日本沿岸における海中生物騒音の分布

誌名	日本水産學會誌
ISSN	00215392
著者	竹村, 陽
巻/号	38巻3号
掲載ページ	p. 201-210
発行年月	1972年3月

The Distribution of Biological Underwater Noise at the Coastal Waters of Japan*

Akira TAKEMURA**

(Received September 13, 1971)

Many well-known scientists are constantly investigating underwater sound with the knowledge that it will be of much benefit to mankind. Such studies like the underwater sounds of snapping shrimps have resulted to the easy location of many species by tracing the produced sound. Location by sound may also be used to gain knowledge of other marine animals in migration, feeding or even spawning.

The author made a general survey of the underwater sounds along the coastal waters of Japan, paying great emphasis in the nature of the waters where observations were made. It was observed that the following factors produce certain effects at various degrees; 1) bottom material, 2) geographical difference in latitude, 3) water depth, 4) distance from the shore and 5) structure of the coastline.

Frying noise was only observed in relatively warm areas below Lat. 41°46′N. For bottom materials, excellent underwater sound recordings were made in muddy areas followed by rock and sand. Frying noise was observed only up to 100 m deep. Considering other factors to be uniform, the distance from the shore produced no change in the frequency of frying noise. In semi-enclosed areas, the sound frequency was greatest at the entrance.

It is well-known that the loud noisy sounds are heard under the sea. It seems that most aquatic animals utilized more extensively the underwater sound (to include propagating wave of density which man can not hear) than the terrestrial animals. It is very difficult to find out the animal which does not emit any underwater sounds. Within the audible frequency range of man includes many kinds of biological sounds. However, outside this range still lies many unheard of biological underwater sounds. It is possible that there are many biological sounds on the ultrasonic and ultra-low frequency ranges. And there are many papers on the underwater sounds of biological origin and those papers covered the lower invertebrates to the higher marine mammals.

The above underwater sounds are powerful, however, they are less compared with the excellent frying noise (which is a kind of underwater noise of biological origin and a series of pulses resembled frying sound) along ordinary coastal waters. The frying noise is always heard in most coastal waters and it is not so much to say that the level of underwater noise which is attributable to biological origin is mostly attributed to frying noise. It seems that this biological noise has influenced the other marine animals as an important ecological factor. When the other kinds of biological underwater sounds were investigated at the sea from the previous results, especially at the coastal waters, the frying noise can not be disregarded considering its influence on biological sounds. Moreover, most

* Part of this study was carried out with "Tansei Maru", research vessel of the University of Tokyo.
** Faculty of Fisheries, Nagasaki University, Nagasaki, Japan (竹村 暘: 長崎大学水産学部)

of the biological acoustic papers in the past are on the studies of level or quality of underwater sound which included the physical background noise. Then, it is necessary to survey the distribution of the real biological underwater noise within the underwater background noise eliminating the physical disturbances. Investigating biological noise, the author found the frying noise as the main criterion. Then, it was investigated that the factor such as water depth, bottom material et al may affect the extent of distribution of the frying noise.

BUSNEL and DZIEDZIC[1)] described the variety of this noise according to the relationship between bottom materials, distance from the shore and water depth. While, similar study had been published by JOHNSON, EVEREST and YOUNG[2)]. WENZ[3)] also described that the contribution of biological noise to the ambient noise in the sea varies with many factors.

Methods

In July and August, 1967, the 23 stations observed were distributed along the coastal waters of Japan Sea to investigate the difference of frying noise in latitude. Those stations are shown in Fig. 1. Stations were located about 45′ in nautical miles. Then as much as possible these stations were located in areas with uniform characteristics. However, the unavoidable differences are shown in Table 1. Therefore, the variety of frying noise will be observed depending upon those factors.

Fig. 1. The stations of coastal waters of Japan.

Around the coastal waters of Nagasaki Prefecture from April 1969 to March 1970, about the middle of every alternate month, year round observation was done at 5 fixed lined containing 5 stations as shown in Fig. 2. These stations were selected for having different bottom materials in contrast with those selected around the coastal waters of Japan Sea. For this investigation, the relation between the distance from the shore and frequency of frying noise were mainly observed and also the variations with seasons.

Table 1. The conditions of stations along the coastal waters of Japan Sea.

Station	Water depth (m)	Bottom material and Biota	Latitude	Description
Hakodate	1	pebble and mud;	41°46′N	beach thoroughly covered with pebble
”	10	mud;	”	centre of bay
Fukaura	2.5	pebble and mud; small snail	40°38′N	sea-weed abundant
Funakawa	3	mud;	39°52′N	located at end of breakwater
Kosagawa	3	rock, sand and pebble; small snail	39°08′N	beach throughly covered with rock
Atusmi	3.5	rock and sand;	38°37′N	beach thoroughly covered with sand and rock
Kashiwazaki	3.5	sand, rock and mud; small sessile univalve mollusk	37°22′N	located at end of breakwater
Itoigawa	3	sand and mud; small sessile univalve mollusk	37°20′N	”
Yokata	4	mud and sand; small sessile univalve mollusk	36°45′N	”
Wajima	4	mud and pebble; small sessile unvalve mollusk	37°24′N	”
”	4	”	”	”
Hashidate	4	mud and sand; small sessile univalve mollusk	36°15′N	located at end of breakwater and beach thoroughly covered with sand
Tsuruga	4	sand and mud; small sessile univalve mollusk	35°40′N	located at end of breakwater
Maizuru	1.5	mud and rock;	35°32′N	entrance of harbor
”	2	rock;	”	beach throughly covered with rock
”	25	mud;	”	centre of outlet of bay
Hamasaka	4	rock and sand;	35°38′N	beach thoroughly covered with sand and rock
Higasaki	3	mud and pebble; fishes and small snail	35°26′N	located at the end of breakwater
Hamada	3	rock; barnacle	34°54′N	rock cove
”	2	mud; oyster and small sessile univalve mollusk	”	located at end of breakwater
”	1.5	mud;	”	artificial channel
Sanmiura	2	mud and pebble; small sessile univalve mollusk	34°24′N	located at end of breakwater
Ainoura	2.5	mud; oyster	33°18′N	”

Moreover, on Sagami Bay, Yomigahama Bay and Tateyama Bay, frying noise was investigated considering water depth, bottom materials and distance from the shore.

In Omura Bay on June, 1970, the 69 stations were selected to investigate the distribution of frying noise at the semi-enclose sea area. This bay is connected with Sasebo Bay through Hario Strait and Haiki Strait. Therefore, water streamed in through those two straits, however, Haiki Strait is very narrow and shallow and the main current streams through Hario Strait with an average of 2.5 knots.[4] Therefore, the current in Omura Bay flows counterclockwise[5]. The water depth is deep on the west side and is shallow on the east side with a flat bottom. Moreover, the similar investigations were carried out in Mitsukabi and Sakume stations which is located far from the outlet of Hamana-Ko. Stations of similar nature were also studied in Dokai Bay, Nagasaki Bay and Tokuyama Bay (it is expected that the result is more different from the open sea, because these bays are not so large and the exchange of sea water with the open sea is not so vigorous.)

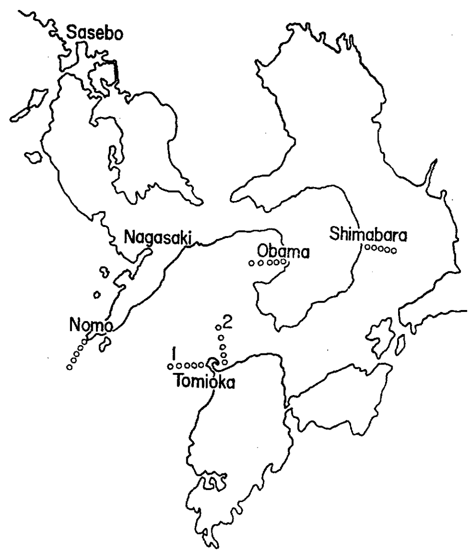

Fig. 2. The stations around the coastal waters of Nagasaki Prefecture.

The instrument used in these investigations were two hydrophones (57-TA and ST-6501, OKI), pre-amplifiers (for 57-TA and ST-65, OKI), precision sound level meter (NA-51, RION), two tape recorders (EM-2 and NAGRA III, SONY) and sound spectrograph (SG-04A1, RION).

The hydrophone was suspended about 5 m under the sea, and in shallow waters, was hung down at 1/3 of the depth from the bottom. The same equipments were used in the previous report and gave similar characteristic response[6]. The sensibility of hydrophones used on these investigations are -90 and -105dB and the gain of pre-amplifiers are about 30dB.

The bottom materials were also investigated at every stations by means of the lead bottom sampler or as indicated in recent charts and by observing the bottom at shallow waters. Moreover, the observation of composition of sessile animals was also carried out at the stations along the coastal waters of Japan Sea and its result was shown in Table 1. These observations were carried out from the shore for coastal waters of Japan Sea, Tokuyama Bay and part of Omura Bay. These investigations of Sagami Bay, Tateyama Bay and Yomigahama Bay were carried out on board "Tansei Maru", research vessel of the University of Tokyo, and those of Omura Bay and coastal waters around Nagasaki Prefecture on board "Kakusui", training boat of Nagasaki University.

Moreover, all mechanical disturbances (i.e., motor, engine and etc.) which may produce noise were eliminated during the investigation. Since diurnal variations of frying noise occurs 2 hours before and after sunrise and sunset, observations were done outside this period[6]. Analyses were carried out within the range between the overall value up to 30 dB of frying noise recorded through these instruments as fixed condition of recording, and frequency per second of frying noise was calibrated.

Results

The results of these investigations were classified by each factor, and the differences of frying noise for each factor are described as follows:

Bottom material It may be possible that the frequency of frying noise is influenced by the other factors. Therefore, at each station in the open sea, Table 2 shows the frequency of frying noise in respective similar sea area classified according to bottom material. In this Table, the average is an arithmetic mean. The frying noise is most powerful at the station where bottom material mainly consisted of mud as shown in this Table. The rock bottom is next and followed by sand. The same relationship mentioned above was also observed for the investigation in Omura Bay. The frying noise in the sea area of bottom with mixed conponents is powerful than that of pure conponent. When the main conponent is mud, its frying noise is stronger than that of the other mixed conponent. None of the various frying noise was heard on the bottom of pure sand and was hardly heard on the rocky bottom. Frying noise was not heard on the observations at the northern stations (Kinkazan and outside of Ozuchi Bay), although the bottom material is rock. The sea area where the frying noise does not exist is very limited because it is very rare that the bottom material consists only of pure sand. It has been observed that most bottoms consisted of several conponents.

Table 2. Frequency difference of frying noise of various bottom material

Bottom material	Frequency of frying noise (number/sec.)			
	Coastal waters of Japan Sea	Omura Bay	Other	Average
Mud and Sand	12.5	5.9	—	6.7
Mud and Rock	10.9	—	19.0	14.5
Mud	12.9	5.0	20.5	12.1
Sand and Mud	6.3	4.8	—	5.4
Sand and Rock	6.2	—	—	6.2
Sand	—	—	0	0
Rock and Mud	—	—	—	—
Rock and Sand	7.7	4.4	—	6.4
Rock	3.9	—	4.6	4.1

JOHNSON, EVEREST and YOUNG[2] described that the sound levels of the bottom of cobbles, boulders and shale rock are higher than would be expected over sand, and BUSNEL and DZIEDZIC[1] reported that the variety of underwater noise on rock bottom was more violent than that on mud or sand.

Latitude On the observations carried out along the coastal waters of Japan Sea, frying noise was not heard at the two stations in Hakodate in spite of two observations made (May and July). On the other hand, frying noise was observed at the station of

Fukaura in Aomori Prefecture which is set apart from Hakodate by Tsugaru Channel. Fig. 3 shows the graph of latitudinal frequency of frying noise at each station which is classified according to main bottom materials. The difference caused by change in latitude is not distinctly observed at each station south latitude of Niigata. On the coastal waters of the Pacific Ocean side, the result at Onahama is also different from that of stations further south. Then, in the bays of Ozuchi and Onagawa, frying noise was recorded although it was not so frequent compared with that of Onahama and the bottom materials of those stations consisted mainly of mud.

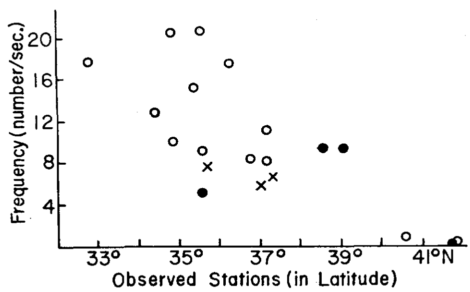

Fig. 3. The graph of latitudinal frequency of frying noise at each station which is classified to main bottom material.
○, mud; ●, rock; × sand

Nevertheless, it is very difficult to conclude that the relation between the frying noise and latitude causes the above difference, since the other factors (especially the bottom material) of each station are not constant. For example, the investigations were carried out at three stations of respectively different bottom material at Maizuru and Hamada, and a great variety was observed at every station as shown in Table 3. In this respect, further observations on the frying noise at the stations of Hakodate according to speculated result of above mentioned relation between bottom material and frying noise should be made.

Table 3. Frequency difference of frying noise of various bottom material at Maizuru and Hamada

Station	Maizuru			Hamada		
Bottom material	Rock	Mud	Mud and Pebble	Rock	Mud (artificial channel)	Mud
Frequency (number/sec.)	5.0	8.6	20.0	2.9	9.4	19.9

When the hydrophone was suspended at 25 m deep at Bering Sea (55°N, 170°E) with water depth of about 3900 m, as expected, frying noise was not observed.

Water depth and distance from the shore The frying noise was investigated at the stations along the coastal waters around Nagasaki Prefecture, Tateyama Bay, Sagami Bay and Yomigahama Bay where the investigations were carried out at some stations along the fixed lines. The water depth, bottom materials and frequency of frying noise of these stations are shown in Fig. 4 and 5. The result of the coastal waters around Nagasaki Prefecture were done at an average of 6 observations for a year. The seasonal variations of frying noise was hardly observed.

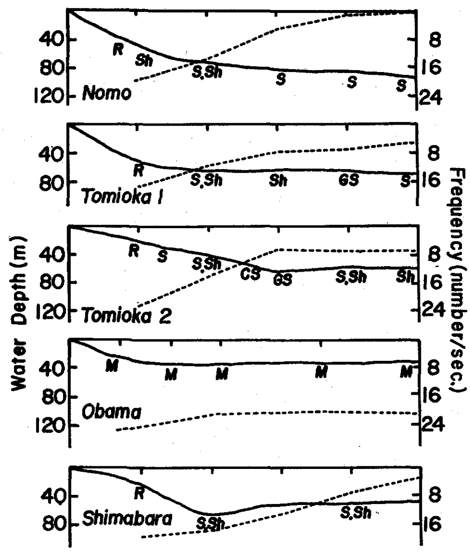

Fig. 4. Relation of frequency of frying noise with water depth and bottom material around the coastal waters of Nagasaki Prefecture.

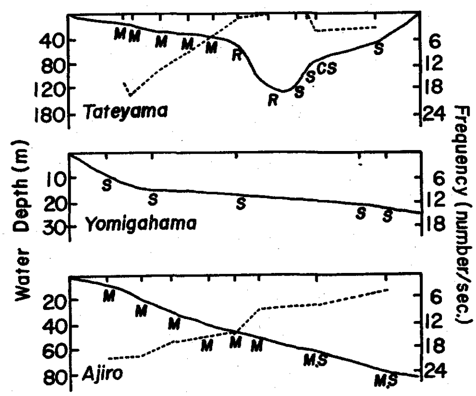

Fig. 5. Relation of frequency of frying noise with water depth and bottom material at Tateyama Bay, Yomigahama Bay and Sagami Bay (Ajiro).

For all the above mentioned areas of investigation, the frying noise decreases with depth of water increases. A faint noise was still observed from 70–80 m. However, this is not true in Yomigahama Bay where totally no noise was observed. The bottom material of this bay was completely sand as shown in Fig. 5. As aforesaid, when the bottom material is completely sand, the frying noise is never heard. Beyond 100 m, no noise was recorded.

The frying noise was observed at the stations of Obama line (7 miles from shore) with water depth of about 30 m. When a station 2 miles from the shore is compared with a station close to the shore, there is no difference in the frequency of frying noise. Therefore distance from the shore is not a factor if the water depth is regular.

Busnel and Dziedzic[1] described that underwater noise increases as the distance from the shore or water depth and its level is not varied according to the depth of hydrophone.

Particular area without frying noise No frying noise was observed in some area where it was expected to exist based on previous investigations. It is not too much to say that frying noise exists on most sea area as above mentioned. Although it is clear that frying noise is influenced by factors such as bottom material, water depth and latitude, the variety of frying noise also depends upon the quality of water such as salinity or dissolved oxygen as much as that of the above mentioned factors.

For example, the frying noise is not heard at the lake or river (i.e., Urakami stream reservior in Nagasaki and Lake Biwa in Shiga Prefecture). At the observations of semi-enclose sea area (i.e., Hamana-Ko, Nagasaki Bay, Dokai Bay, Omura Bay and Tokuyama Bay), frying noise was never heard at the outlet of rivers or at the furthest area from the mouth of bay. Further out from this outlet or this area, the frying noise gradually increases. This result means that only marine organisms emit those frying noise.

Furthermore, frying noise does not exist at the Mitsukabi and Sakume stations which are farthest from the mouth of Hamana-Ko (Fig. 1). These stations resemble in location to that of some stations of Omura Bay which receives the inflow of fresh water, or where the mixing with sea water is rare resulting to lack of dissoved oxygen. Moreover, in Sakume, even with the presence of barnacles and many rafts for culture of oyster, frying noise was not heard as mentioned in previous paper[6]. Accordingly, it is very difficult to conclude that those animals are the main source of frying noise, although BUSNEL and DZIEDZIC[1] described the sound emitted by barnacle very much resembles frying noise.

In the case of Omura Bay, frying noise was heard at the western part of the bay where the exchange of sea water is vigorous. On the other hand, this noise was hardly heard at the stations of eastern part of this bay. The difference of bottom material, water depth, latitude, distance from the shore between eastern area and western area are not main factor to influence the frying noise as shown in Fig. 6. On the contrary, it is natural that frying noise at the eastern stations is more vigorous than that at the western stations. In this bay, it is reported that the lack of dissolved oxygen at the bottom layer or "red water" phenomenon almost always occurs in small scale every year[7]. The above phenomenon had occured on large scale in 1962 and 1965, and extended all over the bay[8]. The past geographical distributions of the lack of dissolved oxygen at the bottom layer in summer[5] very much resemble to that of no-frying noise area distribution. During the investigation, "red water" was not observed, however, it may continue to influence the aquatic animals, especially benthic animals.

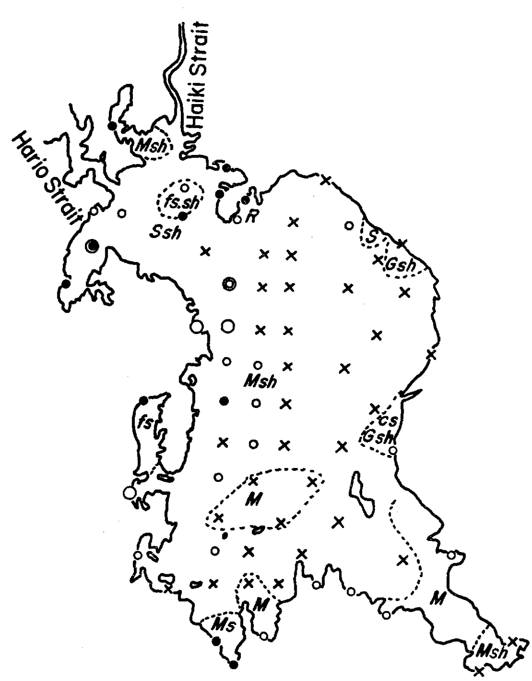

Fig. 6. Distribution of frequency of frying noise with bottom material in Omura Bay. $0 \leqq \times < 1$; $1 \leqq \circ < 5$; $5 \leqq \bullet < 10$; $10 \leqq \bigcirc < 15$; $15 \leqq \circledcirc < 20$

Moreover, in Nagasaki Bay, frying noise was not heard at the limited area influenced by outflow of fresh water from rivers. On the other hand, frying noise was heard at other areas of this bay. At the centre of the bay, the frying noise is as much as that at the entrance of bay. It seems that frying noise at the estuary depends upon the amount of water flowing. These observed stations and their frequency of frying noise are shown in Fig. 7.

This noise in Dokai Bay varies more than that of Nagasaki Bay. Dokai Bay is surrounded by many factories and is thus polluted. The amount of water flowing in from the surrounding rivers is not so much and the bottom is almost consisted of clay at areas far from the outlet of the bay. As shown in Fig. 8, frying noise was not observed at the area which cover 2/3 of the bay.

In Tokuyama Bay which is well-known for the "red water" phenomenon, there is as much outflow from rivers and as many factories as Dokai Bay. However, in this bay, frying noise was observed although it was not so frequent compared with the open sea, and this bay has wider mouth than Dokai Bay, Nagasaki Bay and Hamana-Ko.

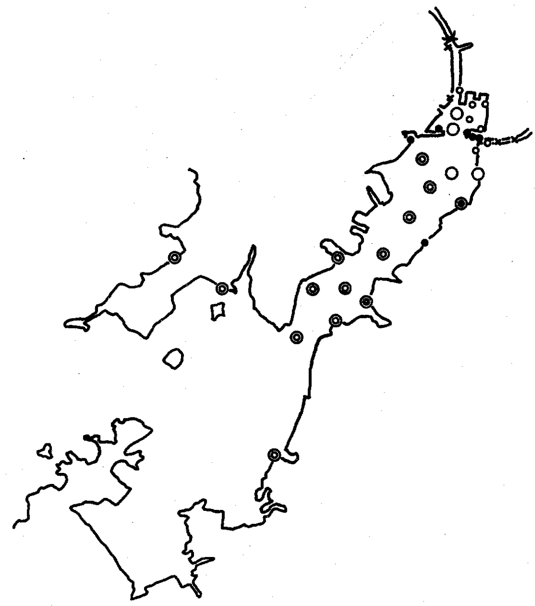

Fig. 7. Distribution of frequency of frying noise in Nagasaki Bay. 0≦×<1;1≦∘<5; 5≦•<10; 10≦○15; 15≦◎<20; 20≦⊙

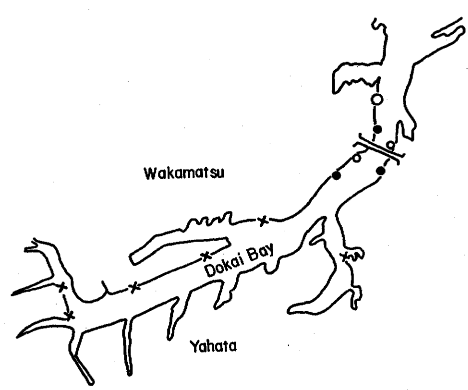

Fig. 8. Distribution of frequency of frying noise in Dokai Bay. 0≦×<1; 1≦∘<5; 5≦•<10; 10≦○<15

Discussions

According to the above mentioned results, it is understood that the origin of frying noise is very much influenced by many environmental factors. It is clear from the previous paper[6] and the above results including the final analysis, the distribution of frying noise is that of aquatic animals emitting frying noise.

For the bottom material, this animal lives on the area of mainly muddy bottom and does not or hardly lives on the area of pure sand or rock.

Then for the different latitudes, this animal is hardly observed at the cold sea area north of Tsugaru Channel and the frequency of frying noise increases towards southern sea area. The difference of its frequency due to latitude is not observed at the stations of southern area of Niigata.

With regards to water depth or distance from the shore, its frequency is not influenced by the distance from the shore, and decreases with the increase of water depth. Beyond the 100 m of depth, frying noise is not observed. Barnacle or oyster which adhere to the upper part of tidal zone are not source of frying noise.

Then the animal emitting frying noise does not live at the fresh water area and the frequency of frying noise is very low at brackish area. In the case of bays with narrow entrance, frequency of frying noise observed is not so high at the further area of the bay from the mouth, because the exchange bay water with the open sea is not frequent. Then its frequency is low at the sea area which is often influenced by lack of dissolved oxygen. Accordingly, even, where there is rehabilitation, the degree for the benthic animals which do not have excellent swimming activity, is not so fast. When the aggravation of environmental factor such as the lack of the dissolved oxygen was piled up, it becomes difficult to increase the frequency of frying noise with that of past conditions.

Acknowledgements

First of all, the author wishes to express his sincere thanks to Dr. Kazuhiro MIZUE and Dr. Kei NAKASAI of Nagasaki University, for their suggestions and kind advices. The author also wishes to thank Dr. Tasae KAWAKAMI, Kyoto University, Dr. Shunpei KOJIMA, Fisheries Experimental Station of Shimane, and Mr. Ichiro NAKAMURA, Prefectural Government of Akita, for valiable consultations. Thanks are gratefully due to Captain Shuji SHIMAMUNE and crew of "Tansei Maru", research vessel of the University of Tokyo, Captain Minoru MICHIWAKI and crew of "Kakusaui", training boat of Nagasaki University and Mr. Sadao YAMAMOTO, of Nagasaki University, who assisted in these investigations.

References

1) R. G. BUSNEL and A. DZIEDZIC: *Cahiers Oceanogr.*, **14**, 293–322 (1962).
2) M. W. JOHNSON, F. A. EVEREST and R. W. YOUNG: *Biol. Bull.*, **93**, 122–138 (1947).
3) G. M. WENZ: *Jour. Acoust. Soc. Amer.*, **34**, 1936–1956 (1962).
4) S. IIZUKA and H. IRIE: *Bull. Fac. Fish. Nagasaki Univ.*, **5**, 1–7 (1957).
5) I. MORI and H. IRIE: *ibid.*, **21**, 103–113 (1966).
6) A. TAKEMURA: *ibid.*, **28**, 31–41 (1969).
7) T. SHIOKAWA, M. TATEISHI, S. IIZUKA and H. IRIE: *ibid.*, **21**, 45–58 (1966).
8) H. IRIE and K. HAMASHIMA: *ibid.*, **21**, 59–65 (1966).