FOODS OF BALEEN WHALES IN THE NORTHERN PACIFIC

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It is well known that the food item of whales is one of the most important problems on the biology of whales. Many studies on foods of whales have been carried out up to the present in the Atlantic and Antarctic waters by many excellent biologists. After Mackintosh & Wheeler (1929) investigated the foods of southern blue and fin whales, Ruud (1932) and Hardy & Gunther (1935) made also comprehensive studies of biology of food planktons. Recently, Peters (1955) discussed some biology of *Euphausia superba*, the main food of whales in the Antarctic baleen whales, and Marr (1956) also discussed the relation between *Euphausia superba* and surface currents of the sea in his preliminary paper. In the northern Atlantic, Hjort & Ruud (1929) and Einarsson (1945, p. 159–160) described the importance of copepods and euphausiids as foods of whales refering to many previous papers. On the other hand, though considerable attentions have been paid to the foods of whales, comparatively little is known of the problem in the northern Pacific before the year 1942. The previous nots on the problems are found in papers by Zenkovitch (1937), Hollis (1939), Ponomareva (1949) and some others. Recently, useful works have been carried out one after another by many biologists to which I refer in the suitable columns of this paper as occasion demands.

In the summer of 1952, the staffs of the Whales Research Institute in Tokyo entered into the studies on foods of whales in order to study the biology of whales and planktons. Thus during the last six years, a large amount of data on foods of whales have been collected through Japanese whaling expeditions. In addition, plankton samples collected in vertical hauls with plankton nets also amount to a considerable number. The present studies is designed to describe the outline on the relation between whales and their foods mainly based above samples. Some biology of euphausiids which consist important parts of foods of whales is also investigated to some extent in this paper.

I would like to express my sincere thanks to Dr. Hideo Omura, the director of the Institute for suggesting this investigation as well as for constant guidance. Thanks are also due to Dr. Yoshiyuki Matsue, Professor of the University of Tokyo and Mr. Yuzo Komaki for valuable suggestions in the course of this work. I am also indebted to Dr.

Albert, H. Banner and Dr. Brian, P. Boden for sending me kindly valuable reprints on euphausiids and kind personal communications.

MATERIAL AND METHOD

The present paper is mainly based on stomach samples of whales captured in the northern part of North Pacific for three years since the year 1954 to 1956, and data on quantity and freshness of stomach contents collected by inspectors and biologists through Japanese whaling expeditions since the year 1952 to 1956. The main part of above materials have been collected by following inspectors and biologists on board.

1952 Haruyuki Sakiura, Katsunari Ozaki, Kazuo Fujino.
1953 Yasutake Nozawa, Iwao Takayama, Takahisa Nemoto.
1954 Setsuo Nishimote, Tamenaga Nakazato, Takehiko Kawakami, Ikuyo Hasegawa, Kazuo Fujino, Seiji Kimura.
1955 Yasutake Nozawa, Saburo Ikeda, Kenichi Iguchi, Kazuo Fujino.
1956 Heihachiro Kawamura, Sumio Matono, Sadao Ishii, Seiji Kimura.

The method of observation on stomach contents has followed the one adopted by previous works (Mizue, 1952 and others). Stomach contents in the first stomach are classified into following species.

Euphausiids
Copepods (mostly Calanoids including *Metridia* species in rare cases)
Fish
Squids

Then, the quantity of stomachs is divided into following classes.

Classes	0	r	rr	rrr	R
Condition of stomachs	Empty	Few	Moderate	Rich	Full

The freshness of the stomach contents is also determined by following grades.

Grades	f	ff	fff	F
Condition of contents	Nearly digested	A little digested	Fresh	Very fresh

Above classifications are made by naked eyes, and not so exact in strict sense. The stomach samples have been collected from a part of contents on board, washed for some times and preserved in 10 percent formalin sea water. The sampling of zooplanktons by plankton nets in the whaling grounds has started in the spring of 1953. Present study is mainly based on the materials collected during the year 1955, through the whale marking cruise by 'Konan Maru No. 5'. All the samples have been taken in vertical hauls with the special net for zooplanktons: Mouth diameter—45 cm; length 80 cm, shape conical, materical synthetic-resin-processed silk grit gauze 54 (aperture 0.33 mm). All plankton samples have been preserved also in 5–10 percent formalin sea water. The sample divider has been used for the fractioning of above samples. The plankton number in a sample is obtained from the multiple inverse proportional to the fractioning. On some of zooplanktons body length is measured for further investigations. Euphausiids are measured from the tip of the rostrum to the end of the telson with an accuracy of 1 mm or 0.5 mm for the smaller specimens, being straightened out on a measuring glass. Copepods are mesured the cephalothorax length with a built in micrometer with bioculer microscope. The papers and books used for the identification of plankton species are listed in the last part of this paper.

WHALING GROUNDS

HYDROGRAPHY

The whaling grounds where now Japanese pelagic whaling operates are all *feeding area type* whaling grounds. Almost all whales swarm on their foods, and the concentration of whales for their reproducting never be considered. Mating grounds, such as whaling grounds off Lower California for grey whales, is considered to be in far south regions. And all Japanese pelagic whaling grounds are situated at the northern part of North Pacific.

Oceanographical studies on these parts of the North Pacific have been carried out by Uda (1935), Barnes & Thompson (1938), Mishima & Nishizawa (1955) and some other workers. Fleming (1955) has advanced, in recent years, a general summery of the oceanographycal conditions of the North Pacific. This conception will surely prove to be of the greatest use for the comprehension of the biological conditions in the whaling grounds. Brief quotations of the review may, therefore, be of interest. I will chiefly use quotations from the paper by Fleming on the point.

Fleming has divided the northern pacific to 3 zone, Boreal zone, Subarctic zone and Central zone. Japanese whaling grounds lies in Boreal and Subarctic zones after his divisions. Fleming, further, points out characteristics of above divisions of zones. Boreal zone is divided into five regions as shown in figure 1. These five regions are as follows:

1. *Kamchata-Kurile coastal region*—Southerly flow of cold, dilute, nutrient-rich. Mostly ice-covered in winter.
2. *Western gyral region*—Irregular currents but average counterclockwise circulation. Very high nutrient content. Strong mixing between Aleutian Islands. Includes part of Alaskan shelf.
3. *Alaskan coastal region*—Northerly flow of warm, dilute, medium nutrient-content water. Mostly Ice-covered in water. Shallow area having an irregular coast with many rivers.

4. *American coastal region*—Northerly flow north of about 50°N and southerly in lower latitudes. Salinities low because of local precipitation and runoff. Temperatures relatively warm in northern part. Nutrients variable but usually moderate to high. Generally irregular coast.

5. *Alaskan gyral*—Subarctic water that turns northward and forms a counterclockwise gyral. Salinity moderate. Temperature relatively high. Divergence supplies nutrients so that content is generally high. Precipitation high. Deep area.

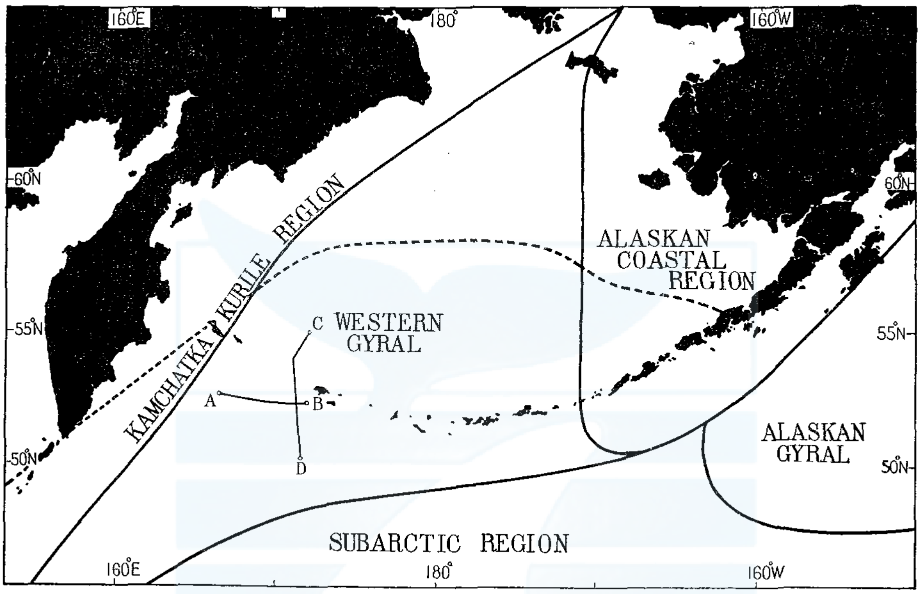

Fig. 1. Natural regions of the northern Pacific Ocean; Broken line—February ice limit. (Divisions follow the figure by Fleming, 1955).

Main Japanese whaling grounds locate along the boundary regions between *Kamchata-Kurile coastal region* and *western gyral region*, between *Alaskan coastal region* and *Alaskan gyral*. Other main whaling grounds locate in the adjacent waters to Aleutian Islands and along the slope of the continental shelf of Alaska. The boundary between subarctic region and boreal zone may have also some value for our pelagic whaling though there has been no observation for whales. The central zone called by Fleming is considered to has no weight for Japanese whaling. From the year 1952 to 1953, Japanese expeditions operated chiefly in the waters of the south-western side of the Aleutian Islands. On the sea condition of the area in early summer, Mishima & Nishizawa (1955) describe that, 'A warm water mass of low salinity is found to flow east to west. It reaches as far west as longitude 165° east, on its way spreading several branches into the Bering', and 'A large clockwise eddy of this water is thus formed to the south or south west of Attu Island'. Whaling grounds lie along above eddy, the boundary between the cold current of low salinity along the eastern side of Kamchatka Peninsula. And a whaling grounds is formed on the branch of above stated cold current bent east from the southern end of that peninsula and flows along the Aleutian Ridge. Japanese whaling factory ship 'Kinjo Maru' operated in early summer in 1954 on the branch

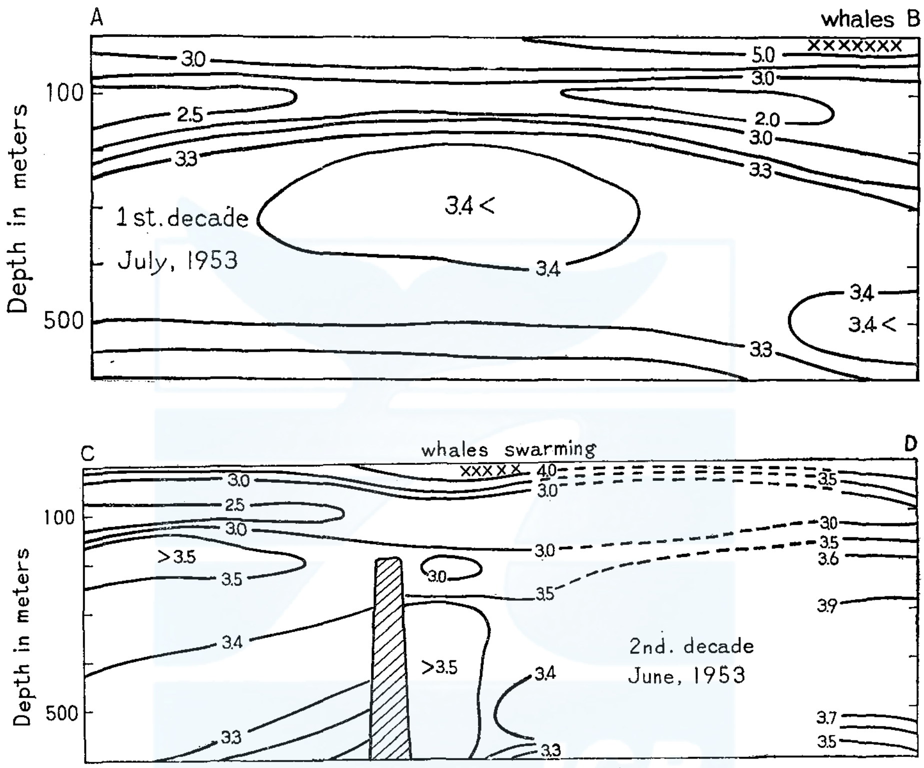

Fig. 2. Vertical distribution of temperature in sections A–B and C–D illustrated in figure 1. (Drawn by K. Nasu).
Crosses—Whales are swarming

and caught considerable number of fin whales. From the data of temperature obtained by the 'Tenyo Maru' cruise in summer of 1953 (Watanabe, 1954), two vertical sections of isotherms are drawn by Keiji Nasu of the Whales Research Institute. In section A–B, the surface water temperatures are higher than 4°C in first decade of July, and the subsurface layer (sensu Mishima & Nishizawa, 1955) is found at 100 m level. The boundary of such cold layer, that is, the sea region under where the cold layer is found, is considered to be good whaling grounds (Uda, 1953; 1954; Uda & Nasu, 1956). In fact, the tendency that whales swarm in such regions has been observed as shown in figure 2. I have observed above tendencies also in the data of the 'Takunan

Maru No. 6' in the adjacent sea waters to Japan in 1955. Some biological result of the latter cruise is also discussed in this volume. In addition to this type of whaling grounds Ruud (1932) fully discussed the general summery to the whaling grounds. Ruud describes, 'if, therefore, an area of production is to possess any importance as a rendezvous of whales there must be a concentration of Krill there. Such concentrations are found in the area of convergence, in backwaters, in the vortices of mixed layers, and at the centre of areas where there is a cyclonic movement'. Such centre area of cyclonic movement is the most favourable whaling ground also in northern hemisphere as discussed by Uda (1954).

Barnes & Thompson (1938) made compehensive study on the north part of the eastern Aleutian Islands and Bering Sea. By their studies the surface currents of north of the Aleutian Ridge, parallele the ridge towards the east near Bogoslof Island, then swing north in the vicinity of Unalaska Islands as the water met the continental shelf and then double back along the shelf as it heads to the north-west just south of the Plibilof Islands. Thus, the upwelling current along the continental shelf by the currents, and backwaters between above currents and the water from Bristol Bay and Yukon Delta, are valid causes for the formation of whales' swarming.

The ice covers the northern half of Bering Sea in winter (Fleming, 1955; Pilot chart of the North Pacific Ocean, 1955), where considerable number of fin, humpback and gray whales are swarming. This migrations of fin, humpback and gray whales to the arctic sea through Bering Strait is proved by the catch data of Japanese whaling expedition in 1940. Whales in these area in summer must retreat to south waters from there before ice prevailing the area exept few whales which inhabit among the broken ice or narrow uncovered sea areas.

WHALING GROUNDS AND CATCH

Japanese northern Pacific pelagic whaling expeditions have been operating since the year 1952. Outlines of the whaling in the North Pacific is discussed by Omura (1955). He also disscusses on the brief history of pelagic whaling in the northern part of the North Pacific. So, I only state short review of the problem here.

Whaling grounds. Japanese main whaling grounds lie along Aleutian Islands, Komandor Islands and off Kamchatka Peninsula as shown in figures 1 and 3. These whaling grounds may be divided for convenience into four grounds. Namely, A ground: the south part of Komandor, off Kamchatka Peninsula and west south of Attu Islands; B ground;

the north part of Komandor Islands; C ground: the north part of the eastern Aleutian Islands; D ground: the south part of the eastern Aleutian Islands. The first whaling grounds divided, by further observations, into two subdivisions. The longitude line 168° east may be the appropriate line by which the first whaling grounds is divided. Japanese whaling expeditions operated only in A ground in years 1952 and 1953. Successive expeditions in 1954, and 1955 operated also in C and D whaling grounds. In 1956, Japanese whaling have operated in B ground besides above A, C and D grounds.

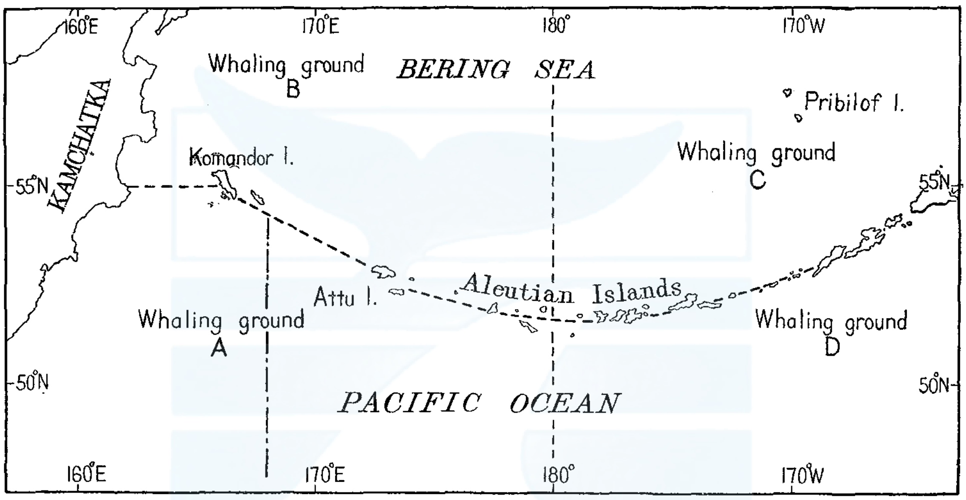

Fig. 3. Whaling grounds in the northern part of the North Pacific.

Catch. Japanese pelagic whaling has captured such number of baleen whales as shown in table 1 since the year 1952. In these five years, Japanese whaling expeditions have caught 429 blue, 4771 fin, 309 sei and 368 humpback whales. When these catch data are divided by above classifications of whaling grounds, some peculial features in them are observed. The species of baleen whales differ considerably in each localities. The considerable difference in the catch is also observed between the catch of two subdivisions of whaling ground A as stated above. In west area of 168°E in whaling ground A, fin whales are dominant in number with considerable catch of blue and sei whales as described in table 1. But fin whales are dominant with some humpback whales in the east of 168°E, and blue and sei whales are captured in far smaller number. In the whaling ground B, the north part of Komandor Islands, fin whales are only dominant whales though very few sei whales are caught in this water. Blue and humpback whales have never been caught by the operation. Especially the fact that no blue whales has been caught by previous Japanese expeditions in waters north of Komandor Islands suggests that blue whales seldom migrate to these waters (Omura, 1955). On the south area of the middle Aleutian Islands, I find no peculiar feature in the composition of whales caught if this area is separated from other parts. So I did not deal with this area as a division. The catch composition of whales in whaling grounds along the east Aleutian Inslands shows remarkable difference from western regions. Only fin whales are caught in the north

TABLE 1. NUMBER OF CATCH BY JAPANESE EXPEDITIONS IN THE NORTHERN PACIFIC SINCE THE YEAR 1952 TO 1956

Whaling ground A (West of 168°E)

Whale species	Year 1952	1953	1954	1955	1956
Blue	29	83	28	23	1
Fin	130	273	442	87	186
Humpback	11	17	15	—	1
Sei	9	96	67	20	29

Whaling ground A (East of 168°E)

Whale species	Year 1952	1953	1954	1955	1956
Blue	26	6	—	—	—
Fin	83	197	122	61	154*
Humpback	25	17	1	18	34
Sei	5	2	21	—	13

* Including 1 whale lost.

	Whaling ground B	Whaling ground C			Whaling ground D		
	Year	Year			Year		
Whale species	1956	1954	1955	1956	1954	1955	1956
Blue	—	—	—	—	117	47	69
Fin	255*	587	1177	774*	165	35	46
Humpback	—	6	10	—	114	89	2
Sei	5	1	—	—	40	1	1

* Including 1 whale lost.

waters of the eastern Aleutian Islands, though 16 humpback and 1 sei whales have been caught in a ambiguous position between Unimak and Atka Pass. As in the northern part of the western Aleutian waters, no blue whale has been caught also in waters north of the eastern Aleutian Islands and in one north of Pribilof Island. On the other hand, comparatively many blue and humpback whales have been caught, and fin whales are not so dominant in the south area of the eastern Aleutian Islands. Blue and humpback whales are important catch in this water. Besides above whaling grounds, the 'Tonan Maru' operated in the arctic sea through the Bering Strait in 1940, and caught fin, humpback and gray whales on which, to my regret, no biological collection is remained. So the discussion on whales in these waters is eluded in this paper.

FOOD OF WHALES

STOMACH CONTENTS OF WHALES

Generally speaking, baleen whales in these waters take mainly zooplanktons as in other parts of the world. And some other foods, such as squids and fish are also occasionaly found in stomachs of them. On this subject, it is proper to treat it by respective whale species as discussed by previous workers.

TABLE 2. STOMACH CONTENTS OF BALEEN WHALES CAUGHT BY JAPANESE WHALING FLEETS FROM 1952 TO 1956 IN THE NORTHERN PART OF NORTH PACIFIC

	Whale species			
Kinds of stomach contents	Blue	Fin	Sei	Humpback
Euphausiids	196	1674	4	201
Eu. & Copepods	2	102	—	2
Eu. & Squids	—	2	—	1
Eu. & Fish	—	3	—	11
Eu., Fish & Squids	—	1	—	—
Copepods	—	667	107	—
Co. & Squids	—	1	4	—
Fish	—	3	4	45
Fish & Squids	—	—	1	—
Squids	—	10	12	1
Empty	228	2292	173	107
No. of stomachs examined	426	4755	305	368
Not examined	3	16	4	—

Blue whales. Blue whales are famous for the plankton feeder, only take euphausiids in the Antarctic waters though some rare appearances of fish, amphipods have been observed (Mackintosh & Wheeler, 1929; Mizue & Murata, 1951). Blue whales feed mostly on *Euphausia superba* in the Antractic, also on *E. crystallorophias* (Marr, 1956) and *Thysanoëssa macrura* (unpublished data by Japanese whaling expeditions in 1956). *Thysanoëssa inermis* and *Meganyctiphanes norvegica* are their favourite foods in the Atlantic (Hjort & Ruud, 1929). Rough classifications of stomach contents of whales examined on board are described in table 2. The table shows blue whales feed only on euphausiids with exceptional whales feeding on the mixture of euphausiids and copepods. This apparently indicates that blue whales are real *euphausiids feeder* in the

North Pacific as considered until now. Matsuura & Maeda (1942) also state blue whales feed on euphausiids and blue whales are not polyphagous. While there are also some different data and conclusions by Mizue (1951) and Sleptzov (1955). Blue whales have sardines and squids respectively in their stomachs (Mizue, 1951), and Sleptsov (1955) describes on blue whales in Kurile waters that they feed sometimes not only on zooplanktons but also on small gregarious fish, whenever blue whales meet those fish. Indeed, 6 blue whales out of 15 whales fed on fish after his data. Perhaps, the Kurile waters are less productive as compared with the northern waters for zooplanktons, so blue whales in the Kurile waters feed on fish for want of their favourite foods of euphausiids. Foods of blue whales investigated by Sars (1874) in the Atlantic are all krill (*Thysanoëssa inermis*), and lodde or capelin has never been found in stomachs of them.

Fin whales. It is thought that fin whales are not so regulate in seasonal migrations as blue whales because fin whales are polyphagous, being able to take their foods anywhere that planktons, fish or squids are abundant. Their staple foods have been considered to be not so restricted as blue whales, though many fin whales are also planktonophager. Fin whales take *Euphausia superba*, *E. cristallorophias*, and *Thysanoëssa macrura* in the Antarctic waters like blue whales. In the Atlantic, fin whales feed not only on euphausiids, *Thysanoëssa inermis*, *Meganyctiphanes norvegica*, but also on swarming fish, such as Sild and Lodde. Copepod, *Calanus finmarchicus*, is also considered one of the staple diet in some seasons in the Atlantic (Hjort & Ruud, 1929).

In the northern Pacific waters, Zenkovitch (1934) describes that herrings are found in stomachs of fin whales and fin whales persue those swarms of herrings in Bering Sea. Matsuura & Maeda (1941) examined stomach contents of fin whales and observed that the most of fin whales in the waters off Kamchatka feed on euphausiids, *E. pellucida* (*E. pellucida* is canceled by Hansen in 1905). Besides, 2 whales feed on *Calanus cristatus* and 5 whales feed on cods. Kasahara (1950) consideres from above facts and data by Mizue (1952) on the whales in the Japanese waters, that euphausiids in the northern Pacific are rather poor as the foods of fin whales. And the polyphagous habit of fin whales may be due to above scantiness of eupnausiids. In recent years, Banner (1949) reports, that 27 fin whales from Akutan Island, feed only on a euphausiid, *Thysanoëssa inermis*, but Sleptsov (1955), Kleinenberg & Makarov (1955) also describe that the considerable parts of food of fin whales are occupied by fish and cephalopods. Sleptsov (1955) states further that cephalopods is confirmed as one of the staple food of fin whales in Aleutian waters. Fish are also considered to be the staple food for fin whales by the latter warkers. Indeed, far many fin whales take fish and squids after them as compared the Japanese data illustrated in table 2. The Japanese data show, the most fin whales take euphausiids and copepods as staple foods though squids and fish are also found in some occasions. However, they never be considered to be the favourite food for fin whales. In the adjacent waters to Aleutian Islands, fish and squids are considered to be only the makeshift foods for fin whales when they meet no swarm of zooplanktons. Collett (1911–12) describes some observation in the Atlantic that, when fin whales has to choose between fish and euphausiid diet, they choose the euphausiids.

It is often observed that fin whales or sei whales taking fish are suffered by the parasitic nematods in their stomachs. As the some larvae of those nematods are considered to originate in fish (Margoris & Pike 1956), the ichthyophager of fin whales may be an acquired taste of some unusual fin whales from the weaning. The fact that some fin whales take fish along Aleutian Islands, is apparently due to that swarming fish are very aboundant as compared with euphausiids or copepods, favourite foods of fin whales.

Humpback whales. Euphausiids are the main food of humpback whales. But humpback whales feed on swarming fish as well as euphausiids in some cases. They take herrings commonly (Zenkovitch, 1934) and considerable number of them feed on fish, cods, sardins, herrings also in recent studies (Sleptsov, 1955; Kleinenberg & Makarov, 1955). In the adjacent waters to Attu Islands, they mainly feed on atka mackerels which constitutes large swarms of themselves by Japanese observations. Copepods and squids are scaresly observed as shown in table 2. Thus, the value of copepods and squids as foods for humpbacks are considered to be very few. Only 2 whales feeds on the mixture of copepods with euphausiids and 2 whales feeds on squids and the mixture of squids and euphausiids. To my regret, the data by Mizue (1951) and the discussion by Kasahara (1950) can not be refered on this point because their division of food 'Krill' contains two different groups, copepods and euphausiids, and their observations are not so accurate. Howell & Huey (1930) describe some foods of whales from California waters, and suggest that 16 humpbacks feed on shrimps (perhaps *Euphausia pacifica*) and 5 whales on sardines. From above many observations, only two different groups, euphausiids and fish are considered to be the favourite foods for humpback whales.

Sei whales. Very famous works have been carried out on foods of sei whales in the north Atlantic until now. The migration of sei whales was also studied in connection with the conditions of zooplanktons (Hjord & Ruud, 1929). Sei whales are noted to favour copepods, *Calanus* *finmarchicus* in the Atlantic, so that abundance of *Calanus finmarchicus* in whaling grounds directly influence the number of whales which swarm in the area. In the northern Pacific the data by previous workers show sei whales take fish and squids as well as 'Krill' (Mizue, 1951) or copepods (Sleptsov, 1955). Sei whales mostly feed on copepods as shown in table 2 in Japanese whaling grounds as in the Atlantic. Only 4 whales take other zooplankton euphausiids only. This number is far smaller when I compare with those in adjacent waters to Japan where many sei whales feed on a euphausiid, *Euphausia pacifica*. From the data of the Whales Research Institute, the favourite foods of sei whales in the Japanese waters are euphausiids, mainly *Euphausia pacifica* sometimes *Thysanoëssa inermis* or *T. longipes* in the cold waters. A copepod, *Calanus finmarchicus* is also found from early spring to summer in these waters (unpublished data of the Whales Research Institute). The indistinct species 'Krill' described by Kasahara (1950) and Mizue (1951) must be corrected by above described species. Besides copepods, 12 whales take squids and 4 whales on fish only. But these foods are considered also incidental appearances in the northern part of the North Pacific where copepods are abundant.

SPECIES OF FOODS

Planktons

The species of food planktons for baleen whales in the sea adjacent to Japan is fully discussed by Nakai (1954), and this paper shows some differences between foods of whales in the northern Pacific and Japanese waters. From summerized review of this survey (Nakai, 1954) and my data, following plankton species are considered as staple foods for baleen whales in the northern part of the North Pacific. As stated in above chapter, main foods of baleen whales in these waters are euphausiids and copepods, and dominant species of them are restricted to some species mostly common in the sea. Some other less significant species are discussed last part of this chapter.

Euphausiids	*Euphausia pacifica* Hansen	Copepods	*Calanus cristatus* Krφyer
	Thysanoëssa inermis (Krφyer)		*Calanus plumchrus* Marukawa
	Thysanoëssa longipes Brandt		*Calanus finmarchicus* (Gunner)
	Thysanoëssa spinifera Holmes		*Metridia lucens* (Boeck)

Euphausia pacifica Hansen. In spite of the fact that *E. pacifica* is one of the most important euphausiid in the adjacent waters to Japan and Korean waters (Nakai, 1942, 1954), very few observations has been made by Japanese workers as disscussed by Nakai (1942). He insists on the importance of it as foods of whales and fish. Indeed, *E. pacifica* is the most dominant food in the adjacent waters to Japan, off Sanriku (the north east part of Japan) and Hokkaido. *E. pacifica* is also noted by Howell & Huey (1930) to play some part of foods of gray, fin and humphack whales in the Californian waters.

The northern distribution of *E. pacifica* is considered from Japanese data as north as Aleutian Islands where considerable number of it found in stomachs of whales. In the north parts of Aleutian Islands, though many specimens are collected by tow nets, it vanishes as dominant species in stomachs of whales. So it is considered the importance of *E. pacifica* as food of whales in Aleutian waters is not so heavy as in Japanese waters. Only 9 specimens out of 126 collected euphausiids samples are filled with dominant patches of *E. pacifica* as shown in

TABLE 3. DOMINANT APPEARANCES OF EUPHAUSIIDS IN COLLECTED SAMPLES

Species of euphausiids	Whale species: Blue	Fin	Humpback	Sei	Total
E. pacifica	2	6	1	—	9
T. inermis	8	65	8	1	92
T. longipes	2	21	1	—	24
T. spinifera	—	1	—	—	1

TABLE 4. APPEARANCES OF EUPHAUSIIDS IN COLLECTED SAMPLES

Species of euphausiids	Whale species: Blue	Fin	Humpback	Sei	Total
E. pacifica	2	14	1	—	17
T. inermis	9	76	10	1	95
T. longipes	5	57	2	2	66
T. spinifera	1	15	3	—	19

table 3. Especially, in the north part of the eastern Aleutian Islands where many whales feed on *T. inermis*, *E. pacifica* has scarecely been observed from Japanese collections. The larval form of *E. pacifica* described by Boden (1950) also seem to be common in southern waters of Aleutian Islands in summer. However, furcilia stages of it do not occur in stomachs of whales as following euphausiids, although some incidental appearances of noupli and furcilia larva of them are observed. Ruud (1932) also describes such conclusion on *E. superba*. The cancelled species *Euphausia pellucida* quoted by Mizue (1952) and Kasahara (1950) perhaps mean this *E. pacifica*, the most dominant species in the waters to which they refered.

Thysanoëssa inermis (Krφyer) Hansen. It is one of the most famous food euphausiid as 'small krill' in the Atlantic. It is so important in some seasons as the migrations of blue and fin whales are affected by the conditions of swarming of it (Hjort & Ruud, 1929). In the northern Pacific, perhaps Banner (1949) is the first to describe this species from the fin whales of adjacent waters to Akutan Islands. He again describes *T. inermis* as dominant foods of whales referring to the distribution of *T. inermis* of those waters (1954). Many collections of the Whales Research Institute show that *T. inermis* is the most important species of euphausiids, as swarms of *T. inermis* have been found as stomach contents of whales in Bering Sea, adjacent waters of Aleutian Islands, Kurile waters and also in Okhotsk Sea. *T. inermis*

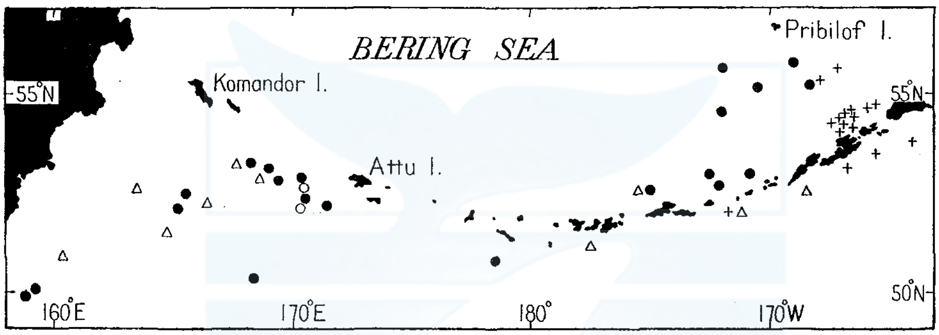

Fig. 4. Main occurrences of some euphausiids: Open circls—*Thysanoëssa longipes* spineless form; Solid circles—*Thysanoëssa longipes*; Crosses—*Thysanoëssa spinifera*; Open triangles—*Euphausia pacifica*.

Fig. 5. Abdominal spines of *Thysanoëssa inermis* (Krøyer) Hansen.
A. Two spine form. B. One spine form with rudimentary spine on 5th segment.

distributes widly in the whaling grounds and the utmost concentration of it is found in C whaling ground. Fin whales in C whaling ground take almost only these swarms of *T. inermis*.

Ten furcilia stages of *T. inermis* (Einarsson 1945), have not been found as foods like *E. pacifica* by my studies. Above fact may be due to the want of storage of fat in larval stages of euphausiids and different biological conditions from adults in depth of distributions or degree of their congregations. The density of swarms of euphausiids is considered to has great significance for feeding habits of whales. I suppose if the patch of euphausiids is not so dense, as in larval stages whales perhaps take no notice of them. And sparse patches of euphausiids may be saved from whales' swallowing.

In some taxonomical points of *T. inermis* differences have been discussed on the Atlantic specimens. Hansen (1915) reports the presence of a spine in the fifth abdominal segments on the Pacific specimens. On the contrary, Einarsson (1945) states 'None of the numerous specimens examined by me have shown eaven the slightest sign of a spine on the fifth segment' on the Atlantic specimens. In vast collections at my hand, the fifth abdominal segments also have usually abdominal spine as described by Hansen (1915). The case wanting the spine is rarely observed. I count these two formes on some collections and the two spined form is dominant in each 100 specimens of collections. As compared with Atlantic specimens discussed by Einersson (1945), one characteristic features of Pacific specimens of *T. inermis* is considered to

TABLE 5. NUMBER OF ABDOMINAL SPINES OF *T. INERMIS*

Year	Samples' no.	One spined form*	Two spined form
1953	475	6	94
1954	K728	10	90
1955	118	13	87
〃	393	7	93
〃	1655	8	92
〃	1811	19	81
〃	1848	30	70
〃	1849	11	89
〃	1871	—	100
〃	1879	2	98
〃	1885	13	87

* Including those with rudimentary spines in the 5th segment.

bear two abdominal spines. The distribution of these two form show some differences even in northern Pacific. However, further discussion on this point needs more examinations.

Thosanoëssa longipes Brandt. *T. longipes* is also the most common euphausiid alike *T. inermis* in northern part of the North Pacific. So it is considered to bear considerable significance as the food of whales (Ponomareva, 1954), though *T. longipes* has occured less in number as dominant foods of whales as shown in table 3. The cases that swarmes of *T. longipes* appeares in dominant number are about one-third of *T. inermis* in the collections. On the contraly, *T. longipes* is the most abundant and frequent in samples collected by surface plankton nets from 200 m. Above data suggests that adults and adolescents of *T. longipes* distribute scatteredly in the surface waters of the sea, not so concentrated as *T. inermis* in every times. *T. longipes* is also found in the Okhotsk Sea and the adjacent waters to Japan as whales' foods.

On the taxonomical points of *T. longipes*, Banner (1949), and Boden, Johnson & Brinton (1955) describe the smaller form of *T. longipes* which lacks the conspicuous abdominal spines. Those spineless form inhabits the whaling grounds in considerable number in the same surface waters. The spineless form has appeared in 2 stomachs of whales dominantly in my collections, and swarms of spine form have been mingled with it.

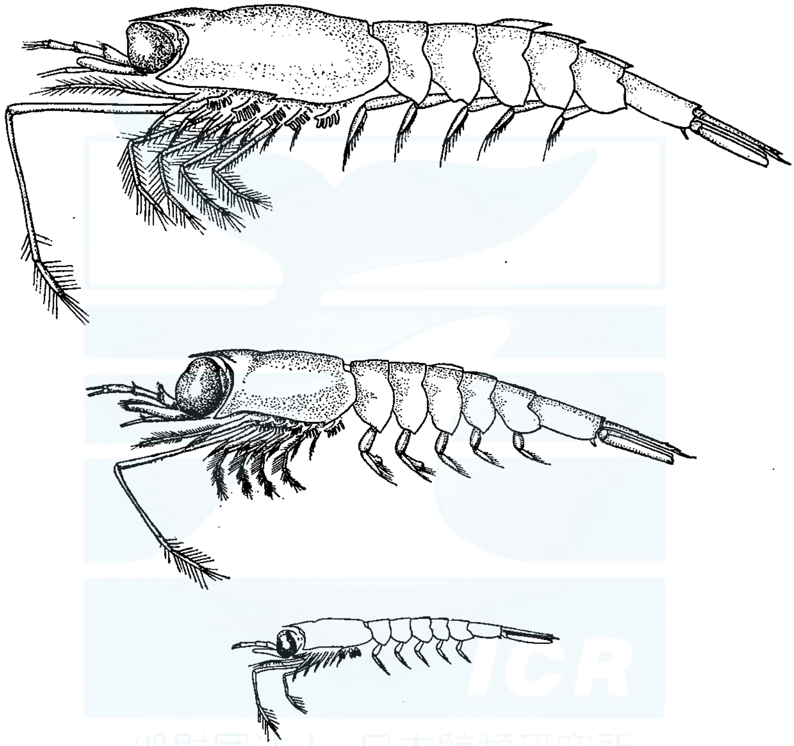

Fig. 6. *Thysanoëssa longipes* Brandt. Upper; Adult female of spine form from the left side. Middle; Adult male of spineless form from the left side. (×4) Lower; Juvenile form of spine form about 7 mm.

The eyes of spineless form is larger than the original form in some specimens as compared the spine form as shown in figure 6. Some of them possess a greatly enlarged eye (Boden, Johnson & Brinton, 1955), which has occurred more frequently in eastern side of the North Pacific in rough speaking. This variation in the size of eyes is formarly noted by Banner. Banner (1949) states 'Both forms of *T. longipes* are fragile. Especially so is the spineless form*. This special feature is well observed in first stomachs of whales. The eyes of *T. longipes* are almost broken by the digestion of whales though eyes of other euphausiids such as *T. inermis* or *Euphausia pacifica* are never broken in the same conditions. The spineless form is more fragile in such cases as stated in Banner's paper.

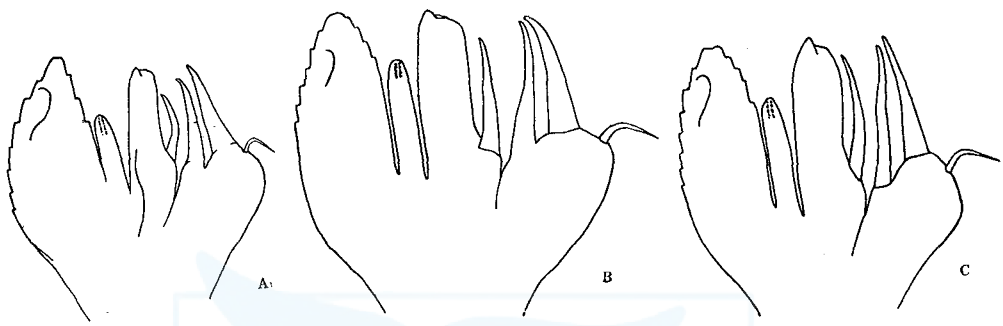

Fig. 7. Male copulatory oagans of *Thysanoëssa longipes* Brandt. A.B. Spineless form. C. Spine form. (×50)

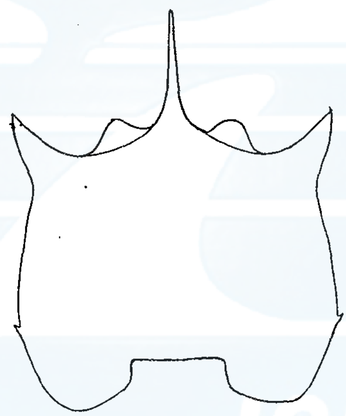

Fig. 8. Carapace of spineless form of *Thysanoëssa longipes* Brandt. (×10)

The position of the lateral denticle of carapace in spineless form differs from that of the original form. The lateral denticle of spine form is located in about middle of the lateral margin of carapace, a little to the back. On the other hand, the lateral denticle of spineless form is

* On the spineless form of *Thysanoëssa longipes*, Drs. Boden and Brinton kindly sent me a letter that 'At present it is best to consider the spineless and spined specimens as "forms" of the same species', and 'It is possible that further information on distribution etc., may cause us to revise our present opinion'. I also consider this spineless form as a form of *Thysanoëssa longipes* in the process of my examinations. But, spineless form differs from spine form of *T. longipes* in some points, such as rostrum, carapace denticles, eyes, some body proportions, body length at the sexual maturity and distributions. So further examination may be able to devide above two forms of *T. longipes*. Here I describe this spineless form as a 'form' of *T. longipes* after the descriptions by Dr. Banner and Drs. Boden and Brinton.

located in the far back position. The length ratio, from the anterior spine to the lateral denticle: lateral margin of carapace, is ranging 50–60% in the spine form, while ranging 70–80% in the spineless form. On the whole, lateral denticles of euphausiids are in fixed positions for each species. *Thysanoëssa raschii* has a pair of well developed denticles always anterior to the middle of the margin, and *E. pacifica* bears strong denticles a little anterior to the middle of lateral margin of the carapace. So the difference between above two forms is the very interesting feature in variations of euphausiids. On this point, though such variation of position of lateral denticles of *Thysanoëssa* species has not been noticed, Hansen (1911) describes the denticle on the lower margin of the carpace of *Nematoscelis* species shows some geographical variations.

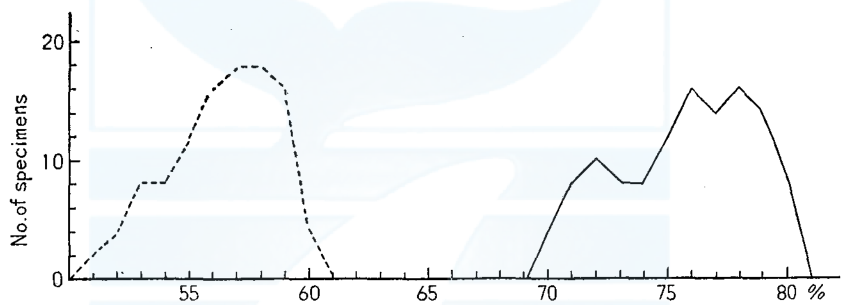

Fig. 9. Length ratio, from the anterior spine to the lateral denticle: lateral margin of carapace, of the *Thysanoëssa longipes* Brandt. Solid line—Spineless form. Broken line—Spine form.

In some larval form (over 7 mm) of *T. longipes* the denticle is located in the middle of the lateral margin of carapace suggesting that it may become the spine form when it will be mature, though the juvenile stages of *T. longipes* bear only dorsal keels on the third, fourth and fifth abdominal segments, and never have acute abdominal spines, and this distinction is the same as the adult spineless form. Moreover the size of such juvenile stages is also in the same range of the latter. In this developmental stages, the position of lateral denticles may be sufficient evidence to divide two forms of *T. longipes*.

On the distributional range of two forms of *T. longipes*. Boden, Johnson & Brinton (1955) state, 'The large specimens of *T. longipes*, which bear abdominal spines, are rarely taken south of 50°N, whereas the southern limit of the range of the smaller form is about 40°N'. Main occurrances of *T. longipes* in my data generally coincide with above statement, exept some of those found in adjacent waters to Japan. Considerable number of fin and sei whales take sometimes swarms of spine form of *T. longipes* at about 40°N, 150°E. The spineless form has not been occurred in adjacent waters to Japan and Okhotsk Sea owing to the scanty collection of stomach samples.

The adolescents of *T. longipes* bear no sings of conspicuous abdominal spines in length about 10 to 12 mm. They bear only dorsal keel and the spine of last abdominal segments like adult spineless forms. But spineless forms have often short spines on fifth abdominal segments. The eyes of them are also easy to be broken by any causes.

Thysanoëssa raschii (M. Sars) Hansen. *T. raschii* has not appeared as foods of whales in samples gathered from 1952 to 1956 in the whaling grounds though recent study by Sleptsov (1955) shows that *T. raschii* is fed by whales in the Kurile Islands waters. According to Banner's description (1949, 1954), *T. inermis* is dominant food for Akutan whales against to *T. raschii* is the only euphausiid found in the cod and pollack stomachs. Banner suggests (1954) that, 'such difference may be due to the fact that *T. raschii* is an inshore species, whereas *T. inermis* is more commonly found the margin of the continental shelf in the Akutan waters'. By Japanese operations, whales mostly have been caught along the margin of continental shelf or in boundaries of different water masses far in the offing, and the catch within the margin of continental shelf are very scarece. Thus, *T. raschii* may be rare as foods of whales in Akutan waters. In the unpublished data from the Okhotsk Sea, considerable specimens of *T. raschii* are found among other euphausiids, *Euphausia pacifica*, *Thysanoëssa longipes*, and *T. inermis*. This occurances of *T. raschii* may be due to the sea depth of whaling grounds. The sea depth of Okhotsk whaling ground is far shallower than the depth of Akutan whaling grounds exept some areas where fin whales caught within the Alaskan continental shelf.

Thysanoëssa spinifera Holmes. This species has been found in less number as foods of whales. Only 1 fin whale took it dominantly, and it is thought *T. spinifera* is not so important as *T. inermis* or *T. longipes*. Hollis (1939) describes that *T. spinifera* occurred as foods of fin and humpback whales dominantly in Bering Sea. He states further, 'The egg masses were particularly numerous in the stomach of a humpback shot on August 26, and would lead one to believe that over a short period of time they may be of some importance as foods'. His suggestion that egg masses may be the food of whales is very interesting. I would like to treat this problem in following chapter. The distribution of *T. spinifera* holds something to be examined. By Hansen (1915), the most western records is taken at 179°07′30″E–54°12′N and Boden, Johnson, & Brinton (1955) describe, 'It occurs along the western coast of North America from northern Baja California to the south-eastern Bering Sea, usually within 200 miles of shore'. In the collected samples, *T. spinifera* has occured mostly along the margin of continental shelf. The most western occurrence is about 170°W–54°N and *T. spinifera* mostly converges on the north waters of Unalaska Islands as shown in figure 4. So, it may be concluded that *T. spinifera* inhabits only eastern side of the North Pacific from these observation. In other words, *T. spinifera* inhabits mainly in natural regions *Alaskan Coastal Region, Alaskan Gyral,* and *American Coastal Region* called by Fleming (1955). Some larval form of *T. spinifera* may be transported by the sea current from the Pacific to Bering seas, because the Pacific waters set north into the Bering Sea at velocities up to 0.4 knot between Unimak and Unalaska Islands (Barnes & Thompson 1938).

Calanus cristatus (Krφyer). Usually, *C. cristatus* is the most famous copepod whaling grounds in the North Pacific. 'Calanus' or 'Red rice' called by whalers means usually this species in the whaling grounds. Fin whales take *Calanus cristatus* most favourably. This is clearly illustrated in table 2. Copepods fed by fin whales in table 2 are almost all *Calanus cristatus* and occurrences of other copepods are only in some occasions as disscussed in the description of *C. plumchrus*. The developmental stage of *Calanus cristatus* is almost all the copepodite 5, and very few exeptional copepodite 4 is found among the former. But no adults has been found in Japanese collections. The patch of *Calanus cristatus* copepodid 5 is considered to be extremely dense in the surface waters. But towards the biological autumn of these areas, *Calanus cristatus* disappeared from the surface waters. Such phenomenon is also fully described by Nakai & Honjo (1954) and Bogorov & Vinogradov (1955). For example, fin whales caught at the south-west area of Attu Islands in June and July in 1953 took no other foods than *Calanus cristatus*. Whereas, when the time of their swarming passed, euphausiids take the place of copepods in late August to September. Bogorov & Vinogradov (1955-a) also examined the distribution of *Calanus cristatus* in Kurile waters in 1953, and lead to the same results. *Calanus cristatus* is important as foods of whale also in the Olyutorskiy Bay. Brodsky (1950) describes that, 280 fin whales out of 304 whales caught in Olyutorskiy Bay took unmixed patches of *C. cristatus*.

All specimens of *Calanus cristatus* belong to the copepodite 5 stage, and *Calanus cristatus* means this copepodite 5 stage in following discussions. The harvest of *C. cristatus* is abundant or poor according to the oceanographical conditions year to year. For example, *C. cristatus* is extremly abundant in 1953, while it is scarce in other years. I would call the year when *Calanus cristatus* is abundant as 'Calanus year', and 'Krill year' when euphausiids are abundant.

Calanus plumchrus Marukawa. *Calanus plumchrus* has been discussed by many biologists from the taxonomical point of view. It has been considered as the synonym with *Calanus tonsus* Brady (Campbell, 1930; Tanaka, 1954) or *Calanus tonsus* f. *plumchrus* (Brodsky 1950; Marshall & Orr, 1955). Brodsky suggests (1950) further that *C. plumchrus* may be a seasonal form of *C. tonsus* f. *typica*. Recently, Nakai (personal communications) and Tanaka (1956) have studied these two species and come to the conclusion that *Calanus plumchrus* is a characteristic copepod of the North Pacific, and is distinct from *Calanus tonsus* Brady of the Antarctic. Detailed description on this point will be found in the discussion by Tanaka (1956), and I use the specific name *Calanus plumchrus* in this report.

TABLE 6. OCCURRENCES OF *CALANUS PLUMCHRUS* IN D WHALING GROUND IN 1954

	Fin whales		Sei whales	
Decades	*C. plumchrus*	*C. cristatus*	*C. plumchrus*	*C. cristatus*
1st. decade June	1	2	—	4
3rd. 〃	6	12	13	2
1st. decade July	1	—	—	—

Calanus plumchrus is considered to be very abundant in those northern part of the North Pacific. The number of *C. plumchrus* is far numerous than any other macro copepods in samples collected by plankton nets. While, *C. plumchrus* is not observed so often as *C. cristatus* dominantly in stomachs of whales. I have noticed no dominant specimens of *C. plumchrus* in data of fin whales of 1952 and 1953, exept sei whales caught in August in A whaling ground fed on *C. plumchrus*. In D whaling ground in 1954 only 1 fin whale take *C. plumchrus* in first decade of June when 33 fin whales caught in the decade. Similarly, 6 whales out of 64 fin whales fed on *C. plumchrus* and 12 whales fed on *C. cristatus* in third decade of June, and 1 whale in July. In this season, sei whales also swarm on the patch of *C. plumchrus* in this sea area. *C. plumchrus* is fed by 13 sei whales out of 15 whales which took copepods in third decade of June.

It may be suggested by above facts that *Calanus plumchrus* never swarm so markedly as *Calanus cristatus* in these waters. Only those whales that skim their foods, such as sei whales or right whales (Ingebrigtsen, 1929), may easily take the sparse patch of *Calanus plumchrus*.

Calanus finmarchicus (Gunner). The most famous copepod *C. finmarchicus* as foods of whales in the Atlantic has been layed aside because it occures not so frequent is Japanese waters. As stated in the part of sei whale, occasionaly it has been taken by sei whales in the adjacent waters to Japan. However, *C. finmarchicus* is considered not so important in the northern part of the North Pacific as in the Atlantic. It has only occurred with other copepods, *C. cristatus* or *C. plumchrus* though considerable number of them has appeared in samples by plankton nets. Besides, the copepods in the samples are not always the typical form of *C. finmarchicus*. Some of them rather resembles to *Calanus helgolandicus*. The relation between above two forms may be the most interesting subject on which many studies have been carried out by many biologists. Extensive discussions of this problem will be found in the papers by Rees (1949), Brodsky (1950) and Marshall & Orr (1955). Including *C. heligolandicus* only the specific name *C. finmarchicus* is used in this paper.

Metridia lucens Boeck. This fine species is not so important as the former 3 species. Matsuura & Maeda (1942) describe this from stomchs of sei whales in the waters off Kamchatka Peninsula, and I observed the stomach of 1 fin whale caught at 55°38′N, 169°00′W with *Metridia lucens*. Other *Metridia* species such as *M. okhotensis* or *M. pacifica* described by Sleptsov (1955) as foods of whales have not been observed in my collections as dominant foods of whales though they are found in few number.

Fish

Some baleen whales in the northern part of the North Pacific take swarming fish too. As shown in table 2, humpback whales in sometimes undoubtedly ichthyophager. A few fin and sei whales also take fish as discussed by many research workers. These fish species are listed following.

Cod	*Gadus macrocephalus*
Whiting	*Theragra chalcogramma*
	Eleginus navaga gracilis
Atka mackerel	*Pleurogrammus monopterigius*
Sand lance	*Amodites hexapterus hexapterus*
Capelin	*Mallotus catervarius*
Rockfish	*Sebastodes polyspinis*
Saury	*Cololabis saira*
See lamprey	*Entosphenus tridentatus*

Pleurogrammus monopterigius and *Cololabis saira* are most commonly found in stomachs of humpback and sei whales respectively. Especially one of favourite foods of humpback whales is Atka mackerels. Humpback whales take mainly it in two regions, the west waters of Attu Islands and the south waters of Amchitka Islands. They have taken no other foods than Atka mackerels in these waters. Atka mackerels may be swarming in large number along the offshore of these Islands, and humpback whales flock togather to take them. To the interest, other fin and sei whales seldom take Atka mackerels although they are swarming in the same waters. The data shows that only 2 fin whales take Atka mackerels at the same time in the sea area. Since the year 1952, 3 fin whales have taken fish dominantly, and 4 whales fish with euphausiids or squids. The latter whales may take those fish which were in taking their foods with swarms of euphausiids. The fact that stomach of fish are satiated by euphausiids suggests those fish are involved in swallowing of whales.

It is often observed that sei whales have taken sauries in the adjacent waters to Japan (Mizue, 1951) and 5 sei whales has been found to take them through this survey. The locations of such whales caught are considered to be limited to the western side of the North Pacific. Those swarmings of saury looking for light of the ship have often been observed from the factory ship in night in the western whaling grounds.

TABLE 7. OCCURRENCES OF SWARMING FISH FOUND IN STOMACHS OF HUMPBACK WHALES

Kinds of fish	Year 1953	1954	1955	1956
Atka mackerel	11	—	13	21
Cod	2	—	—	—
Capelin	—	3	—	—
Sand lance	—	2	—	—
Unknown	—	1	2	—

Sand lance is one of the favourite foods of little piked whales of adjacent waters to Japan (Omura, 1956). Few of them are sometimes found in stomachs of humpback whales in whaling ground D.

Cod and rockfish are considered not to swarm so closely like Atka mackerels as to stimulate whales' appetites. Few baleen whales take cod or rockfish as compared with other fish above described, while many sperm whales take them in these waters (Betesheva & Akimushkin, 1955).

From above observations, I consider that fish are only makeshift foods for blue, fin and sei whales and rather important for humpback whales in the northern part of the North Pacific where zooplanktons are more abundant than any other southern waters.

Squid

Large squids, *Ommastrephes sloani pacificus* is the most important, and some small squid (*Watasenia scintillans*) and opalescent squid (*Loligo opalescens*) are also considered to be appeared in some cases.

Others

Other organisms, such as *Themisto* sp. *Sagitta* sp. are occasionally observed among euphausiids and copepods. These trespassers are so abundant as planktons that whales can hardly help swallowing a certain number as discussed by Mackintosh & Wheeler (1929). Some live specimens of *Pandalus* shrimps are collected in a stomach of a fin whale through Japanese investigations. To the interest, they have survived other euphausiids in the same stomach by about six hours.

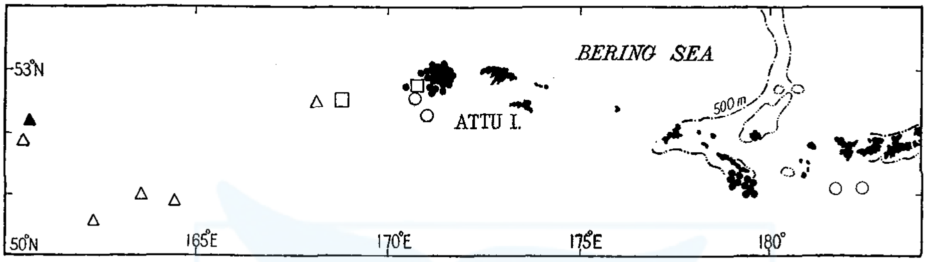

Fig. 10. Occurrences of fish eaten by baleen whales: Solid circles—*Pleurogrammus monopterigius* eaten by humpback whales; Open circles—*Pleurogrammus monopterigius* eaten by fin whales; Solid triangle—*Cololabis saira* eaten by fin whales; Open triangles—*Cololabis saira* eaten by sei whales; Open squares—*Gadus macrocephalus* eaten by fin and humpback whales.

FEEDING HABITS OF WHALES

Preferences for foods by whale species. From the observations on stomach contents of whales, considerable differences are noticed among favourite foods of each whale species as stated in foods of whales. The data at my hand accordingly somewhat differ from those of U.S.S.R. collected in Kurile waters. Sleptsov (1955) states that baleen whales are polyphagous, they take any foods whenever they meet zooplanktons, cephalopods, and swarming fish. But it is considered baleen whales possess remarkable preferences for foods after my observation. The main causes for this phenomenon are considered as follows.

First, the differences of baleen plates may be attributable to their selection for foods. As baleen plates differ in length, breadth, and thickness. The degree of luxuriance, size and length of baleen fringes, these characteristic dispositions of baleen fringes have direct effect to foods of whales. Whales with fine baleen fringes, such as sei whales or right whales (*Balaena glacialis*) are fitted to skim micro-zooplanktons mainly copepods. Blue whales which have fairly rough baleen fringes prefer euphausiids. Marshall & Orr (1955) suggest that *Calanus finmarchicus* possibly may escape capture by some species of whales with rough baleen finges, as *Calanus* is much smaller than euphausiids. It is an interesting illustration on this point that Mizue (1951) states, 'The whales having large sized baleen eat more homogenious food consisting only of small food', that is, 'larger the sized of the whales are the fewer the varieties of food they eat'. However, the degree of luxuriancy of baleen fringes is considered to be not so important as decides food species of whales.

The preference of whales for foods are considered to be affected partly by the ecological condition of food planktons, fish or squids in the sea waters. The condition of density in the sea differs markedly by each species, for example euphausiids bears different form of swarmings from copepods. This must effect the whales in selection of their favourite foods. Heretofore, two types of feeding habits of whales have been considered, *Skimming* and *Swallowing*. Sei whales are observed to 'skim' the food (Ingebrigtsen, 1929), while blue, fin and humpback whales turn over, aften with part of the head above water swallowing foods (Ingebrigtsen, 1929). If some swarmings of zoo-planktons are not so crowded, whales such as blue, fin and humpback whales may pay little attention to such swarming of foods. While some observations in the North Pacific show that sei whales often take copepods, *Calanus plumchrus* or *C. finmarchicus* of comparatively small quantity. The cases, *Calanus plumchrus* found in the west-south of Attu Islands in 1953, or *C. plumchrus* in the eastern-south waters of Aleutian Islands in 1954 are the facts illustrative of above observations. On the whole, the fed copepods are fresh in the first stomachs suggesting that sei whales took them a little while prior to that time of capture. From above observations, it may be concluded that sei whales have skimed the waters to take copepods. They can take the swarm of *C. plumchrus* which is less crowded swarming sparsely as not to stimulate fin whales' appetite. Ingebrigtsen (1929) describes the feeding habit of sei whales as follows: 'It swims at great speed through the swarms of copepods, with half open mouth, its head above water to just behind the nostrils. The copepods rush in with the water and are filtered from the waters by the whalebone plates. When a suitable mouthful of copepods has been taken the whale dives, shuts its mouth and swallows the food'. I observed this *skimming* of sei whales in morning in the adjacent waters to Japan in 1955. If sei whales take their foods in this method, they can take rather rough swarms of copepods as above described.

Kitou (1956) observes many patches of *C. heligolandicus* at the surface of the sea. Many orange coloured patches of *C. heligolandicus*, each of them covering an area of 1 to 4 m^2 and 1 to 2 m deep, distribute so far as 15 miles. These swarms may be favourable condition for sei whales. *Calanus cristatus*, one of the favourite food of fin whales, are always found in a large quantity in stomachs of whales, suggesting that swarms of *Calanus cristatus* are more crowded than *C. finmarchicus* or *C. plumchrus* in these waters. The catch of fin whales in August 1953 in the whaling ground A decreased markedly as compared with the catch in June and July. The phenomenon is considered to be due to the poor of favourite foods, *Calanus cristatus* or euphausiids in this mouth. Fin whales must have gone from these waters to another where their favourite foods were more abundant. In the case that sei whales have taken *C. plumchrus* in the eastern-south of Aleutian Islands in 1954, sei whales have shoaled in large number. These also comparatively many fin whales were found, which scarcely take *C. plumchrus* dominatly. They take mainly euphausiids, thus sei whales and fin whales must have different preferences for food planktons. Hollis (1939) describe very phenomenal occurrences of eggs masses of euphausiids from stomachs of Alaskan whales. If the egg masses of euphausiids is enermous, it is probable that whales are attracted to them.

In next, the depth of distribution of zooplanktons and other organisms must be discussed in relation to the whales' feeding habits. Sei whales, sometimes, have taken squids with copepods. The same freshness of above two species suggests that they have been fed at the same time. This means that the depth of distribution is perhaps same for two species. The sei whales may take squids which come up from the depth to take copepods, because one of favourite foods of squids are copepods in these waters (Sleptsov, 1955).

Feeding activity in a day. When Japanese biologists examine stomachs of whales they describe usually only quantities of stomach contents by the classifications of four grades (R, rrr, rr, r). There are some works carried out to weight the contents (Nishimoto, Tozawa & Kawakami, 1952; Betesheva 1955), however, I have no accurate data if above four classifications mean real volume of contents. Such classifications may be affected by sizes of whales, species of whales, and the decision by naked eyes is of course not so accurate. In addition, the fact, that whales often disgorge their stomach contents when they are attacked by harpoons, has been sometimes observed. For these reasons, the discussion on the data is not so stable. While some interesting tendencies are derived from them.

When I classify the fullness of stomach contents by the time of whales caught, it is indicated that baleen whales caught in the morning take more foods in quantities than those caught in daytime or the afternoon. There is also interesting tendency, whales with stomach contents again increase in number from the evening to night. Figures drawn after the data are shown in figures 11 and 12. The most remarkables of fin whales are found in August and September in 1952, 2nd decade of

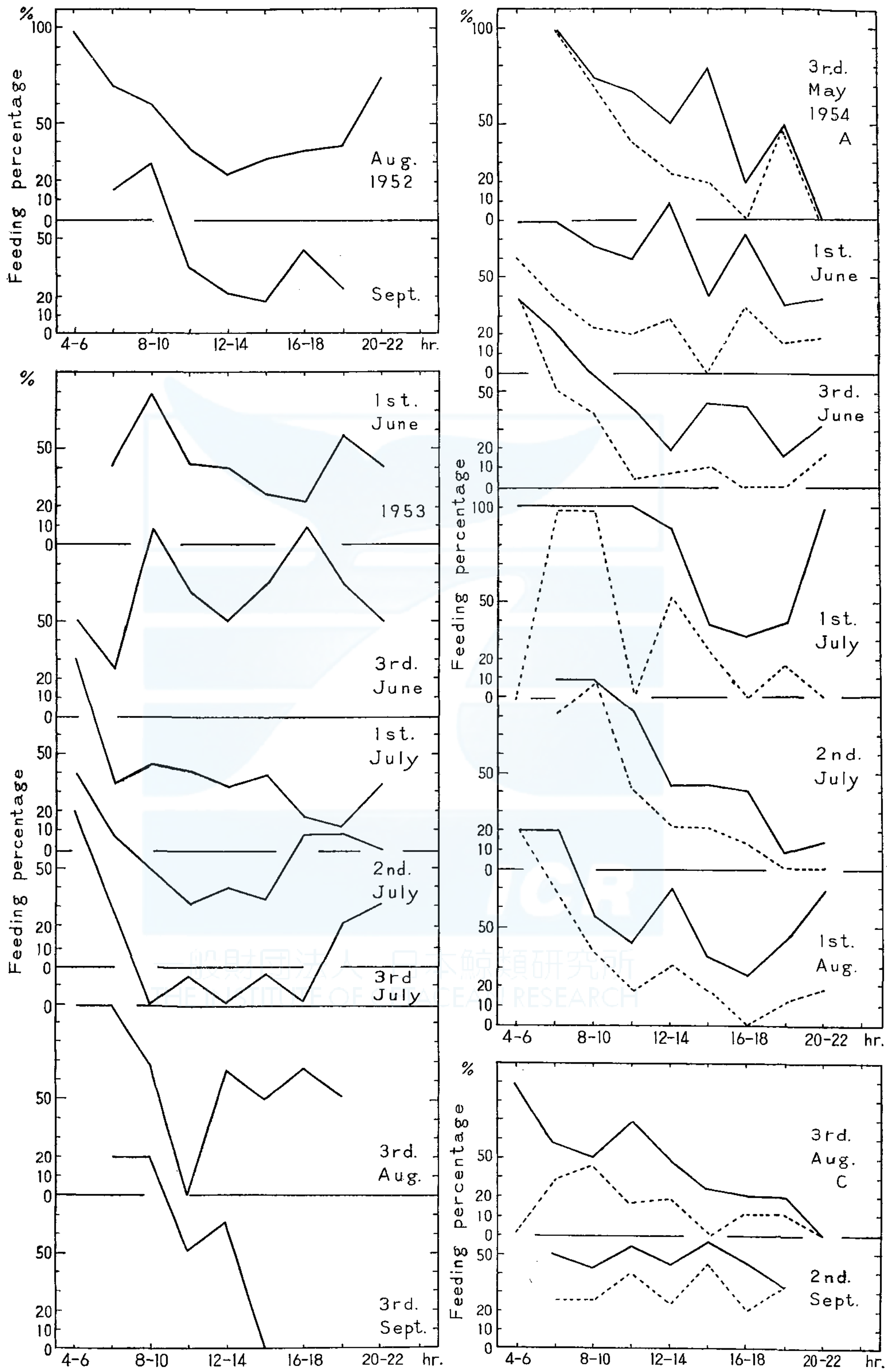

Fig. 11. Feeding percentages of fin whales in A and D whaling grounds. Solid line—The percentage of the number of fin whales with foods in their first stomachs more than r for all whales caught at that time. Broken line—Those more than rr.

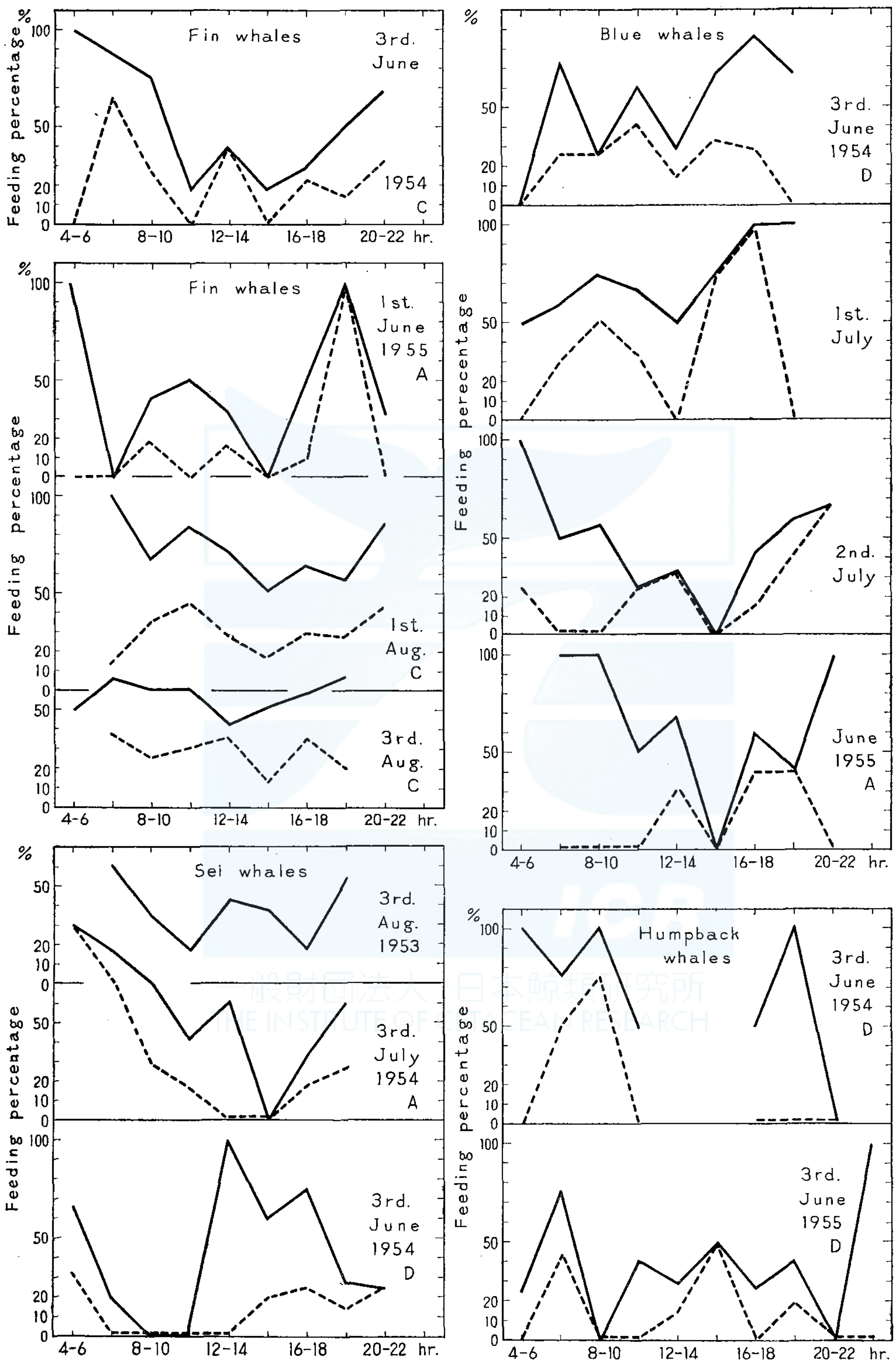

Fig. 12. Feeding percentages of fin, sei, blue and humpback whales in A, B, C and D whaling grounds. Solid line—The percentage of the number of whales with foods in their first stomachs more than r for all whales caught at that time. Broken line —Those more than rr.

July in 1953, and 3rd decade of July in 1953. The figures in some other decades show somewhat indistinct decrease in daytimes. Genellary speaking, feeding activities are comparatively heigh though in the daytime especially in whaling grounds C, where a euphausiid *T. inermis* is abundant along the margin of continental shelf. *T. inermis* in this waters may have more chance to stay at the surface waters owing to the upwelling currents along the margin of the continental shelf. Thus whales may take more foods in the daytime than other whaling grounds. On blue and fin whales in the Antarctic waters, Nishiwaki & Oye (1952) also have noticed the stomachs of whales caught mainly in the afternoon were often vacant. They conclude that more whales take their foods in the morning, and a clear peak in the morning in feeding percentages show that they take their foods once a day. Although they do not allude the slight ascent of feeding percentage is also observed in their figures.

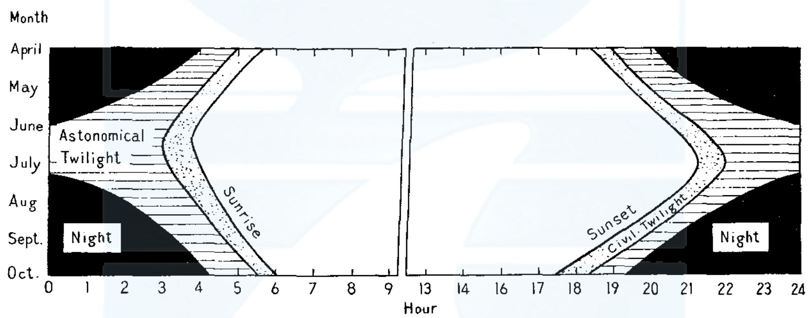

Fig. 13. The duration of twilight of the latitude 50 North after the abridged nautical almanac 1956.

The brief review of the research work undertaken by Slava whaling fleet of the U.S.S.R. (a pamphlet for the International Whaling Commission 7th meeting in Moscow, July, 1955) also alludes to such tendency.

If whales take more foods in the morning or evening than in the daytime, it is considered intuitively that the tendency is partly due to the clear diurnal migrations of zooplanktons. Ingebrigtsen (1929) states '*skimming* of sei whales takes place especially in the evening or early in the morning when the copepods are most at the surface of the sea'.

The diurnal migrations of zooplanktons are well known by many excellent biologists. The research for copepods, mainly *Calanus finmarchicus*, are fully discussed and summerized by Marshall & Orr (1955). From the results of many those works, Marshall & Orr states 'It is now generally agreed that the immediate stimulus to diurnal migration is light, perhaps modified in extreme cases by temperature'. In the whaling ground A, fin whales take *Calanus cristatus* dominantly in June and July as stated before. The feeding percentages in these seasons vary very remarkedly as shown in figure 11. All fin whales caught between four to six o'clock take their foods, and the feeding percentage of whales caught in the next time section between six to eight o'clock suddenly has decreased. As the sun rises at about four o'clock in July in these waters and whaling catchers have commenced their chasing with sunrise, whales which captured at four to six o'clocks must have taken easily swarms of *Calanus cristatus* concentrated at the surface waters in the morning. And feeding percentages have fallen according with the sunrises and *Calanus cristatus* swim down to avoid the light.

Marr (1955, 1956) describes that the adolescents and adults of *Euphausia superba* are mostly limited to the surface waters mainly above 10 meter depth. And typical diurnal migration of *Euphausia superba* is not observed by Hardy & Gunther (1935). By their discussions the behaviour of *E. superba* appeared to be very erratic, but far more specimens are

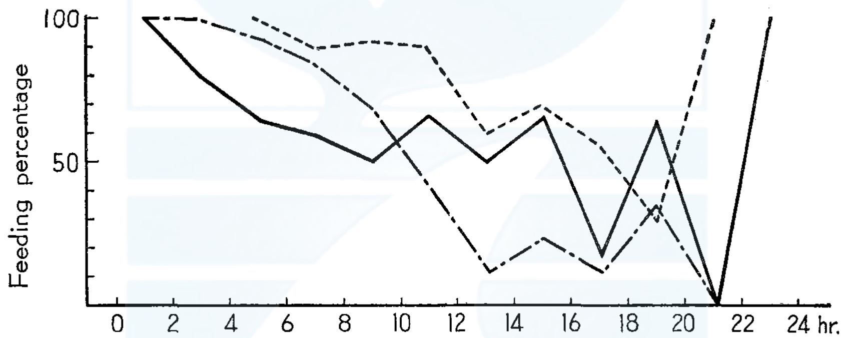

Fig. 14. Feeding percentages of fin whales in the Antarctic in 1955. Solid line—1st decade of January. Chain line—2nd decade of January. Dotted line—3rd decade of February.

taken at the surface during the hour of darkness than during daylight. They suggest that the migration may be less marked when the light become weaker as in the late of March and April in the Antarctic waters. The Japanese investigations on board show that the typical decrease in the feeding percentage through daytimes also occurres in the Antarctic. As shown in figure 14, whales caught in the first decade of January show sudden decrease in feeding percentage from four o'clock. While, feeding percentage of morning shows a low pitched decrease in 2nd decade of January. In 3rd decade of February, the feeding percentage is still heigh between ten and twelve o'clock. As discussed by Hardy & Gunther (1935), the light become weaker towards the end of the summer in the Antarctic. The low pitched decrease corresponds with the intensity of the light in the sea.

The diurnal migrations of zooplanktons are considered to be also affected by the depth of the sea, stages of their biological development

(Marshall & Orr, 1955) and hydrographical condition of the sea. Some biology of *Calanus cristatus* is made by Bogorov & Vinogradov (1955a). They suggest the vertical distribution of *C. cristatus* show pecurial feature in some part of the North Pacific where the intermediate cold waters are found. *C. cristatus* is scarce in the intermediate cold layer, but very abundant above the layer. In waters where the intermediate cold layer vanished, *C. cristatus* is not so restricted at the surface waters. Accordingly *C. cristatus* above the intermediate cold layer swim down not so deep to the cold layer though in the daytimes.

Sei whales often take *Calanus plumchrus* also in daytimes in June in 1954. In other words *Calanus plumchrus* is considered to show not so distinct diurnal migrations because *C. plumchrus* is collected by vertical plankton nets more than other *Calanus* in daytimes' towing. Although sei whales are considered to dive not so deep as other fin and blue whales (Ingebrigtsen, 1929) they must be easy to skim *C. plumchrus* in daytimes if only *C. plumchrus* is limited to the surface waters in some seasons in the North Pacific.

The vertical migrations of zooplanktons are fairly speedy in some cases. Big krill *Meganyctiphanes norvegica* swims vertically about 128 meters for an hour and is capable of bursts of 271 meters in an hour (Bainbridge, 1953). It is thought by some observation *Calanus acutus*, a big Antarctic copepod, migrates vertically 50 m or more in an hour. Recent investigations also show that the deep scattering layer, considered to be of zooplanktons also migrates fairly speedy. The diurnal migration of euphausiids' layer has not been examined in these whaling grounds. But, in the adjacent waters to Japan, Saito & Mishima (1953) observed the deep scattering layer consists of *Euphausia pacifica* in the water off Hokkaido by the echo-sounder. They state the deep scattering layer is observed 50 to 60 m deep from the surface waters at 35 mintes past 4 p.m. Then, it come up gradually and it come up to the surface after the sun-set.

A pending question, how deep whales dive usually below the water surface, has not been dissolved successfully to this time. Ommanney (1932) states, 'It may be said, then that a whale probably does not descent to depth much greater than 130 feet, but can remain below for periods of up to half an hour', from the view of the danger of caisson disease. As adult specimens of *C. cristatus* have been found usually in deep waters below 500 meters in northern part of the North Pacific (Nakai & Honjo, 1954; Anraku, 1954; Nakai & Honjo, 1954) suggest, the fact no adult specimens of *C. cristatus* is found in stomachs of whales means baleen whales dive not so deep as 500 meters. Of course, adult specimens of *C. plumchrus* have been found at the surface waters in northern parts of Bering Sea above 150 meters the presence of them never means such conclusion as *C. cristatus*.

Recently, Owatari, Matsumoto & Kimura (1954) investigated feeding habits of some dolphins, and presume that 'the dolphins do not likely to swim deeper than 40 meters at any time nevertheless there are many sardins escaped from above waters in the deeper waters of 40 meters. The dolphins swim streight rising and falling at the surface waters above 40 meter depth, and when they meet their foods they take foods swimming hither and thither'. Of course, it is true that other sperm whales and baired beaked whales take foods in far deeper waters as described in the paper by Laurie (1933). Sperm whales caught along the Aleutian Islands have often taken deep-sea fish and deep-sea crabs.

In contradiction to this, Matsushita (1955) has examined stomach contens of sperm whales in the Antarctic during the years 1953–54, and states that sperm whales caught at night are less in number but fed better than those caught in daytimes. By his observation, sperm whales caught at early in the morning took abundant foods, but those caught in daytime fed less, and whales fed regained in number in the night. He suggests from above findings, the most favourite food of sperm whales, gigantic deep-sea cephalopods and fish may come up to the sea water surface through night and be caught by sperm whales. If it is true, sperm whales need not dive so deep to take deep-sea cephalopods as considered to this time by Iwai (1956) and others. Sleptsov (1955) also consideres, many deep-sea cephalopods come to the surface through night with other oceanic deep-sea fish, forming good feeding grounds for whales. One of causes for such phenomenon must be the intensity of the illumination by daylight, and the next their main foods, smaller zooplanktons also come up to the surface waters through the night.

On some other marine mammals feeding habits also have been examined. Taylor, Fujinaga & Wilke (1955) describe that feeding activity of seals is probably a response to the upward migration of lantern fish and squids at night. They state that though seals take their foods in night than in daytimes. Main foods of seals are those lantern fish belonging to *Myctophidae* (Taylor, Fujinaga & Wilke, 1955). Thus they conclude seals feed more actively before and during sunrise than during daylight. Alike above seals, sei whales in Bonin waters (Nishimoto, Tozawa & Kawakami, 1952) or in waters off Japan (unpublished data of the Whales Research Institute) take many lantern fish also in twilight time of a day. From above many observations, it may be concluded, feeding activity of whales must be partly affected by vertical diurnal migration of crowding patches of zooplanktons, fish and squids.

THE INFLUENCE OF CHASING TIMES TO STOMACH CONTENTS

The review of U.S.S.R. (1955) shows that the stomach quantity of captured whales are also affected by the time of chasing. Whales caught with short chasing have a few foods at least. On the contraly, the long time chasing causes vacant stomachs of whales. That is, the longer the time of chasing, the fewer whales which have foods in their stomachs.

TABLE 8. FRESHNESS OF THE STOMACH CONTENTS OF FIN WHALES IN 1954

Time of chasing (minutes)	Freshness of stomach contents: Euphausiids				Copepods			
	f	ff	fff	F	f	ff	fff	F
0- 30	13	9	14	1	5	—	4	—
31- 60	19	40	22	5	9	8	—	—
61- 90	31	26	12	2	6	7	3	2
91-120	27	26	10	5	2	7	2	—
121-150	20	14	5	1	7	2	—	1
151-180	6	11	4	—	2	4	—	—
181-210	7	7	3	—	—	—	—	—
211-240	—	6	—	—	—	—	—	—
241-270	1	3	—	—	—	—	—	—
271-300	—	—	—	—	—	—	—	—
301-330	2	1	—	—	—	—	—	—
331-360	—	1	—	—	—	—	—	—

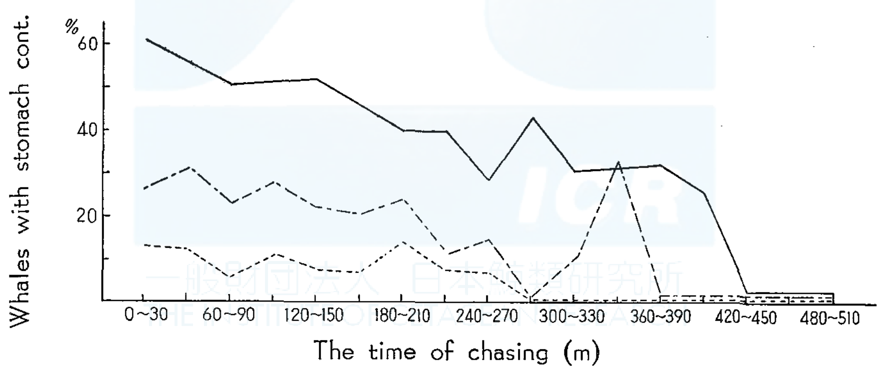

Fig. 15. The variation in stomach quantity of fin whales in 1954 by chasing intervals in minutes. Solid line—More than r. Chain line—More than rr. Broken line—More than rrr.

The quantity of stomachs of whales decreases in accordance with prolongation of chasing as shown in figure 15. This phenomenon at the same time, suggests the whales with full stomachs are more easily caught than with vacant stomachs. The result is essencially similar to that described by Ingebrigtsen (1929), 'When these whales have no copepods they are often so shy and difficult to approach within shooting range, that they may be chased all day without being shot'. The freshness of the stomach contents also declines, as shown in table 8 with prolongations of chasing. As the freshness of foods suffer no peculial change while waiting to be flensed by my observations, the foods is considered to be digested during chasing.

BIOLOGICAL DATA ON FOOD PLANKTONS

AGE AND GROWTH OF EUPHAUSIIDS

The growth of various species of euphausiids has been studied by Ruud (1932) and Einarsson (1945). *Euphausia superba* is biennial in the Antarctic water (Ruud, 1932), and *Thysanoëssa inermis*, the most famous food for baleen whales in the Atlantic, is annual in southern localities, biennial in north and Icelandic waters, and some specimens in West Greenland waters are considered to be triennial (Einarsson, 1945). To the northern Pacific, above conclusions are applied in various points. In the materials composed of stomach samples, I have measured about 30 specimens of each sample as possible at the same time examining the maturity of the external and internal sexual organs. The maturity of the external sexual maturity is determined by the formation of the endopodite of first and second pairs of pleopods in male, and of the thelycum and the presence of spermatophores in females.

The internal sexual maturity is determined by the examination of ovary and the presence of loose spermatophores in the spermatophore sac. As for the grades of maturity of euphausiids, I use the classification described by Einarsson. Those are the following groups: '1. The larval and early post-larval stages, showing no sign of external characters. 2. Juveniles and adolescents showing various degrees of development of the external sexual characters, but not showing mature characteristics. 3. Adults with the external sexual characters fully formed, the males with loose spermatophores in the spermatophore sac, and the great majority of the females fertilized, i.e. with spermatophores inserted into the thelycum. 4. Specimens which are larger than the usual mature size of the species in a certain area, but showing immature external sexual characteristics'. The results of my observation and measurements are shown in following figures. Specimens belong to 1 group and show slight development of external characters, such as only swelling has appeared in the first endopods, are put into 1 group.

Euphausia pacifica. As *E. pacifica* appears in less number among the materials, the exact life cycle is not able to be illustrated. The fertilized specimens of females with spermatophores in their thelycum are also rarely found. However, distinct two size groups are observed as illustrated in figure 16. From June to September, the larger group, perhaps belong to 1 or 2 year group is usually found throughout the summer in the whaling ground A. The smaller groups, ranging from 6 to 12 mm, is found in September in the whaling ground D. They are considered to be 0 year group as sizes of them are suggesting that they have hatched in this spring or early summer. Boden (1950) also describes the latter larval stages of *E. pacifica* are abundant from spring to summer in southern California waters. It is probable that these larval stages may develop to length about 10 mm in autumn, though the growth of euphausiids is completely differs in the locality of them. These juveniles and adolescents may attain to about 20 mm in next year, and

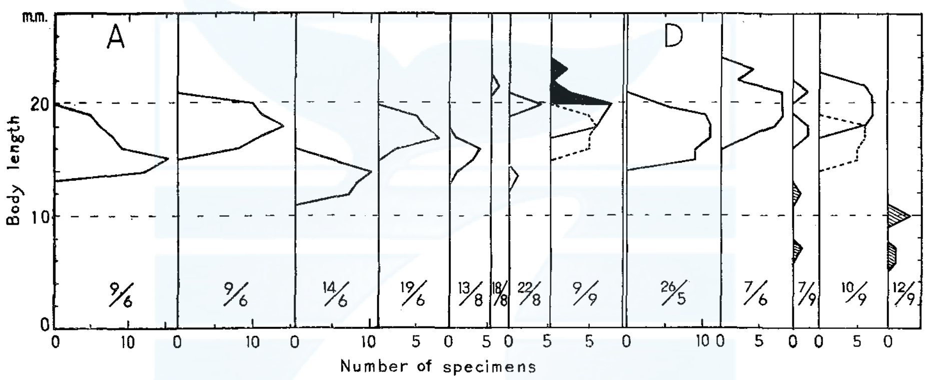

Fig. 16. Size distribution in *Euphausia pacifica* in the whaling grounds A and D. Oblique shading—The larval and early post larval stages, showing no sign of external characters. No shading—Juveniles and adlescents showing various degrees of development of the external sexual characters, but not showing mature characteristics. Blacked—Adults with the external sexual characters fully formed, the great majority of the females fertilized, i.e. with spermatophores inserted into the thelycum. Solid line—Females, broken line—Males.

E. pacifica is considered to reach the sexual maturity in full one year or more. Females collected on 9th in September in the whaling ground A bear spermatophores inserted, eggs of which have also fairly fertilized. But, this is perhaps the rare example, as the spawning of *E. pacifica* may occur in the more early season of a year from above results.

E. pacifica of about 15 mm in length collected in the wamer waters bears full sexual characters. *E. pacifica* may reach to the sexual maturity within a year in the far southern waters of Japanese coast like other euphausiids described following.

Thysanoëssa inermis. *T. inermis* in the North Pacific whaling grounds is divided to three type by developmental conditions. In the west whaling ground A, the specimens with spermatophores are only found in first decade of June. And adolescents with almost grown external sexual characters are found during June to September. Males and females are perfectly classified by the external characters, and the difference in size between males and females is observed from 18 mm in length. These adolescents are considered 1 or 2 year groups. One male specimens of 15 mm in length is collected in the far south waters at 42°28′ N, 149°48′ E in August through 'Takunan maru' cruise, which shows full grown external sexual characters and has loose spermatophore in the spermatophore sac. From the body length, it may belong to 1 year group, judging by comparison with the Atlantic specimens described by Einarsson (1945).

TABLE 9. OCCURRENCES OF FEMALE SPECIMENS OF *T. INERMIS* WITH SPERMATOPHORES

Whaling area	Year	Date	Total no.	With spermatophores
D	1954	5 July	1000	200
〃	〃	19 〃	500	100
〃	〃	30 〃	400	250
A	1955	2 June	280	80
〃	〃	6 〃	170	130
D	〃	1 July	290	200

The collections from the whaling ground C and D show some differences from those from the whaling ground A. Many fertilized specimens are collected in July in the whaling ground D, while all other materials collected after July show no fertilized character. Thus it is considered the mating season of *T. inermis* in the south waters of eastern Aleutian Islands comes to an end in July. Perhaps the mating season of *T. inermis* in this waters begins in early spring, larvae grow about 10 mm or more in next year, those are 1 year group, then it grows in second year about the length 20 mm to 26 mm and spawns. Specimens which are larger than those fertilized mature in sizes, but showing immature external sexual characters are found on 9th September sizes of which are 24 mm to 28 mm. It is not certain if the larger specimens will be mature in the third year. Einarsson (1945) consideres, *T. inermis* in West Greenland waters may be adult in the third year at about 28 mm in length. Thus some specimens of *T. inermis* in this waters may be considered triennial.

In the north parts of the eastern Aleutian Islands the whaling ground C, *T. inermis* shows interesting features. None of specimen in the samples shows any external and internal characters fully developed. While the body length of some of them are exceedingly larger than those collected in the west or southern waters. The figure gives the measurement of these specimens caught in the north part of the eastern

Aleutian Islands. The larger materials collected on 13th September are about 27 mm in length showing no sexual character fully formed. These specimens may develope a little more and spawn in next year. The

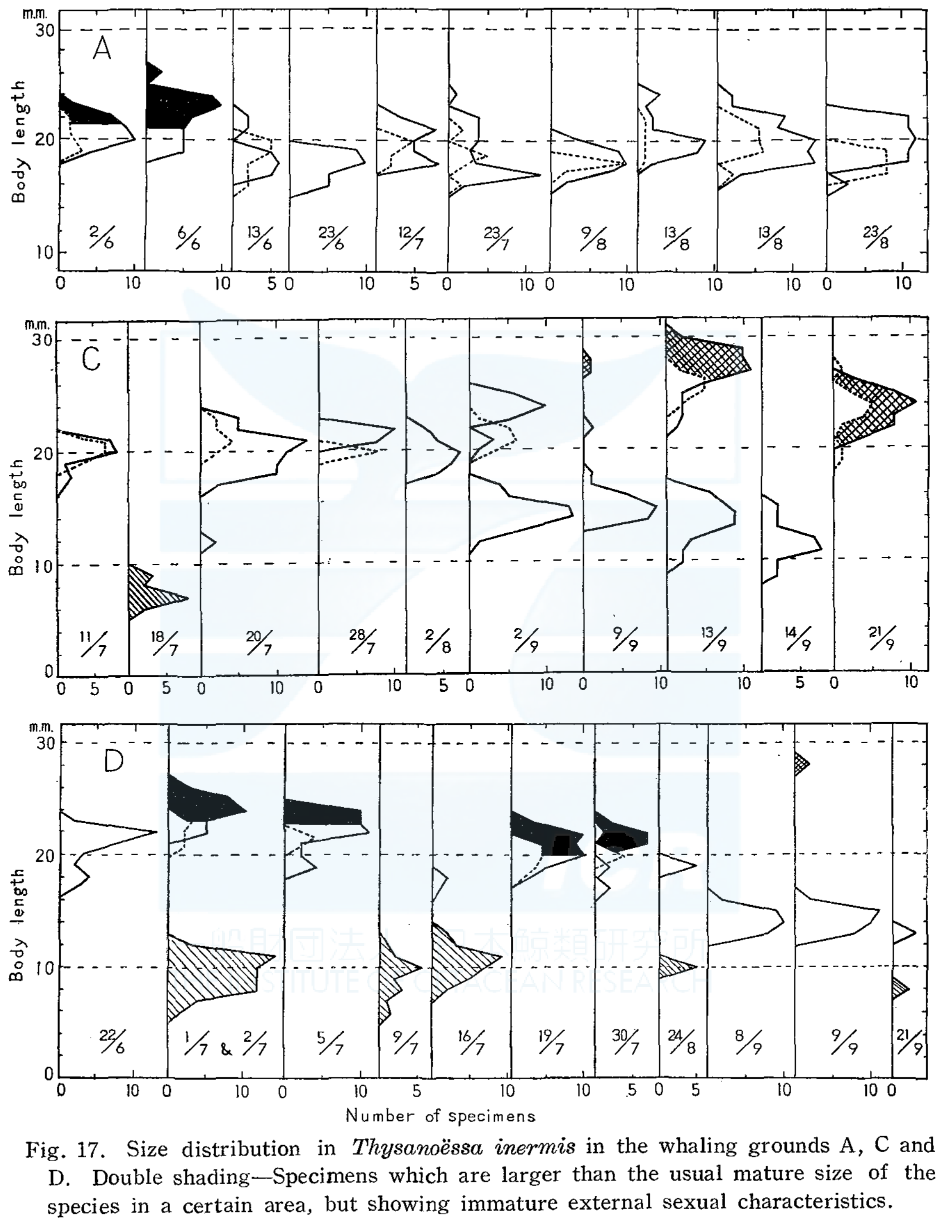

Fig. 17. Size distribution in *Thysanoëssa inermis* in the whaling grounds A, C and D. Double shading—Specimens which are larger than the usual mature size of the species in a certain area, but showing immature external sexual characteristics.

smaller group, about 10 mm to 18 mm also occurres in the late of summer. As compared these size distributions with those reported by Einarsson in West Greenland waters, the *T. inermis* in the whaling ground C, may be generally triennial as the specimens in West Greenland waters. But some of them are considered to be biennal as the speciemens in southern waters. In either case, the complete sexual maturity in two cases is attained in two years at least.

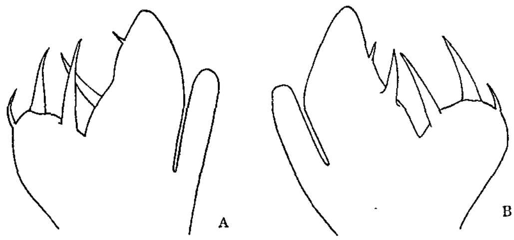

Fig. 18. Immature male copulatory organs of *Thysanoëssa inermis* (Krφyer) Hansen of comparatively large specimens. A, 26 mm. B, 24 mm ×50.

Thysanoëssa longipes. The materials of *T. longipes* in my samples are comparatively abundant as compared with other euphausiids, and the more detailed disscussion can be obtained. In whaling ground A, the firtilized female specimens, such as with spermaphores inserted into the thelycum or eggs are fully developed are found only in June, owing to the scanty data before then. These full developed specimens have sizes from about 20 to 28 mm in female and 18 mm to 24 mm in males. The juvenils and adolescents are suceessively found from June to September. Specimens about 13 mm in length are found 19th July most of which show no sign of external development of sexual characters of males. These specimens may be considered to be 1 year group. In the collections following these, there are many specimens considered to be 1 year group about 20 mm in length. They have well developed external characters, but the thelycum of females is not full grown and therefore it is empty. The differences of size distributions between males and females is observed from this developmental stage as illustrated in figure 19. In the late August, the smaller size group appears in collections by plankton nets. Some furcilia larvae have mingled with them. These specimens are apparently 0 year group, which have hatched in spring of this year. With allowance for the scanty collection of 1 year group in spring, above 0 year group developes to about 15 mm in next spring, and grow about 20 mm in summer successively. Thus it may be concluded *T. longipes* in this waters does not reach sexual maturity before it is two years of age.

The samples from C and D whaling ground show somewhat defferent manner of growth. The fertilized specimens of *T. longipes* have been found only 2 cases in C and D whaling grounds. Specimens collected on 7th July in C whaling ground and 7th July in D whaling ground are all full mature. It is interesting that some full grown specimens are found in summer, which have no signes of mating or spawning though

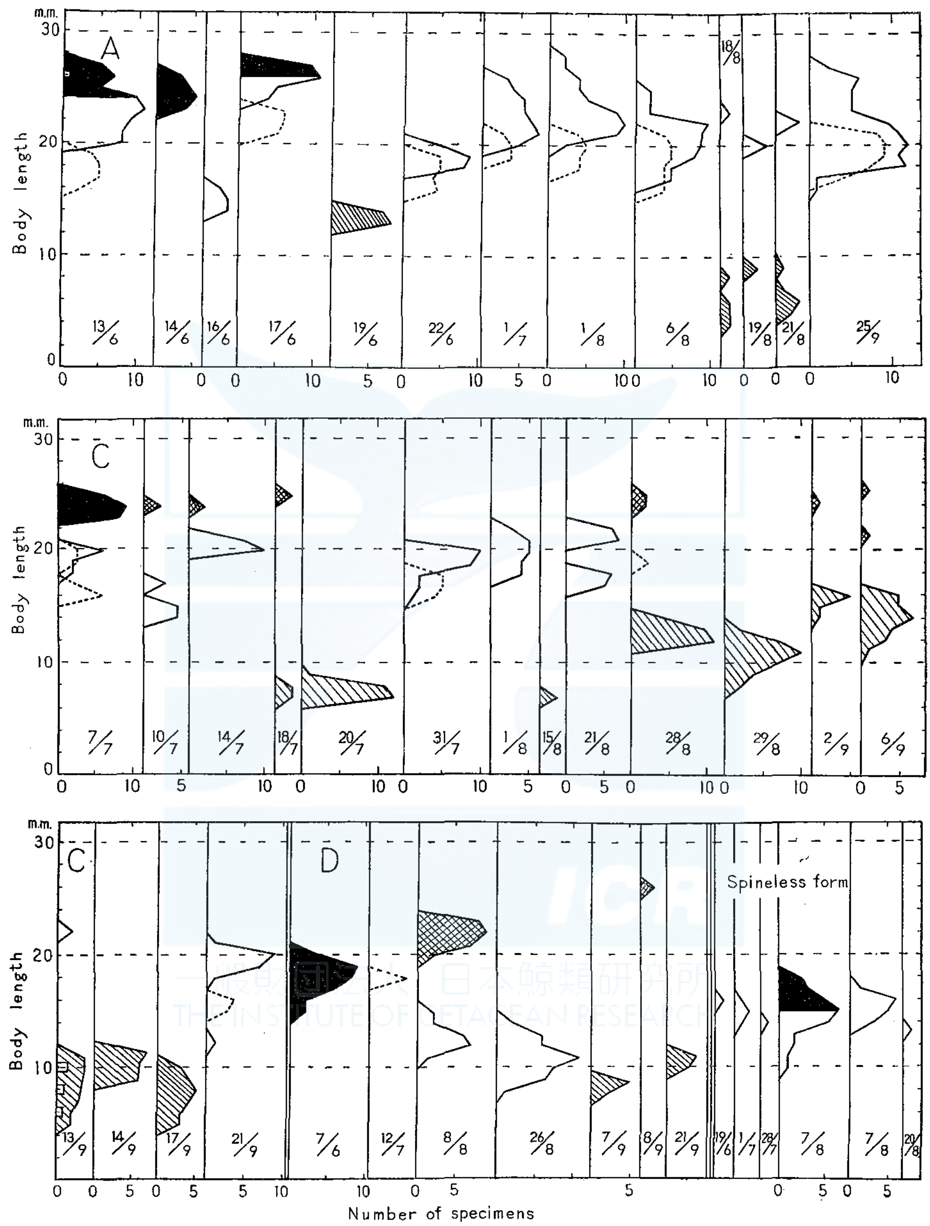

Fig. 19. Size distribution in *Thysanoëssa longipes* in the whaling grounds A, C and D.

they have full developed thelycum and the male copuratory organs. They may survive the winter and spawn in the next spring as the 3 year group.

The smaller specimens are also found in the summer season, so two size groups of immature are observed through the latter whaling season from July to September as shown in figure 19. As to the development of the spineless form of *T. longipes*, I would condider it is usually annual in these waters. Because it have full grown sexual characters at about 15 mm to 18 mm in length, and the larger specimen than 18 mm has never been collected. Female spineless forms collected on 7th in August have

TABLE 10. OCCURRENCES OF FEMALES SPECIMENS OF *T. LONGIPES* WITH SPERMATOPHORES

Whaling area	Year	Date	Total no.	With spermatophores
B	1954	7 June	30	25
C	1955	6 〃	30	20
A	1956	13 〃	100	30
〃	〃	13 〃	440	60
〃	〃	14 〃	20	18
〃	〃	16 〃	20	18
〃	〃	17 〃	45	5
〃	〃	19 〃	200	6

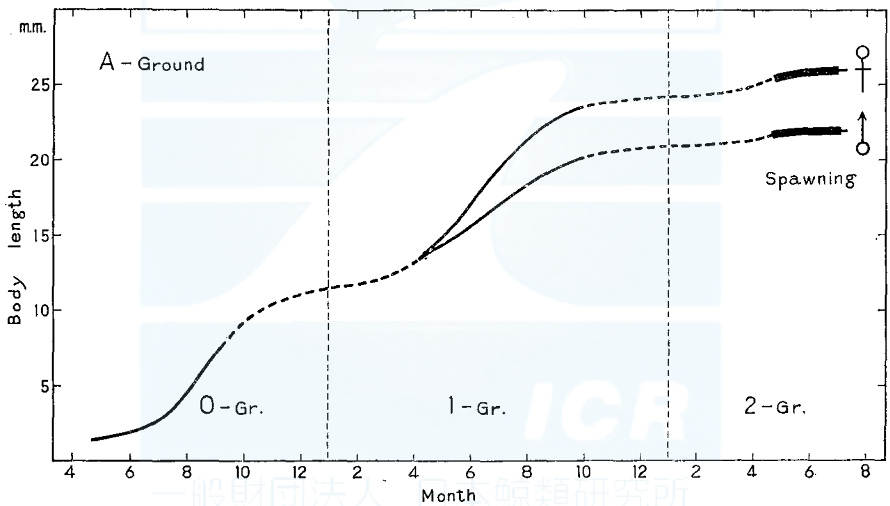

Fig. 20. The life cycle of *Thysanoëssa longipes* in A whaling ground.

spermatophores inserted into the thelycum, while the original form among above spineless form is not full mature. As the furcilia stage of *T. longipes* has the lateral denticles of carapace in somewhat behind position from adult specimens, spineless forms may make rapid progress in genital glands with some features such as the lateral denticle remained as larval form by some stimulant. Above suggestion, however, is uncertain because there is no valid prove for it now.

Thysanoëssa spinifera. *T. spinifera* only distributes in the eastern side of the North Pacific as considered from the stomach contents of whales and samples by plankton nets, and some interesting biology on *T. spinifera* was described by Hollis (1939). Hollis (1939) describes that the egg masses of *T. spinifera* were particularly numerous in the humpback whales shot on August 26 in Alaskan waters. This result suggests that the spawning of *T. spinifera* may occurres in summer. Some specimens in my materials also bear such fertilized features. In nine cases from stomach contents females of *T. spinifera* with spermatophores inserted

TABLE 11. OCCURRENCES OF FERTILIZED FEMALES OF *T. SPINIFERA* WITH SPERMATOPHORES INSERTED INTO THERYCUM IN C GROUND

Year	Date	Total no.	With spermatophores
1954	7 June	1	1
〃	5 July	14	12
〃	5 〃	5	1*
〃	30 〃	6	6
1956	10 〃	14	10
〃	11 〃	6	6
〃	14 〃	70	48
〃	31 〃	30	25
〃	1 Aug.	60	50

* Only one spermatophore.

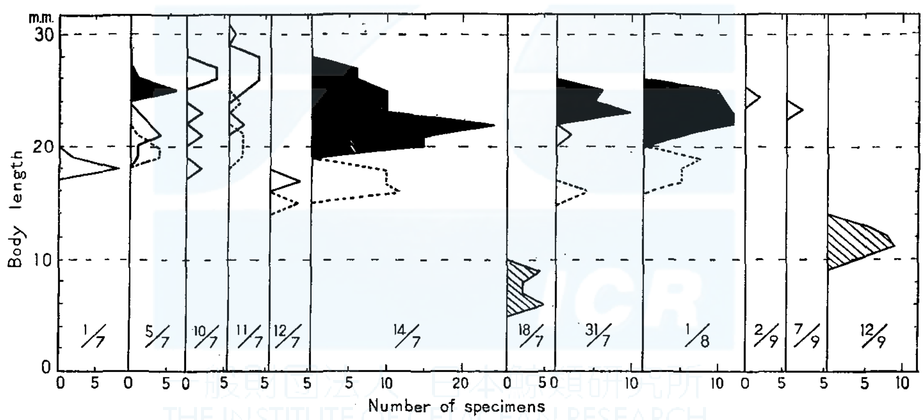

Fig. 21. Size distribution in *Thysanoëssa spinifera* in the north-eastern part of North Pacific.

into the thelycum as shown in table 11. The egg is considerably developing especially in specimens found on 7th June, 5th, 30th July, and also 2nd September besides the formar nine cases.

The first specimen is considered to be full mature, with full grown egg masses in the ovary, though the size of body is 20 mm, rather smaller as compared the latter grown specimens. The latter cases comprise specimens of length between 20 and 28 mm. Males found with above fertilized females also bear the external sexual characters fully formed and with loose spermatophores in their spermatophore sacks. As stated on *T. longipes* males are far smaller than adult females, sizes of males is usually ranging between 15 and 24 mm. Above stated result completely coincides with the one reported by Hollis (1939) that *T. spinifera* may spawn in summer from June to September in Alaskan waters, the whaling grounds C and D.

Juveniles and adolescents bearing no full grown external sexual characters are also found in summer in these waters. Specimens found from whales' stomachs caught on 18th July and 12th September have little signes of such characters. From these samples figures of the size distribution and life cycles of *T. spinifera* may be illustrated. It is, thus considered that *T. spinifera* is biennial, reaching about 10 mm in length in the first year and 20 to 24 mm in the second year when it becomes mature. The difference between males and females in the growth is observed from the first year, and external sexual characters, in endopods of first and second pleopods also begin to grow in the same year. There are some large specimens, about 26 to 30 mm, with mature external sexual characters with no spermatophors. But, I am not sure if the larger specimens of *T. spinifera* in the samples obtained on 10th and 11th July in these waters grow further in the third summer and spawn like *T. inermis* in the Atlantic (Einarsson, 1945, p. 150).

SEX RATIO OF EUPHAUSIIDS

Einarsson (1945) examined the sex ratio of euphausiids and states, 'as the sexes were on the hole found in similer numbers and of similer size, I have not considered it necessary to divide the catches as to sex'. But some different results are obtained through this study. As described in the paper by Ruud (1932), Sars found no males of *Euphausia antarctica*, (synonym *E. superba* juv.) owing to only use the male external character of the endopodite of first and second pairs of pleopods as the marks to divide both sexes. The classification on the sex, therefore, should be ascertained by the presence of spermatheca of females bisides male characters (Ruud, 1932).

The sex of the euphaussiids in my samples, are determined by careful consideration to the points, and males and females are found not in similer numbers. Sizes of specimens by each sex differ also considerably in some species as stated before. Generally speaking, more females are found than males. I count 100 specimens of each adult euphausiids, then females are observed dominantly in almost all samples as shown in table 12. The total occurrences of females are also prevalent in the recent study of euphausiids by Boden (1955).

ZOOPLANKTONS COLLECTED IN WHALING GROUNDS

Besides the stomach samples of whales, many euphausiids and copepods are collected by plankton nets. I would state short review on those samples here. Further discussions on the materials will be given in another article in future. The plankton samples are only restricted to the surface waters' samples collected by vertical hauls from 50, 100, 150 and 200 meters to the surface.

TABLE 12. OCCURRENCES OF MALE EUPHAUSIIDS IN EACH 100 SPECIMENS

No. of males	Species			
	E. pacifica	*T. inermis*	*T. longipes*	*T. spinifera*
10~14	—	5	1	—
15~19	1	3	—	—
20~24	—	3	—	—
25~29	—	8	4	—
30~34	—	3	2	1
35~39	1	—	—	—
40~44	—	1	—	—
45~50	2	—	—	1

TABLE 13. TOTAL OCCURRENCES OF EUPHAUSIACEA PREPARED BY THE FIRST SURVEY OF 'W. SCORESLY', 1950, IN THE BENGUELA CURRENT*

Species of euphausiids	Adult male	Adult female
Thysanopoda microphthalma	—	1
Nyctiphanes capensis	23	75
Euphausia hanseni	—	4
E. lucens	40	304
E. recurva	41	46
E. similis var. *armata*	1	1
E. tenera	—	2
Nematoscelis megalops	3	7
Thysanoëssa gregaria	2	—
Nematobrachion boöpis	—	2

* Figured up from the data by Boden, 1955.

Main species collected by plankton nets are nearly the same as previous reports in this water (Brodsky, 1950; Banner, 1949; Anraku, 1954; Boden, Jhonson & Brinton, 1955). Euphausiids in our samples are as followings:

Euphausia pacifica; *Thysanoëssa longipes*; *T. inermis*; *T. raschii*; *T. spinifera*; *Thessarabrachion oculatus*.

T. longipes is the most dominant euphausiid collected by plankton nets in the samples and *T. inermis* is less in number on the contrary to the result that *T. inermis* is the most dominant foods for baleen whales.

T. raschii and *T. spinifera* are chiefly found in hauls within the margin of Alaskan continental shelf.

The adult *Thessarabrachion oculatus* is usually found below 100 meters (Boden, Jhonson & Brinton, 1955). Only one female of *T. oculatus* is collected by the haul from 50 meter to the surface at the position 51°17′N, 162°56′E.

The main copepods are as follows:

Calanus cristatus Krφyer
Calanus plumchrus Marukawa
Calanus finmarchicus (Gunner)
Calanus helgolandicus (Claus)
Eucalanus bungi bungi Jhonson
Pseudocalanus elongatus (Boeck)
Pseudocalanus gracilis Sars
Centropages abdominalis Sato
Aetideus armatus (Boeck)
Euchaeta japonica Marukawa
Gaidius brevispinus (Sars)
Gaidius tenuispinus (Sars)
Scolecithricella minor (Brady)
Heterorhabdus papilliger (Claus)
Candacia columbiae Campbell
Metridia lucens Boeck
Pleuromamma robusta (Dahl)
Acartia clausi Giesbrecht
Oithona similis Claus

Calanus plumchrus is the most dominant *Calanus* in for '*Calanus*' species. *Calanus finmarchicus* has not been reported by Japanese workers from the whaling ground A (Anraku, 1954). But '*Calanus*' with typical 5th foot of *C. finmarchicus* has been occasionaly found in my samples. Many other '*Calanus*' are rather related to *C. helgolandicus* as described by previous studies (Mori, 1937; Anraku, 1954). The smaller '*Calanus*' *Calanus pacificus* is reported by Brodsky (1950) from Pacific waters. By his descriptions, *Calanus pacificus* is smaller than *C. helgolandicus*, and the endopod of the left leg reaches only to the distal edge of the second segment of the exopod in the male fith foot. '*Calanus*' with such fith pair of foot has also observed in the samples. Tanaka (1956) states on this point, the fith pair of foot of *C. helgolandicus* is very variable, so it is not proper to attach importance to only the fith foot of *Calanus* related to *C. finmarchicus*.

C. plumchrus is the most dominant copepod in the samples collected by plankton nets, the adults of which are considered to distribute in deep waters blow 150 m (Anraku, 1954). By my studies it is observed that the adults occurred in the vertical haul from 150 meter to the surface on 23 August at the position, 53°03′N, 166°58′E. Many adults are collected by the vertical haul from 100 meter to the surface at the position 57°09′N, 173°44′W. Other many specimens are found in vertical hauls from 200 meter to the surface. In the northern area, above facts suggest that the adult *Calanus plumchrus* appears commonly in the surface waters in the northern waters of Bering Sea. In the southern waters along the Aleutian Islands, *Calanus plumchrus* may be commonly found below 150 meter as described by Anraku (1954).

Calanus finmarchicus, *Calanus plnmchrus* and *Metridia lucens* are the most important foods for oceanic fish in these waters. Though they are not so important as whales' foods, Pacific salmons in these waters take many *C. plumchrus* as well as *C. cristatus*. The sparse swarms of *C. plumchrus* are considered to be sufficent to stimulate appetites of such fish. *Calanus pacificus* Brodsky is considered as one of the main foods of baleen whales in the Pacific (Sleptsov, 1955). But, the swarms of *Calanus pacificus* is also considered to be not so congregated as *C. cristatus* in northern part of the North Pacific. Consequently, the swarms of *C. pacificus* in stomachs of whales never have been found by Japanese investigations.

Many specimens of *Encalanus bungi bungi* are observed in plankton samples, though I have few specimens in stomach samples. Sleptsov (1955) describes, *Eucalanus bungi bungi* constitues some part of foods of whales, but it has not been appeared as foods of whales by my observation. This fact suggests, *E. bungi bungi* swarms not so closely as other food copepods, *C. cristatus* and *C. plumchrus*, and not forms huge biological masses. Accordingly, *E. bungi bungi* is considered to be of little importance as foods of whales. Stored fatty nutrients in body of *Eucalanus* are also not so abundant as other calanoid copepods.

Metridia lucens is also very abundant in plankton samples. It is observed from the stomach of a fin whale caught at the position 55°38′N, 169°00′W with euphausiids. This is a only example for the dominant *Metridia* appeared in my observation. The sizes of the *Metridia lucens* are comparative smaller than other locations in the whaling grounds. As they are found in the warm backwaters off the Alaskan continental shelf. These *Metridia* may have developed in such warmer backwaters, and are remained in smaller sizes.

DISCUSSION

The whaling ground of northern Pacific is far smaller as compared with Antarctic one, but it has some peculial features from the view of distribution of foods and oceanographic conditions. The stomach contents of whales show some variations from year to year especially among fin whales. In the whaling ground A, *E. pacifica*, *T. longipes* and *C. cristatus* are main foods of baleen whales from early summer, *T. inermis* is rather less in this water. Generally speaking, euphausiids are more important than *C. cristatus*. While in *Calanus year* as 1953, *C. cristatus* is more dominant from early May to July. Fin whales swarmed in this season to take *C. cristatus*, and many fin whales were caught in from May to July in *Calanus year*. On the other hand, blue whales never migrate to the grounds if euphausiids are not abundant. When euphausiids are abundant as *Krill year* 1954, blue whales arrive at the

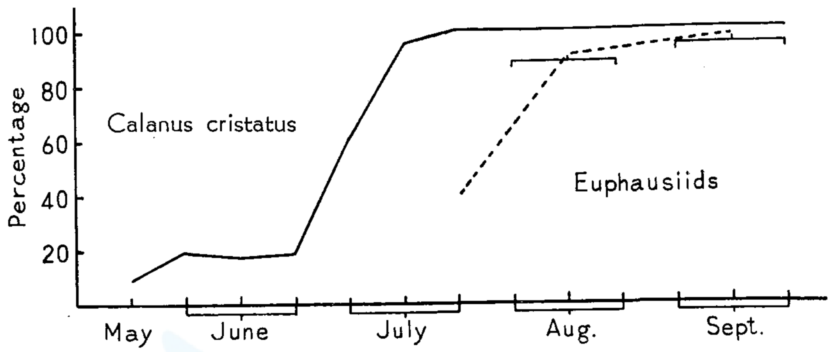

Fig. 22. The transition of foods of fin whales from *C. cristatus* to euphausiids in the whaling ground A.
Broken line—1952. Solid line—1953.

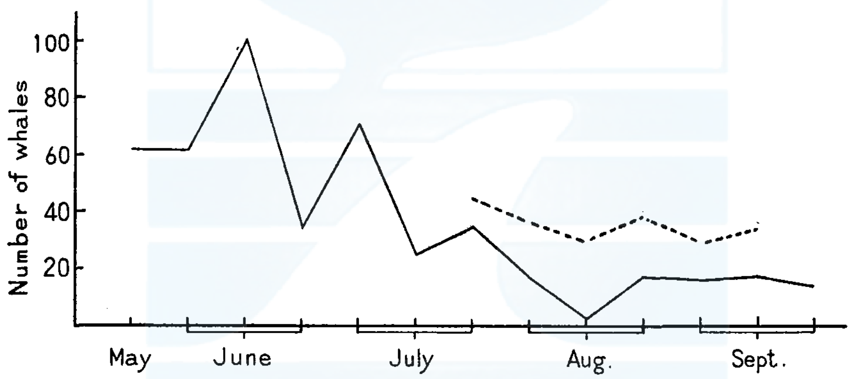

Fig. 23. Number of fin whales caught in the whaling ground A.
Broken line—1952. Solid line—1953.

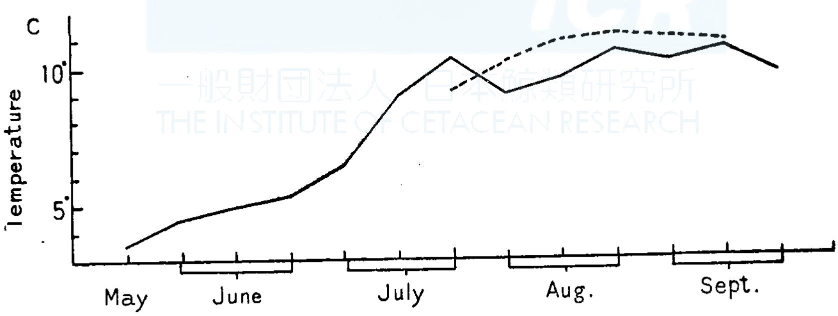

Fig. 24. Mean surface temperature at mid noon position of the factory ship in the whaling ground A. Broken line—1952. Solid line—1953.

whaling ground A already in June from southern waters. In 1953, some blue whales were caught in first decade of July, and many blue whales were captured in September. The height of 2 year group euphausiids was observed in late July, and of 1 year group in September in 1953. Blue whales should swarmed on each euphausiids' swarms. Generally, blue whales approach the cape Kamtchatke Peninsula or waters off Kurile Islands from the south eastern warmer waters. Then blue whales migrate along the Islands towards north-east. As to the migratory routes to north waters, it is considered blue whales follow the routes much further off the coast, while they come back to the south waters along the shore (Omura, 1952). Perhaps it is due to the distribution of eupahusiids.

TABLE 14. STOMACH CONTENTS OF FIN WHALES IN WHALING GROUND A

Kinds of stomach contents	Year				
	1952	1953	1954	1955	1956
Euphausiids	79	83	182	32	149
Eu. & Copepods	4	15	18	1	17
Eu. & Squids	—	—	—	—	1
Eu. & Fish	—	1	—	—	—
Copepods	19	105	92	48	47
Co. & Squids	—	—	—	—	1
Fish	—	1	—	—	1
Squids	1	—	—	—	7
Empty	110	252	272	67	114
No of stomachs examined	213	457	564	148	336
Not examined	—	13	—	—	—

In June and July, the water south-west of Attu Islands at about 52°N, 170°E, attracts many fin whales every year as stated above. It is the most static whaling ground for fin whales in the North Pacific. Those fin whales mostly take *C. cristatus*. When the biological autumn comes in this sea region, *C. cristatus* subsides to deep waters to be mature. Thus *C. cristatus* becames scarce at surface waters in the late of July and euphausiid gradually take copepods' place though euphausiids are still not so abundant in July. The catch of fin whales decrease in number consequently in August in this waters as in 1952 and 1953 as shown in figure 22. Especially only those fin whales with empty stomachs are caught in August of 1953. Bogorov & Vinogradov (1955a) describe that *C. cristatus* was very abundant during May to July in the surface waters off Kamtchatka and Kurile Islands in 1953. Whereas it showed phenomenal decrease in August and vanished from the surface waters in September. This fact endorses above observation obtained through Japanese whaling expeditions. Accordingly whaling grounds consist of *C. cristatus* may be said to be passing prosperity.

One of the causes may be the transition of the water temperature.

The surface water temperature at mid noon position of the factory ship alteres markedly and rise rapidly during the first and second 10 days period of July as shown in figure 24. This marked change in water temperature is regarded as one of the contributing causes of the change in principal whale foods. As *C. cristatus* distributes mainly in the lower temperature waters, Nakai & Honjo (1954) state the sudden rise of water temperature hastenes the subsiding of *C. cristatus*. Bogorov & Vinogradov (1955 b) also observe, the rise of surface temperature causes the subsiding of *C. cristatus* and *C. tonsus* in the north-west part of Pacific. In August, considerable swarms of fin whales are caught in the whaling ground B, the north waters of Komandor Islands in 1956.

TABLE 15. SIZE OF EUPHAUSIIDS MEASURED ON BOARD IN 1954

C whaling ground

	Length (mm)			
Decade	5–15	15–20	20–30	Unknown
1st June	—	—	—	—
3rd 〃	—	—	—	—
1st July	—	1	16	—
2nd 〃	—	1	29	2
1st Aug.	—	—	64	—

D whaling ground

	Length (mm)			
Decade	5–15	15–20	20–30	Unknown
1st June	—	6	7	—
3rd 〃	2	11	38	—
1st July	7	13	51	20
2nd 〃	20	4	44	9

Those fin whales may come from southern waters to take foods, because the southern waters, the whaling ground A are unproductive in August and there are few *C. cristatus* in surface waters in 1956. On the other hand, *C. cristatus* is considered to be at the height in this northern waters, the whaling ground B, just in August about a month late.

In the north waters of east Aleutian Islands, fin whales take *C. cristatus* in off waters from continental shelf slope, while they take *T. inermis* mainly distributing along the continental shelf slope. This fact also suggests that the deep waters is necessary for *C. cristatus* to be adults as considered to these days. On the other hand *T. inermis* spawns on the bank of continental shelf (Hjort & Ruud, 1929; Einarsson 1945) and drift to the surface strata where the larva develops (Einarsson, 1945). So, *T. inermis* circulates in the sea waters from bank of the shelf to off waters and vice versa. The distributions of *T. inermis* as illustrated in figure 25, show apparently this circulation. *T. raschii* and *T. spinifera* are more coastal form as considered to this time, and they never spawn in so off waters. Because no fertilized specimens of above two species have been collected in off waters. The size measurement of euphausiids also has been carried out on board. In 1954, the comparatively much

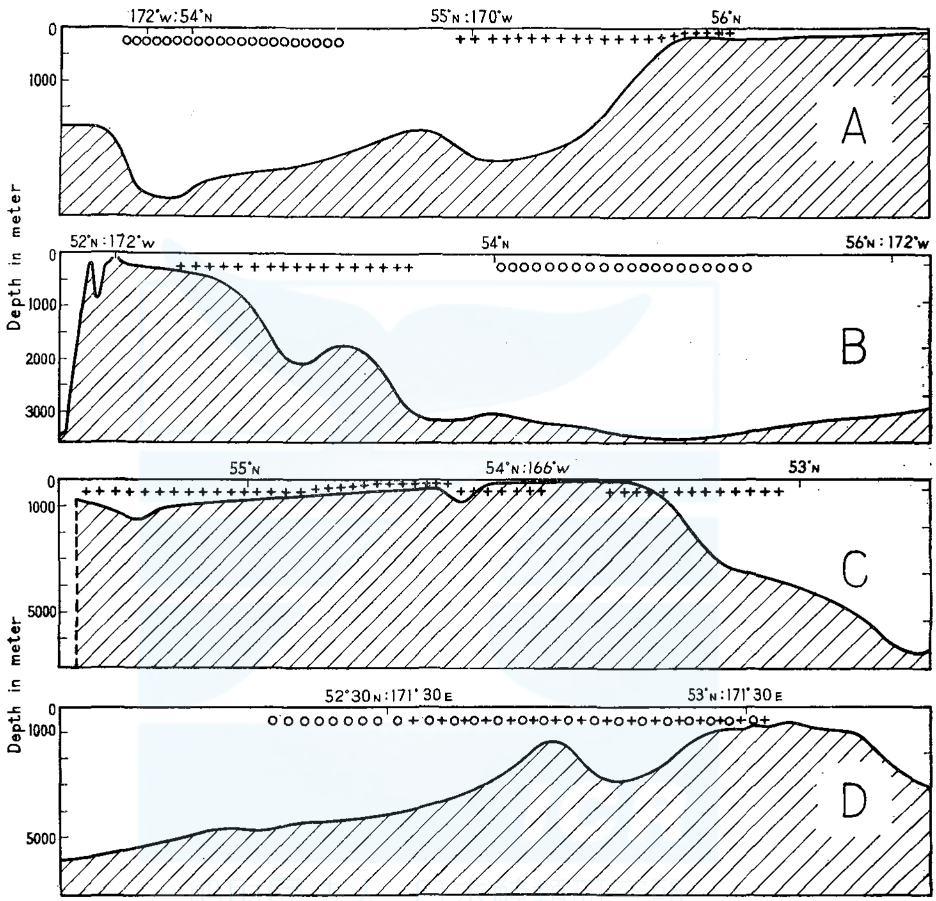

Fig. 25. The distributions of *Calanus cristatus* and *Thyanoëssa inermis* in relation to the sea depth of whaling grounds. Open symbols—*Calanns cristatus*. Crosses—*Thysanoëssa inermis*. C figure,—Cut the center position at an angle of 45° from north-west.

data are obtained as shown in table 15. The larger euphausiids are more dominant in C and D whaling grounds than the smaller one. This smaller group, ranging 5 to 15 mm is directly considered to be 1 year or 0 year groups. I observe the rare occurrences of such 0 year groups in C and D whaling ground chiefly consist of *T. inermis* and *T. longipes*. The furcilia larva of *T. inermis* is observed on 29th July in the stomach of 1 fin whale caught at 54°33′N, 171°43′W.

Rund (1932) and Marr (1956) also consider the occurrences of furcilia stages of *E. superba* in the Antarctic. But the dominant foods for *Balaenopteridae* whales are those over 20 mm or more in length. And as a rule *Furcilia* stages of euphausiids may not be able to be favourite foods of whales as discussed in the special part on euphausiids.

The whaling ground C has large continental shelf in the north-east part. As winds blow usually to north-east in summer, some physical processes of enrichment of surface waters are considered (Cooper, 1952). Cooper states in his summary that, 'Winds blowing intermittently towards a continental slope may produce vertical oscillations which bring about spillage of deeper nutrient-richer water from the ocean to the continental shelf'. With the upwelling current caused by sea currents met the continental shelf from south-west along the Aleutian ridge, the border line of Alaskan continental shelf should be very powerful productive region. Swarms of euphausiids on the border line is also due above causes. Hardy & Gunther (1935), also describe the distribution of blue and fin whales is deduced from the phosphate values of waters by the examination on the waters of South Georgia.

It is often observed by the whalers that, the state of whaling grounds has changed during the stormy weather. They say whales swam in an area migrate to another waters after the storm in some occations. If above observations is true, it may be attributable to the change of aspects in their food planktons by storm. However, Hardy & Gunther (1935) state that their results do not confirm the supposition that plankton organisms tend to sink from the surface layers during stormy weather. And stormy weather does not influence the state of swarms of zooplanktons. Uda & Nasu (1956) describe the relation between the whaling condition and the cyclone. They conclude that 'Shoaling condition of whales on the days after the passage of cyclone was better than that on the days before the passage of cyclone'. But by my observation, whales never shoal or disperse as a rule according with any weather conditions. Whales are considered to only swarm or disperse on their foods or for the reproducting.

The rendezvous of whales is found along the boundary between two currents in the whaling ground A. The center of rendezvous of whales lies in south-east waters in June, whereas the center ascends to north in July. It descends again to south from August to September according with the variation of boundary region. The intensity of the cold current along the Kamchatka Peninsula and the current along the south of Aleutian Islands decide above boundary. The migrating routes of baleen whales appear in the zone of abundant food such as above boundaries, and it seems that the migration of whale schools are subjected by the north and south movement of the front of abundant food zone

(Uda, 1954). The whale schools in the north waters of the eastern Aleutian Islands may attain there along those routes of boundaries.

When the examination on zooplanktons of stomach contents is carried out, the simplicity of dominant species is more often observed than those mingled with two or three species at the same rates. Nakai & Honjo (1954) state those simplicity of foods' species suggest that they apt to form the swarm of single species in the sea. In other words, each zooplanktons tend to form the swarm of themselves. This characteristic feature of planktons may partly due to the different ecological or the different spawning seasons of each species. As stated before, *Thysanoëssa spinifera* may spawn in summer, and *Euphausia pacifica*, *Thysanoëssa longipes* and *Thysanoëssa inermis* spawn during spring to

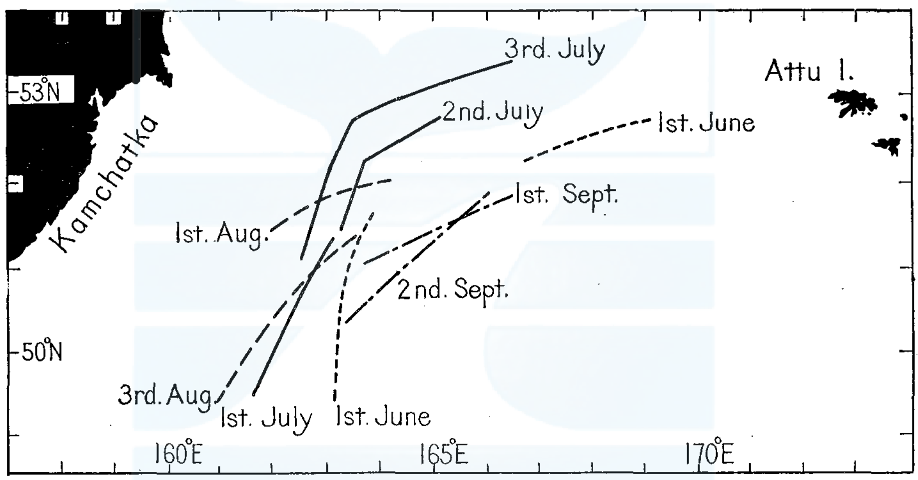

Fig. 26. The centre lines of the whaling ground in 1953 in the whaling ground A.

early summer in these waters. If euphausiids swarms for spawning as considered by Hjort & Ruud (1929), respective eupeausiids swarm separetely for their reproducting. Generally speaking *T. raschii* and *T. spinifera* are coastal forms, usually found within the continental shelf. *T. inermis* is more commonly found beyond the margin of the continental shelf (Banner, 1954). And above respective euphausiids may be carried by water currents of different conditions to the same waters. However, they may never dismiss their swarms.

Each swarms of zooplanktons must have peculial characters as biological masses, and preferences of whales for foods are due to such differences of biological masses. Very rare example, that blue whales took copepods in considerable quantity, are observed in two cases. In both cases, copepods are mingled with euphausiids at about the same rate.

Humpback whales, that never take copepods, also take the mixture of euphausiids and copepods. Above facts suggest that, the swarming mixtures of copepods and euphausiids bear the characteristic features of euphausiids' swarms, and blue and humpback whales take the swarms of copepods and euphausiids for the swarms of euphausiids. It is a very interesting fact that the mingled swarms of euphausiids and copepods stimulate blue and humpback whales' appetite, which have poor appetites for swarms of copepods.

In the first stomachs of whales, it is occasionaly found that foods are digested different grades in the first stomachs of whales. Further observations reveal that the foods of different digested grades are also considered different swarms of euphausiids. Because the species of each swarms are different from each other. I use every attention in dealing with such samples of different groups, as the simplicity of swarms is very important for the biology of euphausiids, and it is considered, whales should have taken successively such swarms of different species in the neighbourhood in the sea waters.

SUMMARY

The first summarized study on foods of baleen whales in the northern Pacific is stated. The essential points are concluded as follows.

1. The hydrographic conditions of the whaling grounds are discussed referring mainly to the papers by Barnes & Thompson (1938), Mishima & Nishizawa (1955), and Fleming (1955).

2. Generally speaking, baleen whales are planktonophager in the northern part of the North Pacific. Blue whales feed only on euphausiids, and fin whales feed mainly on euphausiids. When those zooplanktons are poor fin whales take fish or squids instead of zooplanktons. Only humpback whales take fish as well as euphausiids, but they never take copepods and squids favourably. The most favourite foods of sei whales is copepods though some of them take euphausiids, fish and squids. Baleen whales are not polyphagous animals in the northern part of the North Pacific.

The swarms of zooplanktons have peculial features according with the species of zooplanktons. Their characteristic features must have influence on the preferences of whales for their favourite foods.

3. Then, the important foods of baleen whales is as follows :

Euphausiids	*Euphausia pacifica*
	Thysanoëssa inermis
	Thysanoëssa longipes

Copepods	*Calanus cristatus*
	Calanus plumchrus
Fish, Atka mackerel	*Pleurogrammus monopterigius*

Thysanoëssa inermis and *Calanus cristatus* are the most important foods among them. The harvests of above two species in each whaling grounds control the migrations of whales, and whales never migrate to such area as their favourite foods are scanty. The spineless forms of *T. longipes* have also appeared as a large swarms of euphausiids in two occasions.

For baleen whales two forms of taking foods are considered. 'Skimming' by sei and right whales, and 'Gulping' or 'Swallowing' by blue, fin and humpback whales. The former method is able to take any sparse patches of zoöplanktons in the sea. The preferences of baleen whales for foods are affected by the degree of the congregation of zooplanktons. If swarms of zooplanktons are sparse, the *Swallowing* type of whales can not take them so successfully as *Skimming* type of whales.

4. Feeding activity of whales may partly be a response to the upward migration of zooplanktons, fish and squids. More whales take their foods in the morning or in the evening than in daytimes. The quantity of stomach contents decrease in accordance with prolongation of chasing. The freshness of stomach contents also declines with prolongations of chasing by catcher boats.

5. The age and growth of euphausiids in the northern part of the North Pacific may be summarized as follows:

Euphausia pacifica becomes mature at the age of two year about 20 mm in length in adjacent waters to Aleutian Islands. Spawnings take place in early spring to summer. *Thysanoëssa inermis* is also biennial in the adjacent waters to Aleutian Islands. In far southern localities it becomes mature in one year and spawns at a length 15 to 18 mm. Some specimens of *T. inermis* may be triennial in the north waters eastern Aleutian Islands. *T. longipes* becomes mature at the age of two years and spawns at a length of 20 to 28 mm. Spineless sorms of *T. longipes* matures in on year and spawns at a length of 15 to 18 mm. Some of the original forms of *T. longipes* may survive in the third year and spawn. Mating and spawning take place in late spring to early summer. The spawning of *T. spinifera* takes place in summer in Alaskan coast waters. As to the sex ratio of euphausiids, males are dominant usually in the swarms of euphausiids.

6. In the northern part of the North Pacific, and the Bering Sea, following species of zooplanktons are commonly found in the surface waters.

Adolescents and juveniles of *Thysanoëssa longipes* are the most abundant in the surface water in summar. *T. inermis* and *Euphausia pacifica* come next. *Thysanoëssa spinifera* and *T. raschii* are only found in the coastal waters. Among copepods, *Calanus plumchrus*, *C. finmarchicus*, *C. helgolandicus*, *C. cristatus*, *Eucalanus bungi bungi*, *Metridia lucens* and *Oithona similis* are the main constituents of the samples collected palnkton nets. The typical form of *C. finmarchicus* is also found in the samples. Other organisms *Sagitta elegans*, *Tomopteris pacifica*, *Limacina helicina*, and *Themisto* sp., are also very abundant in the surface samples collected by plankton nets.

7. It is considered that there are *Calanus year* when copepods are abundant, and *Euphausiid year* when euphausiids are abundant. Fin whales stay in the whaling ground consists of *Calanus* for a long date in *Calanus year*, and if there is the transition time from *Calanus cristatus* to euphausiids as in 1953 in the whaling ground A, fin whales leave the waters to seek their foods. Thus, the catch of fin whales in the whaling ground A is inconstant in the each period of seasons. The whaling ground consists of *C. cristatus* may be passing prosperity, on the other hand, the whaling ground consists of euphausiids along the margin of continental shelf is far stable through out the season.

8. The migrating route of baleen whales appears in the zone of abundant foods, and the whaling grounds are mainly situated along the boundary of different water masses, along the slope of Alaskan continental shelf. The concentration of euphausiids and copepods by currents are found in the areas of convergence, in backwaters and at the center of areas where there is a cyclonic movement.

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