FOOD OF SEI WHALE TAKEN BY JAPANESE WHALING EXPEDITIONS IN THE ANTARCTIC SEASON 1967/68

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INTRODUCTION

The comprehensive study on the food of baleen whales caught in the Antarctic by Japanese fleets has long been treated and analysed chiefly by Dr. T. Nemoto, formerly a staff of the Whales Research Institute, on the materials collected since 1954/55 Antarctic whaling season until 1960/61's, and several number of the important reports have been published in these decades (Abe, 1957; Nemoto, 1959, 1961, 1962, 1966; Nemoto and Nasu, 1958). In addition to these studies a brief observations on the food of baleen whales have been carried out as a part of the general biological investigations of whales (e.g. Nishiwaki and Hayashi, 1950; Nishiwaki and Ohe, 1951 etc.). One of those studies by Nemoto (Nemoto, 1959) was a summarized fine piece of work which was comprised from the available data having been accumulated till then, which greatly contributed to increase our knowledge on the food of baleen whales in both hemispheres. By a series of those elaborate works several number of food organisms such as *Thysanoëssa macrura*, *Parathemisto gaudichaudii*, and *Drepanopus pectinatus* were added to the diet list of baleen whales in the Antarctic. However, no reports on the food of baleen whales by Japanese catch in the Antarctic waters have been appeared since 1961/62 Antarctic season onward as well as those in the northern North Pacific.

In this report I will give a brief result of my observations on the general features of the food of sei whales recently taken in the Antarctic by reasons of as follows: firstly, the catch of sei whales in the Antarctic and also in the northern North Pacific had been so small in proportion to the total catch of baleen whales in the earlier days by which situation our knowledge on the food of sei whales was relatively poor among the other baleen whales; secondly, recent increase of the sei whale catch (see Gambell, 1968) especially by the Japanese fleets resulted a northerly or southerly shifts of the main whaling grounds both in the Antarctic and the North Pacific. The shift of main whaling grounds brought some new situation on the food of sei whales there, and thirdly, there are a gradual tendency to increase the catch of fin whales in place of sei whales in the very recent operations, which may leads to some difficulties of getting a food materials of southern sei whales in near future.

MATERIALS

In 1967/68 season of the Antarctic whaling four Japanese fleets operated in the following areas (Fig. 1):

1) Area III and IV between 49°E and 100°E, chiefly in the surrounding

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waters of Kerguelen and Crozet Islands.

2) Area IV and V between 83°E and 160°W, including Tasman Sea
3) Area V between 160°E and 160°W, in the vicinity of New Zealand

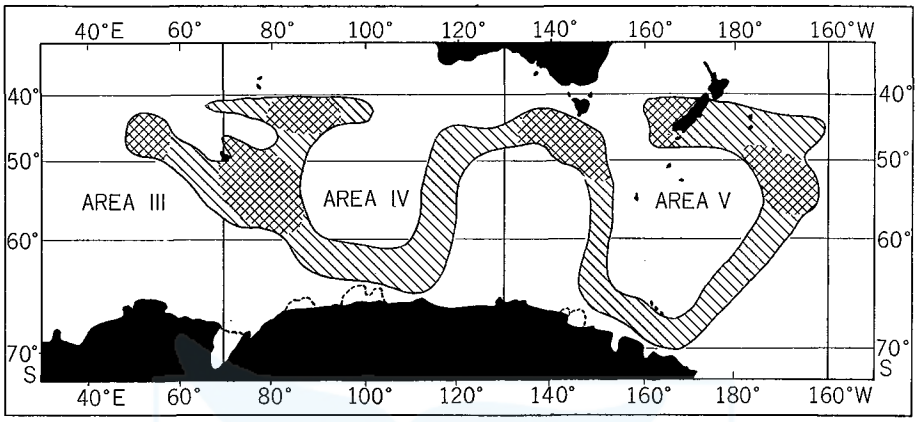

Fig. 1. A schematic map of the Antarctic whaling grounds operated by the four Japanese fleets in 1967/68 season. Shade with cross shows the principal whaling grounds.

The total catch of sei whales by the Japanese fleets throughout the season was 7,119 whales, from which 117 samples of stomach contents were collected, *i.e.* 15 samples by " Nisshin Maru No. 3 " (Area IV & V), 3 samples by " Kyokuyo Maru No. 3 " (Area V), and 99 samples by " Nisshin Maru " (Area III & IV). Being on board of the F.S. " Nisshin Maru " in her 1967/68 operation, I made the observations of whales food on the deck as one of the items of the general biological investigations (e.g. Nishiwaki and Hayashi, 1950) to get a considerable amount of data concerning on the food and feeding habit of sei whales in addition to the food samples.

The food samples were usually collected from the first stomach of whales while they were flensed on the deck. Sometimes the food samples were obtained from the mouth where the stomach contents being retained on the baleen plates by vomit. The stomach contents collected were washed by rinsing them in the clear running sea water to remove the blood or oily materials, and then preserved in vials with 10 percent buffered formalin for later examination.

One of the another materials which I used in the report was a routine record of biological observations on whales compiled by the whalers and by the whaling inspectors of the Fisheries Agency on board. In this record a rough classifications of food organisms such as 'Calanus' (=copepoda), amphipoda, euphausiids, fish, squids etc. were adopted as a result examined by naked eyes. The positions where the samples were obtained were represented by the every day's position of mother ships at noon.

SPECIES OF FOOD ORGANISMS

Euphausia superba had long been considered as a initial food staff of baleen whales in the Antarctic feeding grounds, for instance, Mackintosh and Wheeler (1929), and

Matthews (1938) found none but *E. superba* as a food of fin or sei whales in the South Georgian waters. However, as the study on the food of baleen whales has been progressed since then with the advent of a shift of main whaling ground in accordance with the composition change of the whale species hunted, several number of euphausiids, copepods, and amphipods were gradually added to the diet list of baleen whales (Marr, 1956; Peters, 1955; Nemoto and Nasu, 1958; Nemoto, 1961, 1962; Bannister and Baker, 1967; Best, 1967; Brown, 1968; Pervushin, 1968).

TABLE 1. SPECIES OF THE FOOD ORGANISMS OF SEI WHALES CAUGHT BY JAPANESE WHALING EXPEDITIONS IN THE ANTARCTIC SEASON 1967/68

Copepods	*Calanus simillimus* GIESBRECHT
	Calanus tonsus BRADY
	Drepanopus pectinatus BRADY
	Clausocalanus laticeps FARRAN
Amphipods	*Parathemisto gaudichaudii* (GUÉRIN)
	f. *compressa*
	f. *bispinosa*
Euphausiids	*Euphausia superba* DANA
	Euphausia vallentini STEBBING
	Thysanoëssa vicina HANSEN
Fishes	*Gymnospelus nicholsi* (GILBERT)
	Myctophum subasperum (GUNTHER)
Others	*Cleodora sulcata* (PFEFFER)
	Clione antarctica E. A. SMITH
	Eukrohnia hamata (MÖBIUS)

In the materials of 1967/68 season the kind of food staff found in the stomach contents of sei whales was relatively poor in the number of species (Table 1). Among those species, however, I may describe the following two copepod species as being found firstly as a presumably staple food staff of sei whale in the Subantarctic waters, *i.e.*, *Calanus tonsus* Brady and *Clausocalanus laticeps* Farran. Judging from the number of whales fed on both *Calanus simillimus* and *Calanus tonsus*, they were considered to be the most important copepods as the staple food of sei whales in the Subantarctic waters of relatively lower latitudes. As *Calanus tonsus* was already described as a food of sei whales in the South African waters in the vicinity of the Cape Province (Best, 1967), this species is known to occur very abundantly in the surface waters of the Subantarctic regions (Brodskii, 1964), especially in the south or south-east waters off New Zealand (Farran, 1929; Jillett, 1968).

Copepods

Although *Calanus tonsus* was firstly described by Brady, there were some taxonomical confusion between *Calanus tonsus* and *Calanus plumchrus* of the North Pacific (Tanaka, 1954; 1956). However, the comparative morphological study of this species on more closer examinations, and the finding of an adult mature male from the southern hemisphere made it possible to distinguish *Calanus tonsus* as a typical endemic species in the surface waters of the Subantarctic (Tanaka, 1954, 1956,

1960; Brodskii, 1964; Vervoot, 1965; Jillett, 1968).

In 1967/68 season *Calanus tonsus* was found in 321 sei whales which were caught at the areas lying in the north-east of Kerguelen Island during December 12–29, and also in the Tasman Sea during January 4 to February 2, then in the south to south-east waters off New Zealand during December 12 to March 22 (Figs. 2a–b). In the

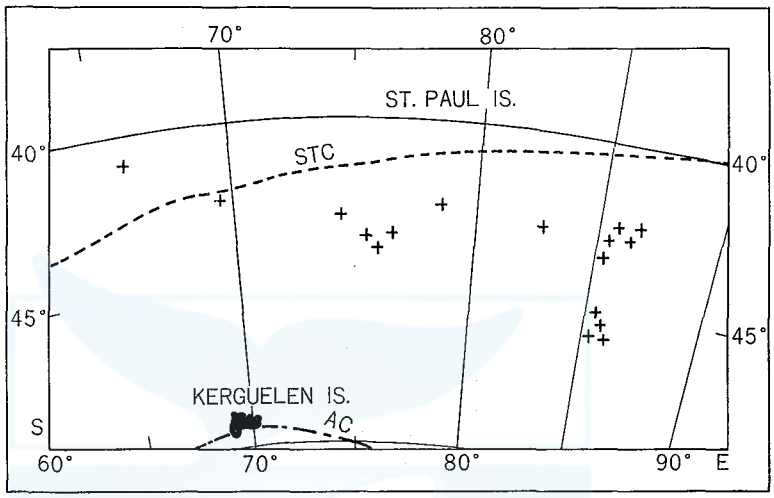

Fig. 2-a. Positions with *Calanus tonsus* in the Areas III and IV.
STC: Subtropical Convergence AC: Antarctic Convergence

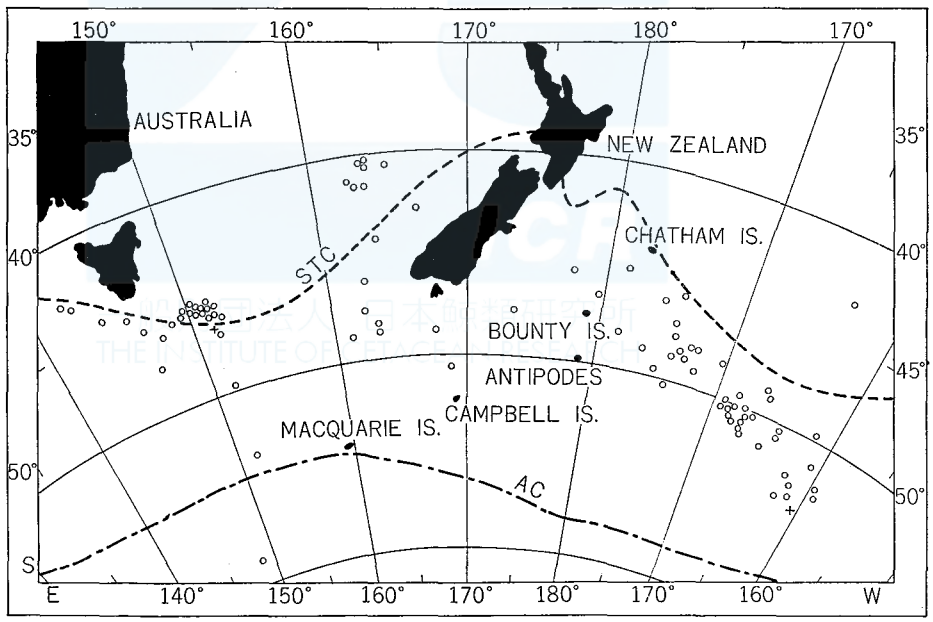

Fig. 2-b. Positions with *Calanus tonsus* (cross), and the possible occurrence (open circle) in the Areas V and VI.

whaling area so called the Area IV sei whale fed almost exclusively on *Calanus tonsus* at least in the early summer season.

Calanus tonsus found in the stomach contents was usually consisted of both adult female and copepodite V though sometimes copepodite IV was found with copepodite V population but very few. The upper and lower extremes of body length in the copepodite V were 4.0 mm and 2.8 mm, and those of adult female were 4.5 mm and 3.4 mm respectively. These body length approximately agrees with the results having been obtained by Vervoot (1957) and Brodskii (1964). As shown in Figs. 2a–b, the principal distributional area of *Calanus tonsus* widely expands in the area between the Subtropical and the Antarctic Convergences with surface temperature of 5°–15°C. According to Jillett (1968) the sea temperature at 25 m depth where the highest number of *Calanus tonsus* occurred was found between 8.5°C and 12.3°C in the waters off South Island of New Zealand. There were no clear differences in the distribution of adult female and copepodite stages.

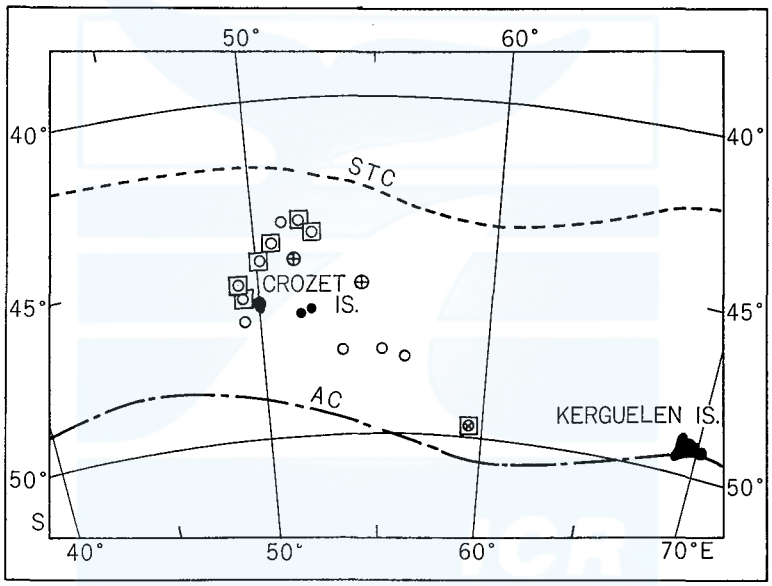

Fig. 3. Positions with *Calanus simillimus* in the Area III.
Copepodite IV (cross), Copepodite V (open circle), Adult female (square)

From the number of whales fed on *Calanus tonsus*, this copepod would be regarded to make one of the most important food sources for the Antarctic sei whales during late spring to early summer. However, since *Calanus tonsus* of copepodite V as well as *Calanus plumchrus* in the North Pacific leave the surface water in late summer for wintering in deep water (Jillett, 1968), the whaling ground formed by this copepod would last for but relatively short period than that formed by another kind of food organisms such as *Euphausia superba* or *Parathemisto gaudichaudii*.

Calanus simillimus is one of the another important endemic species which also predominantly distributes in the Subantarctic waters (Brodskii, 1964; Vervoot,

1965). In 1967/68 season this food species occurred in the surrounding waters of Crozet Islands in late January to mid February when the temperature of surface water was about 5.0°–9.10°C (Fig. 3). In the stomach contents, adult female, copepodites IV and V were occurred together though copepodite V was usually predominant among them as well as the case of *Calanus tonsus*. As shown in Fig. 3 there were no characteristic features in the geographical distributions between adult female and the young copepodite stages. The body length varied between 2.1 mm and 3.2 mm while those obtained by Farran (1929), Vervoot (1951; 1957), Tanaka (1960), and Brodskii (1964), were 2.86–3.42 mm in the male and 2.62–3.65 mm in the female. Relatively small body length found in the present study may be the result that the material was collected at relatively lower latitudes in the Subantarctic waters than those collected by other workers, since the body length of *Calanus simillimus* shows a considerable meridional variations in general (Farran, 1929).

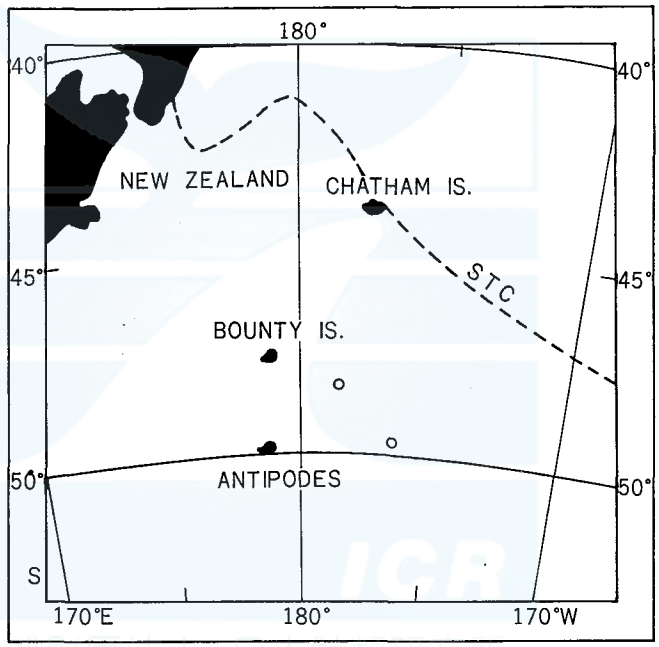

Fig. 4. Positions with *Clausocalanus laticeps* in the Area V.

Both *Calanus tonsus* and *Calanus simillimus* are generally recognized as the typical Subantarctic copepods, and are equally found as a staple food staff of sei whales. It is noticed, however, that there were distinct differences in the geographical distributions betwen these two species; *i.e.*, *Calanus tonsus* was chiefly found in the more warmer northern waters of the Subantarctic close to the Subtropical Convergence, while *Calanus simillimus* was found in the more colder waters with southerly shift of principal distributional area. The sea temperature of 10 m depth at the positions where the bulk of them were found was never overlapped each other (see also p. 131). According to Kawamura and Hoshiai (1969), *Calanus simillimus* in the Indian sector of the

Antarctic disappeared at about 45°S with sea temperature 7.6°C along the meridional line which connects between the Showa Base and Cape Town, while *Calanus tonsus* begin to occur in place of *Calanus simillimus* in the waters north of 45°S. This fact suggests that *Calanus simillimus* prefers more colder waters than *Calanus tonsus*, and that the latter must be regarded as a important food staff in the early whaling season in the Subantarctic waters throughout the area at least Areas IV and V. *Calanus simillimus*, on the other hand, could not observe in the waters south of New Zealand through December to March while their fairly well occurrences have been recorded in the above region (Brodskii, 1964). This species may be regarded as slightly little important than *C. tonsus* since there were another food sources such as *Drepanopus pectinatus*, *Parathemisto gaudichaudii*, and *Euphausia vallentini* in almost the same region.

According to the Russian investigations on the food of sei whales in the area of Crozet Islands, Pervushin (1968) found no whales which fed on Calanoida through December to February. However, as it will be described in the later the sei whales of Japanese catch exclusively fed on copepods; *Calanus tonsus*, *Calanus simillimus*, *Drepanopus pectinatus* and even a so small copeped, *Clausocalanus laticeps* though the amount of stomach contents of these copepods was relatively few when compared with more larger sized organisms such as euphausiids or amphipods.

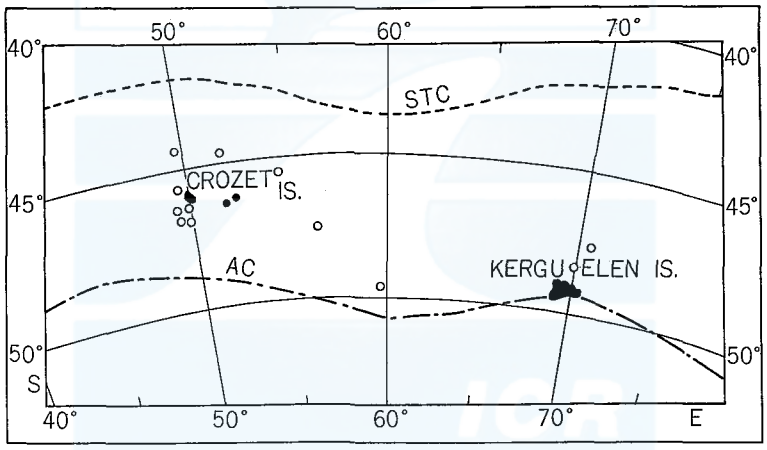

Fig. 5. Positions with *Drepanopus pectinatus* in the Areas III and IV.

The most small sized food, *Clausocalanus laticeps* was found in two whales which were caught in the waters east of Bounty and Antipodes Islands (Fig. 4). This food, like others was exclusively consisted of *Clausocalanus laticeps* of adult male, female and copepodite V. The body length were 1.15–1.37 mm on an average. This fact suggests that *Clausocalanus laticeps*, like other food species, sometimes occurs in a quite dense shoals, so called 'patchy distribution' as to be fed by baleen whales. In the waters off Cape Province, South Africa, the copepod, *Clausocalanus arcuicornis* was fed by sei whales (Best, 1967). In South Georgian waters this species is regarded as one of the important copepods (Hardy and Gunther, 1935), and vast numbers of occurrence was reported from the Bouvet Area and from Tasman

Sea (Vervoot, 1951, 1957). From these facts the copepods genus *Clausocalanus* could be considered to have a important role as the food sources for sei whales in the Subantarctic waters or at least in the lower latitudes of the whaling Area V.

One of the another small copepods, *Drepanopus pectinatus* was firstly introduced to the diet list of sei whales caught in the surrounding waters of Kerguelen Island (Nemoto, 1962). It is proved that this food was found again in 1967/68 season being fed by a considerable number of sei whales caught in the waters between Crozet and Kerguelen Islands. The occurrence of this copepod was more distinct in the Crozet whaling ground than the Kerguelen's (Fig. 5). In the east of the Area IV and V no whales fed on this species. It is considered that *Drepanopus pectinatus* make up a part of important food sources in the Kerguelen-Crozet whaling ground. It could be said in general that the epi-planktonic copepods in relatively lower latitudes of the Subantarctic waters in the Areas III to V carry out a quite important role as the staple food sources of sei whales which entered into the region from the north.

Amphipods

Both *Parathemisto gaudichaudii* forma *compressa* and forma *bispinosa*, were found in the stomach contents of sei whales. In contrast to the northerly occurrence of copepod food, *Parathemisto gaudichaudii* was fed preferably in the more southerly waters especially in the out side from the Antarctic Convergenge (Figs. 6a–b). This species

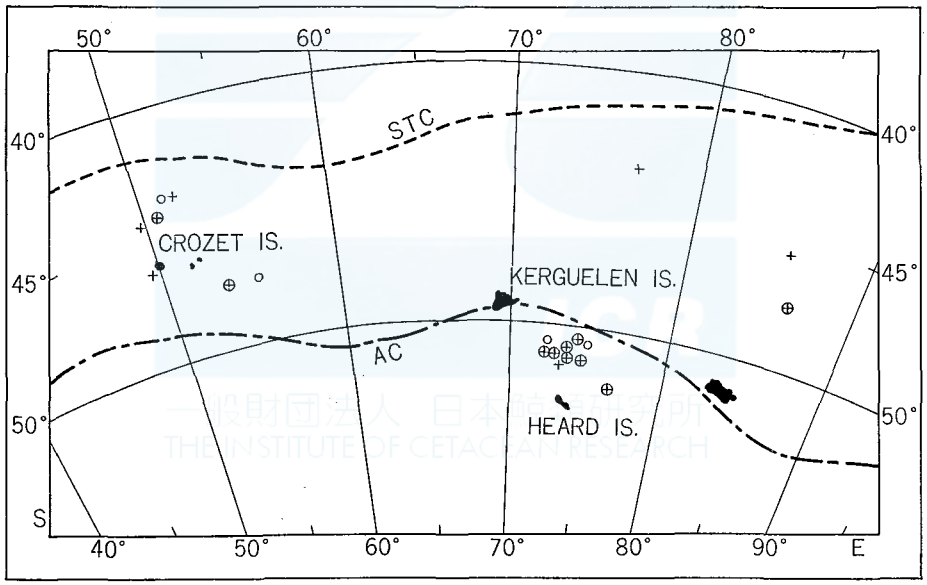

Fig. 6-a. Positions with *Parathemisto gaudichaudii* f. *compressa* (cross), and f. *bispinosa* (opencircle) in the Areas III and IV.

is well known by its cosmopolitic bipolar distribution (Stephensen, 1947) extending far to the Hudson Strait where the northern most occurrence of *P. gaudichaudii* f. *compressa* was found at 60° 23.5′ N, 64° 50.5′ W in Forbes Sound (Dumbar and Grainger,

1952; Dumbar, 1954). In the southen ocean, Baker (1954) showed its circumpolar distribution which covers far north to the Subtropical Convergence. In the latitudinal distributions, however, Kane (1966) demonstrated a quantitative discontinuity of occurrence where *Parathemisto gaudichaudii* is scarce at the Antarctic Convergence,

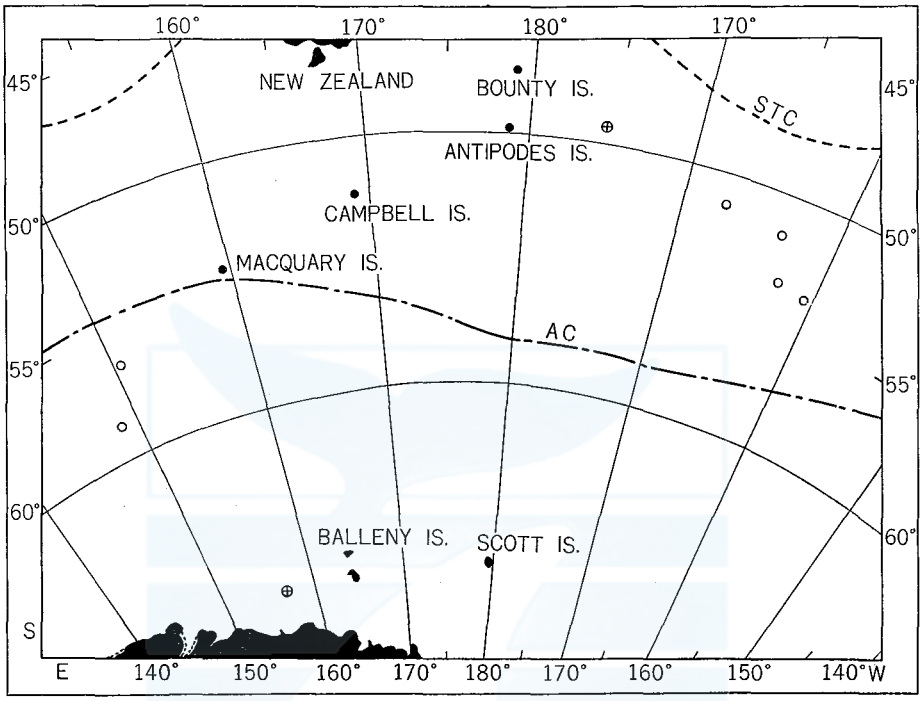

Fig. 6-b. Positions with *Parathemisto gaudichaudii* f. *compressa* (cross), and f. *bispinosa* (open circle) in the Area V.

while they are rich in the north or south from the convergence. However, there were much cases of the sei whale to feed *Parathemisto gaudichaudii* in the south of the Antarctic Convergence while it is expected more abundant distribution in the north of the Antarctic Convergence. There are no fact to explain this curiosity. One of a possible causes is the selective feeding by sei whales as observed between *E. recurva* and *Thysanoëssa gregaria* in the South African waters (Bannister and Baker, 1967), *i.e.*, the sei whale feed preferabley on copepod than amphipod when they occur in the same water bodies.

Euphausiids

Three species of euphausiids which were reported previously were found in the stomach contents (Table 1) though the occurrence of *Thysanoëssa vicina* is in some doubtful because of the ill condition of materials due to heavy digestion. *Euphausia vallentini* was recorded in 1960/61 season as a principal food of pygmy blue whale (*Balaenoptera musculus brevicauda*) in the Kerguelen whaling ground (Nemoto, 1961), though Mackintosh (1960) had mentioned the importance of *E. vallentini* as a food

of blue whale in the Kerguelen waters preceeding to Nemoto's report. At any rate *Euphausia vallentini* could be regarded as quite important food for baleen whales in the neritic waters of the Subantarctic as well as copepods.

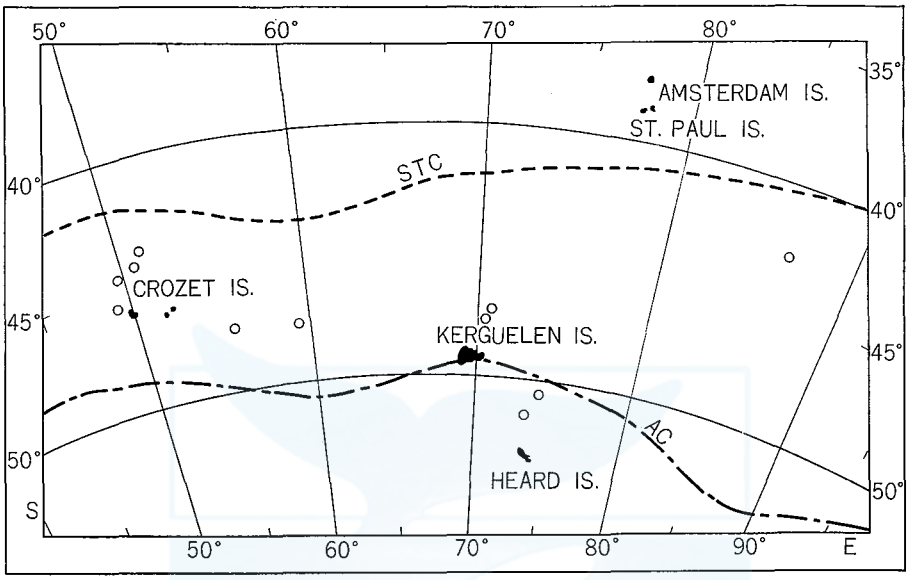

Fig. 7. Positions with *Euphausia vallentini* in the Areas III and IV.

In 1967/68 season *Euphausia vallentini* was found chiefly in the waters between Kerguelen and Crozet whaling grounds especially in the waters north of Crozet Islands (Fig. 7). It was also found in the Area V between 51°–53°S and 166°–167°W though very few. The northern and southern extremes of the occurrence of *Euphausia vallentini* through the Areas III to IV were 43°44′S, 51°26′S, and those in the Area V were 51°22′, 53°20′S respectively. The result of Russian investigations in the waters of Crozet Islands also shows the occurrence of *Euphausia vallentini* in the stomachs of sei, fin and blue whales (Pervushin, 1968). It is considered from this facts that *Euphausia vallentini* is quite important as a staple food source for sei whales in the surrounding waters of Crozet Islands.

Euphausia superba, on the other hand, seems to be minor importance as a food of sei whales when it is compared with *Euphausia vallentini* since the most sei whales were catched in the far north apart from the principal distributional area of *Euphausia superba*. In the Area IV *Euphausia superba* was exclusively found in the far more south of the Antarctic Convergence between 53°S and 59°S than the area of *Parathemisto gaudichaudii*. In the Area V close to the Antarctica near by Balleny Islands there were only four feeding records of *Euphausia superba*.

Others

The small fish, *Gymnospelus nicholsi*, *Myctophum subasperum* and other organisms; *Cleodora antarctica*, *Clione antarctica*, and *Eukrohnia hamata* were found in the stomach

but very few. They showed only a occasional occurrence such as *Electrona* fishes observed in South Georgian waters (Brown, 1968), and are considered to be a minor importance among the food of copepods or euphausiids since these organisms were presumably fed by a chance while they were swarming in the surface waters to feed on those copepods or euphausiids in such a situation as Currie (1953) showed in his report.

COMBINATION OF FOOD ORGANISMS

The stomach contents of baleen whales usually consisted of a definite organisms which

TABLE 2. STOMACH CONTENTS OF SEI WHALES CAUGHT IN THE ANTARCTIC OCEAN DURING DECEMBER 12, 1967 TO MARCH 20, 1968

Kinds of stomach contents*	Number of whales examined	Dominant forms of the food organisms		
		I	II	III
Calanus tonsus	23	CV & F		
C. tonsus—Parathemisto gaudichaudii f. compressa	1	CV	F	
C. tonsus—P. gaudichaudii f. bispinosa	1	CV	F	
C. tonsus—Euphausia vallentini	2	CV & F	F & Juv	
C. tonsus—Euphausia sp.	2	CV & F	Furcilia	
C. tonsus—E. vallentini—Eukrohnia hamata	1	CV	F	
C. tonsus—P. gaudichaudii f. compressa—E. vallentini	1	CV	F	M, F & Juv
C. tonsus—E. hamata—Clione antarctica & Cleodora sulcata	1	CIV & V		
Calanus simillimus	4	CV & F		
C. simillimus—Drepanopus pectinatus	3	CIV & V	Juv	
C. simillimus—E. vallentini	2	CV	M, F & Juv	
C. simillimus—Euphausia sp.	1	CV	M & Furcilia	
C. simillimus—P. gaudichaudii f. compressa	2	CV	M & F	
C. simillimus—P. gaudichaudii f. bispinosa	2	CV	F	
C. simillimus—Gymnospelus nicholsi	1	CV		
C. simillimus—P. gaudichaudii f. compressa—E. vallentini	1	CV	M & F	Juv
Drepanopus pectinatus	4	M, F & Juv		
D. pectinatus—C. simillimus	2	Juv	CIV, V & F	
Clausocalanus laticeps	2	F & Juv		
P. gaudichaudii f. compressa	9	F		
P. gaudichaudii f. bispinosa—f. compressa	18	F	F	
P. gaudichaudii f. bispinosa—E. vallentini	1	F	M & Juv	
P. gaudichaudii f. compressa—P. gaudichaudii f. bispinosa—E. superba	1	M & F	M & F	M & F
P. gaudichaudii f. compressa—P. gaudichaudii f. bispinosa—E. vallentini	1	F	F	M, F & Juv
P. gaudichaudii f. bispinosa—E. vallentini—C. simillimus	1	F	Juv	CV
Euphausia superba	14	M, F & Juv		
E. superba—Myctophum subasperum & Gymnospelum nicholsi	1	M, F & Juv		
Euphausia vallentini	10	M & F		
E. vallentini—D. pectinatus	1	Juv	Juv	

* Quantitative importance of each food species is on decrease from left to right.

are liable to swarm in a dense shoals as Hardy and Gunther (1935) called ' patchy distribution '. However, it is often observed that several kinds of food organisms distribute in the same feeding ground to make the stomach contents be complex as having been observed in Japanese waters (Nemoto, 1959), or in the waters near to the Cape Province, South Africa (Best, 1967). The sei whales, different from the case of blue and fin whales, are considered as ' microplanktonophagi ' (Tomilin, 1954), and a considerable kinds of organisms might be an object for feeding.

In the Antarctic as shown in Table 2, most of sei whales caught in the Areas III and IV were found to feed chiefly on small copepods such as *Calanus tonsus*, *Calanus simillimus*, *Drepanopus pectinatus*, and an amphipods, *Parathemisto gaudichaudii* come to the next then euphausiids, *Euphausia superba* and *E. vallentini* follow them. It is noticed in the table that the following four species, *i.e. Calanus tonsus*, *Parathemisto gaudichaudii*, *Euphausia superba*, and *E. vallentini* are more likely to be fed as a monotonous population in many cases, while the others are fed as the mixture composed of more than two species. However, those mixture food being mingled in parallel relationship in terms of the quantity of each species are scarecely found but usually occurred with a remarkable dominant forms among them. So it can be said that the food of sei whales in the recent Antarctic feeding grounds or at least in the Areas III and IV, is represented with *Calanus tonsus*, *Calanus simillimus*, *Parathemisto gaudichaudii*, *Euphausia superba* and *Euphausia vallentini*. The preference of food organisms by sei whale has been known in the northern North Pacific (Nemoto, 1957). Nemoto (*loc. cit.*) described that sei whales prefer to feed on small copepods than euphausiids, and in the subsequent report he (Nemoto, 1959) gave the order for sei whales on this matter, *i.e.* small sized *Calanus* preferred firstly then euphausiids, small fishes or squids follow them. In South African waters, Best (1967) demonstrated the same order for sei whales though there were so scarce instances of mixture of food more than two species. My result agrees in general with the result of those previous workers though I consider that *Parathemisto gaudichaudii* should be added and placed in the next to euphausiids at least in the Indian sector of the Subantarctic waters.

FEEDING PERCENTAGE

The kind of stomach contents of each baleen whales is usually observed by eyes, and recorded according to a rough classifications, *i.e. Calanus* (=copepoda), amphipoda, and euphausiids as shown in Table 3. A symbol " Calanus " in the table does not mean exact taxonomical nomenclature but actually means " copepoda ". Euphausiids are divided into three classes according to their body length after the manner adopted by Mackintosh and Wheeler (1929) and other Japanese workers thereafter; L: large (50 mm—), M: medium (40–50 mm), and S: small (—40 mm). It can be considered in this report that the large and medium sized euphausiids are mostly represented by 1 or 2 year group of *Euphausia superba*, and small one by *Eupahusia vallentini*. Although " empty ", the whales of no stomach contents was the most cases among examined whales, it is noticed in the table that the feeding percentage of *Calanus* gradually increases toward the Pacific sector of the Antarctic (Areas V and

VI) from the Indian sector, while amphipoda makes a important food sources in the Indian sector of the Antarctic (Areas III and IV). It must be noted that relatively low feeding percentages of *Calanus* in the Areas III and IV are the result from a short duration of whaling in the Subantarctic waters. By supposing the case above mentioned, it might be nearly as same with other food species. Euphausiids are also more important in the Areas IV to VI than the Areas III and IV. No occurrence of large and medium sized euphausiids from the Areas V and IV suggests the complete absence of *Eupahusia superba* from these two whaling grounds. It is interesting that the sei whales in the south of New Zealand almost exclusively fed on small sized euphausiids which were consisted of *Euphausia vallentini*. Sei whales in the Areas III and IV chiefly feed on copepods in December.

TABLE 3. NUMBER OF SEI WHALES IN RELATION TO THE KINDS OF FOOD AND WHALING AREAS IN THE ANTARCTIC SEASON 1967/68. THE PERCENTAGES TO THE TOTAL NUMBER OF WHALES EXAMINED ARE GIVEN IN ITALICS.

Area & Sector	Kind of stomach contents							
	"Calanus"	Amphipoda	Euphausiid L	Euphausiid M	Euphausiid S	Unknown[3]	Empty	Total
Area III & IV	207[1]	191	115	23	59	—	919	1518
(Indian Ocean)	*13.64*	*12.58*	*7.58*	*1.52*	*3.89*		*60.54*	
Area IV & V	357[2]	73	61	17	203	—	537	1248
(Tasman Sea & Pacific Ocean)	*28.61*	*5.85*	*4.89*	*1.36*	*16.27*		*43.03*	
Area V & VI	888	70	—	—	575	9	1008	2550
(Pacific Ocean)	*34.82*	*2.75*			*22.55*	*0.35*	*39.53*	

1) Including *Drepanopus pectinatus*.
2) Including *Clausocalanus laticeps*.
3) Not examined.

A considerable high percentages of empty stomach in those areas suggests a poor availability of copepod food, since there is a fact that the Russian investigation made on the sei whale caught in the vicinity of Crozet Islands showed low feeding percentages due to the proportional increase of Calanoida among other food organisms (Pervushin, 1968). It is also noticed that relatively high percentages of amphipoda and large sized euphausiids in the Areas III and IV mean the formation of staple feeding ground of sei whale in relatively higher latitudes. These are, however do not always be accompanied by the distribution of sei whales since they liable to feed on copepod in the lower latitudes by 'skimming' even if the population density of copepods is poor. The most of sei whales caught in the *Calanus* ground in lower latitudes of the Areas III and IV had a small quantity of stomach contents less than 50 percent, and no whales with the stomach of "full" were observed. As it is shown in the Figs. 2a to 5, a chief diet in the lower latitudes of the Area III and the surrounding waters of Crozet Islands during December and late January to mid February was represented by *Calanus tonsus*, *Calanus simillimus*, *Drepanopus pectinatus* and *Euhausia vallentini*. Pervushin (1968) on the other hand, demonstrated a quite different

result. Mentioning on the feeding behavior of baleen whales in the area of Crozet Islands, he (Pervushin, 1968) showed that 63.0–88.5 percent of sei whales were proved to feed on euphausiids such as *Euphausia vallentini* and *E. frigida* during December to February. He also showed that the real Antarctic copepods, *Calanus propinquus* and *Calanoides acutus* were found as a food of sei whale in the Crozet whaling ground. However, judging from the negative records of those two species in my collection from those waters, and also the negative record shown by Brodskii (1964), and positive records in the southern waters far beyond the Antarctic Convergence by many workers (e.g. Tanaka, 1960, 1964; Kawamura and Hoshiai, 1969), the occurrence of *Calanus propinquus* and *Calanoides acutus* in the surrounding waters of Crozet Islands is considered in some doubtful, since they are regarded as a real endemic species in the high Antarctic (Ottestad 1932, 1936), and *C. propinquus* is found usually at the depth of 100–250 m in the north of the Antarctic Convergence where the sea temperature lies between −1.6°C and 0.3°C (Vervoot, 1957). On the other hand, the observed temperature in the waters of Crozet Islands during January to February in 1967/68 season was quite high between 5.0°C and 9.0°C, where *Calanus simillimus*, a typical subantarctic species was exclusively fed on.

LATITUDINAL SUCCESSION OF FOOD ORGANISMS

Among four Japanese fleets operated in 1967/68 season two of them fished around so as to cover a relatively wide area in meridional direction. In Figs. 8–9, the succession of food organisms in the north-south direction in terms of the feeding percentages is shown with approximate positions of the Subtropical and the Antarctic Convergences in the area concerned. In the Subantarctic waters of lower latitudes of the Indian sector of the Antarctic, only " Calanus " was fed by sei whale. " Calanus " in this area was represented by a typical Subantarctic endemic species; *Calanus tonsus*, *Calanus simillimus* and *Drepanopus pectinatus*. Although *Calanus tonsus* and *Calanus simillimus* showed somewhat similar charactor in their geographical distribution, it must be kept in mind that there was a time lag about a month in the time of their occurrence, *i.e.*, *Calanus tonsus* was found exclusively in December while *Calanus simillimus* was in mid January to February. Still more, there are the fact to suggest the presence of some ecological differences between these two copepods; the former prefers more warmer water (7.0–13.4°C) than the latter (5.9–9.1°C). According to the plankton data obtained by the 7th Japanese Antarctic Research Expedition (Kawamura and Hoshiai, 1969), the boundary where alternation of the successive occurrence of *Calanus tonsus* to *Calanus simillimus* takes place was found at approximately 45°S with temperature and salinity of 7.5°C and 34.07‰ respectively. The high feeding percentages at 45°S as shown in Fig. 8 would be due to the result fed on *Calanus simillimus* and *Drepanopus pectinatus* in the Crozet whaling ground. The dominant occurrence of copepods in the Subantarctic waters is clearly shown in Figs. 8 and 9 though *Euphausia vallentini* makes one of another chief food sources in the Pacific sector of the Antarctic.

An amphipoda, *Parathemisto gaudichaudii* comes next to copepods in fairly narrow

latitudinal zone which lies in the slightly north of the Antarctic Convergence. It must be noted that almost complete alternation of chief diet of sei whales from copepods to *Parathemisto gaudichaudii* takes place in the south of Subantarctic waters,

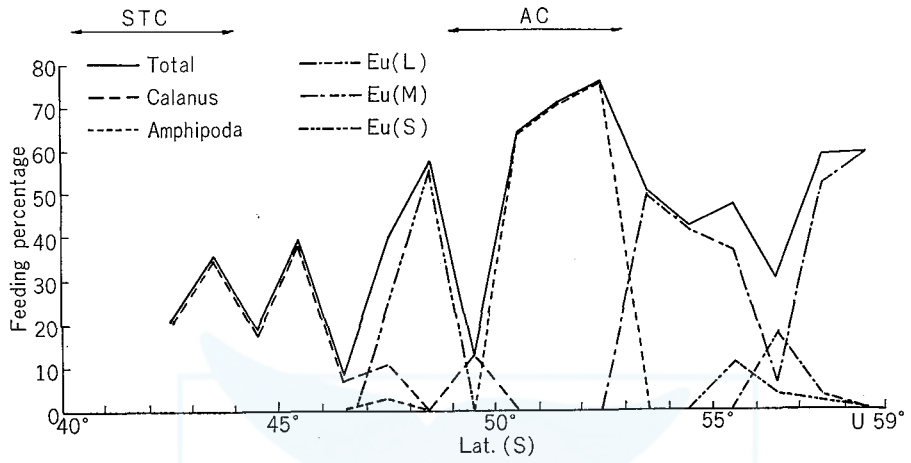

Fig. 8. Latitudinal succession of the food organisms of sei whales in the Indian sector of the Antarctic.
STC: Subtropical Convergence AC: Antarctic Convergence

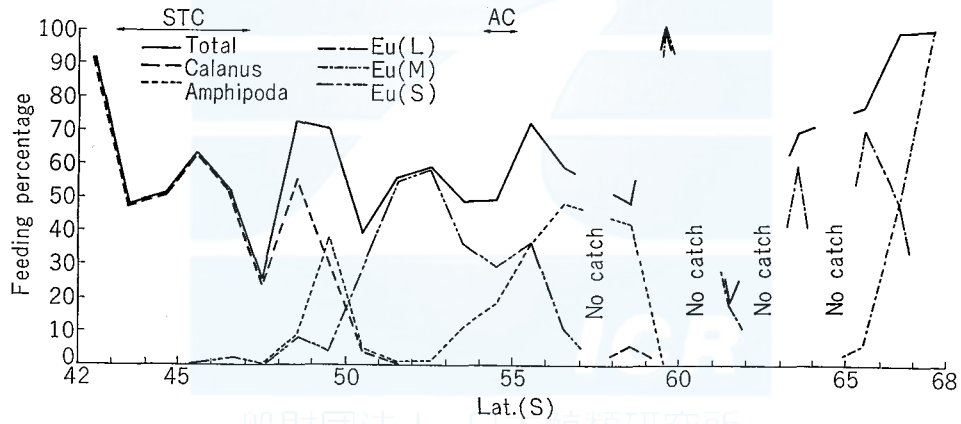

Fig. 9. Latitudinal succession of the food organisms of sei whales in the Pacific sector of the Antarctic including the Tasman Sea.
STC: Subtropical Convergence AC: Antarctic Convergence

i.e., both amphipoda and copepoda hardly coexist with each other so as to make up a food of sei whales in the same area. One of the causative reasons for a quite high feeding percentages in Fig. 9 would be in the curious distributional features of *Parathemisto gaudichaudii* which was demonstrated by Kane (1966, p. 176, Text-fig. 6). He (1966) describes on this matter, "but there are evidently two zones in which it is particularly abundant. These are separated by a belt in the vicinity of the Antarctic Convergence in which the population is small".

In the south of the Antarctic Convergence higher than 53°S, the large sized euphausiids consisted of *Euphausia superba* begin to appear in place of *Parathemisto gaudichaudii* in the Areas III and IV though sometimes small or medium sized individuals which are represented by adolescent of *Euphausia superba* appear as a supplemental food sources. In the Area IV and V, chiefly the Pacific sector of the Antarcic the general features of latitudinal succession of food organisms could be considered to follow the same pattern with those observed in the Indian sector. It is also noticed in Fig. 9 that small sized euphausiids consisted of *Euphausia vallentini* seems quite important food sources in the Subantarctic waters in the vicinity of the Antarctic Convergence where the sudden diminution of population size of *Parathemisto gaudichaudii* takes place. Brown (1968) thought that *Parathemisto gaudichaudii* fed by sei whales in South Georgia might have been fed in the far northen waters than the food of euphausiids such as *Euphausia superba*. In the southern water far beyond 65°S, a considerable number of medium sized euphausiids consisted of 1-year group of *Euphausia superba* were fed by sei whale.

FEEDING TIME

General features

The fin and blue whales were the main species having been caught previously, and fin whales were the most well studied on their feeding habit. Sei whales on the other hand, were known a little due to so quite few catches among the baleen whales. It has been known that the feeding activity of baleen whales in a day in terms of the percentages varies in general with a bimodal curve which has a maxima in the early morning and in the evening (Nemoto, 1957, 1959). One of his results (Nemoto, 1957) suggests that baleen whales somewhat actively feed twice a day in many cases though each patterns of feeding activity are variable with the kind of food partaining to their diurnal vertical movement, seasons, latitudinal positions, or sometimes with the bottom topography of whaling grounds. Finding myctophid fishes, *Electrona subasper* and *Electrona normani*, Brown (1968) suggested that sei whale is more likely to feed actively in the twilight evening in the South Georgia. Sometimes, however, the baleen whales show a evidence suggesting to feed only once a day (Nishiwaki and Ohe, 1952). In any case, it is considered to be quite important to accumulate the evidences on the feeding habit of baleen whales especially of sei whales in relation to estimating the nutritional budget among the food webs in their feeding grounds. However, it is also nesessary to figure out the feeding patterns of baleen whales by theoretical and experimental methods by assuming such a feeding model as Klumov (1961) instituted for this purpose.

The daily change of feeding activities in terms of the percentages of the stomach with food against the whole number of stomach examined is supposed to be affected chiefly by the diurnal vertical migrations of food organisms, because the most of all food organisms listed in Table 1 were known as to show a quite distinct diurnal vertical migrations in the South Georgian whaling ground (Mackintosh, 1934, 1937; Hardy and Gunther, 1935; Ommanney, 1936). Accordingly, it is necessary

to examine the whales food by the species since each food organisms has their own peculiar migratory patterns in a day. The feeding activity by the five kinds of food organisms is shown in Figs. 10a–b. Fig. 10a demonstrates the feeding activity

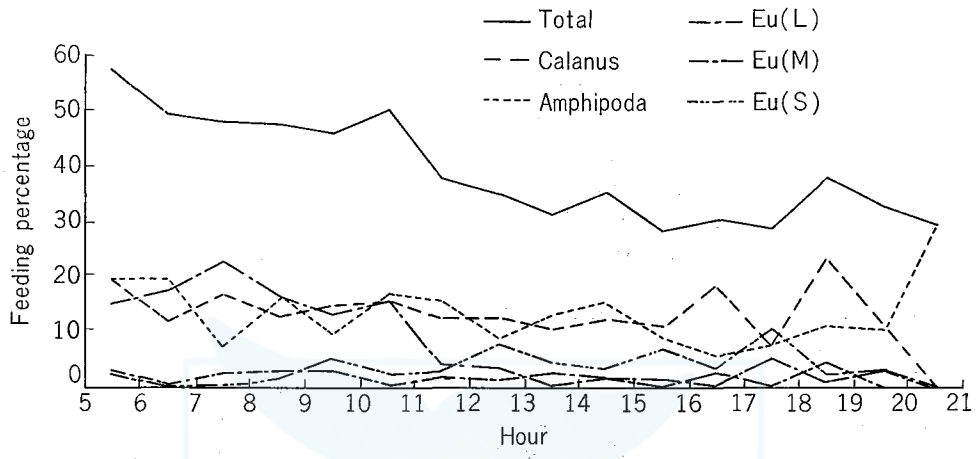

Fig. 10-a. Feeding percentages of sei whales by the kinds of food organisms in the Antarctic, Areas III and IV.

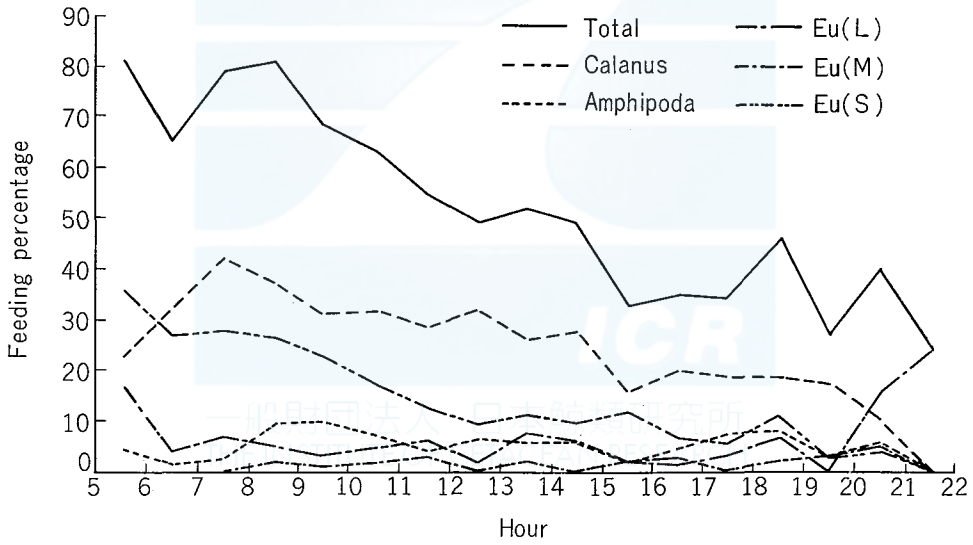

Fig. 10-b. Feeding percentages of sei whales by the kinds of food organisms in the Antarctic, Area V.

in the whaling Areas IV and V, while Fig. 10b does the Areas III and IV. It is noticed in the figures that a quite high feeding percentages are observed in the early morning, and no distinct recovery occurs in the evening. It is also noticed that the most causative organisms to bring on the daily variation of feeding activity are chiefly responsible in the case when amphipoda, large sized euphausiids or "Calanus" were

fed. Medium or small sized euphausiids seems to be fed whenever they are available. The upper and lower extremes of feeding percentages were 57 percent and 28 percent in the Areas IV and V, and that in the Areas III and IV were 82 percent and 25 percent respectively. The general trends of feeding activity of sei whales in the Subantactic waters differ considerably from those of fin and sei whales obtained in the northern North Pacific where it varied between 0 to 100 percent in most cases (Nemoto, 1957). This may be attributed partly to the differences of the kind of food organisms taken in both whaling grounds. From the figures, it is naturally considered that the most of sei whales in the Antarctic heavily take a dense population of food once in the morning possibly by ' swallowing ' or ' skimming ', and take a relatively scattered poor population of food organisms by ' skimming ' during the daytime towards the evening, as the manner described by Ingebrigtsen (1929) and Nemoto (1957, 1959).

The case of Calanus tonsus and Calanus simillimus

The components of the " Calanus " food are represented by two dominant species, *Calanus tonsus* and *Calanus simillimus*. In the Indian sector of the Antarctic a considerable number of both *Calanus tonsus* and *Calanus simillimus* occurred as principal food sources of sei whales while only *Calanus tonsus* was observed in the Tasman Sea and in the Pacific sector of the Antarctic (Area IV and V). As there

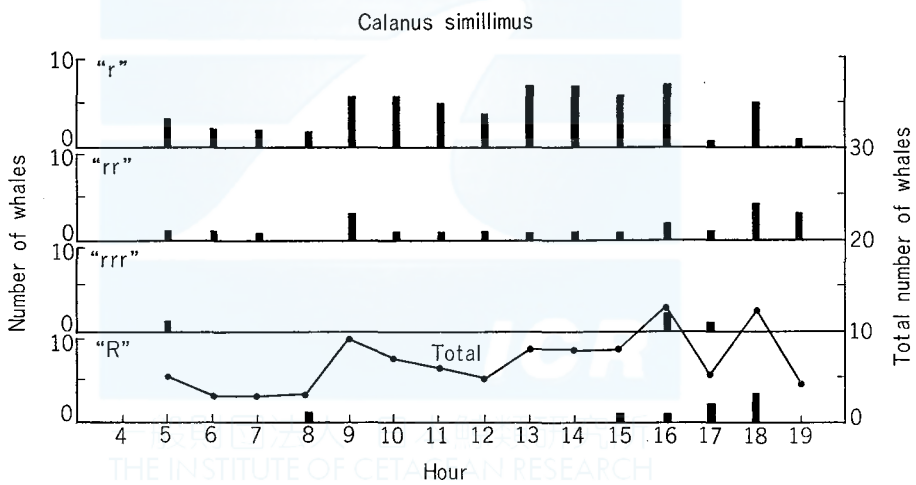

Fig. 11-a. Frequency of the number of whales fed on *Calanus simillimus* by the four different degrees of stomach repletion in a day.
Degree of repletion :
" r " : less than 25 percent
" rr ": 25–50 percent
" rrr ": 50–75 percent
" R " : 75–100 percent

are considerable differences of the behaviour of diurnal vertical migration between *Calanus tonsus* and *Calanus simillimus* the extent of the repletion of stomach contents by the time was also differed in these two copepod species (Figs. 11a–b). In both *Calanus tonsus* and *Calanus simillimus*, the repletion of stomach was relatively small with the

quantity of food less than 50 percent during the daytime. It is noticed clearly that the almost fully repleted stomachs ("rrr"—"R") with *Calanus tonsus* occurred more frequently than *Calanus simillimus*, and the former was fed with a same feeding percentages during the daytime while the bulk of *Calanus simillimus* was exclusively fed only in the evening. This fact would be the result from being exactly followed to the differences of the migratory habit of both species. According to Hardy and Gunther (1935), *Calanus simillimus* is regarded as one of the quantitatively important copepods in the South Georgian waters, and this species shows a distinct diurnal vertical migration as well as *Drepanopus pectinatus;* the bulk of *Calanus simillimus* population begins upward movement at about 1700 hours in the evening and reachs to 10–20 m depth at 1800 hours. They remain at the surface layer during the night then begin to move into the deep down to about 100 m depth in very early morning at least 02–03 hours. This behavior leads to the consideration that there would be only a chance for sei whales to feed on *Calanus simillimus* in the evening in a day. It is interesting to find that the stomach of "full" occurred very frequently in the evening so as to support the consideration of feeding 'once' in a day.

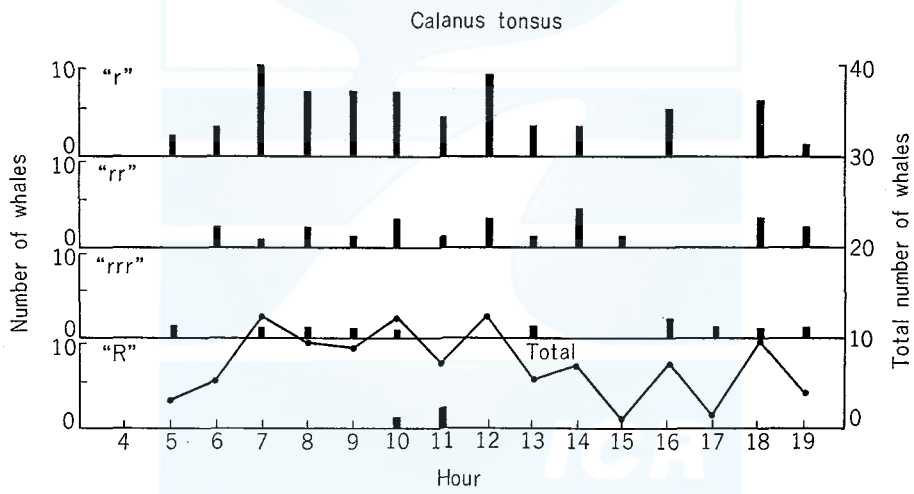

Fig. 11-b. Frequency of the number of whales fed on *Calanus tonsus* by the four different degrees of stomach repletion in a day. Legend as in Figure 11-a.

Calanus tonsus, on the other hand, is a comparable species to *Calanus plumchrus* in the northern North Pacific, and this species is recognized in general to show no such a distinct diurnal vertical migration as *Calanus simillimus*. Judging from its hydrological and taxonomical affinities to *Calanus plumchrus* (Tanaka, 1954, 1956; Jillett, 1968) at least in the 5th copepodite stage, it might presumably be considered that *Calanus tonsus* of 5th copepodite stage does not show any distinct diurnal migration. The occurrence of "full" or "rich" stomachs of *Calanus tonsus* during the daytime suggests a quite well availability of this copopod in the surface waters so as to be fed by sei whale throughout a day.

AMOUNT OF STOMACH CONTENTS

It has long been the obscure mystery or the matter of interest how much the baleen whales take a food in a day. According to Nemoto (1959). Collet (1912) earlily estimated the amount of food taken by the Atlantic blue whale, and showed that they had taken at least 1,000 liters of euphausiids. Betesheva (1954) showed that the North Pacific sei whale can feed 600 kg of squids or 50–370 kg of *Calanus plumchrus*, while Best (1967) given 59 kg of zooplankton from South African waters, and 175 or 305 kg of krill for Antarctic sei whales (Brown, 1968). There are some more data about this problem which has been accumulated on the whales of northern hemisphere though most of them were on fin whales (e.g. Nishimoto, et al., 1952; Nemoto, 1959; Klumov, 1961). Nemoto (1959) demonstrated that the fin whales of 57 feet in the northern North Pacific fed on 759.0 kg. of Alaska Pollack and found a considerable variations in the amount of stomach contents (91.0–759.0 kg) notwithstanding the fact that the majority of all stomachs concerned were repleted as " full " by eyes. His result also suggests that the weight of stomach contents filled with copepods usually very little than those by fishes or euphausiids.

TABLE 4. AN AVERAGE AND THE MAXIMUM AMOUNT OF STOMACH CONTENTS OF SEI AND FIN WHALES IN THE ANTARCTIC

Whale species	Body length (m)	Sex	Number of whale examined	Average		Maximum	
				Total weight (kg)	Volume (l)	Total weight (kg)	Volume (l)
Sei whale	13.0–13.9	F	2	171	202	182	204
		M	0	—	—	—	—
	14.0–14.9	F	2	118	149	141.3	180
		M	5	116	140.4	154.6	200
	15.0–15.9	F	1	152	200	152	200
		M	3	159.2	208.5	228	312
	16.0–16.9	F	1	196.5	255	196.5	255
		M	0	—	—	—	—
Fin whale	18.0–18.9	F	0	—	—	—	—
		M	1	301.3	391	301.3	391
	20.0–20.9	F	1	567	700	567	700
		M	0	—	—	—	—
	21.0–21.9	F	0	—	—	—	—
		M	2	510	700	885	1000
	22.0–22.9	F	1	133	238	133	238
		M	0	—	—	—	—

In the Antarctic, as I showed in a brief note (Kawamura, 1968) the amount of stomach contents of 14 sei whales which fed on *Calanus tonsus*, *Parathemisto gaudichaudii*, *Euphausia superba* and *Euphausia vallentini* was measured (Table 4). The weighing of stomach contents were carried out on the stomachs being judged as " full " by eyes, and full data including fin and minke whales were given in *Appendix*. The

highest value observed was 228.0 kg of *Parathemisto gaudichaudii*, which was fed by 15.2 m of male, while it was only 68.0 kg in the *Calanus tonsus* food. Nemoto (1962) mentioned that there were quite well agreement between the weight and the degree of replation of stomach judged by eyes. However, as shown in *Appendix* there were considerable variations in the case of the Antarctic sei whale. It can be said in general that the whales caught before 0900 hours carry somewhat fresh and large amount of stomach contents, and their proportional weight of water gradually increases toward the noon due to digestion.

The highest and averaged amount of stomach contents show that the males of both sei and fin whales likely to feed on much food than the females though feeding percentage seems to be high in the female (Brown, 1968). It is noticed that the stomach is hardly repleted when the whales feed on copepods than fish or euphausiids. This fact leads to a consideration that the larger the size of food organisms, the larger amount of stomach contents is expected. Such a tendency is also shown in the North Pacific fin whales (Nemoto, 1959, Table 24). From my result I may describe the following weights as an approximate amount of stomach contents usually seen in the Antarctic:

Sei whales:	Copepoda	less than 100 kg
	Amphipoda	150—250 kg
	Euphausiids	150—200 kg
Fin whale:	Euphausiids	300—900 kg
Minke whale:	Euphausiids	30 kg

By comparing these values with those obtained by other workers (e.g. Klumov, 1961; Brown 1968), the amount of stomach contents of sei whale in the Antarctic does not differ so much from those obtained in the northern North Pacific.

SUMMARY

1. In the Antarctic whaling season 1967/68 four Japanese fleets operated in the whaling Areas III-V, and 7,119 sei whales were caught during the season.

2. The general biological observations such as the body length, thickness of blubber, mammary gland etc., including the stomach contents were carried out on every whales. In addition to this 117 samples of the stomach contents of sei whale were obtained from three fleets for taxonomical and biogeographical study of food organisms.

3. The quantitatively important food organisms found in the samples were: *Euphausia superba*, *E. vallentini*, *Thysanoëssa vicina*(?), *Calanus tonsus*, *C. simillimus*, *Clausocalanus laticeps*, *Drepanopus pectinatus* and *Parathemisto gaudichaudii*. Two of them, *i.e.*, *C. tonsus* and *Clausocalanus laticeps* seems to be recorded for the first time here as the staple food sources of the Antarctic sei whale.

4. Both *C. tonsus* and *C. simillimus* are recognized as a endemic species of Subantarctic waters. *C. tonsus*, however, seems more characteristic in the northern warmer waters with sea temperature of 9.50–12.0°C while *C. simillimus* is distinct in the more

colder waters with sea temperature of 5.0–9.10°C.

5. In the whaling grounds south of New Zealand and in the Tasman Sea, *Calanus tonsus* is the most important food species for sei whale while *C. simillimus*, *C. tonsus*, *Drepanopus pectinatus* and *Euphausia vallentini* were important in the surrounding waters of Crozet Islands.

6. The occurrence of *Calanus propinquus* and *Calanoides acutus* as the food of sei whale in the waters near to Crozet Islands by Russian investigation seems to be less probable or quite unusual by the fact that those two copepod species are the real Antarctic species being found in more higher latitudes, and also no reports mentioning on the occurrence of these copepods in such a northern warmer waters as 46°S.

7. Judging from the general composition of stomach contents the sei whale chiefly feeds on a monotonous population of food organisms, *i.e.*, there were so few cases of mixture food.

8. The feeding percentages of sei whale were relatively low especially in the case of "Calanus" food. "Calanus" is, however, the most important food in the whaling Area V, while it was replaced by *Parathemisto gaudichaudii* in the Areas III and IV. *Euphausia vallentini*, on the other hand, was preferably fed throughout the Areas III to V.

9. The chief diet of sei whale showed a clear latitudinal succession from the north to the south in the following order: *Calanus tonsus*—(*Clausocalanus laticeps*)—*Calanus simillimus*, *Drepanopus pectinatus*, *Euphausia vallentini*—*Parathemisto gaudichaudii*—(*P. gaudichaudii*, *E. superba*)—*Euphausia superba*

10. Sei whale actively feeds twice a day in general though the feeding activity varies considerably with the kind of food species which have a peculiar pattern of diurnal vertical migration. The sei whale when feeds on *C. simillimus* could presumably feed them once in the evening while it is expected to feed twice or anytime in a day in case of *C. tonsus* food.

11. The amount of stomach contents of sei whale usually large when euphausiids or amphipods are fed. It is considered that the larger the size of food organisms the larger amount of stomach contents are expected. The Antarctic sei whales with " full " stomach proved to carry a crustacean food of approximately 150–200 kg.

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AUTHORS' NOTE

In the course of this paper being submitted for publication a quite interesting paper by D. E. Sergeant (Feeding rates of cetacea. *FiskDir. Skr. Ser. HavUnders.*, 15 : 246–58, 1969) appeard. Following Ivelev (1961) Sergeant proposed to use the term "Feeding rate" as a index daily ration expressed as percent of body weight.

"Feeding percentage" used in this paper and also in Nemoto (1957, 1959) basically differs from Sergeants', *i.e.*, the term means the ratio : number of whales with food/total number of whales examined.

Although both terms differ as they are, it is considered that Sergeants' proposal would be reasonable, and much care will be payed to avoid any confusion when those matters are expressed in "Feeding percentage".

APPENDIX. AMOUNT OF FOOD TAKEN BY THE ANTARCTIC FIN, SEI AND MINKE WHALES.
("NISSHIN-MARU" FLEET IN 1967/68)

No. of whales	Species	Sex	Body length (m)	Stomach contents	Position taken	Date taken	Time (L.T.)	Net weight of food (kg)	Water (kg)	Total weight of stomach contents (kg)	Volume (l)	Remarks
300	Sei	M	14.4	Calanus	45°25′S 85°39′E	28 XII '67	1115	54.0	14.0	68.0	66	a)
427	Sei	M	14.1	Amphipoda	50°37′S 74°05′E	6 I '68	0600	136.5	18.1	154.6	171	b)
609	Sei	M	14.2	Amphipoda	51°05′S 73°25′E	15 I '68	0800	73.5	14.5	88.0	109.2	c)
324	Sei	M	14.6	Amphipoda	47°21′S 86°06′E	30 XII '67	1105	98.0	30.0	128.0	156	a)
462	Sei	M	15.2	Amphipoda	51°12′S 72°51′E	7 I '68	0925	200.0	28.0	228.0	312	
612	Sei	M	15.1	Amphipoda	51°05′S 72°25′E	15 I '68	1455	57.6	13.8	71.4	93.6	
1397	Sei	M	14.7	Eu-L	56°14′S 81°00′E	21 II '68	1050	142.0	0.0	142.0	200	
554	Sei	M	15.1	Eu-S	47°50′S 70°36′E	13 I '68	1345	149.6	28.6	178.2	220	d)
1477	Sei	F	13.0	Eu-L	57°10′S 83°38′E	23 II '68	0830	149.0	33.0	182.0	200	
534	Sei	F	13.2	Eu-S	47°52′S 70°33′E	12 I '68	1940	135.6	24.4	160.0	204	d)

(Continued)

1437	Sei	F	14.3	Eu-L	56°24′S 80°46′E	22	II '68	0925	128.7	12.6	141.3	180	e)
532	Sei	F	14.7	Eu-S	47°52′S 70°33′E	12	I '68	1745	79.1	15.4	94.5	119	
1471	Sei	F	15.6	Eu-L	57°10′S 83°38′E	23	II '68	0540	148.0	4.0	152.0	200	
665	Sei	F	16.2	Eu-LMS	55°10′S 78°21′E	18	I '68	0855	159.0	37.5	196.5	255	
699	Fin	M	18.6	Eu-L	57°11′S 72°22′E	21	I '68	1015	273.7	27.6	301.3	391	e)
1608	Fin	M	21.0	Eu-L	54°36′S 80°42′E	2	III '68	0820	785.0	100	885	1000	
1376	Fin	M	21.1	Eu-L	54°12′S 79°35′E	20	II '68	0640	286.0	28.0	314.0	400	e)
1384	Fin	F	20.2	Eu-L	56°14′S 81°00′E	21	II '68	0550	556.5	10.5	567	700	
706	Fin	F	22.1	Eu-L	57°11′S 72°22′E	21	I '68	1115	127.4	5.6	133.0	238	
6	Minke	F	8.0	Eu-L	57°11′S 72°22′E	21	I '68	1805	22.4	4.0	26.4	31.2	

Calanus: *Calanus tonsus*, Amphipoda: *Parathemisto gaudichaudii*, Eu-L or -M: *Euphausia superba*, Eu-S: *Euphausia vallentini* (except no. 665)

a) Approximate values.
b) Estimated by the stomach volume averaged on 13 sei whales.
c) Calculated by the mean weight of a unit volume of amphipod food of 4 sei whales.
d) Calculated by the mean weight of a unit volume of small-sized euphausiids taken by no. 532 sei whale.
e) Calculated by the mean weight of a unit volume of large-sized euphausiids taken by 6 fin whales and 1 minke whale.