whales and these names are described.

14. Fin whales in the Okhotsk sea feed on mainly euphausiids, *Euphausia pacifica, Thysanoëssa inermis, T. longipes* and *T. raschii.* Little piked whales are also feeding on *Euphausia pacifica* in the coastal waters. Some other fish, sand lance, herring, cod and Alaska pollack are found in the stomachs of both species of whales.

15. In the Japanese main shore whaling grounds in Sanriku and Hokkaido, the food of sei whales are euphausiids, fish and squids. The species of euphausiids are *Euphausia pacifica, Thysanoëssa longipes* and *T. inermis* in the Hokkaido waters, and *Euphausia pacifica* in the Sanriku waters. Among the fish, anchovy, sardin, mackerel and saury are

the most important species. Anchovy is dominant in the early season and saury is dominant in the latter season of the waters. Squid (*Ommastrephes sloani pacificus*) is also important in the Sanriku and Hokkaido waters. Some occurrences of *Calanus* copepods are also suggested.

16. Bryde's whales in the Wakayama waters take a euphausiid *Euphausia similis* and anchovy, and the latter is dominant in June and July. Bryde's whales in Bonin water take also *Euphausia similis* and *Euphausia recurva*, Myctophid and Gonostomid fish (*Yarrella microcephala* and *Myctophum asperum*). In the catch of probable sei whales from December to April, the occurrence of some copepods is considered.

17. In the East China sea and west Kyushu area, fin whales feed on a euphausiid *Euphausia pacifica*. Bryde's whales caught along the west coast of Kyushu feed on anchovy and horse mackerel dominantly.

18. Foods of baleen whales in the other part of the world are described according to published papers. The foods of baleen whales in the subtropical waters and the North Atlantic need further investigations.

19. Basing on the data of stomach contents of baleen whales, the distribution of euphausiids is discussed. New consideration on the distribution of the spineless form of *Thysanoëssa longipes* and one and two spine form of *Thysanoëssa inermis* is suggested.

20. Feeding habit of baleen whales is examined. Swallowing and Skimming types are considered as feeding types of baleen whales. Blue, fin, Bryde's, little piked and humpback whales are Swallowing type and right and Greenland whales belong to Skimming type. Sei whales take above two feeding methods in general.

21. These feeding types of baleen whales show some effect on the selection or preference for their food. These subjects are discussed and the examples are given in the paper. The favourite food of baleen whales differ in the local waters, in each whale species, and there are selection orders among foods. These feeding types are described on each species.

22. Food patchs also have characteristic features, which affect the feeding of baleen whales. The congregation, diurnal migration and inhabiting depth of food planktons and fishes are the main factors to have relations to the feeding habits of whales.

23. Feeding activity is considered to be active in the morning and in the evening in baleen whales of euphausiids feeder. In the shallow water regions, the feeding activity is still high in the daytimes. Squids are also fed mostly in the morning and in the evening, but *Calanus plumchrus* is fed still in daytimes at the surface of the sea.

24. The exact weights of the stomach contents of fin whales are obtained in the northern part of the North Pacific. Fin whales take foods

about 100 kg to 700 kg in the full stomach condition in the North Pacific. Bryde's whales also take foods from 100 to 200 kg in the adjacent waters to Bonin Islands and sei whales take foods from 100 to 400 kg in the Kurile Island waters.

25. The distribution of baleen whales in the North Pacific is discussed considering the catch of each whaling center and the shape of the sea. Baleen whales migrate and distribute in the sea according to the shape of the sea. These distributional types are 'ocean denizen' (blue, sei and Bryde's whales), 'ocean and marginal sea denizen' (fin, right, little piked and grey whales) and marginal sea denizen (Greenland whale). Some oceanographical conditions are examined to make general comprehension of the distribution of baleen whales and special characteristics of whaling grounds.

26. Migration and movement of sei and Bryde's whales are examined and discussed by the catch statistics and whale marking research. The migration and the movement of Bryde's whales cover tropical, subtropical and warm temperate waters more than 20°C and never go down to waters under 15°C.

27. Sei whales are considered to be also warmer water species than other blue, fin and humpback whales. The movement of sei whales in the adjacent waters to Japan has close relation to the oceanographical conditions and the distribution of their foods. The probable segregation in the composition of migrational herds of sei whales is suggested both in the Antarctic and in the North Pacific.

28. Seasonal movement and distribution of fin whales in the North Pacific are discussed basing on the data of the food distribution and catch statistics. The clear movement of fin whales in the northern part of the North Pacific following the favorable feeding area is described. A local group of fin whales in the east China sea, which does not migrate to the higher latitudes is suggested by the catch statistics and other biological characters.

29. The results of Japanese marking research on fin whales in the northern part of the North Pacific are examined in view of the seasonal movement. The term 'dispersive movement' is used and discussed to describe the movement of fin whales in the northern part of the North Pacific. But the marking research in the waters needs further investigation to reach the definite conclusion.

30. The segregation in the migration of fin whales is examined by sex, age, pregnancy and maturity of whales and physical condition of whales, and those physical factors have close connection with the migrational segregation of whales in the feeding area.

31. The diatom infection is examined to study the migration of whales,

and it is considered not to show the typical indication of the stage of migration, but the infection shows some indication about the migration of whales.

32. It is desirable to accumulate the further collection of data on foods of whales and the whale marking research to get the definite information of whales' migration. And it is hoped to examine foods of baleen whales in many localities of whaling grounds in the world in connection with the oceanographical conditions for some years.

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APPENDIX I. JAPANESE MARK RECOVERY FROM FIN WHALES IN THE NORTHERN PART OF THE NORTH PACIFIC

Mark	Body length	Sex	Date marked	Date recovered	Position marked		Position recovered		Year group
4266	62	F	1954–7– 7	1954–7– 8	54–29N	166–10W	54–35N	165–45W	0
4725	59	M	〃 8–11	〃 8–24	54–08N	166–55W	53–55N	167–36W	0
4270	63	F	〃 7– 7	〃 9– 2	54–29N	166–10W	54–09N	167–17W	0
3369	65	M	〃 8– 6	〃 9– 6	53–30N	169–50W	54–00N	167–40W	0
4802	65	F	〃 8–11	〃 9–13	54–01N	167–03W	53–40N	167–27W	0
4684	61	F	〃 8–11	〃 9–13	54–08N	166–55W	54–10N	166–56W	0
4560	59	M	〃 9–21	〃 9–22	54–22N	165–44W	54–13N	166–43W	0
4658	58	F	〃 8–10	1955–7– 6	54–10N	166–58W	54–31N	166–23W	1
4516	61	M	〃 9–13	〃 7–17	54–20N	166–21W	54–30N	171–02W	1
4451	56	M	〃 8–10	〃 7–22	54–18N	166–40W	54–11N	169–30W	1
4281*	?	?	〃 7– 7	〃 7–14–22	55–09N	165–47W	?	?	1
4604	61	M	〃 9–11	〃 8– 1	53–46N	168–10W	54–45N	171–50W	1
4543	66	F	〃 9–13	〃 8– 2	54–20N	168–11W	54–32N	170–55W	1
J 5966* J 5968*	58	M	1955–7–18	〃 9– 2	54–06N	167–04W	54–30N	167–20W	0
J S 6989	?	?	〃 9– 3	〃 9– 8	53–44N	168–08W	?	?	0
J 6050	56	M	〃 9– 8	〃 9– 9	53–37N	164–57W	53–42N	165–04W	0
J S 7000*	?	?	〃 9– 8	〃 9– 9–10	53–37N	164–57W	?	?	0
4641	60	M	1954–8–10	〃 9–16	54–10N	166–58W	55–22N	167–34W	1
J 6060* J 6061*	?	?	1955–9–12	1956–6–18	54–15N	169–56W	?	?	1
3243	55	F	1953–6–23	〃 6–23	50–25N	170–22E	53–14N	168–33E	3
J S 7002	58	M	1955–9– 8	〃 7–12	53–37N	164–57W	54–37N	165–45W	1
4267	63	F	1954–7– 5	〃 7–13	54–16N	160–10W	54–32N	165–55W	2
3213	63	F	1953–5–12	〃 7–25	51–16N	177–50E	54–02N	170–31W	3
4552	62	F	1954–9–19	〃 7–25	54–08N	167–45W	54–50N	169–54W	2
4461	59	M	〃 8–29	〃 7–31	54–38N	165–44W	54–32N	166–28W	2
J 6042	64	F	1955–9– 7	1957–5–19	54–08N	166–51W	52–18N	162–38E	2
J S 6987	62	M	〃 9– 3	〃 6–20	53–42N	167–17W	49–53N	167–20W	2
J 5995	65	F	〃 8–11	〃 7– 2	52–49N	175–16W	49–48N	168–12W	2
J S 7269*	?	?	1957–6–10	〃 ?	55–47N	169–04W	?	?	0
4558	62	M	1954–9–19	〃 7–12	54–08N	167–45W	54–15N	169–50W	3
J S 6939	64	F	1955–8–10	〃 7–18	53–24N	173–05W	55–19N	169–55W	2
J S 6923	64	F	〃 7–28	〃 7–26	56–36N	173–00W	59–58N	176–46W	2
J 5979	58	M	〃 7–29	〃 8– 5	59–20N	176–25W	59–48N	177–58W	2
J 6511*	?	?	1957–7– 8	〃 8– 8	59–05N	176–06W	?	?	0
J 6506	?	?	〃 7– 6	〃 8–11	56–62N	170–45W	?	?	0
J S 7720	66	F	〃 7–19	〃 8–24	55–37N	168–35E	53–49N	170–10E	0
J 6834	61	M	〃 9–11	1958–5–27	54–49N	167–04W	52–00N	171–26E	1
J S 7026	62	M	1955–9–15	〃 7– 3	54–33N	166–10W	53–34N	170–45W	3

APPENDIX I. (Continued)

Mark	Body length	Sex	Date marked	Date recovered	Position marked		Position recovered		Year group
J 6837 J 6831	58	M	1957-9-11	1958-7- 3	54-48N	167-04W	53-42N	169-54W	1
J 6815	60	F	〃 9-10	〃 7- 4	54-40N	168-47W	54-11N	170-31W	1
J 6264	56	M	1956-9- 4	〃 7- 7	54-15N	166-55W	55-56N	169-09W	2
J 6843	56	F	1957-9-11	〃 7- 8	54-48N	167-09W	54-21N	166-49W	1
J 6829*	?	?	〃 9-11	〃 7- 8	54-48N	167-04W	?	?	1
J S7745	62	M	1958-6-24	〃 7- 8	54-29N	166-43W	54-49N	166-28W	0
J 6801 J 6802	58	F	1957-9-10	〃 7-11	54-41N	168-41W	54-28N	169-44W	1
3391	64	M	1954-8- 6	〃 7-11	53-24N	169-55W	54-23N	169-30W	4
J 6804*	?	?	1957-9-10	〃 7-11	54-40N	168-47W	?	?	1
J S7243*	?	?	〃 6- 3	〃 7-11	54-26N	160-50W	?	?	1
J 6859*	?	?	1958-6-17	〃 ?	50-37N	168-33W	?	?	0
J 6149	?	?	1956-7-18	〃 ?	54-42N	159-25W	?	?	2
J 6799	59	M	1957-9-10	〃 7-16	54-30N	168-50W	50-53N	170-10W	1

* These marks are found in cooker or refrigerator ship and the exact position of recovery is unknown but estimate data are obtained.

APPENDIX II. JAPANESE MARK RECOVERY FROM SEI AND BRYDE'S WHALE IN THE NORTH PACIFIC

Mark	Species	Body length	Sex	Date marked	Date recovered	Position marked		Position recovered		Year group
0876	*	41 ft	M	1950-5-21	1950-5-22	27-14N	144-14E	27-10N	144-00E	0
0916	*	42	F	〃 5-21	〃 5-22	27-17	144-08	27-15	144-03	0
0781	*	43 or 39	F	〃 5- 8	〃 7-15	26-43	142-40	Ca37-02	Ca143-02	0
1772	*	44	F	1951-5-15	1951-5-27	25-35	143-45	25-47	143-40	0
2058	*	44	M	〃 8-23	1952-7- 6	41-33	147-32	38-31	144-16	1
0910	*	44	F	1950-5-21	〃 8-21	27-24	144-23	37-51	143-22	2
2675 2687	*	43	F	1952-9- 2	〃 10-21	38-46	149-25	38-24	142-26	0
0086	*	47	F	1949-7-21	1953-6-25	39-15	149-36.5	38-42	143-34	4
3826	*	45	F	〃 7- 9	1953-7-10	42-27.5	148-32	42-37	147-57	0
3782	*	43	F	〃 7- 7	1953-9-12	42-19.3	149-37.5	38-55	145-37	0
3823	*	42	M	1953-7- 9	1955-7-10	42-27.5	148-32	40-17	147-43	2
2761 2762	*	40	F	1952-9- 7	〃 8- 8	40-15	150-01	41-26	145-53	3
2769 2770	*	50	F	〃 9-11	1955-9-15	43-08	147-54	42-26	146-28	3
3027 3043	*	47	F	〃 9-12	〃 9-17	43-54	149-05	43-07	147-21	3
2691 2692	*	47	M	〃 9- 3	〃 9-25	39-33	153-17	41-07	147-59	3
1365	*	42	M	1950-9- 7	1956-7- 9	40-10	155-50	44-53	149-30	6

APPENDIX II. (Continued)

Mark	Species	Body length	Sex	Date marked	Date recovered	Position marked		Position recovered		Year group
2852 2853 2854	Sei	46	F	1950-9- 5	1957-8- 5	39-25	155-32	39-30	144-01	5
3042	Sei	42	F	〃 9-12	〃 9-17	43-54	149-05	42-10	149-30	5
2819	Sei	45	M	〃 9- 4	1958-6- 4	39-27	154-02	37-33	145-30	6
0775	Bryde's	42	F	1950-5- 8	〃 8-10	26-43	142-40	38-10	145-20	8
3783	Sei	45	F	1953-7- 7	〃 9-29	42-19.7	149-26	41-24	145-03	5
2271	Bryde's**	44	F	1952-6-29	1959-7- 9	25-08	142-06	33-46	136-38	7
2334	Bryde's**	41	M	〃 7- 1	〃 7-21	26-28	142-35	32-45	136-26	7
4196	Sei	47	F	1954-6-13	1958-7-22	53-26	163-22W	49-58	177-49W	4
4201	Sei	?	?	〃 6-13	〃 7-12	53-26	163-22W	Ca50-00	Ca178-00W	4

* These whale species are sei or Bryde's whales, but exact examination has not been made at their flensing.

** These marks are found after completion of the paper, which clearly show the migration of Bryde's whales from Bonin Islands to Oshima, Wakayama prefecture.

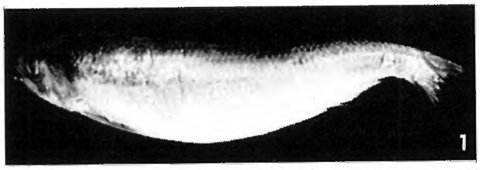
EXPLANATION OF THE PLATE

Showing the relative size of each foods of baleen whales

Upper: Food fish from stomachs of baleen whales in the northern Pacific. Fig. 1—Herring from a stomach of a fin whale in the waters off Cape Navarin. Fig. 2—Alaska pollack from a fin whale in the Bering sea. Fig. 3—Saury from a sei whale in the waters off Kamtchatka. Fig. 4—Atka mackerel from a humpback whale in the adjacent waters to the Near Islands. Fig. 5—Capelin from a fin whale in the waters off Navarin. Fig. 6—Alaska pollack from a fin whale caught in the waters in the middle of Bering sea. Fig. 7—Atka mackerel from a fin whale in the waters of Near Islands. Fig. 8—Mackerel from a sei whale in the waters adjacent to Japan. Fig. 9—Anchovy from a sei whale in the waters adjacent to Japan. Fig. 10—*Myctophum asperum* from a Bryde's whale in the Bonin Islands waters. Fig. 11—*Yarella microchephala* from a Bryde's whale in the Bonin Islands waters.

Middle: Food planktons in the North Pacific. Figs. 1 & 2—*Thysanoëssa inermis* from a stomach of fin a whale in the Bering sea. Figs. 3 & 4—*Thysanoëssa longipes* from a fin whale in the waters off Kamtchatka. Fig. 5—*Euphausia pacifica* from a fin whale in the waters adjacent to the Near Islands. Fig. 6—*Thysanoëssa longipes* from a fin whale in the south waters adjacent to the eastern Aleutian Islands. Fig. 7—*Euphausia pacifica* from a fin whale in the East China sea. Fig. 8—*Thysanoëssa longipes* from a blue whale in the south waters adjacent to the eastern Aleutian Islands. Fig. 9—*Calanus cristatus* from a fin whale in the waters off Kamtchatka. Fig. 10—*Calanus plumchrus* from a sei whale in the south waters adjacent to the eastern Aleutian Islands.

Lower: Food planktons in the Antarctic waters. Figs. 1, 2, 3 & 4—*Euphausia superba* of 2 years group. Figs. 5, 6, 7, 8, 9 & 10 *Euphausia superba* of 1 year group. Figs. 11 & 12—*Thysanoëssa macrura*. Figs. 13 & 14—*Parathemisto gaudichaudi*.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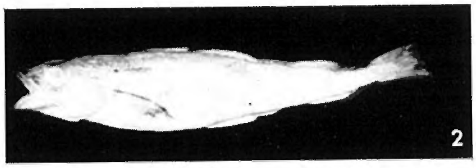
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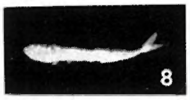
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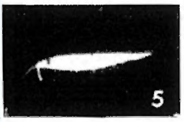
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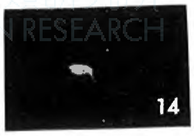
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5 cm

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OSSEOUS LABYRINTH OF CETACEA

MUNESATO YAMADA* AND FUMIHIKO YOSHIZAKI*

Since as early as the eighteenth century, the cetacean labyrinth has been referred to by the pioneers of comparative anatomy including Cuvier, Monro and v. Baer. But it was not until 1789 that Monro and Comparetti discovered the disproportionately minute semicircular canals, apparently one of the most important peculiarities in the cetacean ear. However, the author who first took out the cetacean labyrinth by means of cast preparation was probably Rapp (1837), and this monograph was followed by a fascinating one by Hyrtl (1845) which also dealt with a number of cetacean species. Gray (1907–08) was another who ingeniously prepared and described the membranous labyrinth of vertebrate animals also including some cetaceans.

The present investigation was attempted with the initial intention of affording fundamental data and knowledge towards a histological research proposed by the senior author (Yamada). His impression is that the previous records do not help the intended purpose. This applies not only to the cetacean labyrinth alone but to general labyrinthine anatomy including man and the so-called experimental animals. This is because the criteria of the measurements, for instance, are not always clear, and also because something else had to be contrived in order to present its morphology as such. The present paper was first read in 1957, and incidentally, it became more than a mere presentation of the cetacean varieties. This work has become a starting point so that in fact some novel data and propositions have been developed with the aim to standardize the sectioning and indexing of the human labyrinth (Yamada, 1959).

MATERIAL AND METHOD

Material of the present investigation consists of sixteen species from fourteen genera representing the two suborders of Cetacea as follows:

Mystacoceti or Whalebone whales	1 *Balaenoptera* (three species); 2 *Megaptera*; 3 *Eubalaena*;
Odontoceti or Toothed whales	4 *Physeter*; 5 *Kogia*; 6 *Berardius*; 7 *Ziphius*; 8 *Globicephala*; 9 *Grampus*; 10 *Feresa*; 11 *Lagenorhynchus*; 12 *Delphinus*; 13 *Prodelphinus*; 14 *Neomeris*.

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Labyrinths of each of the above species were cast in a small number of specimens but in many cases in one example only. The findings on these casts were supplemented in some instances by the direct method, in which direct access was made to the labyrinthine interior by grinding the bone with dental engine or lathe. Such a small number is obviously far from sufficient in order to discuss the specific characteristics, but altogether they accumulate a good sum of findings so that the cetacean labyrinth may be considered as a whole.

One each specimen of *Delphinus* and *Lagenorhynchus* perioticum came from Prof. Ogawa's collection, and *Megaptera* came from the Antarctica by courtesy of Mr. G. Tandai. The authors acknowledge their great indebtedness to the above donators.

Cast specimens were made by use of acrylic resin in a way not very unlike the dental routine. After complete maceration and rinsing, the whole or part of the perioticum, depending on the size, is embedded in an investment flask within gypsum plaster. Plaster should be made in separable strata of base, so that the bottom seizes the bone capsule and the upper negative can be detached. As the resin paste is made to permeate into the labyrinthine lumen through the openings, such as two each of fenestrae and aquaeducts and the internal acoustic meatus, these openings should be so placed as to line up and open in the demarcation of the two plaster bases.

After these preliminary procedures, a proper amount of resin paste is squeezed into the lumen by pressure of a screw press. The plaster bases tightly encapsulate the bone and thus prevent the raw resin from leaking out when the flask is pressed. However, this moulding technique is a matter of considerable difficulty. This is followed then by polymerization as indicated, and the cast is taken out. To remove the petrous tissue of the perioticum, 5% nitric acid is applied. Ordinary alkali solution has no effect, especially in the case of Odontoceti perioticum. As the semicircular canals are generally so minute, cast of these by alloy either of Wood or Lipowitz hardly survives such decalcification, although alloy is really wonderful material for casting purposes.

However, resin cast is easy to examine, and this advantage may be enhanced when the transparent resin is used, because it renders, for instance, the lamina spiralis well visible if they remain encapsulated within the cast specimen. Another advantage of the transparent resin may be well appreciated in the stereographs (Pls. I–III).

Measurement was made exclusively under microscope or according to microscopical drawing of low magnification. By such drawing, the method of which is to be briefly described, perfect parallel-ray-projection is attained. A specimen is observed under microscope and is traced along its contour by an intersection of a crossline plate, or preferably a net micrometre plate, which is incorporated within the micrometre eyepiece. Now that the intersection is fixed this is attained by shifting the specimen horizontally with the mechanical stage. The contour is thus plotted on graph paper as loci of nonius readings of the mechanical stage at a convenient magnification, for example 10× or 20×. The most important advantage of this method is that the drawing is rendered absolutely free from any optical distorsion or perspective. This is because all the points are read on one definite axis within the optical system. The use of verniers limits the errors within the order of one tenth of a millimetre. Besides, no danger of destroying the specimen by touch is incurred, which is otherwise by no means avoidable.

Measurement of the cochlear canal length was made according to a map, which is composed of a sequence of subdivided drawings. In order that each successive portion to be drawn may be placed horizontally under microscope, a special holder was designed in the ball-and-socket principle. Any portion of the specimen may in this way be evenly focused by an adequate tilting of the holder. A small amount of modelling compound used for dental purposes has proved suitable for fixing a specimen onto the holder.

Photography was made in all instances with a Leica, screwed on an arm vertically adjustable, and 135 *mm* objective at a fixed bellows extension 1:1. For stereo-photography (Pls. I–III), a special semicylindrical holder was designed in order to rotate the specimen. A couple of photographs taken before and after an adequate angle of rotation make a stereo. The specimen was water-immersed.

SIZE AND GENERAL NOTE

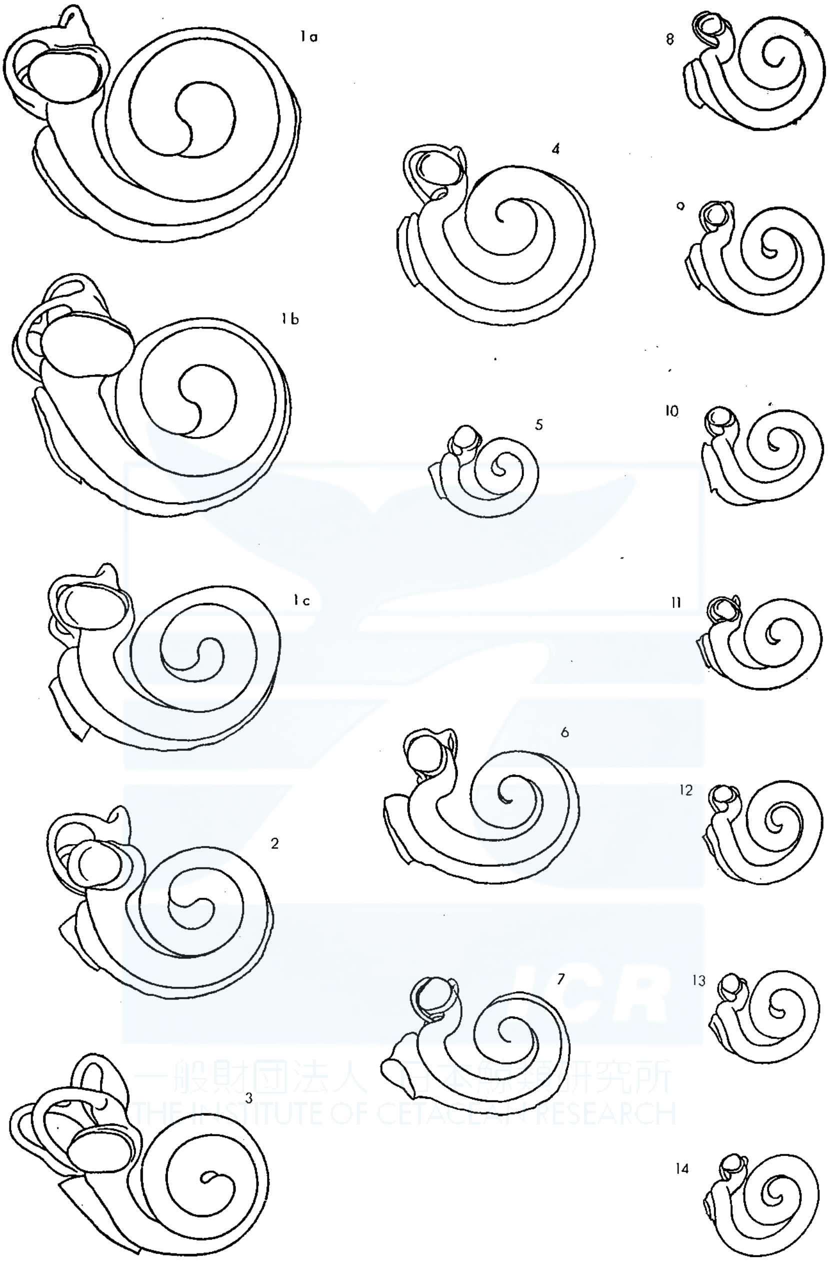
Text-fig. 1 illustrates the labyrinths of all the species examined at uniform 1.5× magnification. It is self-explanatory, and therefore no figures are given, for a common measuring criterion is rather difficult to set up. At any rate, the size of labyrinth corresponds roughly, except in the case of Physeteridae, with the body length of the species concerned. For instance, that of *Balaenoptera musculus*, the greatest creature which ever lived on earth, is the biggest, whereas *Kogia* possesses the smallest one. Thus a special remark may be made that the two genera belonging to Physeteridae possess labyrinths of reduced size in comparison with the body length.

Remarkable cetacean peculiarities are generally seen. The flat type of cochlea is observed to have a rather small number of turns. The whorl pattern is unusually robust and loose, and the vestibule and semicircular canals are disproportionately minute. Closer examination and comparison reveal however, that a rough division may be made according to the taxonomic position of each whale species. As regards the whorl pattern of the cochlea, for instance, they may be divided in four categories as: 1) Balaenidae, 2) Balaenopteridae, 3) Physeteridae-Ziphiidae and 4) Delphinidae. The labyrinth of *Eubalaena* (Balaenidae) is so different and non-cetacean that for the sake of convenience and emphasis the species will be discussed as a separate matter at the end.

COCHLEA

The number of cochlear turns has been a main topic of interest in labyrinthine morphology, and it more or less exceeds two in Mystacoceti, with an exception of *Eubalaena*, in which it is two and a half. In Odontoceti on the other hand, it is slightly below two. The authors do not intend to enter into more details because they are not inclined to ascribe to the number of turns such a significance as has commonly long been attributed to them. This is because the criteria are again not easy to set up. The authors are inclined rather to put the matter in the hands of those who are interested in the question, and actually they can find out as they wish from the diagrams of Text-fig. 1.

As a matter of fact, whorl radius decreases as the cochlear canal goes from the vestibular extremity up towards the apex. The rate of



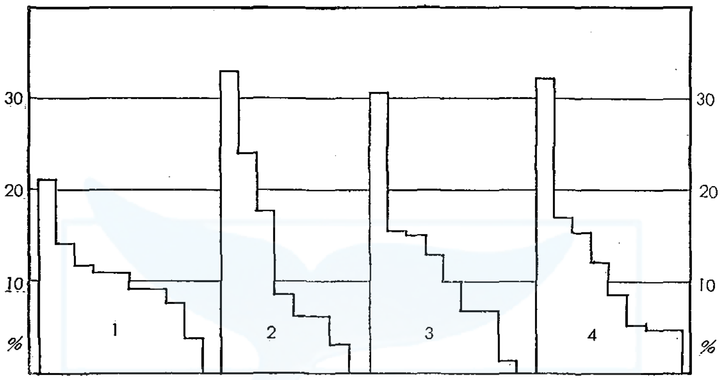
Text-fig. 1. Cast specimens of cetacean labyrinths (1.5×). The modiolus of cochlea is situated upright in all the drawings so that the number of turns of each may be estimated according to the reader's criteria. 1-a. *Balaenoptera musculus*; 1-b. *B. physalus*; 1-c. *B. borealis*; 2. *Megaptera*; 3. *Eubalaena*; 4. *Physeter*; 5. *Kogia*; 6. *Berardius*; 7. *Ziphius*; 8. *Globicephala*; 9. *Grampus*; 10. *Feresa*; 11. *Lagenorhynchus*; 12. *Delphinus*; 13. *Prodelphinus*; 14. *Neomeris*.

such decrease is different from one species to another, namely it is gradual in Mystacoceti and more abrupt in Odontoceti. In Mystacoceti, the apical whorl covers a part of the more basal portion in a way similar to many terrestrial mammals. In its apical aspect, however, Mystacoceti is characteristic. Here a considerable space is unoccupied, embraced by an arc of apical whorl in a form not unlike a large comma, so that whole of the canalicular system within the upper modiolus is exposed as cast. In Odontoceti, on the other hand, neither of these peculiarities occurs. There is no portion of the cochlear canal covered by the other. The portion at the apex coils so tightly that the whorl radius progressively decreases, and in the result there is no space as in the one observed in Mystacoceti. However, space is seen towards the widely expanded base, particularly within the first quadrant of the cochlea. In short, the cochlear pattern of Cetacea is, with the exception of *Eubalaena*, loose in two ways. That of Balaenopteridae is loose on the apex, and that of Odontoceti in the basal portion or in the beginning.

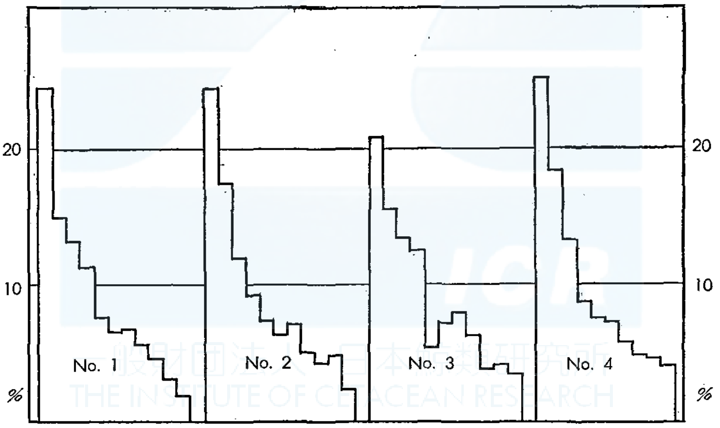
The rate of ascent of the cochlear canal is also different according to species. Delphinidae is among others very unique particularly in the first quadrant of *Neomeris* as is shown in Plate-fig. 10. In addition to the peculiarity as observed in its apical aspect (Text-fig. 1, *14*) that this portion of the cochlea considerably swerves out towards the bottom, left of the reader, it does undulate also up over the round window and down further, and up again. The dètour over the round window is seen in many mammalian cochleae, although it is very conspicuous in Cetacea and especially in Delphinidae. It should be noted that the portion that swerves abruptly inclines from above the round window. The canal also inclines even sideways. It seems natural therefore that the cochlear canal is conspicuously elongated within the first quadrant.

In order to put the matter in a more objective light, the cochlear canal was sectioned by an optical method up into quadrants, and the length of each was measured. The result (Text-fig. 2) reflects clearly, as was expected in advance, the nature of whorl pattern. For instance, the first quadrant of Odontoceti cochlea well exceeds 30% of the total length. Graph of *Physeter* is a regular one, and well represents its regular vorticose pattern. That of Balaenopteridae does not differ greatly from the more common mammalian pattern belonging to the higher type of cochlea. In other words, there are three categories of quadrant graphs, as Balaenopteridae, *Physeter* and Delphinidae. Those of *Kogia* and Ziphiidae do not differ from Delphinidae, and may be included herein.

For a reference purpose, the human cochlea was sectioned in a similar way (Text-fig. 3). It is noticed, in this higher type of cochlea, that occasional irregularities occur in the graphs. The authors are of the opinion, however, that this is due rather to the deviation involved in the measuring procedure than to the actual differences among individuals. It is apparently because the section of cochlea in quadrants involves some arbitrary factors, especially pertaining to the uprightness of the modiolus. In other words, if the modiolus is slightly tilted, the length of some or all quadrants as measured may deviate more or less.



Text-fig. 2. Graphs of quadrant-length of the cochlear canal.
1. *Balaenoptera* (*musc.*); 2. *Physeter*; 3. *Kogia*; 4. *Globicephala*.



Text-fig. 3. Graphs of quadrant-length of the human cochlear canal. Occasional irregularity may not necessarily be the result of individual variation, but probably measuring artefact which is not avoided in the case of higher type of cochlea.

Because of these experiences the authors propose not to put too much weight on the number of turns, especially in a way that according to the sequence of turns a particular locus of the cochlea is mentioned.

In view of the enormous variety of the cochlear pattern ranging from Monotremata to Rodentia, the authors should like to remind the reader of the fact that the cochlea is really nothing but a blind canal system. Its number of turns may be the result of the ultimate length of the canal itself and the space available to invest the organ. Chronological relationships during development in between various tissue components may also influence its final vorticose pattern. The authors thus believe that a particular locus in the cochlea should be indexed by its distance from the vestibular extremity in percentage of the total length. This applies to all kinds of cochlea alike, and is not a question of cetacean ear alone. The senior author actually has published recently some data on its practical application to the human labyrinth (Yamada, 1959).

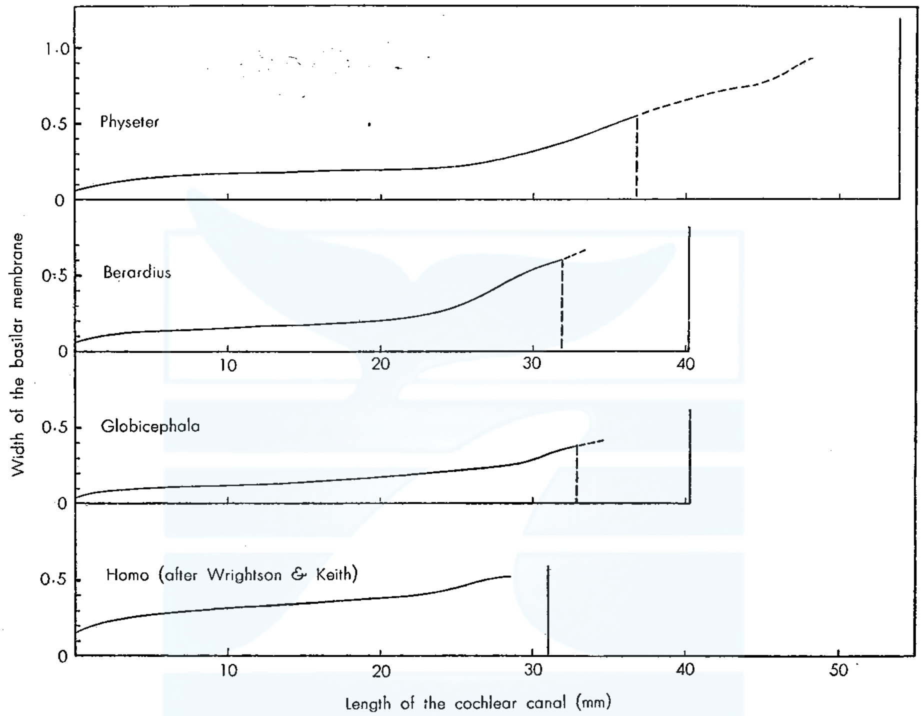
It is observed finally in the apical aspect that the scala tympani is characteristically spacious and exceeds the scala vestibuli in the basal portion of larger cochleae. This is observed in Mystacoceti, except *Eubalaena*, and in Odontoceti representatives such as *Physeter*, *Berardius* and *Ziphius*. There is a noteworthy contrast between the surfaces of the two scalae. That is to say, the scala tympani is rough, whereas the scala vestibuli is smooth. Besides, on the surface of the latter in Odontoceti, stand out radial markings for cochlearis propria arteries.

LAMINA SPIRALIS SECUNDARIA

A trial to estimate the basilar membrane was made by the senior author on macerated material of *Berardius* (Yamada, 1953, Fig. 29). This was possible because the secondary lamina spiralis of *Berardius* develops well in a way that it is situated in the bottom of ligamentum spirale, and therefore, this supports the whole ligamentum, in the range of basal 80% of the cochlear canal, almost to the attachment of the basilar membrane. Therefore, the spiral slit, where it comes out in macerated specimen between the two bony laminae, reasonably corresponds with the actual expansion of the basilar membrane. Later investigation has revealed that this structure is commonly seen in Odontoceti. The width of spiral slit, in other words the width of the basilar membrane itself, increases as it transits towards the apex of the cochlear canal. Width increase of the basilar membrane is a fact very well known in all mammalian cochlea, but there is a peculiarity which may be ascribed to Odontoceti.

Text-fig. 4 shows some examples of such transition as compared with a curve of human basilar membrane after Wrightson and Keith (Fletcher, 1939). Although this is presented according to a histological investigation, these may be compared with each other, and it is noticed that in

Odontoceti nearly half of the canal length is occupied by a very gradual increase of the width, generally in a range of 0.1–0.2 *mm*. This is not the case with the human cochlea, nor with an instance of *Balaenoptera physalus* examined. This slow increase and striking development of the secondary lamina spiralis in Odontoceti may be regarded altogether as morphological evidence supporting our increasing knowledge of the cetacean hearing capabilities, namely that these whales can hear a wider range of frequencies and especially high pitches of sound including ultrasonics (e.g. Kollogg, 1953).



Text-fig. 4. Rate of the width increase of the basilar membrane in Odontoceti representatives, as estimated from the slit between the two spiral laminae. Upper limit of the secondary lamina is also shown (perforated lines), which is 68% for *Physeter*, 79–82% for *Berardius*, and 81% for *Globicephala*. Note over-all similarity of the three, each representing its own family. Curve of human basilar membrane after Wrightson and Keith is for reference. Similar data for Mystacoceti is obtained in too small a range because of the far weaker development of the secondary lamina. Curve of 15% range of *Balaenoptera physalus* falls on that of man. From the macerated specimen no further information is available.

The spiral laminae are delicate but they may be well preserved in some instances as Plate-figs. 4 and 6 show, where they are observed satisfactorily well through the transparent cast material. In many instances however, they are broken and the débris are scattered and give to the cast an ugly appearance (Plate-figs. 7–10).

In Mystacoceti, however, the secondary lamina spiralis is definitely weaker. Reysenbach de Haan (1957) wrote as though there was certain controversy about Mystacoceti cochlea in this particular respect. According to him, similar development of the secondary lamina is seen also in some rodents and Chiroptera, and he expected the same to occur in Mystacoceti also. However, the difference between the two cetacean suborders in this respect is in actual fact definite as stereographs of *Balaenoptera* and *Megaptera* (Plate-figs. 1–2) show it clearly. In one example of *Balaenoptera physalus*, the secondary lamina is to be seen in a much shorter region of no more than 40% of the total length, and the slit measures 0.19 *mm* in width at the vestibular extremity. So far as the basal approximate 15% is concerned, where the slit is expected to coincide with the actual basilar membrane, the width increases in a similar curve like the one of human membrane after Wrightson and Keith (Text-fig. 4).

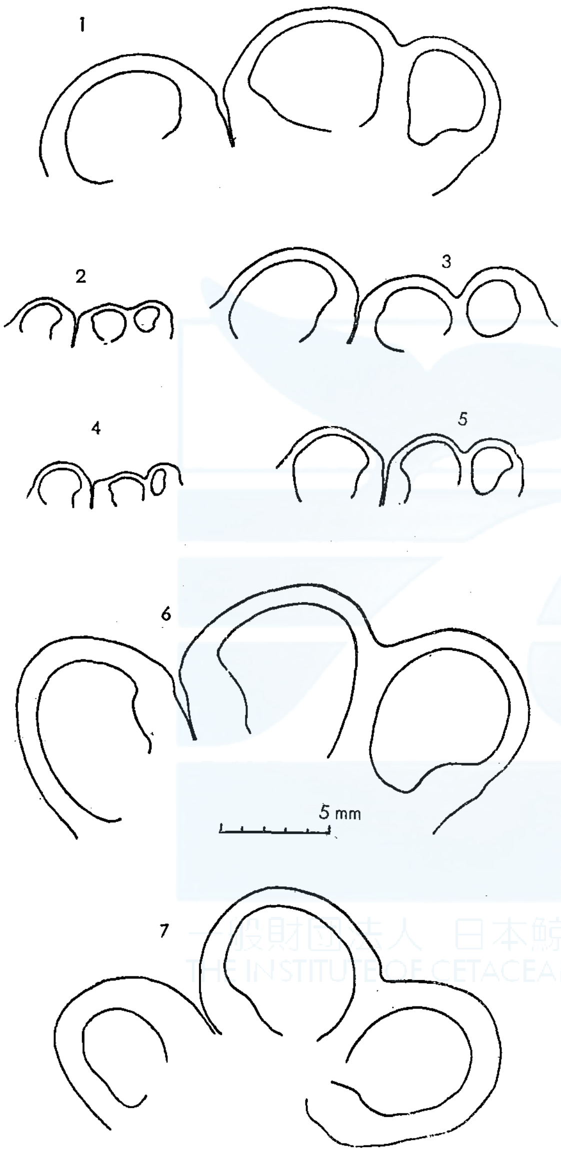
SEMICIRCULAR CANALS

Text-fig. 5 shows some examples of semicircular canals presented in a form comparable with those of the human labyrinth. The canal system is a three-dimensional structure, and it is consequently difficult to illustrate. Text-fig. 5 is, in that sense, a new type of illustration, in which crus simplex of the lateral or horizontal canal is dislocated at the base and the whole canal system is arbitrarily expanded in a single plane. An important advantage of this is probably appreciated that the three canals are put into a better comparison both in form and dimension. It is again self-explanatory to a certain extent.

The size differs roughly in accordance with the body length, and *Neomeris* is the smallest of all. However, dimensions of the ampullae as well as the span of each canal are not exactly proportionate. In other words, in smaller canals the height of arch becomes progressively less and the ampullae relatively greater. It is observed, in histological sections and whole preparations of the membranous labyrinth, that the osseous canals do not directly reflect the actual calibre of the membranous ductus within them. Thus the membranous ductus is relatively thicker in smaller canals.

But the most conspicuous respect of the semicircular canal system of Cetacea is the dimensional relationship of the three. It is noticed generally that the posterior canal is, with the exception of *Eubalaena*, the smallest of the three. In Odontoceti, this is more conspicuous and the lateral canal is, in good contrast with the posterior, the greatest. The superior or anterior canal is the intermediate. This is really striking because in many of the land mammals, either anterior or posterior canal is the greatest, whilst the lateral is always the smallest.

It may be too early to mention from this finding that the horizontal movement either of the head and neck or the entire body is of the most important functional significance in cetaceans. But the authors' impression is that such muscular control as is called upon by the vestibular reflex, originating among others in the lateral canal, may be a unique one which the cetaceans have learned in the long course of evolution to be important in the life under water. Such control might be needed the more in Odontoceti which is generally supposed to be more alert and active.

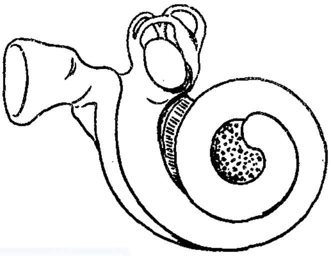


Text-fig. 5. Semicircular canals, arbitrarily expanded. In all the drawings the canals are from left to right: lateral, anterior and posterior. 1. *Balaenoptera* (*musculus*); 2. *Kogia*; 3. *Physeter*; 4. *Neomeris*; 5. *Ziphius*; 6. *Eubalaena*; 7 Man (for reference).

EUBALAENA GLACIALIS; A STRIKING EXCEPTION

Finally special mention should be made of the right whale, *Eubalaena glacialis*. The labyrinth of '*Balaena*' has been described and illustrated only once by Hyrtl (1845) as reproduced in

Text-fig. 6. His illustration was also reproduced in Bolk's *Handbuch der vergleichenden Anatomie* by de Burlet (1934). Gray (1907) was another who mentioned the labyrinth of '*Balaena australis*', but no illustration was given because his specimen of the membranous labyrinth was far from perfect due to the putrefactive changes. However, his comment seems worthy of quotation: "From what could be seen the labyrinth differed from that of the porpoise only in size".



Text-fig. 6. *Balaena mysticetus*, only one illustration of this sort given by Hyrtl (Natural size reproduction after Fig. 7 in Taf. IX). Obviously the species is not genuinely identified.

The present authors themselves, and probably all those who were interested in the topic alike, could hardly suspect the genuineness of these previous findings. Consequently, it has long been a widely accepted view that there exists such a general uniformity which may be called "cetacean" as was mentioned previously. It was only recently, however, when two specimens of *Eubalaena* were captured in the Japanese waters for a scientific survey (e.g. Omura, 1957) and when the authors were blessed with the opportunity of examining these animals that the labyrinth of right whale was first known, against the common belief, as an extraordinary exception.

Cast specimen is illustrated stereographically (Plate-fig. 3), and one may at first sight notice this. The cochlea is of rather pointed high type in two and a half turns which coil tightly. The semicircular canal system is not diminished. Moreover the conspicuous relationship, noticed in the size of the semicircular canals generally, is not apparent in the right whale. Any significant difference is not noticed in the dimension of the three canals. In actual fact it is rather terrestrial, and strikingly "non-cetacean". It is obvious therefore that the right whale of neither Hyrtl nor Gray was genuinely identified.

The authors are not in the position to raise a speculation as to the reason of diminished vestibular organ of the cetaceans, but it seems worth while to pay attention to a recent paleo-biological statement by Edinger (1955). According to her, the cerebellum develops in early cetaceans better than the cerebrum, vestibular nerve being dominant to the acoustic. Such interrelationship apparently has been reversed during the course of evolution as the function demands. In view of the fact that the unveiled findings on the right whale have something in common with Edinger's statement, it may well be mentioned that the right whale is, at any rate, probably a species which still retains to a marked degree such primitive status as the early fore-runners had once possessed. This whale is, in that sense, a "Living Fossil" in the cetacean evolution. The authors naturally look forward to the possibility of examining a fossil labyrinth. Gray whale (*Rhachianectes*) may be another species that should be investigated.

One more mention may be made in this connexion of a recent communication by Aoki (1957). A high school boy, who is diagnosed as cerebellar ataxia, is incidentally an excellent swimmer but strongly ataxic when he tries to stand and walk. It is suggested in the résumé that the cerebellar innervation of muscular tonus is under-developed and that the tonus itself becomes unnecessary to such an extent, when the subject is in the water, as up to the amount of floating force which reduces his body weight considerably. Although nothing is known about the vestibular system of the patient, neither in the central nervous system nor in the labyrinth itself, this may eventually be a representation of the actual transition that happened in the cetacean history.

The posture is, in Cetacea, no longer balanced on the limbs as in the land animals. The authors have become rather inclined therefore, to believe that the noticeable alteration of the balancing in Cetacea might be responsible for the diminution of the semicircular canals. No doubt, however, much evidence should be extensively collected, probably also in the central nervous system, before anything more definite can be said. Previous views on this problem will be discussed when such opportunity arises.

SUMMARY

With the aim of obtaining fundamental data for subsequent histological investigation, labyrinths of 16 species of Cetacea were investigated, mainly on cast specimens. New findings and remarks are summarised as follows.

1) As regards the dimension of the labyrinth, Physeteridae representatives (*Physeter* and *Kogia*) are relatively small in comparison with the body length. Otherwise the dimension diverses roughly according to the specific body length.

2) Vorticose pattern of the cochlea is different according to the taxonomy. In Mystacoceti the vortex is open on the apex, and in Odontoceti, especially in Delphinidae, the cochlear canal of the first quadrant region swerves in a unique way away from the modiolus. In the consequence of such détour, the first quadrant is strikingly long. The length exceeds 30% of the total length.

3) Since the cochlear pattern differs considerably according to species, a proposition is made to adopt widely an " index method " in order to indicate a particular locus of the cochlea. In place of the more popular method, in which the sequence of turns is mentioned, the proposed method puts the special weight on the distance of each locus from the vestibular extremity in percentage of the total length. This is not so difficult a matter as might be expected, and it has been found to be practical. This applies not only to Cetacea, but to all mammals including man and experimental animals.

4) A unique peculiarity of Odontoceti is that the secondary lamina spiralis develops up to as far as 68–82% of the cochlear canal. There is evidence that the slit between this and the primary lamina spiralis coincides, within this range, with the actual basilar membrane. In the first 50% range, the basilar membrane increases its width at an extremely slow rate, generally between 0.1–0.2 *mm*. This is probably related to the high frequency hearing capability of those animals. In Mystacoceti, the secondary lamina spiralis is far less noticeable. In one example of *Balaenoptera physalus*, the slit between the two laminae is estimated to coincide only in the first 15% range with the basilar membrane. Width increase in this range is as in human membrane.

5) As regards the semicircular canals, which as unanimously agreed are extraordinarily diminished, the size of each is in a reverse relationship in contrast to many, if not all, terrestrial mammals. The lateral is the greatest and the posterior the smallest, especially in Odontoceti.

6) *Eubalaena* presents a serious exception, in which none of the known cetacean peculiarities are to be found. Cochlea is of high type, closely coiled in two and a half turns. Semicircular canals are well preserved, and the general impression is strikingly " non-cetacean ". This is an absolutely new finding. In view of paleontological transition between the equilibrial and acoustic nervous components (Edinger, 1955), *Eubalaena* may well be called as a " Living Fossil " in the cetacean descent.

The authors are grateful to Professor H. Outi for his encouragement and helpful criticism. Miss D. E. L. Brown kindly read the script and made corrections.

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EXPLANATION OF PLATES

Specimens are generally so placed that as good as possible comprehension of the structure may be attained, hence there is no uniformity as to the direction like that of Text-fig. 1. Specimens are water-immersed. As regards the method of photography see ‘Material and Method’.

PLATE I

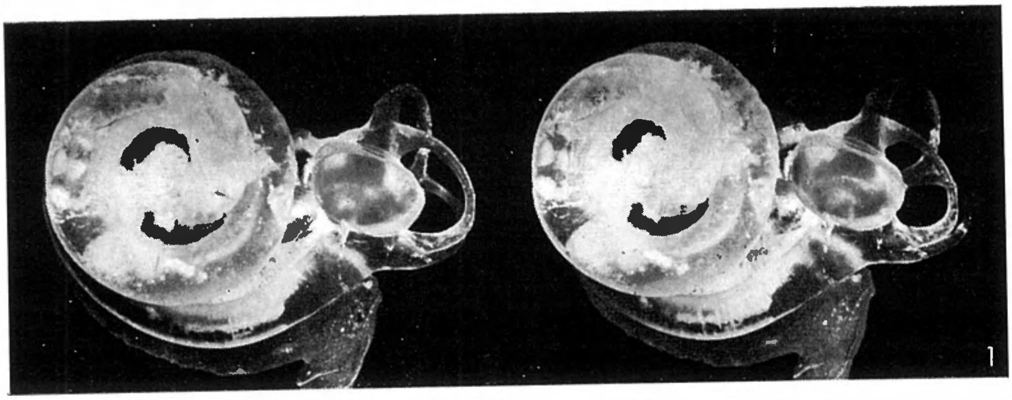
Fig. 1. *Balaenoptera musculus* (left). 2.0 ×
Fig. 2. *Megaptera nodosa* (right). 2.6 ×
Fig. 3. *Eubalaena glacialis* (right). 2.6 ×

PLATE II

Fig. 4. *Physeter catodon* (right). 2.6 ×
Fig. 5. *Kogia breviceps* (right). 4.6 ×
Fig. 6. *Berardius bairdii* (right). 3.0 ×

PLATE III

Fig. 7. *Globicephala melaena* (right). 3.2 ×
Fig. 8. *Delphinus delphis* (right). 3.8 ×
Fig. 9. *Neomeris phocaenoides* (right). 4.3 ×
Fig. 10. *Neomeris phocaenoides*. 4.7 × The same specimen as Fig. 9 is seen from the side. Note the strong détour and undulation of the cochlear canal in the first quadrant region.



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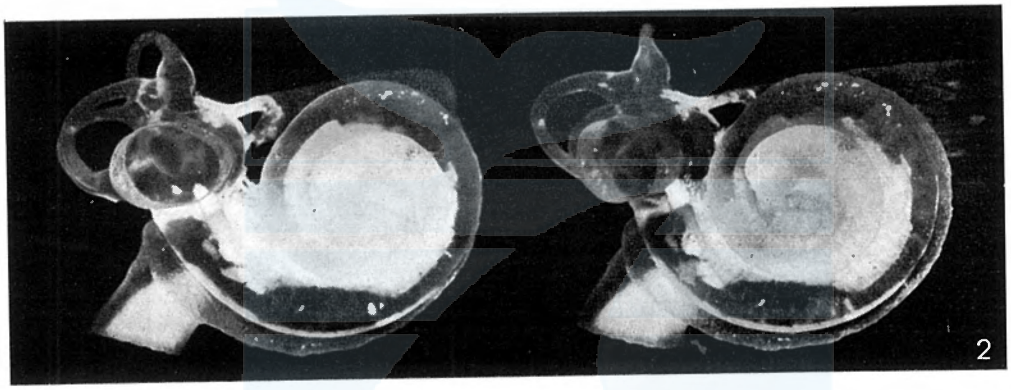

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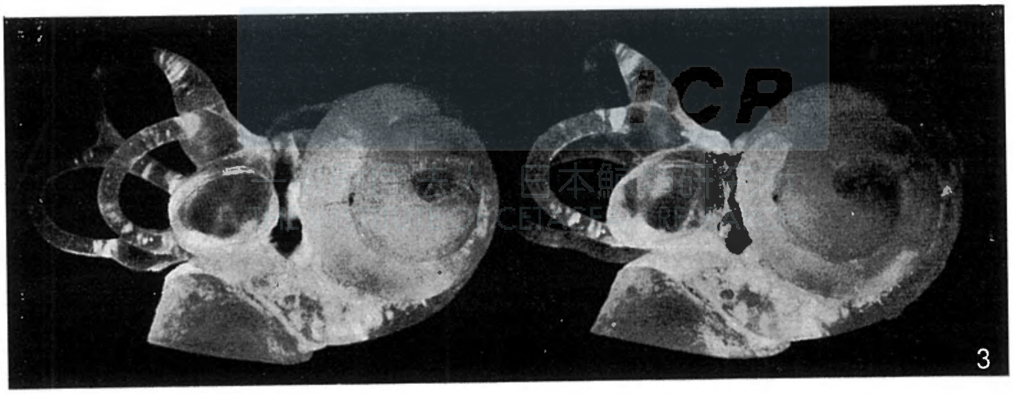

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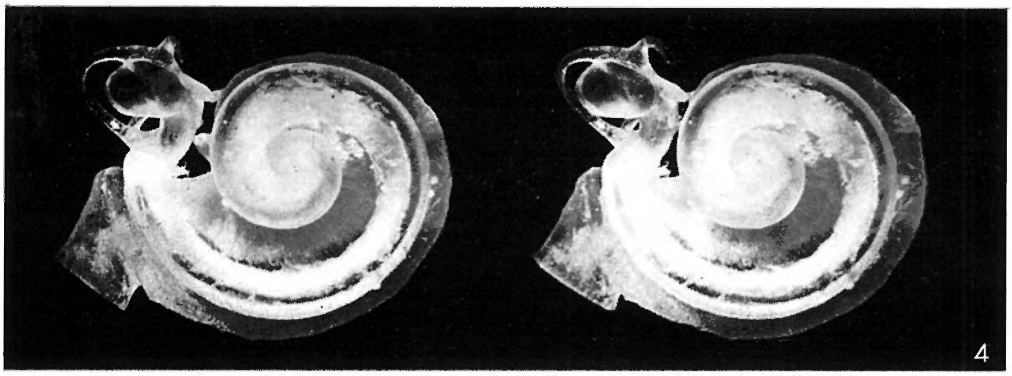

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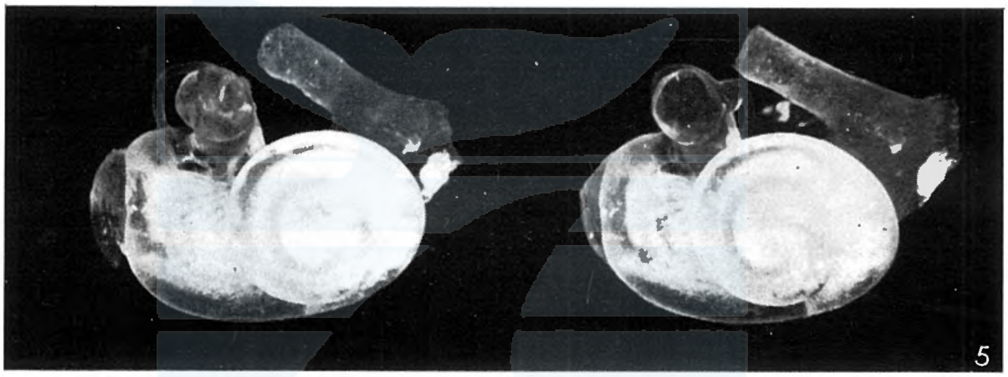

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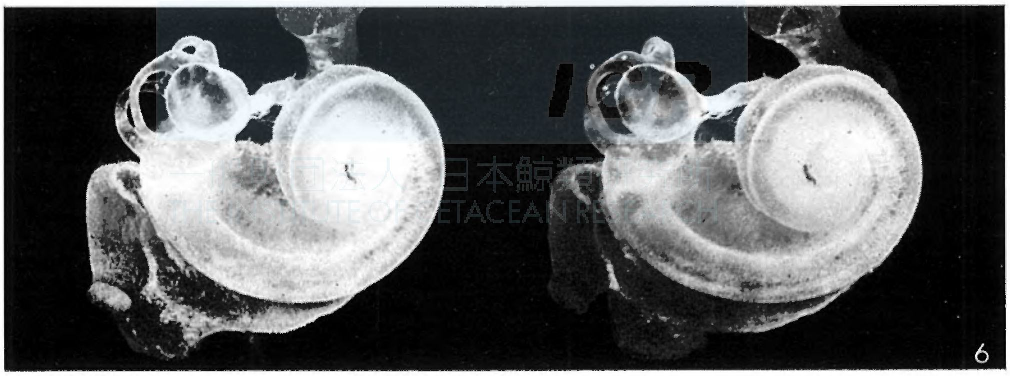

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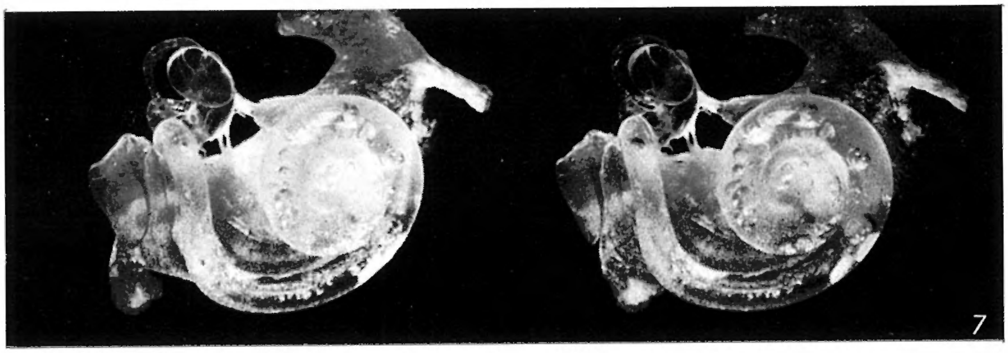

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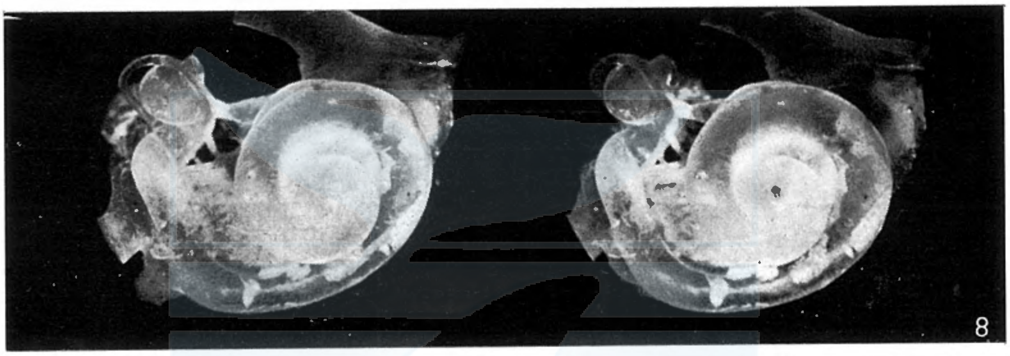

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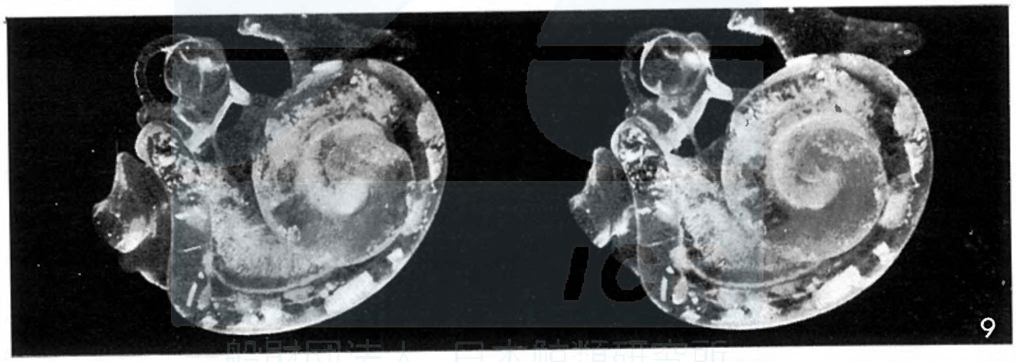

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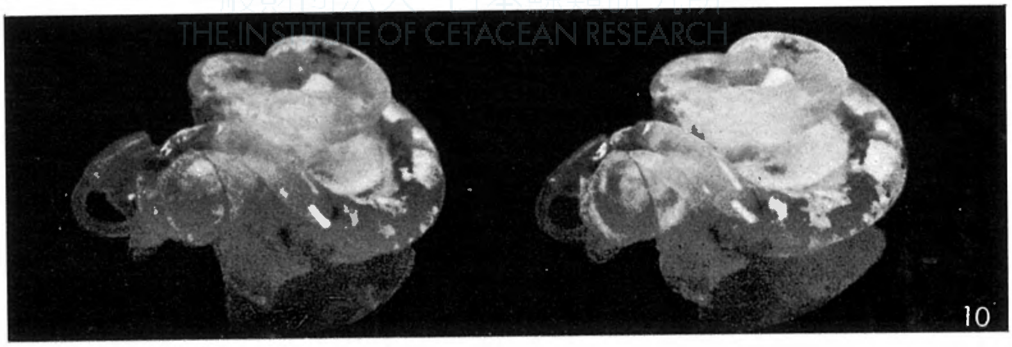

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DISTRIBUTION OF AMINO ACID IN PROTEINS FROM VARIOUS PARTS OF WHALE BODY

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(DIRECTED BY PROF. SHICHIRO AKIYA**)

INTRODUCTION

Numerous studies have been already made on amino acid distribution in tissue and organ proteins of terrestrial mammals, and most of their results have been taken in the Block and Weiss' handbook (1956). As regards whales, however, there have been only a few works. It is not only a contribution to our biochemical knowledge of whales to clarify the amino acid distribution in tissue and organ proteins of whales but also necessary in order to find out better utilization of whales. The present study was undertaken with the author's such intention. Proteins obtained from muscle meats of fin, sei, sperm, and baird beaked whales, muscular tissues of diaphragm and heart, mucous membranes of first stomach and small intestine, pancreas, liver, cerebrum, lung, spleen, testis, crystalline lens, aorta and epidermis (black skin) of baird beaked whale, and also gum and baleen plate of whalebone whales were quantitatively analyzed for their constituent amino acids, and results obtained were discussed.

AMINO ACID DETERMINATION

In the present study, the author intended to carry out the determination of amino acids chiefly by means of the direct photometry on ascending one-dimensional paper chromatograms. Many solvent systems which had been recommended in literature for quantitative separation of each amino acid on one-dimensional paper chromatograms were traced in the present work, but unsatisfactory results were obtained in these many cases. Probably it was due to circumstances that the experimental conditions in the present work, especially the kind of filter paper, the method of development and temperature during developing were unable to be brought into line with those in the literature. On the basis of results of the author's many experiments, a method for direct estimation of 18 amino acids on paper chromatograms was devised, which was summarized in Table 1. Estimation of amino acids on the chromatograms that were revealed with color reagents was carried out by the author's modification of the procedure of measuring maximum color

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densities of individual spots (Block, 1950; McFarren and Mills, 1952) except the case of methionine where the method of measuring area of the spot (Block et al. 1958) was employed.

Histidine estimation was not mainly made by this method, but by the elution method, i.e., aqueous eluate of the histidine area of the finished one-dimensional chromatogram was subjected to the Pauly's diazo-reaction and estimated colorimetrically.

By means of these methods, 18 kinds of common, naturally occurring amino acids except tryptophan and hydroxyproline were easily and economically determined with satisfactory results.

EXPERIMENTAL

I. *Direct Estimation on Paper Chromatograms*

1. *Filter Paper.* Toyo No. 51 filter paper sheets 30 *cm.* wide and 30 *cm.*, 40 *cm.* and 43 *cm.* long respectively are used for 24 *cm.*, 30 to 35 *cm.* and 36 to 38 *cm.* of solvent run (cf. Table 1).

TABLE 1. OUTLINE OF THE PRESENT METHOD FOR DIRECT ESTIMATION OF AMINO ACIDS ON PAPER CHROMATOGRAMS

	Solvents	Lengths of solvent run beyond original spots	Color reagents*	Amino acids estimated
1.	n-Butanol · acetic acid · water (4:1:1 v/v)	33–35 *cm.* Develop 3 times	I	Arginine, cystine, hydroxylysine, phenylalanine
2.	n-Butanol · acetic acid · water (25:6:25 v/v) (Block and Weiss, 1956)	35 *cm.* Develop 3 times 24 *cm.*	I II III	Lysine, histidine, arginine, alanine, tyrosine Proline Methionine
3.	n-Butanol · acetic acid · water (40:5:7 v/v) (Rao and Wadhwani, 1955)	35 *cm.*	I	Phenylalanine, tyrosine
4.	n-Butanol · ethanol · water (20:1:4 v/v)	36–38 *cm.* Develop 3 times	I II	Leucine Proline
5.	Phenol saturated with pH 12 phosphate buffer of 0.067 *M.* (Treat filter paper with the same buffer before sample application) (McFarren, 1951, 1952)	30–32 *cm.*	IV	Threonine, glycine, serine, glutamic acid, aspartic acid
6.	Pyridine · isoamyl alcohol · water (1:2:1 v/v)	35 *cm.* Develop 3 times	I	Isoleucine
7.	Pyridine · isoamyl alcohol · water (10:10:7 v/v) (Giri, 1953) (Treat filter paper with 0.05 *M* sodium acetate solution before sample application)	34–35 *cm.*	I	Valine

* Color reagents:
I = 0.4% (w/v) ninhydrin in acetone.
II = 0.2% (w/v) isatin in acetone.
III = 4 *cc.* of 0.002 *M* PtK_2Cl_6, 0.25 *cc.* of 1*M* KI, 0.4 *cc.* of 2*N* HCl, 76 *cc.* of acetone (Toennies and Kolb, 1951; Block and Weiss, 1956).
IV = 0.4% (w/v) ninhydrin, 4% (v/v) acetic acid in acetone.

The buffered paper sheets (No. 5 and No. 7 in Table 1) are prepared by dipping filter paper sheets, 30 × 60 *cm.*, into the buffer solutions, air-drying by suspending by one end and cutting into the desired size. pH 12 phosphate buffer solution is prepared according to McFarren (1951).

2. *Preparation of Protein Hydrolyzate.* 200 *mg.* of protein is hydrolyzed with 2 *cc.* of 6 *N* HCl in sealed glass tube in an oven at 110°C for 24 hrs. The contents of the tube are filtered through a glass filter, and after thoroughly washing the precipitate thus obtained with water, the combined filtrate and washings are concentrated to dryness on a steam bath. The residue is then dissolved in 10 *cc.* of water, again evaporated to dryness, and placed in a vacuum desiccator over KOH for 24 hrs. The residue is finally taken up in 2.0 *cc.* of water (Original solution).

For estimations of leucine and hydroxylysine, this original solution is used as it is, and for estimations of the others, four or two times dilution of the original is used in most cases.

3. *Preparation of Standard Solution.* 50 *mg.* glycine, 50 *mg.* DL-alanine, 70 *mg.* DL-valine, 80 *mg.* L-leucine, 60 *mg.* DL-isoleucine, 50 *mg.* DL-serine, 50 *mg.* DL-threonine, 30 *mg.* L-methionine, 10 *mg.* L-cystine, 50 *mg.* L-phenylalanine, 50 *mg.* L-tyrosine, 65 *mg.* L-proline, 70 *mg.* L-aspartic acid, 120 *mg.* L-glutamic acid, 40 *mg.* L-histidine·HCl·H_2O, 70 *mg.* L-arginine·HCl and 100 *mg.* L-lisine·HCl are dissolved in water under addition of an adequate quantity of 6 *N* HCl, and the solution is made up to a final volume of 10.0 *cc.* 2.0 *cc.* of the solution is evaporated to dryness on a steam bath. The residue is dissolved in 10 *cc.* of water, again evaporated to dryness, and placed in a vacuum desiccator over KOH for 24 hrs. The residue is finally dissolved in 2.0 *cc.* of water (Original standard solution).

For estimation of leucine, this original solution is employed as it is, and for estimation of the others, four or often two times dilution of the original is employed.

As the standard of hydroxylysine, a gelatin hydrolyzate in which hydroxylysine content was already determined by periodate oxidation (Block and Bolling, 1951) is employed.

4. *Application of Solutions.* On a line 5 *cm.* from the lower edge of the paper, seven points are marked at 2.5 *cm.* or 3.0 *cm.* intervals. The standard and the test sample are applied at alternate points with a self-filling micropipette. The desired concentration on the paper is built up by repeated sequence of spotting and drying. Every spotting must be

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Amino acid specimens employed as the standards were manufactures of Ajinomoto Co., Ltd. and Tokyo-Kasei-Kogyo Co., Ltd. These were paper-chromatographically pure.

made in the same quantity of the solutions. In the author's experiment, one spotting was 77×10^{-5} *cc.* in quantity. The standard solution is applied 1, 2, 3, and 4 times at the range of four respective points, and the test solution, in most cases, 2 to 3 times at the range of three respective points.

5. *Developing Solvents.* The solvent mixtures in Table 1 are prepared in the usual fashion.

6. *Development of Chromatograms.* Being spotted, the paper sheet is suspended in air at room temperature for more than one hour. Then, the sheet is formed into cylinder, and subjected to the ascending development.

In the case that one of the solvents No. 1, 2, 4, and 6 is used, the multiple development technique (Jeanes et al., 1951) is adopted, i. e., the sequence of developing and air-drying is repeated for a total of 3 times. In the case of 35 *cm.* solvent run using one of the solvents No. 2, 3, and 6, it is recommended that the paper is allowed to remain in the developing chamber for several hours more after the solvent front has reached the upper edge of the paper.

The development on the pH 12 buffered paper should be commenced within 20 hrs. from the time when the air-drying of the paper moistened with the buffer solution was commenced. If not so, the resolution of amino acids will grow worse owing to decline of the buffer action of the sheet.

7. *Color Formation of Amino Acids.* At the completion of the development, the paper is dried in a gentle current of air at room temperature. The sheet is then dipped in a color reagent and again dried at room temperature. When one of the ninhydrin solutions in Table 1 is employed as the color reagent, the color is developed by heating in an oven at 60° to 63° C. for 15 minutes. When the isatin solution is used to reveal proline, the color is developed by heating at 70° to 73°C. for 10 minutes. Proline gives a blue spot on a yellow background. The oven should be saturated with water vapor in every case.

Platinum reagent for methionine must be prepared with acetone purified with use of $KMnO_4$ and K_2CO_3 (Block and Weiss, 1956). On treating the sheet with this reagent, methionine gives a white spot on a red-purple background without heating.

8. *Measurement of Maximum Color Densities of Amino Acids except Methionine.* After the revealed chromatogram has been allowed to keep at room temperature for more than one hour, the color densities of the spots are determined with a photoelectric colorimeter as in the following.

Each spot is cut out of the chromatogram and fastened with the aid of clips to a sample holder which contains an aperture of suitable size.

In order to reduce the experimental error which may be derived from unevenness of thickness of paper in the same sheet, it is advisable that the size of the aperture is made as large as possible within the size of the spot to be estimated, provided that the separation of the spot allows. Shape and size of the aperture should be properly changed according to shape, size, and separation of the spot to be estimated. However, when a series of spots of the same acid is estimated on the same chromatogram, the same aperture must be used for every spot. In the author's experiment, circular apertures 7 *mm.*, 9 *mm.*, 11.5 *mm.*, and 14 *mm.* in diameter and rectangular apertures 3×14 *mm.*, 5×14 *mm.*, and 10×14 *mm.*, have been employed.

9. *Measurement of Areas of Methionine Spots.* Circumferences of white spots revealed with the platinum reagent are marked in pencil, and the areas are determined with a planimeter.

10. *Calculation.* The standard curve for each amino acid is prepared from the values at individual concentrations of the standard. The amino acid concentration in each spot of the test solution is estimated by interpolation from the curve, and then the content of each amino acid in the sample of protein is calculated. The result obtained at every spot of each amino acid is averaged. An example of calculation formula is as follows:

If A = quantity (*mg.*) of protein before hydrolysis contained in 2.0 *cc.* of the hydrolyzate (original),

B = the number of times of spotting the hydrolyzate (4 times dilution of the original),

C = quantity (*mg.*) of each amino acid in 10.0 *cc.* of the standard solution (original), and

D = the number of times of spotting the standard solution (4 times dilution of the original) being equivalent to B ('D' is estimated from the standard curve), then

each amino acid content in protein (*g.* per 100 *g.* of protein) $= 20 \cdot C \cdot D / A \cdot B$

In order to employ this formula, concentrations of the amino acid and test sample in every spot should be expressed in numbers of times of spotting the standard solution and hydrolyzate respectively, as mentioned above.

II. *Determination of Histidine by the Elution Method*

0.025 to 0.1 *cc.* of a solution containing 25 to 200 γ histidine is applied as a streak, 18 *cm.* long and about 3.0 *mm.* wide, on a line 5 *cm.* from the bottom of a sheet 30 *cm.* square of Toyo No. 131 filter paper. One drop of the same solution is also placed at each point 1 *cm.* from each end of the same line, with the object of preparing guide strips. After the solvent, n-butanol·acetic acid·water (4 : 1 : 1 v/v), has upwards run about 17 *cm.* past the line, the guide strips are cut off and sprayed with a diazo-reagent (Block et al., 1958, p. 133) to reveal histidine spots. The location of histidine area in the remaining part of the sheet is presumed from the results of the guide strips. A strip about 2.4 *cm.* wide which contains the whole histidine area is cut out of the remaining sheet and irrigated with water by the same technique as descending paper chromatography. The lower end of the strip should be cut in a wedge form. First 2 *cc.* of the eluate is subjected to the Macpherson's modification (1946) of the Pauly-reaction to estimate histidine, excepting the electrodialysis in his method.

III. *Determination of Tryptophan and Hydroxyproline*

Tryptophan was determined by Spies and Chambers' 'procedure H' (1949). Test solution for the determination was prepared as in the following: About 0.5 *g.* of each protein was weighed accurately, boiled with 10 *cc.* of 5 *N* NaOH in an oil bath at 125° C. under reflux for 5 hours, and then the solution was made up to a whole volume of 50.0 *cc.* with adding water.

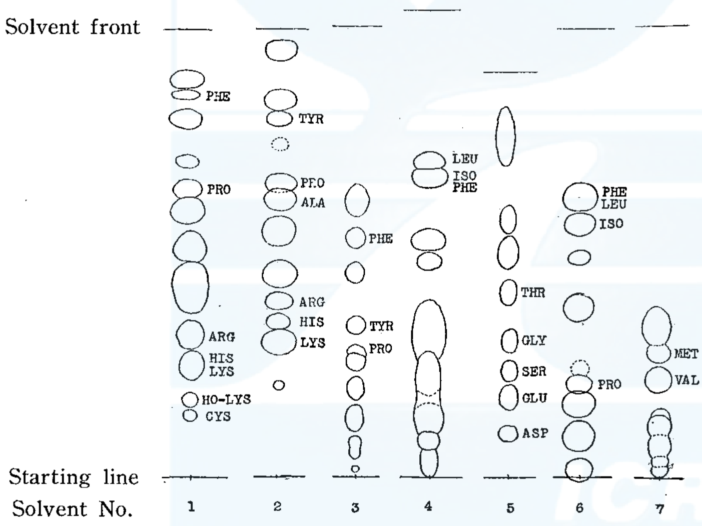
Hydroxyproline was determined by Neuman and Logan's method (1950). The preparation of the test solution was as follows: 200 *mg.* of protein was hydrolyzed with 2 *cc.* of 6 *N* HCl in a sealed glass tube in an oven at 110° C. for 24 hours. The contents of the tube were filtered through a glass filter, and after washing the precipitate with 10 *cc.* of water, the combined filtrate and washings were concentrated to dryness on a steam bath. The residue was then taken up in 10 *cc.* of water, again concentrated to dryness, dissolved in 30 *cc.* of water, and after neutralized with *N* NaOH, evaporated to dryness. The residue was finally taken up in 10.0 *cc.* of water. At the time of the determination the solution was diluted so as to contain $10-40\gamma$ of hydroxyproline per *cc.*

DISCUSSION

The previously published methods of amino acid estimation using one-dimensional paper chromatography have adopted mostly the descending developing technique. With the descending technique, the desirable prolongation of the length of solvent run is easily achieved by properly extending the length of development time, and consequently, there is the possibility of promoting the resolution of amino acids in this way (Roland and Gross, 1954). With the ascending development technique, there is a limit to the length of solvent run as is generally known, and consequently the resolution of amino acids are restricted in some measure by this fact. However, the ascending technique has been exclusively adopted in the present work because of its merits of simplicity of apparatus and the ease with which a large number of analyses may be made (Williams and Kirby, 1948).

I. *The Direct Estimation on Paper Chromatograms*

The resolution patterns (Fig. 1) is scarcely distorted by considerable variations of experimental conditions, especially temperature during the development. In choosing the solvents, the author paid attention to this point also, because all the developments in the present work had to be made at room temperature. Conditioning the filter paper in the developing chamber before development is unnecessary.



Abbreviations

GLY	Glycine
ALA	Alanine
VAL	Valine
LEU	Leucine
ISO	Isoleucine
SER	Serine
THR	Threonine
CYS	Cystine
MET	Methionine
PHE	Phenylalanine
TYR	Tyrosine
PRO	Proline
ASP	Aspartic acid
GLU	Glutamic acid
ARG	Arginine
HIS	Histidine
LYS	Lysine
HO-LYS	Hydroxylysine

Fig. 1. Resolution Patterns

In most cases of paper chromatography with the ordinary solvents, leucine and isoleucine as well as methionine and valine overlap each other. It is these amino acids that the author took pains in resolving.

The solvent No. 4 used for separation of leucine is the author's modification of one of the Rao and Wadhwani's solvents (1955) used in their quantitative circular paper chromatography. Leucine and isoleucine as well as phenylalanine still overlap slightly, but the estimation of leucine is completely achieved with use of a narrow aperture at the time of measuring color densities of the spots. In the present experiment, apertures 3 *mm.* and 5 *mm.* wide were employed for estimation of leucine.

Isoleucine is sharply separated from other amino acids with the aid of the solvent No. 6.

With the use of the solvent No. 7, valine is separated even on unbuffered paper, but in such a case, the color of the spot is uneven and consequently the estimation is unable to be made. The unevenness of the color is presumably caused by hydrochloric acid contained in the protein hydrolyzate and the standard solution. The author could remove this hindrance by means of buffering the paper sheet with sodium acetate solution before the sample application.

A portion of methionine is autoxidized into methionine sulfoxide on the paper during development and air-drying, and so, applying the multiple development technique to the estimation of methionine (Block and Weiss, 1956, p. 78) is unadvisable. Thus, some amino acid and methionine sulfoxide often overlap each other on the chromatograms made by the multiple development technique. The author, therefore, paid attention to this point when this technique was adopted for resolution of amino acids.

In descending (McFarren, 1951, 1952; Reidel and Bienenfeld, 1956; Lange, 1956; Schnuchel, 1956; Roberts and Kolor, 1957) and circular (Krishnamurthy and Swaminathan, 1955) paper chromatography, the pH 12 buffered phenol has been favorably used for separation of aspartic acid, glutamic acid, serine, glycine, threonine and alanine, but in ascending chromatography, according to the author's experience, alanine is incompletely separated. In the author's method, therefore, this solvent is used only for separation of the five amino acids other than alanine.

The location of hydroxysine on the chromatogram was experimentally determined basing on the author's investigation of chromatogram of a hydrolyzate of gelatin which contains a comparatively large amount of this amino acid, the fact that this amino acid is precipitated with phosphowolframic acid, and Inskip's study (1951).

Hitherto, determination of hydroxylysine has been made exclusively by periodate oxidation (Block and Bolling, 1951; Akabori and Mizushima, 1954), but its procedure is complicated and a relatively large amount of the test sample is required for one estimation. By use of the abovementioned technique, the determination of this amino acid is simplified and enabled to be made in a micro- or submicro-scale.

The present method was successfully applied to determination of 17 amino acids in casein.

Casein (E. Merck) desiccated in vacuo over H_2SO_4 was hydrolyzed with 6 *N* HCl, as above described, for 24 hrs. for estimation of methionine, phenylalanine and tyrosine, and for 48 hrs. for all the other amino acids.

The values obtained in the present experiment and also the values reported in literature are listed in Table 2. There is a good agreement between the values in both cases. The values for serine and threonine in the literature include corrections made for decomposition of these acids during acid hydrolysis of protein, but the values obtained in the present experiment include no correction. In the literature, tyrosine was estimated on alkaline hydrolyzates, and in the present experiment, on the acid hydrolyzate. This is presumably the reason of the fact that the present value for tyrosine is somewhat lower than the values in the literature.

TABLE 2. RESULTS OF AMINO ACID DETERMINATION ON CASEIN

	Values expressed in *g.* per 100 *g.* protein			Values expressed in *g.* amino acid N per 100 *g.* protein N	
Constituent	Present Work	Gordon et al. (1949, 1950)	Sundararajan et al. (1957)	Present Work	Gordon et al. (1949, 1950)
Total N	15.02	15.63	15.56		
Glycine	2.0	2.00	1.90	2.5	2.39*
Alanine	3.4	3.20	3.38	3.6	3.22*
Valine	7.2	7.2	6.94	5.7	5.5
Leucine	9.7	9.2	9.54	6.9	6.3
Isoleucine	6.1	6.1	6.13	4.3	4.2
Proline	10.9	10.6	11.72	8.8	8.3*
Phenylalanine	4.9	5.0	4.98	2.8	2.7
Tyrosine	5.2	6.3	6.32	2.7	3.1
Serine	5.0	6.3	6.27	4.4	5.4
Threonine	4.3	4.9	5.28	3.4	3.7
Cystine	0.31	0.34	0.35	0.24	0.3
Methionine	2.9	2.8	2.93	1.8	1.7
Arginine	3.8	4.1	3.92	8.1	8.4
Histidine	2.9	3.1	3.03	5.2	5.4
Lysine	7.6	8.2	8.18	9.7	10.1
Aspartic acid	6.5	7.1	7.66	4.6	4.8
Glutamic acid	21.4	22.4	21.62	13.6	13.6

* The author's calculation from figures in the literature expressed in *g.* per 100 *g.* protein (Gordon et al., 1950).

Because accuracy of the quantitative paper chromatography using the maximum color density technique was exhaustively discussed already (Salander et al., 1953 ; Roland and Gross, 1954 ; Block and Weiss, 1956 ; Roberts et al., 1957, 1958), no attempt on it has been made in the present study.

Block (1958, p. 117) pointed out that cystine was decomposed when a hydrolyzate was allowed to stand. In the present experiment the same tendency was observed with methionine.

II. *Determination of Histidine by the Elution Method.*

In the Macpherson's method (1946) for histidine estimation, histidine is separated from tyrosine, which also presents the Pauly-reaction, by means of electrodialysis. In the author's procedure, the separation is easily achieved by means of the one-dimensional paper chromatography.

There is such satisfactory reproducibility as the results of two times determination on 3 samples of protein are shown in Table 3.

TABLE 3. HISTIDINE CONTENT IN THREE SAMPLES OF PROTEIN DETERMINED BY ELUTION METHOD

Values are expressed in *g.* per 100 *g.* of dry protein.

	Total N	Histidine
Meat, fin whale	15.29	2.69 2.63
Liver, baird beaked whale	14.59	2.81 2.88
Pancreas, baird beaked whale	15.23	2.79 2.42

After the present experiment of determining histidine contained in tissue and organ proteins of whales was finished, Frank and Petersen (1956) published a similar technique in their study on estimation of histidine concentration in blood-plasma.

MATERIALS AND PREPARATION OF SAMPLES OF PROTEIN

All the muscle meats used in the present work were dorsal muscles.

Muscle Meat of Fin Whale (*Balaenoptera physalus*). The material was taken from a male fin whale 61 feet in body length which was caught at the position of 54° 14′ N, 166° 40′ W on Sept. 19th 1954. About 2.5 hours elapsed from the time of killing to the commencement of the treatment. A lump of meat was taken out of the carcass by Mr. K. Fujino of the Whales Research Institute and refrigerated until the commencement of the experiment (Oct. 10th 1954).

4 *kg.* of minced meat was boiled with water twice as much as the meat for 5 minutes and then filtered under pressure. The residue was boiled again with water and filtered as above. The final residue was air-dried. 50 *g.* of the air-dried matter was treated with tepid water, boiling water, alcohol, and ether successively as muscle meat of baird beaked whale mentioned below.

Muscle Meat of Sei Whale (*Balaenoptera borealis*). The material was taken from a male whale 44 feet in body length which was killed at the position of 51° 44′ N, 173° 00′ E on Aug. 4th 1952. About 4 hours elapsed from the time of killing to the commencement of the treatment. The material was taken by Mr. K. Fujino and refrigerated until the commencement of the experiment (Oct. 1st 1952). 16.4 *kg.* of minced meat was treated similarly as fin whale meat.

Muscle Meat of Sperm Whale (*Physeter catodon*). A piece of muscle meat was taken from a male whale 41 feet in body length which was killed off the coast of Kinkazan Island on Dec. 6th 1948. Presumably about 18 hours elapsed from the time of killing to the arrival at the landstation. The grade of freshness of the carcass (Nakai, 1948) at the commencement of treating was about 70. Without delay, the material was minced, treated with acetone and ether successively and then air-dried. Thus treated material was further treated with tepid water, boiling water, alcohol, and ether as muscle meat of baird beaked whale in the following.

Muscle Meat of Baird Beaked Whale (*Berardius bairdii*). A lump of meat was taken from a male whale which was killed off the coast of Kinkazan Island in the summer of 1953. Presumably about 10 hours elapsed from the time of killing to the arrival at the landstation. The carcass at the commencement of treating was in good fresh condition. 60 *g.* of minced and then thoroughly mixed material was mixed with 60 *cc.* of acetone to prevent subsequent decay and brought to the laboratory. Acetone was distilled off on a steam bath. The residue was extracted with 120 *cc.* of tepid water for 30 minutes under occational stirring and then filtered. The filtrate yielded no proteinous coagulation when it was boiled for a short time, and so it was abandoned. The extraction was repeated twice. The meat residue was treated 3 times with succesive 120 *cc.* portions of boiling water for 5 minutes each on a boiling water bath under occational stirring and filtered with suction. 120 *cc.* of alcohol was added to the residue, boiled in a water bath for ten minutes and sucked off. The extraction was repeated twice with renewal of alcohol at each time. Alcohol which was included in the final meat residue was evaporated on a water bath. Then, the meat residue was submitted to the ether extraction using the Soxhlet's apparatus and then air-dried. Protein thus obtained was desiccated over sulfuric acid under a reduced pressure.

Muscular Tissues of Diaphragm and Heart of Baird Beaked Whale. The whales from which the materials were taken, were killed off the coast of Kinkazan Island in the summer of 1953 as in the foregoing. The muscular tissue of ventricle of the heart was taken from a male whale and the phrenic muscular tissue from a female one. These materials were similarly treated as muscle meat of baird beaked whale.

Various Tissues and Organs. Cerebrum, aorta, epidermis (black skin) and mucous membrane of small intestine were sampled from male baird beaked whales. Pancreas, lung and mucous membrane of first stomach were sampled from female ones. Lenses were taken from male and female baird beaked whales, and mixed. Sex of baird beaked whales from which spleen and liver were taken and also sex of the sei whale from which gum* was taken, are unknown. These whales were killed off the coast of Kinkazan Island in the summer of 1953 and were in good fresh condition until the commencement of the treatment at the landstation. A baleen plate which had been taken from a whalebone whale (probably, *Balaenoptera edeni*) caught in the adjacent waters of Ogasawara Islands and then air-dried was used as a material for the present experiment.

From mucous membranes loose connective tissue under the membranes (tela submucosa) and others were removed as perfectly as possible by macro-observation, and then the membranes were washed with water to remove mucos.

From pancreas, liver, cerebrum, lung, spleen, and testis, were removed capsules, connective tissues, and blood vessels as much as possible.

From epidermis the outermost thin layer, namely, horny layer (stratum corneum) being apt to peel off was removed. Thus treated material, therefore, consists mainly of germinal layer (stratum germinativum).

The aorta was free from surrounding connective tissues.

The lenses taken from the whales were slightly washed with water to remove the remainder of vitreous body and others.

The minced materials, except the baleen plate, were mixed with the same amount of acetone to prevent subsequent decay and brought to the laboratory. Acetone was distilled off on a steam bath. The residue was treated with tepid water, boiling water, alcohol, and ether successively in the same manner as the baird beaked whale meat. The baleen plate was cut in thin slices and then treated with tepid water and others as above. Samples of protein thus prepared were desiccated over sulfuric acid under a reduced pressure.

RESULTS

Results obtained are listed in Table 4. The blank means that the corresponding amino acid was not determined because its existence in the test sample was not confirmed by means of qualitative paper chromatography. For comparing with whale meat, values of beef reported in literature are also listed in Table 4.

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* The 'gum', in the present paper, means a elastic tissue which occupies the gaps between roots of adjacent baleen plates and is grayish white in color.

DISCUSSION

The whale meat is an important proteinous food-stuff in Japan. The result of the feeding experiment with albino rats carried out by Suzuki et al. (1919) revealed that its protein seems to be not inferior to proteins of other food-stuffs in nutritive value. However, very few studies (Okuda and Okimoto, 1919; Yamakawa and Shibuya, 1926; Schulze, 1949; Carpenter et al., 1955; Ogawa et al., 1958) have been made of its amino acid composition by which the nutritive value should be substantiated, and Ogawa and co-worker's study (1958) on fin whale meat is the only one which achieved neary complete amino acid analysis on whale meat. In the present work, amino acid composition of muscle proteins of four important species of whales in the adjacent waters of Japan was revealed.

As shown in Table 4, there is a close resemblance of the amino acid composition of the first five voluntary muscles. Especially, muscle meats of the two species of toothed whales (sperm and baird beaked whales) resemble very closely each other. It seems that the resemblance between muscle meats of the two species of whalebone whales (fin and sei whales) is somewhat inferior to that between the muscle meats of the toothed whales. It is interesting that in the amino acid composition of protein of muscle meat, sperm and baird beaked whales which are classified into different families (*Physeteridae* and *Ziphiidae* respectively) resemble each other rather more closely than the two species of whalebone whales which are classified into the same family (*Balaenopterydae*).

In comparing the whalebone whales with the toothed whales on each amino acid content in protein of muscle meat, it is noticed that the former is richer in arginine, methionine, cystine, aspartic acid and valine, and the latter in histidine, phenylalanine, tryptophan and glycine. It can readily be imagined that histidine content in muscle protein is pretty affected by myoglobin content in muscle because of the large content of histidine in myoglobin (Schmid, 1949). The relatively large content of histidine in muscle meats of the two species of toothed whales and in the phrenic muscular tissue of baird beaked whale is presumably due to the large content of myoglobin in these tissues. It is already known that the myoglobin content in muscles of sperm whale is much larger than that in muscles of sei whale (Tawara, 1950). Muscle meat and phrenic muscular tissue of the beaked whale are almost black in color as sperm whale meat, and so myoglobin content in these tissues must be also very large. From the results in Tawara's work (1950), it is probable that the amount of myoglobin contained in muscles of

TABLE 4. AMINO ACID COMPOSITION OF

Values expressed in

Protein of	Species of whale	Total N	GLY	ALA	VAL	LEU	ISO
Muscle meat	Fin	15.29	3.8	6.4	5.3	9.9	5.5
Muscle meat	Sei	15.01	4.0	6.1	5.6	10.4	6.5
Muscle meat	Sperm	15.78	4.4	6.2	5.1	10.1	5.4
Muscle meat	Baird beaked	15.52	4.3	5.8	4.4	11.4	5.1
[Beef (Bigwood, 1953)			4.5	6.4	5.0	8.2	5.2
Phrenic muscular tissue	Baird beaked	14.87	4.5	6.0	4.2	11.1	5.3
Cardiac muscular tissue	〃	15.26	5.1	6.0	5.0	10.2	3.9
Mucous membrane of first stomach	〃	15.90	11.8	6.1	4.4	7.3	3.5
Mucous membrance of small intestine	〃	16.11	12.6	6.8	4.3	6.5	2.9
Pancreas	〃	15.23	7.8	6.1	5.3	8.7	4.5
Liver	〃	14.59	5.6	6.8	5.7	9.5	4.4
Cerebrum	〃	13.42	4.4	5.7	5.3	9.2	4.0
Lung	〃	15.32	7.2	7.4	6.4	11.2	2.8
Spleen	〃	15.34	6.5	7.5	6.3	10.7	2.8
Testis	〃	14.34	8.5	6.3	4.9	7.5	3.4
Lens	〃	15.44	4.4	3.3	5.1	9.2	4.6
Aorta	〃	15.48	17.8	11.7	9.3	6.5	2.9
Epidermis	〃	15.45	5.8	4.5	4.5	9.0	4.1
Gum	Sei	15.38	5.2	4.6	4.9	10.2	4.5
Baleen	*Balaenoptera edeni ?*	14.69	6.2	4.1	4.3	8.3	3.5

Abbreviations:

GLY	Glycine	LEU	Leucine	TRY	Tryptophan
ALA	Alanine	ISO	Isoleucine	PHE	Phenylalanine
VAL	Valine	PRO	Proline	TYR	Tyrosine

TABLE 5. AMINO ACID COMPOSI

Amino acid content is expressed in

Investigator	Sample	Total N	GLY	ALA	VAL	LEU	ISO	PRO
Ogawa et al.*	Fresh meat	3.85	4.8	5.1	3.5	5.1	3.2	2.6
Nakai	Protein	15.29	4.6	6.6	4.1	6.9	3.8	3.0

* Values of amino acids were calculated from the figures in the original paper ex-

TISSUE AND ORGAN PROTEINS OF WHALES

g./100 *g.* protein

PRO	TRY	PHE	TYR	SER	THR	CYS	MET	ARG	HIS	LYS	ASP	GLU	HO-PRO	HO-LYS
3.8	1.06	4.2	3.8	4.4	5.0	0.97	2.5	7.2	2.66	9.4	9.1	16.0		
3.6	1.08	3.8	3.5	4.2	5.4	1.0	2.4	6.6	3.6	9.5	9.9	13.6		
3.7	1.23	4.8	3.4	4.5	5.2	0.77	2.2	5.9	4.3	9.8	8.7	16.2		
3.4	1.22	4.6	3.4	4.5	5.2	0.83	2.1	5.9	5.6	9.8	8.5	15.1	0.24	
3.6	1.1	4.5	4.1	4.5	4.7	1.3	2.9	5.4	3.8	9.3	9.8	15.9]		
4.4	1.05	4.7	3.3	3.8	5.2	0.75	2.1	6.0	4.5	9.4	8.2	15.1		
4.7	0.83	4.0	2.9	4.9	5.1	0.99	2.4	6.0	2.7	7.8	9.1	12.9	0.86	±
8.7	0.57	3.3	2.7	4.7	4.1	1.0	1.4	7.4	1.7	5.8	7.9	10.9	6.3	0.37
8.6	0.57	3.3	3.2	4.7	4.0	1.0	1.3	7.6	1.7	5.1	7.3	10.5	7.2	0.43
5.8	0.94	4.2	3.6	4.2	4.7	1.4	1.8	7.1	2.6	7.1	7.5	10.4	2.7	+
6.1	0.87	4.3	3.1	4.2	5.5	0.86	1.6	6.3	2.84	6.7	8.3	10.2	1.2	±
4.0	0.89	4.4	4.0	4.9	5.0	1.4	2.0	6.0	2.5	6.9	7.5	10.0		
5.7	0.82	4.5	2.7	4.1	4.7	1.0	1.3	5.0	4.2	7.3	9.4	9.8	2.0	+
4.9	0.92	5.0	3.1	4.2	6.3	0.97	1.5	5.3	3.6	8.6	8.3	8.4	0.95	±
6.5	0.81	3.6	2.9	4.2	4.6	1.1	1.3	6.1	1.9	6.0	7.3	11.2	2.94	+
4.6	2.58	6.6	8.0	6.9	3.4	2.0	2.2	11.7	4.1	4.8	9.2	13.0		
12.4		3.7	3.0	2.5	2.8	0.58	0.34	4.6	0.62	2.3	3.6	5.7	4.84	0.23
6.5	0.46	3.4	3.5	6.2	4.6	3.0	1.8	6.2	2.0	7.8	7.8	14.3		
4.1	0.47	3.5	3.9	6.8	5.2	3.2	1.3	7.3	1.9	5.9	8.9	16.0		
6.1	0.47	2.7	6.3	7.4	5.0	6.5	0.99	7.7	1.8	4.5	7.6	12.3		

SER	Serine	MET	Methionine	LYS	Lysine	HO-PRO	Hydroxyproline
THR	Threonine	ARG	Arginine	ASP	Aspartic acid	HO-LYS	Hydroxylysine
CYS	Cystine	HIS	Histidine	GLU	Glutamic acid		

TION OF FIN WHALE MEAT

g. amino acid N/100 *g.* total N

TRY	PHE	TYR	SER	THR	CYS	MET	ARG	HIS	LYS	ASP	GLU
0.89	2.0	1.5	3.7	3.2	0.31	1.5	9.7	6.9	8.5	6.1	7.6
0.95	2.3	1.9	3.8	3.8	0.74	1.5	15.2	4.72	11.8	6.3	10.0

pressed in *g.* amino acid/100 *g.* total matters.

whales is closely associated with their habitual lengths of time of diving, which are relatively constant depending on whale species. As is generally known, both sperm and baird beaked whales are long and deep divers, and their chief foods are both alike and mostly consist of squids. Thus, the author believes that the similarity of the amino acid composition of muscle proteins of these animals is closely connected with the similarity of their ecology.

As compared with beef, whale meat seems to be inferior to it in contents of the sulfur-containing amino acids, namely, methionine and cystine. However, in contents of the so-called essential amino acids other than methionine, whale meat is not always inferior to beef.

The heart muscle protein contains larger amounts of hydroxyproline, proline, and glycine, and smaller amounts of isoleucine, tryptophan, tyrosine, histidine, lysine, and glutamic acid than the voluntary muscle proteins. The existence of hydroxylysine in the heart muscle protein was also proved. As described below, hydroxyproline and hydroxylysine are nearly peculiar to collagen, and so the collagen content in heart muscle must be much larger than that in voluntary muscles. Presumably, this fact suggests that heart muscle contains the intercellular substance more abundantly than voluntary muscles. Assuming that whole amount of hydroxyproline in proteins of muscle meat and heart muscle exists as collagen and that collagen contains hydroxyproline at the ratio of 13.5% (Buddecke, 1958), the collagen content in proteins of muscle meat and heart muscle of baird beaked whale comes to 1.8% and 6.4% respectively.

In Table 5, the present results of protein of muscle meat of fin whale are compared with the Ogawa and co-workers' values of fin whale meat (1958). There is considerable disparity of each amino acid content between both cases. It is probably due to the facts that in Ogawa and co-workers' study, fresh meat was itself hydrolyzed, but in the author's experiment, the protein free from nitrogenous extractive, fat, etc. was hydrolyzed and also both cases differed from each other in the technique of protein hydrolysis.

Striking similarity of the amino acid composition of mucous membranes of the first stomach and small intestine should be noticed.

It is worth noticing that all four samples of protein of digestive system have relatively large contents of hydroxyproline and hydroxylysine. (The author found also that protein of parotid gland of a rabbit contained hydroxyproline at the ratio of 3.5%.) Especially, the mucous membranes contain much greater quantities of these amino acids than all the other samples. The distribution of both amino acids in nature seems to be nearly confined to collagen. The hydroxyproline content in collagen is about 14% (Akabori and Mizushima, 1954-5;

Buddecke, 1958; Block and Weiss, 1956). According to results of some investigators' experiments, hydroxyproline seems to be contained also in elastin, but the content in this protein is only about 1.5% (Block and Weiss, 1956). As shown in Table 4, the hydroxyproline content in proteins of mucous membranes and pancreas is much greater than the content in elastin. Accordingly, it is evident that the greater part of hydroxyproline in proteins of mucous membranes and pancreas exists as collagen or collagen-like substance. The existence of hydroxylysine in proteins other than collogen and gelatin hasn't been confirmed. From these facts, it is inferred that each of the analyzed tissues and organs of digestive system contains a large quantity of collagen or collagen-like substance. The much larger content of glycine in proteins of mucous membranes as compared with the alanine content is also an evidence for this inference, because collagen contains a very large quantity of glycine and a slightly large quantity of alanine while elastin contains very great quantities of both glycine and alanine (cf. Table 6.). Assuming that whole amount of hydroxyproline in proteins of mucous membranes exists as collagen and that collagen contains hydroxyproline at the ratio of 13.5% (Buddecke, 1958), the collagen content in proteins of mucous membranes of first stomach and small intestine comes to 46.6% and 53.3% respectively, namely about half of the whole quantity of each sample. It is supposed that such a large content of collagen in mucous membranes has some important meaning concerning their physiological functions. Collagen is a kind of scleroprotein and not easily affected by proteolytic enzymes. It is, therefore, presumable that the large content of collagen (or collagen-like substance) in mucous membranes of stomack and small intestine may be one of the reasons why these mucous membranes can withstand the action of their own proteolytic enzymes.

TABLE 6. APPROXIMATE AMINO ACID COMPOSITION OF COLLAGENS AND ELASTINS

Calculated to 16.0 *g.* of Nitrogen (Block & Weiss, 1956, p. 343)

	Collagens	Elastins		Collagens	Elastins
Glycine	21.9	24.2	Threonine	2.6	1.1
Alanine	9.1	21.3	Cystine	0.2	0.2
Valine	2.8	15.6	Methionine	0.9	0.2
Leucine	3.2	7.6	Arginine	7.7	1.2
Isoleucine	1.6	3.4	Histidine	0.8	0.1
Proline	12.8	13.0	Lysine	4.0	0.5
Tryptophan	0.0	0.1	Aspartic acid	5.7	0.7
Phenylalanine	2.2	4.3	Glutamic acid	10.1	2.8
Tyrosine	0.9	1.9	Hydroxyproline	12.4	1.5
Serine	4.0	0.9			

The nutritive value of mammalian liver has been often discussed from old times. When liver is regarded as a kind of protein food-stuff, the liver of baird beaked whale is probably inferior to muscle meat in nutritive value because its contents of a number of essential amino acids, namely, methionine, lysine, tryptophan and isoleucine are considerably smaller than the contents of these amino acids in muscle meat.

The cerebrum protein, as compared with other tissue and organ proteins, contains a remarkably small amount of total nitrogen. The similar fact is also observed with other kinds of animals (Block and Weiss, 1956, p. 284). In the amino acid composition, this protein shows no noteworthy special feature.

The amino acid composition of crystalline lens protein is considerably characteristic. In contents of arginine, tryptophan, phenylalanine and tyrosine, the lens protein is the largest among all the samples of protein treated in the present work, and the smallest in the alanine content.

The amino acid composition of aorta protein is specific. The value of nearly every amino acid contained in this protein is either always larger or always smaller than values of the same amino acid in all other kinds of protein analyzed in the present work. As is generally known, elastin is principal constituent protein of arteries (Akabori and Mizushima, 1954, Vol. II, p. 2 and 7). As shown in Table 4, the aorta protein contains a pretty large quantity of hydroxyproline and also an appreciable quantity of hydroxylysine. It is, therefore, undoubted that collagen is also an important constituent of the aorta. The amino acid composition of aorta protein shows that the protein consists mainly of elastin and collagen, which is easily understood when the aorta protein is compared with elastin and collagen in amino acid composition (Table 6).

Epidermis and gum resemble closely each other in amino acid composition. From their good similarity in amino acid composition, elasticity, appearance and others, the author believes that both tissue proteins are substantially the same. From their relatively high content of cystine, it is probable that these proteins contain some amounts of keratin.

The baleen is regarded as a kind of crude keratin. Its high content of cystin is an evidence for that.

From the results obtained in the present work, generally, it is found that internal organ proteins, as compared with protein of muscle meat, contain larger quantities of glycine, proline, hydroxyproline, and hydroxylysine and smaller quantities of isoleucine, tryptophan, methionine, lysine, and glutamic acid. This fact shows that internal organs are much richer in quantity of collagen than muscle meat. That is easily understood from the amino acid composition of collagen and from the fact that hydroxyproline and hydroxylysine are almost peculiar to collagen as stated before. In other words, the aforesaid fact shows that internal organs, as compared with muscle meat, are much richer in quantity of connective tissue, because collagen is the principal constituent protein of connective tissue.

Internal organ proteins are probably inferior to protein of muscle meat in nutritive value on account of their smaller contents of the above-mentioned essential amino acids, namely, isoleucine, tryptophan, methionine and lysine.

SUMMARY

1. In order to carry out the present study, a simple and economical method for direct estimation of 18 common amino acids except tryptophan and hydroxyproline on ascending one-dimensional paper chromatograms was devised and Macpherson's method for dermination of histidine was modified. By use of the former, determination of hydroxylysine was also enabled to be made in a micro- or submicro-scale.

2. Amino acid distribution in proteins obtained from muscle meats of fin, sei, sperm, and baird beaked whales, muscular tissues of diaphragm and heart, mucous membranes of first stomach and small intestine, pancreas, liver, cerebrum, lung, spleen, testis, lens, aorta, and epidermis of baird beaked whale, and also gum and baleen plate of whalebone whales was investigated.

3. Proteins of voluntary muscles, especially muscle proteins of sperm and baird beaked whales resemble very closely each other in amino acid composition. It seems that the similarity of the amino acid composition of muscle proteins of these animals is closely associated with the similarity of their ecology.

4. The whale meat seems to be inferior to beef in contents of sulfur-containing amino acids, but not always inferior to beef in contents of essential amino acids other than methionine.

5. Heart muscle differs considerably from voluntary muscles in amino acid composition. Collagen content in heart muscle is much larger than that in voluntary muscles. From this fact it is presumed that heart muscle contains the intercellular substance more abundantly than voluntary muscles.

6. Large content of collagen in each digestive organ protein was inferred from its amino acid composition. The collagen content in proteins of mucous membranes of first stomach and small intestine reaches about half of the whole quantity of each sample. The large content

of collagen (or collagen-like substance) in the mucous membranes may be one of the reasons why these membranes can withstand the action of their own proteolytic enzymes.

7. Lens protein is characterized by its large contents of tryptophan, phenylalanine, tyrosine, and arginine.

8. Aorta protein consists mainly of elastin and collagen. The value of nearly every amino acid contained in this protein is either always larger or always smaller than values of the same amino acid in all other samples of protein analyzed in the present work.

9. Gum and epidermis without horny layer are substantially the same.

10. Generally, internal organ proteins, as compared with protein of muscle meat, contain larger quantities of glycine, proline, hydroxyproline, and hydroxylysine and smaller quantities of isoleucine, tryptophan, methionine, lysine, and glutamic acid. This fact shows that internal organs are much richer in quantity of connective tissue than muscle meat, and that internal organ proteins are probably inferior to protein of muscle meat in nutritive value.

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