FOOD AND FEEDING OF SEI WHALE CAUGHT IN THE WATERS SOUTH OF 40°N IN THE NORTH PACIFIC

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ABSTRACT

Results on the food and feeding conditions of sei whales caught by Japanese whaling fleets in the waters south of 40°N of the North Pacific during the 1972 season were preliminary reported. In the region south of 40°N the whaling ground was mainly found only in the limited sea area: in the environs of the southern tip of the Emperor Seamount Chain, although the fleets were in search of whaling ground between 165°E and 165°W. The feeding conditions of sei whales in those regions in terms of feeding percentages did not differ so much when compared with those have been found in the northern regions (1967–1971), *i.e.*, 34.4% in the south of 40°N while 55.1% in 40°–50°N zone, and 50.2% between 50°N and Aleutian Islands. Most of sei whales in the south of 40°N fed exclusively on a copepod, *Calanus pacificus* along with several species of euphausiids and fishes. In view of the frequency of occurrence, *Calanus pacificus* population being consisted of copepodites IV and V, young fishes of Japanese mackerel, *Scomber japonicus* and Japanese sardine, *Sardinops melanosticta* were the most important foodstuff. By examining prey organisms of these food fishes, it was found that most of them fed solely on *C. pacificus* or on a mixture of *C. pacificus* with *C. plumchrus* or with *Eucalanus bungii bungii*. The whaling ground found in the south of 40°N can be interpreted hydrobiologically as having been formed primarily by the rich mass occurrence of *C. pacificus* by the aid of intrusion of migrating populations of young fishes which were presumably in search of foods. In this connection it was strongly suggested that two heterotypical communities of food organisms are distinguished (see Figs. 4 and 6), and the whaling ground is divided by such ecological discontinuity which runs along the Emperor Seamount Chain. This ecological discontinuity would possibly be correlated hydrologically with the East Kamchatka Current Extension on which Uda (1971) has pointed out its importance in relation to the formation of fishing ground in the region.

INTRODUCTION

Japanese pelagic whaling in the North Pacific Ocean have been restricted its operation area with the lines of 40°N or 45°N latitudes as its southern most limit by the measures of Japanese Government in addition to the regulation by the IWC's arrangements on the whole. It was, however, decided to lift the ban to some extent in 1972 and by this decision the sea region down to 20°N was newly opened chiefly

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in the zone of central Pacific between 159°E and 150°W (see Ohsumi, 1973).

Since the beginning of Japanese whaling operation in the North Pacific in 1952 the main whaling grounds have been restricted almost in the northern North Pacific and Bering Sea (Nasu, 1966), and consequently our knowledge on the food of baleen whales was also biassed (Nemoto, 1957, 1959). Under these circumstances little is known on the food and feeding conditions of baleen whales in the southern sea regions above mentioned. The whaling ground south of 40°N may be one of the least studied regions in the North Pacific possibly due to its geographical position, the south of the Subarctic front. By knowing the opening of new whaling region, some biological investigations including a collection of foodstuff of whales were established. During the whaling season of 1972 Japanese fleets entered into those newly opened region including 40°N chiefly in July and caught 884 sei, 5 bryde's and 8 fin whales from which I got some amount of food samples. The results of examination and analysis on the food and feeding conditions of sei whales are reported.

MATERIALS

Among many biological examinations on each whale carcases, kind of food organisms, an approximate amount and freshness of foodstuff in the first stomach were examined by eyes on the ship's deck. A total of 34 food samples was also collected from the whales caught in the south of 40°N and they were preserved in formalin. Methods of observation and description on food organisms and feeding conditions in the field were not different from those having been undertaken in the Antarctic (see Kawamura, 1970). Since many food fishes occurred were consisted of the well known species in the North Pacific region, they were remarked by the common name in addition to the records by ordinary classification of " Fish " by the observers. Euphausiids are usually expressed as " Eu " by the three different sizes among which *Sergestes similis*, a macruran shrimp, is also included by confusion. They are, however, reasonably distinguished by the size record of " Large " since there are no such euphausiids as equivalent to this category in the North Pacific region (Omori *et al*, 1972). Although the number of collected samples was slightly few against the number of whales, it was possible to estimate the kind of food organisms of each animals by refering both to the results of identification on collected samples and catch records.

WHALING GROUND SOUTH OF 40°N IN THE NORTH PACIFIC OCEAN

Many whaling grounds which have been developed and exploited in the world are located chiefly, if not entirely, in the higher latitudes of the seas most of which show a distinct fertility in standing crops of zooplankters and other organisms during warm season. These whaling grounds are undoubtedly some peculiar regions formed through productive food chains such they usually called as feeding ground. The northern North Pacific and Bering Sea where many whalers have been in chase of whales do not differ from the others in its basal formation. From this point of view pelagic whaling operations by the Japanese fleets since 1952 in the northern North

Pacific between 50°N and 60°N must be quite natural as well as the case of many other fisheries in that region. Much accumulations of whales are usually expected in these seas during warm season.

Baleen whales, however, are distinct migrator that move between warm and cold seas by seasons with an approximately a year cycle, and such whale movements as a unit of whole population do not always proceeded continuously with any completion by season since they are considered to show somewhat variable stream like movements as its situation has been suggestively demonstrated by Mackintosh and Brown (1956), and Mackintosh (1965). It may possible that when the whales migrating in the head of a population will have already entered into the feeding ground of higher latitudes while the others are still far outside from it. Although many of the rest may enter soon or later into those food rich ground, this discrepancy in time and space makes it difficult to know or predict exact movements of whales at their feeding ground. The whaling operation in 1972 can be regarded to have undertaken under these circumstances in general.

On the other hand, it is well known fact that the Subarctic boundary which lies roughly along 40°N latitude divides the northern North Pacific into two regions of distinctly different waters both in physical and biological characters (e.g. Zenkevitch, 1963). Comparing latitudinal standing stocks of zooplankton in that regions, Odate (1966) and Vinogradov (1968) demonstrated its difference in biological characters between boreal and northern temperate waters which prevail in both regions: the faunistic abundance in the south of the subarctic boundary is hardly comparable to that of boreal regions. In this connection the sea region lies in the south of 40°N–41°N in the North Pacific probably deviate from those general idea as a feeding ground of higher latitudes. However, the newly opened whaling ground where actually operated and caught the whales were found only in the west side of 180° longitude, and can not be considered analogous with any other areas south of 40°N since a distinct mixed waters of Kuroshio and Okhotsk Sea origin which are supposedly more fertile prevail in the region west of 180° (Dodimead *et al*, 1963). In such a whaling ground, whether or not any amount or kind of food organisms which must be principally gregarious organisms along with considerable large population size will be found, are undoubtedly much interesting in connection with both the formation of feeding ground of whales and general zoogeography.

CATCH DISTRIBUTION OF WHALES

A rough sketch of whaling region operated by three Japanese fleets in the 1972 season is demonstrated in Fig. 1. The shaded areas in the figure indicate principal whaling ground. As it is shown in the figure Japanese fleets slightly entered into Bering Sea but caught a little. The main whaling ground was found in two areas, *i.e.*, the whaling ground in the east longitudes and that in the west longitudes. Zonal formation of main whaling ground like this pattern seems characteristic in recent operations, and considerable heavy catch in the waters south of 40°N in 1972 might be rather the result beyond expectation. In spite of being opened the whaling

region southerly down to 20°N the whaling ground actually operated in the south of 40°N was diminutive in July where the southern most position was 34°N in the zone between 170°E and 180°. No notable catch was recorded in the south of 40°N region of west longitudes.

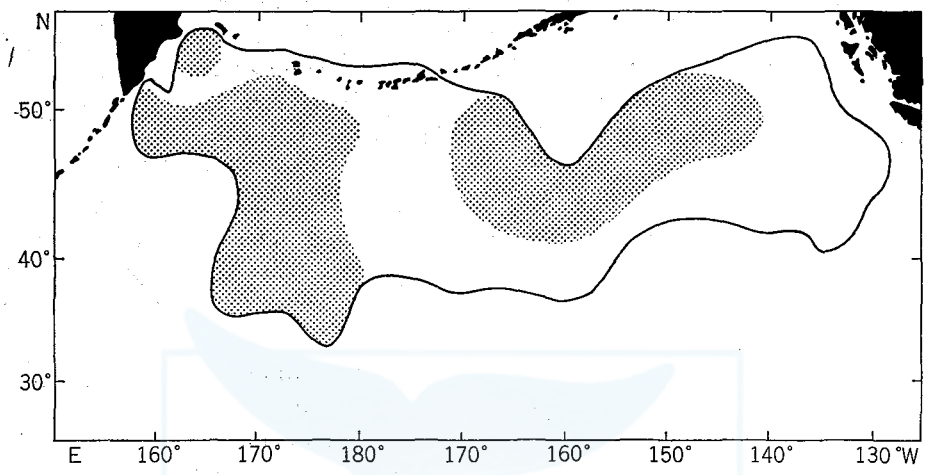

Fig. 1. The North Pacific whaling ground operated by three Japanese fleets in the 1972 season.

TABLE 1. CATCH DISTRIBUTION OF SEI, BRYDE'S AND FIN WHALES CAUGHT IN THE WATERS SOUTH OF 41°N LATITUDE IN THE NORTH PACIFIC, 1972.
NUMBER OF ANIMALS: SEI/BRYDE'S/FIN

Longitude	Latitude (N)						
	34	35	36	37	38	39	40
165°E–170°E			8/–/–	41/2/–	36/–/–	85/–/–	14/–/–
171°E–179°E	31/–/1	174/2/2	74/1/–	120/–/1	110/–/–	108/–/2	31/–/1
172°W–177°W*						21/–/1	20/–/–
168°W–169°W							11/–/–
Total	31/–/1	174/2/2	82/1/–	161/2/1	146/–/–	214/–/3	76/–/1

* No catch in 176°W zone.

In the region of south of 41°N sei, bryde's and fin whales were caught, and the number of animals caught by 10° longitude are given in Table 1. It is clear in the table that the newly opened region benefited almost exclusively for sei whaling and the catch of both fin and bryde's whales were sporadically. It is also shown that latitudinal spread of sei whale ground is found between 35°N and 39°N, which is presumably correspond to the general features of bottom topography, *i.e.*, the presence of the Emperor Seamount Chain.

FEEDING BY SEI WHALE IN THE SOUTH OF 40°N

In the waters south of 40°N of east longitudes relatively warm waters high above

14°C in the surface prevailed during July of 1972 at 40°N with remarkable temperature gradient of about 1.6°C/1° lat. toward the south to show 21°C or more at 35°N (Fig. 2). The meandering isotherms run SW to NE direction on the whole, and the intrusion of tongue like warm or cold waters from south or north between 165°E and 178°E was distinct. The overall surface sea conditions can be seen as those of subtropical characters.

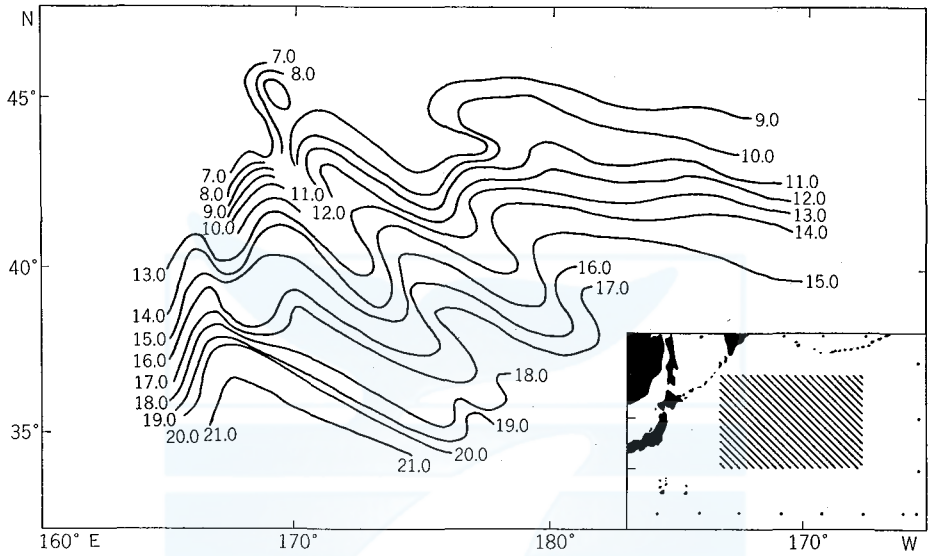

Fig. 2. Distribution of surface sea temperature (°C) in July, 1972.

TABLE 2. STOMACH CONDITION OF SEI WHALE CAUGHT IN THE WATERS SOUTH OF 41°N IN THE NORTH PACIFIC, 1972.

Longitude	Stomach with food	Empty	No. of animal examined	feeding percentage
165°E–170°E	68	116	184	38.0
171°E–179°E	195	453	648	30.1
172°W–177°W*	18	23	41	43.8
168°W–169°W	11	—	11	100.0
Total	292	592	884	33.05 (Av.)**

* No catch in 176°W zone.

** 168°–169°W zone is excluded.

Feeding percentages, the ratio of food containing animals to the total animals examined are demonstrated in Table 2. Although some figures may be unreliable due to poor number of material source, stomach conditions of sei whale in terms of the feeding percentages in the south of 40°N as far as the zone between 165°E and 179°E concerned, could be considered to be about 30–40% with 33.05% on an average. Comparing these figures with those of averages obtained from the

northern whaling ground north of 40°N where 50% or more are expected (Table 3), the whaling ground south of 40°N showed slightly poor feeding conditions on the whole but could be regarded as still rich to some extent in availability of foodstuff. Relatively poor feeding conditions in the south of 40°N are also shown by the fulness of stomachs in terms of the amount of food as expressed in percentage figures (Table 4). It is curious, however, that considerable high percentages of whales were found to be carrying well repleted stomachs in contrast to very slight numbers in northern whaling grounds.

TABLE 3. LATITUDINAL CHANGE IN FEEDING PERCENTAGES OF SEI WHALE.

Latitudes	Feeding percentage	
50°–60°N I*	21.83	
II**	50.19	Av. 1967/71
40°–50°N	55.01	
20°–40°N***	34.40	Av. 1972

* Bering Sea.
** northern North Pacific between 50°N and Aleutian Islands.
*** Actual southern most position: 34°N.

TABLE 4. STOMACH CONDITIONS IN PERCENTAGE FIGURES BY NUMBER OF ANIMALS

Latitudinal area	Amount of food			
	Few	Moderate	Rich	Full
North of 40°N*	60.2	26.8	9.6	3.4
South of 40°N*	43.9	26.3	12.7	17.1
North of 40°N**	63.2	25.9	6.2	4.7

* 1972
** Average: 1967–1972

Characters of the southern whaling ground as feeding place were examined geographically or quantitatively in view of the availability of foodstuff, and revealed that the southern whaling ground by no means so poor in feeding conditions as having been supposed in general. Table 5 shows one of another characters, the qualitative peculiarity of the region. It is noticed in the table that great deal of foodstuff in the south of 40°N are solely comprised of fishes while they are almost less important in the northern whaling ground. On the other hand, copepods comprised only 7.2% among all foodstuff while they are 80% or more in the north. These qualitative characters indicate that the formation of whaling ground in the waters south of 40°N possibly relates to the accumulation of young fishes under feeding migrations as well as whales.

KIND OF FOOD ORGANISMS

Table 6 demonstrates the kind of food organisms found in 1972 materials which in-

clude the food samples collected in the waters north of 40°N up to 50°N but a little. Relatively large number of food species was found especially in euphausiids and fishes. To describe biological characters of the population of food organisms something more in detail would be as follows: both *Calanus cristatus* and *Calanus plumchrus* were entirely consisted of copepodite stage V which is only one copepodite stage showing gregarious occurrence during warm season in the North Pacific as having been reported in many previous works (e.g. *Fac. Fish. Hokkaido Univ.*, 1961).

TABLE 5. A GENERAL FEATURES OF FEEDING CONDITIONS IN THE NORTH PACIFIC SEI WHALE THROUGH PAST SIX SEASONS*

Whaling Season	Feeding** percentage	Food organism			
		Euphausiid	Copepoda	Fish	Squid
1967	73.1***	22.0	76.7	0.6	0.3
1968	60.9	9.0	89.9	0.2	0.7
1969	60.8	6.3	81.6	9.1	3.0
1970	64.1****	13.8	81.6	4.2	0.3
1971	54.5	17.7	75.5	4.9	1.9
1972	54.4	2.7	7.2	24.6	—

* Number during 1967–1971 represents the whole area of the North Pacific north of 40°N, and that 1972 represents only the area south of 40°N.
** No. of stomach with food/No. of stomach examined.
*** 0.4% of amphipoda is excluded.
**** 0.1% of unlisted organism is excluded.

TABLE 6. FOOD ORGANISMS OF SEI WHALE CAUGHT IN THE NORTH PACIFIC WHALING GROUND, 1972.

COPEPODA
Calanus cristatus Kröyer
Calanus plumchrus Marukawa
Calanus pacificus Brodsky
EUPHAUSIID
Euphausia recurva Hansen
Euphausia pacifica Hansen
Euphausia diomedeae Ortmann
Euphausia tenera Hansen
Thysanoessa inermis (Kröyer) Hansen
Thysanoessa spinifera Holmes
Nematoscelis difficilis Hansen
Nematoscelis gracilis Hansen*
DECAPODA: Macrura
Sergestes similis Hansen
FISH
Scomber japonicus Houttuyn
Sardinops melanosticta (Temminck & Schlegel)
Engraulis japonica Houttuyn
Cololabis saira (Brevoort)
Maurolicus muelleri (Gúerin)
Pseudopentaceros richardsonii (Smith)
CEPHALOPODA: *Decabrachia*
Two or three species unidentified

* Identification is doubtful due to the damage of specimens.

Calanus pacificus was separated from *Calanus finmarchicus* or *Calanus helgolandicus*, and established as warm water prefering species being prominent in Far Eastern Seas by Brodsky (1948). Among the occurrence of *C. finmarchicus* and *C. helgolandicus* in the surrounding waters of Japan, some of which might be included *C. pacificus* since the species prefers well much warmer waters than the two others. It

seems the first record that *C. pacificus* is reported as a principal food sources of baleen whales in the North Pacific region. *C. pacificus* which was found to be the primalily important foodstuff of sei whales in the waters south of 40°N, was also represented by copepodite stage V but copepodite stage VI of both sexes also occurred. However, the number of adult males and females in the population was hardly comparable to that of copepodite V and an approximate ratio of each stage was: CV: CVI (female): CVI(male)=60: 3: 1. There was a net plankton sample collected in the whaling ground and it revealed that copepodites III and IV of *C. pacificus* also present in the region with slightly larger numbers in the latter.

In euphausiids, *Euphausia pacifica* was found most frequently and most of them were consisted of both adult and adolescent individuals some of which carried sperm sacs on the belly. *E. recurva* and *E. diomedeae* were also found being consisted of adult forms of both sexes with almost same number though slightly less female in the latter species. Some females carried sperm sac. *Nematoscelis* spp. and others were consisted of both sexes with some mixture of adolescent forms. None of these species were found carrying about sperm sac.

The only one macruran, *Sergestes similis* was in the body length of 26.3–47.0 mm though most of them were found to be larger than 40 mm. Their body lengths, however, did not differ much by each collected samples, and this fact suggests that mass occurrence in patchness would be consisted of the individuals of nearly same developmental stages possibly due to a sort of segregation by year class.

Many individuals of Japanese anchovy, *Engraulis japonicus* were 9.0–10.5 cm in fork length and supposed to be a spring population of current year almost attained at the maturity from their sizes (Kondo, 1971). Japanese mackerel, *Scomber japonica* was the most dominant food fish, and all of them was sexually immature from their body length of 8.4–11.7 cm (Usami, 1968). Body length of Japanese sardine, *Sardinops melanosticta* and Pacific saury, *Corolabis saira*, was 8.3–11.6 cm and 10.5–17.7 cm respectively. They were also sexually immature from their body length (Kondo, 1964; Hotta, 1964), and Pacific saury was possibly a offspring of the spring in current year (Hotta, 1964). A Gonostomatiid fish, pearlsides (*Maurolicus muelleri*) showed 4.7–4.8 cm in their fork length.

Although there were many kind of food organisms as mentioned above, a bulk of these food organisms can be considered being consisted of zooplankton and fish species which prefer rather warmer waters when compared with those having been found previously in the northern waters (see Nemoto, 1957, 1959), that is, *Calanus pacificus*, *Nematoscelis gracilis*, *N. difficilis*, *E. diomedeae*, *E. tenera* and some fishes such as Japanese mackerel.

Food organisms in detail with corresponding number of whales are given in Table 7. It is clear in the table that a typical cold water copepods, *C. cristatus* and *C. plumchrus* were exclusively fed by the whales in the northern waters north of 40°N, while *C. pacificus*, the warm water copepod, was the representative in the south of 40°N. Table 7 also indicates that the fin whales feed more preferably on euphausiids than copepods as Nemoto (1959) early reported their food preference. To see the overall results it is no doubt that the essential diet of sei whales in the waters south of

40°N is formed almost solely by *C. pacificus* and small fishes. It is notable that both *C. cristatus* and *C. plumchrus* correspond to *C. pacificus* in the north of 40°N, and euphausiids and macruran, *Sergestes similis* (Kawamura, 1970, 1971; Omori *et al.*, 1972) also taken over the role of small fishes. As it will be mentioned later the majority of those food fishes prey upon *C. pacificus*. Euphausiids were also fed but very few. This indicates that they are less important as whales food in the waters south of 40°N. Among the food fishes both Japanese mackerel (*Scomber japonicus*) and Japanese sardine (*Sardinops melanosticta*) were the most important.

TABLE 7. NUMBER OF ANIMALS BY THE FOOD ORGANISMS IN SEI AND FIN WHALES IN THE NORTH PACIFIC, 1972.

Kind of organisms	South of 40°N	North of 40°N	
	sei	fin	sei
C. cristatus		2	18
C. plumchrus		1	6
C. plumchrus–C. cristatus			1
C. pacificus	7*		
C. pacificus–E. recurva	1		
E. pacifica		3	3
E. recurva	1		
E. diomedeae	1		
E. tenera	1		
Th. inermis		2	
Th. spinifera		1	
Th. inermis–Th. spinifera		3	
N. gracilis (?)	1		
N. difficilis	1		
S. similis		1	2
S. similis–C. cristatus			1
S. similis–E. pacifica		1	
S. similis–C. plumchrus–C. cristatus			1
S. japonicus	10		
S. japonicus–C. pacificus	1		
S. japonicus–S. melanosticta	1		
S. japonicus–E. japonicus	1		
S. melanosticta	3		
E. japonicus	1		
C. saira	1		1
M. muelleri	2		
M. muelleri–S. saira–Squid	1		
P. richardsonii larva (?)	1		
Squid			2

* One material collected by the net is included.

In summerizing the results it is confirmed that *C. pacificus*, *S. japonicus* and *S. melanosticta*, all the warm water food organisms, essentially made the whales accumulate for feeding in the waters south of 40°N. A clear latitudinal succession in the species composition of food organisms or in its community also make us

confirm that the subarctic front had undoubtedly positioned in the vicinity of 40°N in the east longitudes during July of 1972.

DISTRIBUTION OF FOOD ORGANISMS

Food organisms occurred can be divided into three major groups: copepods, euphausiids and fishes. Figs. 3 and 4 demonstrate a rough sketch of their distribution being arranged by examining the food samples and the record of eye observations made on the ship's deck. As the latter covers all of whales caught while the food

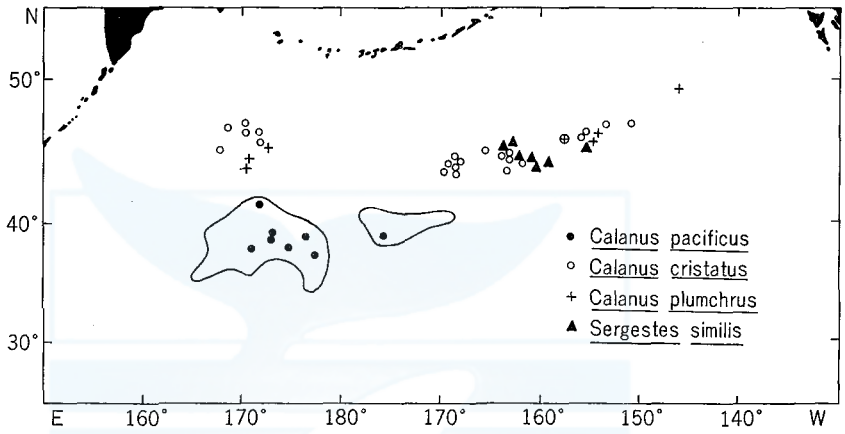

Fig. 3. Distribution of food copepods and macruran shrimp, *Sergestes similis*.

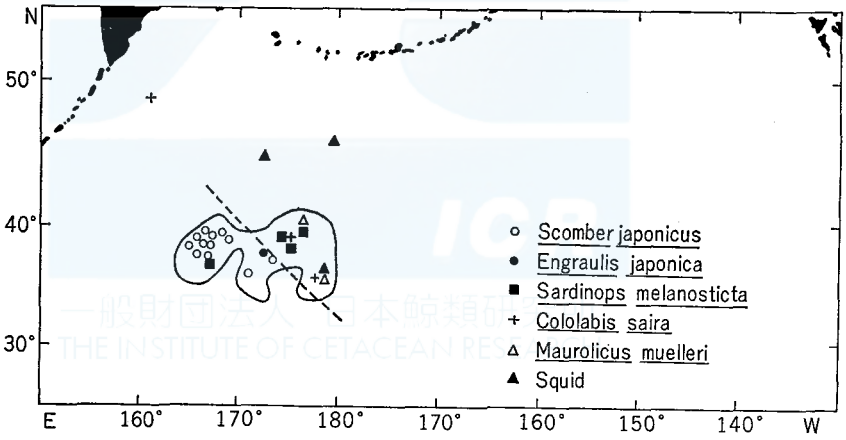

Fig. 4. Distribution of food fishes and squids. Broken line indicates the zoogeographical discontinuity.

samples were collected sporadically, the spread of distibution range shown in the figures does not follow exactly to the positions or the range by the food samples. Fig. 3 shows the distribution of copepods and a macruran, *Sergestes similis*. It is clear in the figure that *C. pacificus* occurs only in the waters south of 40°N while *C.*

plumchrus and *C. cristatus* predominate extensively in the northern waters. The actual southern most position of the occurrence of *C. pacificus* was found in 34°N and that of northern most was in 41°20'N, 170°E. Taking some allowance into consideration on their distribution range, *C. pacificus* may occur up to 42°N or thereabouts with a considerable large size stocks so as to be fed by the whales. *Sergestes similis*, on the other hand, occurred only in the waters of west longitudes with its distribution center in 44°–46°N, 160°W. The occurrence of *S. similis* in this way is very characteristic as having been reported and pointed out its importance as whales food in these region (Omori *et al.*, 1972). A majority of euphausiids in the northern waters were represented by *Euphausia pacifica*, *Thysanoessa spinifera* and *Th. inermis* though they might be less important in the region where mass occurrence of *S. similis* is expected.

There are noticeably different features of distribution between Japanese mackerel and Japanese sardine (Fig. 4). In the waters south of 40°N Japanese mackerel occurred exclusively in 165°–173°E while Japanese sardine was found in 174°–178°E. Composition of whales food fish was relatively complicated in the region east of 174°E where young Pacific saury of 10.5–17.7 cm and pearlsides of 4.7–4.8 cm occurred along with Japanese sardine. Very small larvae presumably of boar fish, *Pseudopentaceros richardsonii*, also occurred though sporadic. All these small but swarm forming fishes did not occur in the waters north of 40°N except a very few instances of Pacific saury. In general, population of fishes as food of sei whale in the waters south of 40°N can be considered to be consisted of two groups of food-

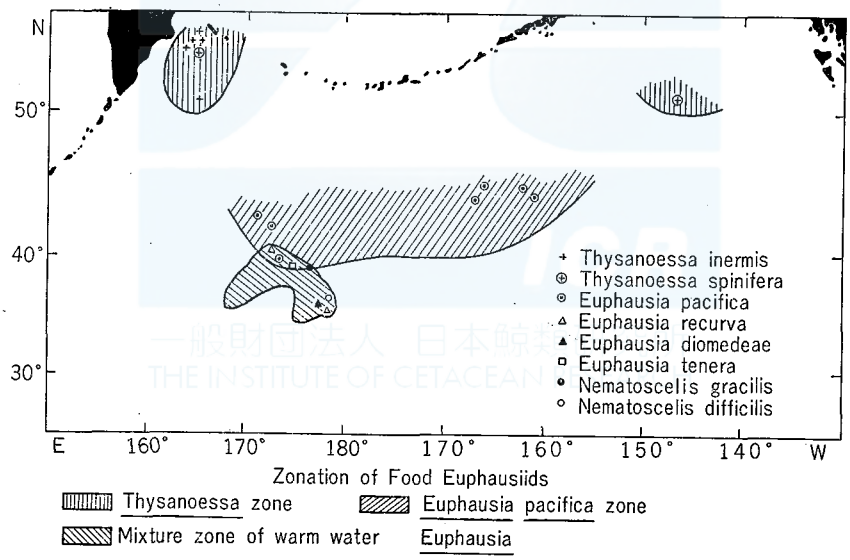

Fig. 5. Distribution of food euphausiids and their possible zonation of occurrence as whales food. The mixture zone in the figure does not mean the interspecific mixing but the species occur in complete monotypic population under a condition of rather sporadic occurrence each other.

stuff of fishes: Japanese mackerel alone or it accompanying Japanese anchovy population in the west side region, and Japanese sardine population with several numbers of cold water or cosmopolitic fishes. These food fish populations divide the region into two parts that different fish communities predominate roughly with their occurrence border crossing northwest to southeast direction between 170°E and 180° as shown by a broken line in Fig. 4.. Recognition of whaling ground by this way can also be interpreted by the pattern of occurrence in euphausiids (Fig. 5).

PREY OF FISHES FED BY WHALES

As it was mentioned in the preceding section a considerable part of foodstuff of sei whales in the waters south of 40°N was consisted of small sized but school forming fishes, and such sea conditions as feeding ground seem somewhat characteristic when compared with those formed by the planktonic organisms since the fishes above mentioned can be regarded as competitors to feed on the whales food. In connection with this circumstances the whaling ground in the south of 40°N would be regarded as that formed secondarily although there seems still in need of further examination on foodstuff in the fishes fed by the whales.

As it is shown in Table 8 great deal of fishes found in the stomach of whales had fed solely on copepods of one or two species. Among copepods fed by the fishes of whales food, *C. pacificus* was most predominant being followed by *C. plumchrus* and *C. cristatus*. It was also noted that one of the typical cold water copepod species, *Eucalanus bungii bungii* which was completely absent from the foodstuff of sei whale occurred along with *C. pacificus*. Some individuals of Japanese mackerel

TABLE 8. STOMACH CONTENTS OF FISHES FED BY SEI WHALE.

Food organisms of fishes	Kind of food fishes*				
	Sj	Cs	Ej	Sm	Mm
C. cristatus–C. plumchrus	1				
C. plumchrus	1				
C. pacificus	2		1	1	
C. pacificus–C. plumchrus	1				
C. pacificus–E. bungii bungii	1				
C. pacificus–C. plumchrus–amphipoda (Gammariid)	1				
Others	2**				4***
Unknown****	4	1			2
Empty	5	2	1	3	

* Sj: *Scomber japonicus*, Cs: *Cololabis saira*, Ej: *Engraulis japonicus*, Sm: *Sardinops melanosticta*, Mm: *Maurolicus muelleri*.

** *Euchaeta* sp., *Phronima* sp., *Sapphirina* (?), *Eucalanus* sp., *Oikopleura* sp., *Salpa* (?).

*** *Pseudocalanus elongatus*, *Eucalanus bungii bungii*, *Candacia colombiae*, *Oncaea* sp., Euphausiids furcilia, Amphipoda, *Phronima* sp.

**** decomposed.

and pearlsides (*M. muelleri*) fed on a mixture of many kind of zooplankters. These fishes seem undoubtedly to have preyed upon the zooplankters being present in-

discriminately without any selection. It is interesting that warm water zooplankton species such as *Phronima* and *Sapphirina*, were found as a food of young Japanese mackerel which somewhat prefers warm water while *M. muelleri*, a cosmopolitic species fed on cold water zooplankters. By examining on the foodstuff of both whales and their food fishes, it is confirmed that they are closely linked up solely through *C. pacificus*. In these prey—predator relationships the whaling ground in the south of 40°N can be recognized as being formed at its beginning by the distributional characters peculiar in *C. pacificus*, which would possibly related to some hydrodynamical processes of past seasons in the northern waters. In approaching to the causation of aggregations of whales through the formation of their feeding ground, manifold composition of foodstuff in pearlsides seems less important than Japanese mackerel which feeds exclusively on monotypic swarms of copepods.

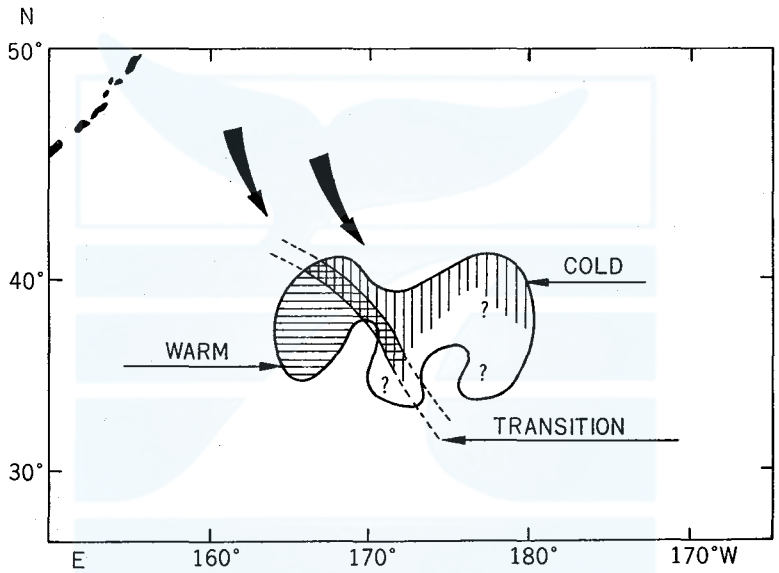

Fig. 6. Schematic zonation of whaling ground in the waters south of 40°N as based on the distribution of prey organisms of sei whales and their food fishes. 'WARM' in the figure is the zone characterized by *C. pacificus* or its mixture with various warm water copepods, and 'COLD' is those by *C. plumchrus* or its mixture with *C. cristatus*. Both 'WARM' and 'COLD' zones meet and mix with each other at the 'TRANSITION' zone. Arrow shows a possible penetration of subsurface cold waters from the EKCE.

By plotting the occurrence of prey organisms of fishes fed by whales, two ecologically heterogeneous regions could be distinguished (Fig. 6). One of them is characterized by *C. pacificus* or a mixture of various warm water zooplankters, and the other is by *C. plumchrus* or a mixture of *C. plumchrus* and *C. cristatus* populations. It is also noticed that there are transision zone with some width where the prey organisms of fishes intermingled with those in both regions each other. These distinguished regions agree well with the result obtained in food fish populations, but

the location of transision zone seems likely to shift rather southward than the location of ecological discontinuity which is shown in Fig. 4.

DISCUSSION

The region which lies in the south of 40°N of the North Pacific does not seem to be kept under such a conditions of good feeding ground as make the whales, if not entirely, be accumalated for a while when considered from the point of views of an abundance in food organisms. This is the problem of gross availability of food organisms as it is generally indicated by feeding condition of whales. Feeding percentages, the ratio of food containing animals to the total examined in sei whales in the waters north of 40°N through past five years were 62.7% on an average while those in the south of 40°N revealed it remains at about 30–40%. Under a rather barren sea conditions, however, the region lies between 160°E and 180° zone in the south of 40°N seems to be distinct being covered with some peculiarities under the influence of prevailing current.

Mentioning on the upwelling of suarctic intermediate waters in relation to the character of subarctic front in the zone of east longitudes of the North Pacific, Uda (1971) proposed the presence of a southeasterly branch from the East Kamchatka Current, which is called as the East Kamchatka Current Extension (EKCE), and it presumably influences upon the sea conditions in the environs of 40°N, 160°–170°E region. The EKCE which originates from the region about 50°N, 160°E extends south to southeast direction, shifting its direction more easterly when it meets with the Oyashio front at about 40°N. This cold southeasterly current must presumably be causative for the meandering in surface temperature distribution along with the influence of a complex bottom topography by the Emperor Seamount Chain, and further, it possibly relates to the extension of mixed waters of the Kuroshio and Okhotsk Sea as Dodimead *et al*, (1963) figured out. Recent work presented by Kishi and Uda (1973) makes me confirm those hydological peculiarities of the whaling ground under consideration. Analyzing on the depth distribution of 10°C waters based on the enourmous amount of data during 1935–1969, they (Kishi and Uda, 1973) found a steady southerly intrusion of the cold EKCE waters into the south of 40°N region between 150°E and 160°E.

The whaling ground in the south of 40°N would be divided into two regions of relatively warmer and colder characters by the intrusion of colder waters from the north, and they are formed in the both southwest and northeast side of the region (see Figs. 5 and 6). In this connection the proposed ecological discontinuity which was interpreted from the results of examinations both on whales food and the prey organisms of the fishes of whales food agrees well with the hydrological characters on the whole, and supports Uda's proposal on the EKCE on biological basis although the location of the discontinuity may shift to some extent by seasons and years. In the populations of Japanese sardine and pearlsides the latter fed exclusively on boreal or cold arctic zooplankton species such as *Pseudocalanus elongatus* not with standing the fact that both fish species occurred in almost the same region. On the other hand,

it was more in the southerly waters that monotypic aggregations of *C. pacificus* were found in the stomach of Japanese mackerel. Both *C. cristatus* and *C. plumchrus* as a foodstuff of sei whales never occurred in the waters south of 40°N while they were found in the further south to some extent as a prey of food fishes of whales. These circumstances seem to be discrepant but it would be explained as follows though still have not proved yet: Both *C. cristatus* and *C. plumchrus* are the important foodstuff of baleen whales through widely in the northern North Pacific (Nemoto, 1963), and they could occur by forming a dense swarms so as to be fed by the whales in the north of 40°N. In the south of 40°N, on the other hand, it is far out side from their usual habitat, and as any of both species could not be present as swarms in the surface so were they in the northern waters. *C. cristatus* and *C. plumchrus* found in the stomach of Japanese mackerel might not be preyed upon their swarming populations but possibly upon rather sporadic and dispersed populations having been carried by the intermediate waters from the north. The general features in the zoogeographical successions of fish foods suggest that some mixing of water would take place in or near by those discontinuous borders mentioned previously, and it might presumably be due to the influence of the EKCE, since cold waters widely found over this region can be recognized as the subsurface Oyashio origin waters which penetrated into the region at the depth of about 50–100 m. (Kishi and Uda, 1973).

According to Betesheva (1954) fin whales feed on anchovy in the waters of Kurile region during August and the anchovy population often accompanies *Thysanoessa raschii*, a cold neritic species (Boden *et al*, 1955). Japanese anchovy found in the North Pacific in 1972 occurred at the southern most part of its distribution in Japanese sardine—pearlsides populations. This fact suggests also the succession of water masses more colder toward north to northeast side in contrast to warming toward south to southwest, that is, more stronger influences of warm water in the south. In this respect Omori (1965) reported an interesting result, that is, *C. pacificus* distributes fairly wide in the zone of 40°–50°N of the North Pacific during June to August but it is only in the west of 170°W that *C. pacificus* often occurs being accompanied by warm water copepods such as *Calanus tenuicornis*. This fact would explain the biological character of newly opened whaling ground and its peculiarity as mixing region in general.

Consulting with the general faunistic features around the region in the south of 40°N of the North Pacific (Zenkevitch, 1963), the whaling ground operated in the south of 40°N resembles well to the features usually found off Sanriku, the southeast coast of northern Japan, and it is something likely to their extension with slight addition of more boreal characters. Although a considerable number of *C. pacificus* occurs far in the Gulf of Alaska (Omori, 1965), they are usually accompanied with *C. plumchrus*. These difference in their specific combinations as a communities of food organisms, though it resembles at a glance, should be noted since it might give the sea quite heterogeneous characters. In concluding on the whaling ground along with its formation in the south of 40°N in the North Pacific, it is considered that the key factor is found solely in the distributional ecology of *C. pacificus*. However, the feeding ground of baleen whales as Kawamura (1973a, b) has firmly

pointed out should not be considered solely on the basis of each food species alone but of their community which embodied through the food chains. *C. pacificus* is usually found widely over the northern North Pacific but no other staple feeding ground of baleen whales as exploited in the zone of east longitudes would possibly be found in the zone of west longitudes.

SUMMARY

1. In accordance with lifting the ban of whaling activities by the measures of Japanese Government in the waters south of 40°N of the North Pacific in 1972 a total of 34 food samples of sei whales was collected in the newly opened region, and their food and feeding conditions were examined.

2. The main whaling ground in the south of 40°N was located only in the zones between 165°E and 180° with 34°N as its southernmost position, where the Emperor Seamount Chain ends. The surface sea temperature of 14°–21°C prevailed during July in the region with a remakable meandering pattern which jaggs northwest to southeast direction.

3. The sea conditions were complex under a possible influence of the East Kamchatka Current Extension, and the formation of whaling ground seems rather the peculiar case in the waters south of 40°N.

4. The ratio of food containing animals to the total examined in percentage figures showed 33.05% on an average while it was 50.0% or more in the waters north of 40°N through past five seasons.

5. In connection with the feeding percentages the fertility of the region south of 40°N as feeding ground of baleen whales is considered to be not so barren as having been supposed previously.

6. The foodstuff of sei whales in the waters south of 40°N was almost solely comprised of fishes (24.6%) and copepods (7.2%), while they showed less than 5% and 80% or more respectively in the northern waters.

7. More than 20 species of food organisms were identified. A large number of them was comprised of warm or cold temperate species especially in euphausiids, but only *Calanus pacificus*, Japanese mackerel (*Scomber japonicus*), Japanese sardine (*Sardinops melanosticta*) and Japanese anchovy (*Engraulis japonica*) were the main constituents of the food of sei whales.

8. The *Calanus pacificus* population was represented by the copepodites V and VI of both sexes, and that of the fishes was by the young individuals of sexually immature.

9. Distribution of food organisms revealed that the main whaling ground in the south of 40°N is likely to be divided by a zoogeographical discontinuity into two heterogeneous regions under different faunistic characters.

10. Examination on prey organisms of the fishes fed by sei whale prooved that they also feed chiefly on *C. pacificus* or its mixtures with *C. cristatus* or *C. plumchrus*.

11. Above results seem to support again the presence of the ecological dis-

continuity, and at the sametime, the intrusion of cold intermediate waters into the region.

12. The whaling ground in the south of 40°N was presumably formed solely by a bulk of mass occurrence of *C. pcificus* at its beginning, and the concentration of young fishes under feeding migration also made the sea region so fertile as to be the staple feeding ground of baleen whales.

13. It was known in this study that the feeding ground of baleen whales has been usually recognized as being formed chiefly by the aggregations of primary consumers of planktonic crustaceans, but it would also be formed or at least supplemented considerably by the organisms of more higher trophic levels, and that the condition of available foods for baleen whales in the region should not be considered by each food species alone but more comprehensively by the community of organisms.

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