ON THE FOOD OF BRYDE'S WHALES CAUGHT IN THE SOUTH PACIFIC AND INDIAN OCEANS

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ABSTRACT

A total of 225 Bryde's whales was caught in the Coral Sea, South Pacific and southwestern Indian Oceans during the 1976/77 Antarctic season under the scheme of special permission (Figs. 1A-B), and their stomach contents along with feeding conditions in terms of the state of repletion were examined. In the South Pacific regions 75% of animals was found to be repleted with under various state whereas it was 46.7% in the animals caught in the temperate Indian Ocean. (Tables 1A-B). The occurrence of fully repleted animal during the daytime suggests that there seems to exist a considerable availability of whales food even in the pelagic waters over the tropics (Tables 2A-B). The stomach contents were solely comprised of three species of euphausiids: *Euphausia diomedeae*, *Euphausia recurva* and *Thysanoessa gregaria*. There found to exist a possible differences in the fashion of geographical distributions among those euphausiid species as whales food (Table 3). Both *E. diomedeae* and *E. recurva* occurred dominantly over the whaling regions in question with monospecific or mingled composition whereas *Th. gregaria* alone was completely absent from the Indian Ocean animals.

INTRODUCTION

During 1976/77 Antarctic season two Japanese whaling fleets, Tonan Maru No. 2 and Nisshin Maru No. 3, caught a total of 225 southern Bryde's whales in the Coral Sea, tropical South Pacific and southwestern Indian Oceans under the scheme of special permission for the scientific purpose.

The report on the general topics and some biological observations performed on those Bryde's whales was preliminarily documented by Ohsumi (IWC/SC/38/1977). This report deals with the food habits of the Bryde's whales which are identical to that above mentioned but very briefly since the examination on the stomach contents collected by each factory ship are still halfway of microscopic observations at present. Therefore, the argument was focussed on discussing the marine biological purport for taking the whales under special permission rather than describing the result in detail. However, the article as a whole hopefully be regarded as a supplement to the document by Ohsumi.

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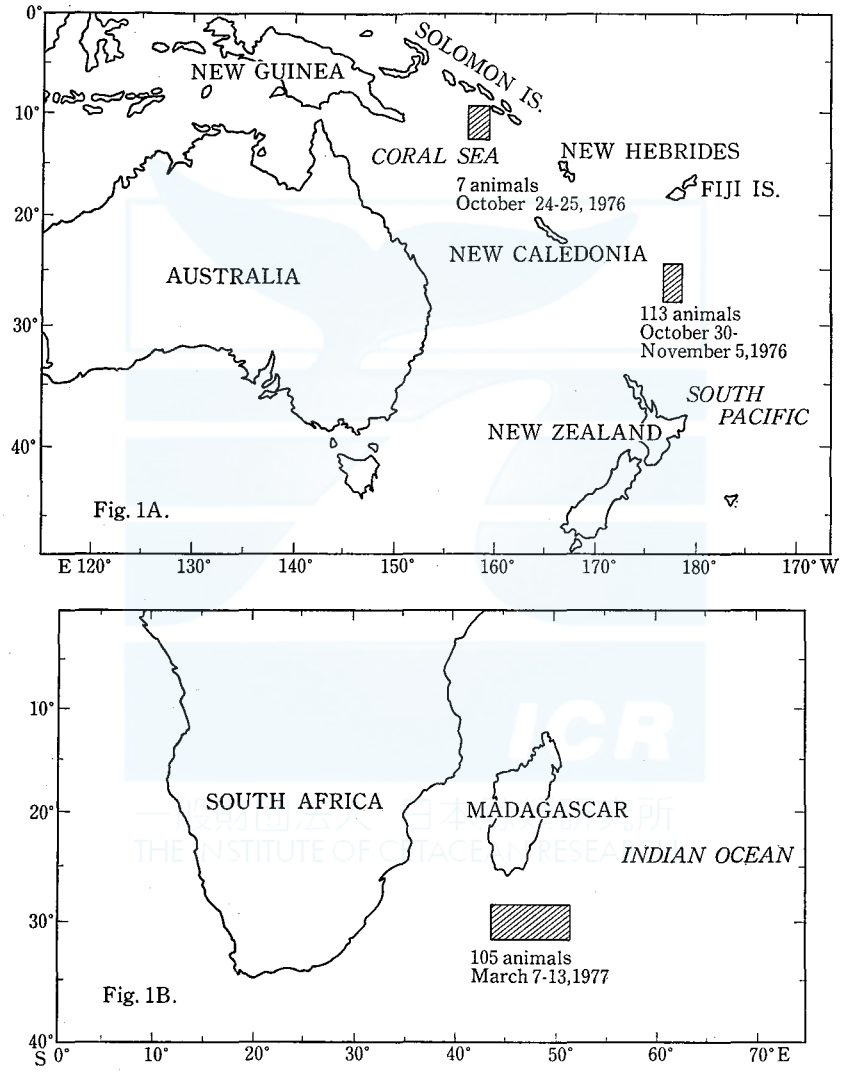
MATERIAL

Seven Bryde's whales out of 225 animals were caught in the Coral Sea during October 24–25, 1976, and 113 were caught in the tropical South Pacific between Fiji Islands and New Zealand during October 30-November 5, 1976. The rest 105 animals came from the catch in the waters off Madagascar, southwestern Indian Ocean. The approximate locality where the catches took place is demonstrated by the hatched squares in Figs. 1A and 1B.



Figs. 1A-B. Whaling ground for the Bryde's whales caught by Japanese whaling fleets, (1A) Tonan Maru No. 2 and (1B) Nisshin Maru No. 3, under the special permission for the season of 1976/77. Location of catch is indicated by the hatched squares framed by the farthest extremes of catch positions.

A total of 121 stomach contents was collected from the identical number of animals, of which 69 samples were obtained from the South Pacific and Coral Sea regions, and 52 were from the southwestern Indian Ocean.

The collected stomach contents were preserved in 10% formalin solution. Although a considerable amount of the stomach contents was heavily digested leaving a very small fraction of the appendages of prey organisms, it was rather easy to identify euphausiid species by the remains of male copulatory organ on the 1st–2nd swimming legs and spermatophore in female since there was quite clear biasing in sex composition by each euphausiid species.

Apart from sampling the stomach contents, eye observations on the stomach of each carcass were made by a personnel on board, and the results were recorded by the kind of food organisms on all animals. By examining this results, there found no descriptions of food items other than euphausiids.

RESULT

Stomach condition in general

The overall state concerning the amount of stomach contents was based on eye observations by classifing it into five quantitative categories. One of summed up figures was given in Tables 1A and 1B by the whaling ground. In the animals caught in the Coral Sea and tropical South Pacific waters, 75% of animals were found to be repleted with food to some extent under varying quantity. Although the majority of those repleted animals showed few in the quantity of stomach contents, say, 57.5% of animals were repleted less than half of the stomach volume, it is noteworthy or even amazing that there occurred 17.5% of animals which were repleted almost fully (' Rich ' plus ' Full ' in the table-A) in those pelagic waters of the tropics where the quantitative distribution of planktonic organisms is very scarce in general.

TABLES 1A-B. THE OVERALL STATE OF THE STOMACH CONDITION IN BRYDE'S WHALES CAUGHT IN THE CORAL SEA AND SOUTH PACIFIC OCEAN DURING OCTOBER 24—NOVEMBER 5, 1976 (A), AND IN THE SOUTHWESTERN INDIAN OCEAN DURING MARCH 7-13, 1977 (B).

(A)*

Amount of stomach contents	Empty	Few	Moderate	Rich	Full	
No. of animal	30	49	20	13	8	(=120)
% to total	25.0	40.8	16.7	10.8	6.7	(=100)

* catch by the Tonan Maru No. 2 fleet

(B)**

Amount of stomach contents	Empty	Few	Moderate	Rich	Full	
No. of animal	56	21	10	1	17	(=105)
% to total	53.3	20.0	9.6	0.9	16.2	(=100)

** catch by the Nisshin Maru No. 3 fleet

In contrast to the animals in the South Pacific regions, there occurred considerably large number of poorly fed animals in the southwestern Indian Ocean. The number of whales with empty stomach roughly doubled in this whaling ground. However, there still exists about 50% of animals of being well repleted stomach, and the percentage figures combined both 'Rich' and 'Full' are very similar to that found in the South Pacific animals.

The stomach conditions in southern blue and fin whales, for instance, show very frequent occurrence in the number of animals with empty stomach in the Ross Sea region, and its percentage figures usually vary between 40% and 57% (Kawamura, 1977). By comparing these figures with those found in the southern Bryde's whales, it may be considered that the relatively frequent occurrence of well fed animals both in the South Pacific and southwestern Indian Oceans is significant evidence in connection with dealing the ecosystem through food webs in the pelagic waters of the tropics.

Occurrence of stomach contents by the local time

In the animals caught in the South Pacific and Coral Sea regions, there seems to be no clear trends in the stomach condition by the local time of catch. The animal caught in October showed somewhat large number in the frequency of empty stomach (44.4%) while it was reduced to 13.3% in November (Av. 25.0%), but there was a slight difference in the Indian Ocean. (Tables 2A and 2B).

The number of animals of being repleted stomach in terms of the percentage figures is very large throughout every time series of catch. Both upper and lower most extremes of the percentage in the South Pacific animals repleted with some amount of food for given time series was 87.5% for 0900 hour and 60.0% for 0800 hour respectively, while they were 66.7% and 16.7% in the Indian Ocean animals. The very high percentage occurrence of animals of repleted stomach through a series of daily catch time (0500–1800 hours) suggests that there must be considerably rich availability of food organisms for baleen whales, and that possibly for many other key members involved in the tropical food webs. No animal with repleted stomach was found in 0500, 1000 and 1100 hours, but perhaps it was due to poor catch number during those time zones. One of important facts in Tables 2A and 2B should be found in the occurrence of 'Rich' and 'Full' stomachs during the daytime (1200–1400 hours). These animals undoubtedly preyed upon euphausiids within the past several hours prior to their capture. This indicates that there exists an abundant food organisms even during the daytime and that *E. diomedeae*, *E. recurva* and *Th. gregaria* occur with large biomass by forming the mono-specific surface swarms instead of remaining in deep waters.

Species of food organisms

From a total of 121 stomach samples following three species of euphausiid were indentified:

Euphausia diomedeae Ortmann
Euphausia recurva Hansen

TABLES 2A-B. FREQUENCY DISTRIBUTION OF THE NUMBER OF ANIMALS BY THE LOCAL TIME OF CATCH AND THE STATE OF STOMACH CONTENTS, (A) OCTOBER—NOVEMBER, 1976 IN THE SOUTH PACIFIC AND CORAL SEA, AND (B) MARCH, 1977 IN THE SOUTHWESTERN INDIAN OCEAN.

(A) Tonan Maru No. 2 fleet

Period	October 24–30, 1976					
Amount of stomach contents	Empty	Few	Moderate	Rich	Full	Total
05	1	—	—	—	—	1
06	3	—	—	—	—	3
07	3	2	—	—	—	5
08	—	1	—	—	—	1
09	1	3	1	—	—	5
10	1	—	—	—	—	1
11	1	—	—	—	—	1
12	1	—	—	2	1	4
13	1	—	—	1	1	3
14	2	1	—	1	—	4
15	1	4	—	—	—	5
16	4	—	—	1	1	6
17	1	2	—	—	—	3
18	—	2	1	—	—	3
Total	20	15	2	5	3	45
%	44.4	33.3	4.4	11.2	6.7	100.0

continued . . .

November 1–5, 1976						Grand total	% animal with food
Empty	Few	Moderate	Rich	Full	Total		
—	—	—	—	—	—	1	—
1	6	2	—	—	9	12	66.7
2	8	4	3	1	18	23	78.3
4	3	1	—	1	9	10	60.0
—	—	—	—	—	3	8	87.5
1	—	—	—	—	1	2	—
—	3	1	—	—	4	5	80.0
1	—	1	1	2	5	9	77.8
—	1	3	—	—	4	7	85.7
—	4	2	—	—	6	10	80.0
1	—	1	3	—	5	10	80.0
—	4	2	1	1	8	14	71.4
—	1	1	—	—	2	5	80.0
—	1	—	—	—	1	4	80.0
10	34	18	8	5	75	120	
13.3	45.3	24.0	10.7	6.7	100.0		

(B) Nisshin Maru No. 3 fleet

Period	March 7–13, 1977						
Amount of stomach contents	Empty	Few	Moderate	Rich	Full	Total	% animal with food
06	1	1	1	—	—	3	66.7
07	7	5	1	—	1	14	50.0
08	16	3	1	1	7	28	42.9
09	6	6	3	—	3	18	66.7
10	9	—	—	—	2	11	18.2
11	2	1	1	—	1	5	60.0
12	7	2	2	—	2	13	46.2
13	3	2	1	—	—	6	50.0
14	5	—	—	—	1	6	16.7
15	—	1	—	—	—	1	100.0
Total	56	21	10	1	17	105	
%	53.3	20.0	9.5	1.0	16.2	100.0	

Thysanoessa gregaria G.O. Sars

The population of *Euphausia diomedeae* occurred in the Coral Sea during October was comprised of adult of both sexes except an instance which was solely comprised of female, and there found a single spermatophore attached to the thelycum in female or to the external genital aperture in male in some individuals. In the South Pacific and Indian Ocean population of *E. diomedeae*, however, male individual was complete absent to result complete mono-sexual composition. The stomach contents of Bryde's whales caught in the Coral Sea were represented solely by *E. diomedeae* without exception.

In contrast to the case in *E. diomedeae*, *Euphausia recurva* population was comprised of adult male. Female did not occur completely in this species. *E. recurva* occurred both in the South Pacific and southwestern Indian Ocean, but not in the Coral Sea. There were no individuals carrying spermatophores in the specimen came from the tropical Pacific whereas some few individuals from the Indian Ocean carried a single spermatophore on the genital aperture although the majority was not.

Thysanoessa gregaria was comprised of both adult male and female. Both *E. diomedeae* and *E. recurva* distributed widely over the whaling grounds in question,

TABLE 3. COMPOSITION OF THE FOOD OF BRYDE'S WHALES CAUGHT IN THE CORAL SEA, SOUTH PACIFIC AND SOUTHWESTERN INDIAN OCEANS FOR THE 1976/77 ANTARCTIC SEASON. FIGURES IN THE TABLE INDICATE THE NUMBER OF ANIMALS.

Sea area	S. Pacific & Coral Sea	S. W. Indian Ocean
Fleet	Tonan Maru No. 2	Nisshin Maru No. 3
No. of animals caught	120	105
No. of stomach contents examined	69	52
Euphausia diomedeae	17[5]	4
E diomedeae/E. recurva[1]	12	17
E. diomedeae/Th. gregaria	1	—
Euphausia recurva	—	2
E. recurva=E. diomedeae[2]	9	15
E. recurva/E. diomedeae	2	8[6]
E. recurva+E. diomedeae[3]	3	5
E. recurva≤E. diomedeae/Th. gregaria	3	—
Euphausia sp.[4]	7	1
Thysanoessa gregaria	10	—
Th. gregaria/E. diomedeae	1	—
Th. gregaria/E. recurva	1	—
Th. gregaria/E. diomedeae+E. recurva	3	—

[1] by the order of dominancy

[2] mixture of closely equal quantity

[3] mixture of two species but quantitative share among them is unknown due to heavy digestion

[4] the fraction of appendages and spermatophore strongly suggest that the species may possibly be composed of *E. diomedeae* and/or *E. recurva*

[5] of which five animals out of seven in all caught in the Coral Sea are included

[6] including one stomach contained a single specimen of hatchetfish

but *Th. gregaria* tended to show a sporadic occurrence which suggests the presence of possible five different local groups. There were however, no noticeable indications in the environmental condition which may explain their characteristic occurrence. The occurrence of *Th. gregaria* was fairly restricted in the whaling ground of the South Pacific regions.

The Bryde's whales caught in the Coral Sea, South Pacific and southwestern Indian Ocean preyed upon these three euphausiid species with some local differences in the species composition. As it is shown in Table 3 the food of Bryde's whales which distributes in the pelagic waters of the tropics was found to be comprised of monospecific or mixtured swarms of euphausiids. Comparing this with the stomach contents having been known throughout the so-called boreal and antiboreal feeding grounds, the revealed composition of prey organisms in terms of the variety of species in the tropical waters is considered to be rather monotonous. To see Table 3 there may be found differences but slight between South Pacific and Indian Oceans: One of clear differences was complete absence of *Th. gregaria* from the stomachs in the Indian Ocean, instead, *Euphausia recurva* was possibly dominant in this locality. The result shows in general that both *E. diomedeae* and *E. recurva* are considered to be very important food items among all in a scope of studying the energy flow through marine food webs in the tropical seas where micronektonic organisms other than euphausiids have been considered likely to be the key biotic group in the ecosystem of those waters.

DISCUSSION

It is well known fact in general that the abundance of zooplankton in the waters over the tropics is very poor. The stomach contents of surface dwelling fishes such as albacore, yellowfin and skipjack suggest that micronektonic fishes and squids may possibly be the key members in the pelagic food webs in those warmer waters (e.g. Roger and Grandperrin, 1976). Analysing the stomach contents of above mentioned tunas in the tropical Pacific, Roger and Grandperrin (1976) reported that 60% of the diet of tunas was comprised of micronektonic fishes, and euphausiids accounted only about 12% of the food of preyed fishes or may account only 7% of the food of tunas through the predation by their prey fishes.

The Bryde's whales have been considered to be the inhabitant of warm waters of the surface temperature higher than 20°C (Omura and Nemoto, 1955). They possibly share an identical ecosystem with tunas, surface dwelling fishes and other many micronektons in those tropical waters. The baleen whales undoubtedly feed to some extent on some organisms while they are in warmer waters. An example suggesting their active feeding may be found in the behaviour of excreting reddish faeces by blue whales in the Indian Ocean (Gambell *et al.*, 1974), and the similar one was observed in Bryde's whales during the marking cruise of Miwa Maru to the equatorial western Pacific (Far Seas Fish. Res. Lab., 1975; Wada, 1975). By considering those facts along with some speculations, it may be considered quite naturally that the Bryde's whales are likely to feed mainly on small gregarious fishes, larvae or

juvenile of larger fishes and/or micronektonic organisms. However, one of the evidences revealed in the present study on the feeding of Bryde's whales that inhabit in the tropical South Pacific and southwestern Indian Oceans suggested somewhat different from that have been considered previously. The Bryde's whales under consideration preyed exclusively upon euphausiids. There occurred no other kind of food organisms. Although the importance of euphausiids as food of Bryde's whales in the tropical seas is still obscure since the material did not cover over the sufficient period and amounts. However, the fact that euphausiids occurred significantly over the different time and space suggests their importance as the stable foodstuff not only for Bryde's whale but also perhaps for all other baleen whale species occurring in those warm waters regardless the origin of whales whether the animals were endemic or migrants. In this respect the Bryde's whales in the tropics are by no means at higher trophic level than any other migrating baleen whale species, and the ecological niche for those Bryde's whales is considered very similar to that known throughout balaenopterid whales.

The euphausiids species, *E. diomedeae*, *E. recurva* and *Th. gregaria* are very common over the waters from tropics toward the warm temperate regions. Usually these euphausiids migrate vertically for a considerable distance of about several hundred meters and are considered seldom to occur in the near surface during the daytime (e.g. Boden *et al.*, 1955; Ponomareva, 1963; Mauchline and Fisher, 1969). According to Roger and Grandperrin (1976), only *Stylocheiron* species may become available for its predators during daytime in the tropical Pacific. *Euphausia* species, on the other hand, may become more important at night (Roger, 1973a, b). However, the occurrence of *E. diomedeae*, *E. recurva* and *Th. gregaria* largely in the stomach contents of Bryde's whales even in the daytime suggests the primary importance of these food species at some restricted time and space over the pelagic waters of the tropics. Apart from the diurnal behaviour pattern, the formation of swarms at this time of the season in these euphausiid species might relate to their reproduction, which is indicated by an extremely biased sexual composition occurring only male for *E. recurva* and female for *E. diomedeae* of the South Pacific populations, and several other characteristics such as that the spermatophore frequents in *E. diomedeae*.

The mass occurrence of euphausiids in the tropical seas so abundant as to be utilized by the predators is again significant phenomenon in considering the energy budget of baleen whales. Through the calculation of energetic budget in the southern baleen whales, Kawamura (1975) suggested that the overall estimations may fulfill the energetic requirements by migrating animals, but at the sametime there exists very ill fed animals with thin blubber, and these animals perhaps must to feed on the way to and from the so-called breeding ground in the warmer waters. One of questions arose from the discussion was whether there were any possibility to come across suitable feeding place for those stenophagous filter feeders in the tropical seas, and the failure in this may suggests a critical situation for the mulnutritioned animals. Although the mass occurrence of euphausiids in the austral spring as was suggested through this study did not coincide with a possible seasons of appearing

the migrating whales, it can be said that the swarms of euphausiids may occur over the whole warmer season at least in some restricted localities. The occurrence of euphausiids both in October-November and March with considerable availability may support this, and there have been reported a considerable amount of half-grown to adult specimens of *E. diomedeae* occurred during the austral winter in Siboga-Expedition (Hansen, 1910).

In concluding with the discussion, the occurrence of euphausiid swarms in the tropical South Pacific and in the southwestern Indian Ocean strongly suggests its importance in considering the pelagic ecosystem through the food webs in the tropics as well as the identical subject taking place in the feeding ground of the mid- to higher latitudes. The consumption of planktonic crustaceans by baleen whales may amount significantly among many other predators even if the whale does not feed so much as to fulfill its nutritional daily ration. Although the role of euphausiids in the tropical marine ecosystem does not seem such magnitude as to noticeable extent in the overall energetic flows, the swarming of these crustaceans may be one of the phenomena that can not be overlooked from the ecological aspects. The swarms of euphausiids possibly be utilized largely by many kind of predators in addition to the Bryde's whales, and the latter undoubtedly accounts an indispensable role as the biotic members in the tropical marine ecosystem. More accumulation of this kind of knowledge is therefore needed to fulfill the biased knowledge both the biology of whales and biological oceanography since many similar evidences for the latter topics have been known solely by studying on the food of baleen whales (e.g. Nemoto, 1962; Omori *et al.*, 1972; Kawamura, 1974).

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Note: According to Best (1974) there exist clear difference in the dietary habit of Bryde's whales in the South African waters: his 'inshore form' feeds mainly on fish (*Engraulis capensis, Trachurus trachurus, Sardinops ocellata*) whereas 'offshore form' does euphausiids (*Euphausia lucens, E. recurva, Nyctiphanes capensis, Thysanoessa gregaria*). As far as this result is concerned, the animals caught in the Coral Sea, tropical South Pacific, and Indian Ocean seem to represent his 'offshore form'. Although Best's result provides very important knowledge on the southern Bryde's whales, there was no other way but exclude his result throughout my discussion since the document (Best, P. B., 1974: IWC/SC/SP/74/DOC4) has not been published yet at the moment of publishing this article.