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# HORIZONTAL DISTRIBUTION AND DIEL MIGRATION OF A MESOPELAGIC MICRONEKTONIC FISH, *Diaphus suborbitalis*, IN SURUGA BAY, JAPAN

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## ABSTRACT

*Diaphus suborbitalis*는 日本 駿河灣에 있어서 中·深層性 魚類 micronekton의 主要種이다. 本硏究에서는 本種의 生態究明의 一環으로서 地理分布와 日周垂直移動의 樣式을 밝혔다.

試料는 1971年 5月부터 1977年 4月까지 東京大學 海洋硏究所 硏究船 淡青丸과 底引網漁船에서 採集했다. 採集에는 6ft.의 IKMT, 口徑 160cm의 大型플랑크톤네트(ORI), 口徑 56cm의 MTD플랑크톤네트와 底引網을 使用했다.

1971年 5~6月의 灣內全域에 걸친 調査에 의하면, 本種은 沿岸性이 强하여 灣의 안쪽부분으로부터 灣西部에 있어서의 200~500m 等深線에 따른 海域에 分布의 中心을 갖고, 灣中央部와 灣南東部 및 灣入口에서는 出現量이 적다. 이것은 本種이 *Sergestes lucens*, *Diaphus watasei*, *Maurolicus muelleri* 等과 함께 灣內에서 大陸棚斜面 周邊海域에 分布의 中心을 갖는 生物群集의 一員임을 나타내고 있다.

魚群探知機와 Net採集에 의한 試料에 의하면, 本種의 層間의 棲息層은 水深 200~400m 前後의 大陸棚斜面의 近底層이다. 日沒時부터 音波散亂層(DSL)을 形成하는 다른 生物과 함께 上昇하기 시작하여, 夜間은 水深 50m 前後層을 中心으로 分布한 後 새벽녘에 下降을 開始하여 다시 層間의 棲息層으로 移動한다.

## INTRODUCTION

The search for new fisheries resources has been emphasized because increasing catch of the conventional fish stocks is in the state of maximum exploitation or even over-exploitaion. At present, it seems that the most promising resources are krill, mesopelagic fish and cephalopods.

Not much concern for the mespelagic micronektonic fish, however, has been shown in learned and industrial activities because of the technical difficulty of sampling. Lately, their role in biological production and food chain of the ocean has been of importance according to the development of sampling method. The potentiality of unused fisheries resources, being tremendous, has also intensified the need of study.

The micronektonic fish *Lampanyctodes hectoris* of the family Myctophidae has been caught commercially for some years off South Africa, and about 43,000 tons were caught with trawls in 1973 (Anon, 1974). The fish has been used for fishmeal and oil production. Experimental fishing for *Maurolicus muelleri* of the family Sternoptychidae has been carried out in south east Australian waters (Anon, 1977). In the Arabian Sea (Gjösaeter, 1978), and off north west Africa (Gjösaeter and Blindheim, 1978), the prospects of commerical fisheries for the mesopelagic fish seem promising.

*Diaphus suborbitalis* is a main species of mesopelagic micronektonic fish in Suruga Bay, on the Pacific side of central Japan. The ecological studies of this species on aging and lifespan, and growth pattern have been made by Go *et al.* (1977 a,b). This paper describes horizontal distristribution and diel vertical migration of the species.

## MATERIALS AND METHODS

Collections of mesopelagic fish were made on the cruses of the *R/V Tansei Maru*, the Ocean Research Institute, University of Tokyo, and the bottom trawl, from May 1971 to April 1977.

Biological samples were carried out by a 6-ft Isaacs-Kidd midwater trawl (IKMT) with 0.5 mm×0.5mm mesh at the cod end, ORI-C and ORI-100 nets with 160cm in mouth diameter and 750cm in length, and MTD plankton net with 56cm in mouth diameter, 155cm in length and 0.33mm×0.33mm mesh. The detailed construtions of the nets are described by Omori (1965) for the ORI net, and Motoda (1971) for MTD plankton net. The outline of each cruise for sampling is presented in Table 1.

A fish-finder Sanken Super Televigraph, 200 KHz, equipped in the *R/V Tansei Maru*, was used to find diel migration. Sampling by IKMT and MTD plankton net was carried out at the same time to corroborate the distribution layer and the abundance of the species. The sound scattering layer was consecutively investigated at a depth of 200～500m (mainly 200m) on the inner part of the bay between Yui and the River Fuji on April 22, 1700 hours-April 23, 0800 hours (Cruise KT 77-4). In each sampling the nets were simultaneously towed horizontally and obliquely for about 2 hours along the center of the scattering layer.

## RESULTS

### Horizontal distribution

Track chart and sampling stations for investigations of horizontal distribution of *Diaphus suborbitalis* over all the bay are presented in Figs. 1 and 2.

As shown in Fig. 2, the frequency of appearance of the species was high not only on the inner part of the bay, that is, the waters off Numazu, Hara, the River Fuji, and Yui, but also on the western part, that is, off Yaizu and the River Oi. However, the frequency of appearance on the central part, the south east part, and the mouth of the bay was low, and there was little in quantity. These results are in agreement with those obtained on the cruises KT 75-1 (Jan. 22-30, 1975), KT 75-10 (July 24-29, 1975) and KT 77-4 (April 21-28, 1977) by the *R/V Tansei Maru*.

While *Diaphus suborbitalis* was mainly distributed in the waters along the continental slope where located on or around 200～500m isobath, the occurrence of the species in the

**Table 1.** Cruise data for sampling *Diaphus suborbitalis* by *R/V Tansei Maru* in Suruga Bay.

| Cruise | Date | No. of sampling station | Sampling gear |
|---|---|---|---|
| KT 71- 6 | 1971, May 25～June 3 | 61 | IKMT-6ft<br>ORI-C |
| KT 75- 1 | 1975, Jan. 22～30 | 22 | IKMT-6ft |
| KT 75-10 | 1975, July 24～29 | 45 | IKMT-6ft<br>ORI-100 |
| KT 76-14 | 1976, Aug. 31～Sep. 6 | 59 | IKMT-6ft<br>MTD |
| KT 77- 4 | 1977, Apr. 21～28 | 30 | IKMT-6ft<br>MTD |

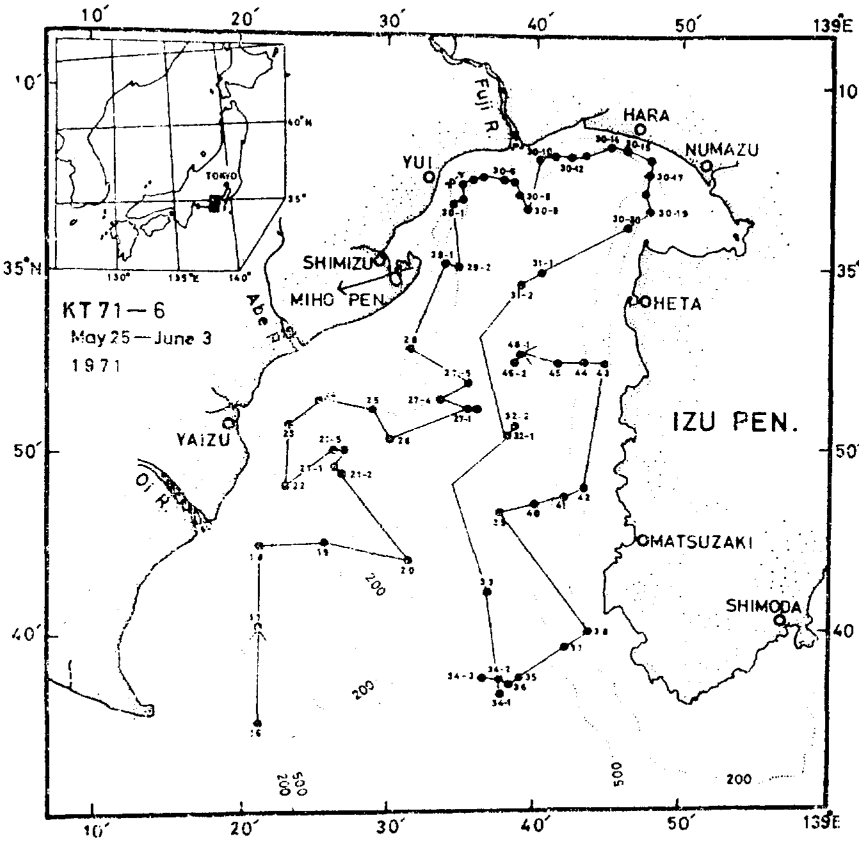


Fig. 1. Stations and track chart on the Cruise KT 71-6 in Suruga Bay.

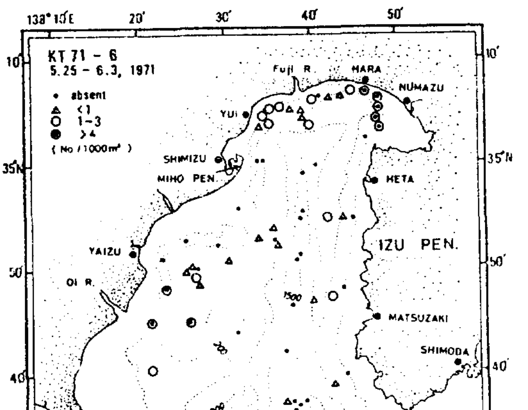


Fig. 2. Horizontal distribution of *Diaphus suborbitalis* in Suruga Bay (Cruise KT 71-6).

waters deeper than a depth of 1,000m was extremely low.

From the facts described above, the distribution of the species is most numerous in the waters located on the 200~500m isobath from the inner part of the bay between Heta and Miho Peninsula to the western part around the River Oi. This indicates that *Diaphus suborbitalis* is the main species among the organisms caught with commercially important sergested shrimp (*Sergestes lucens*) which is abundant on the inner and western parts of the bay.

## Diel vertical migration

Fig. 3 and Plate 1 show the movement of the significant sound scattering layer. On April 22, 1977, the scattering layer appeared

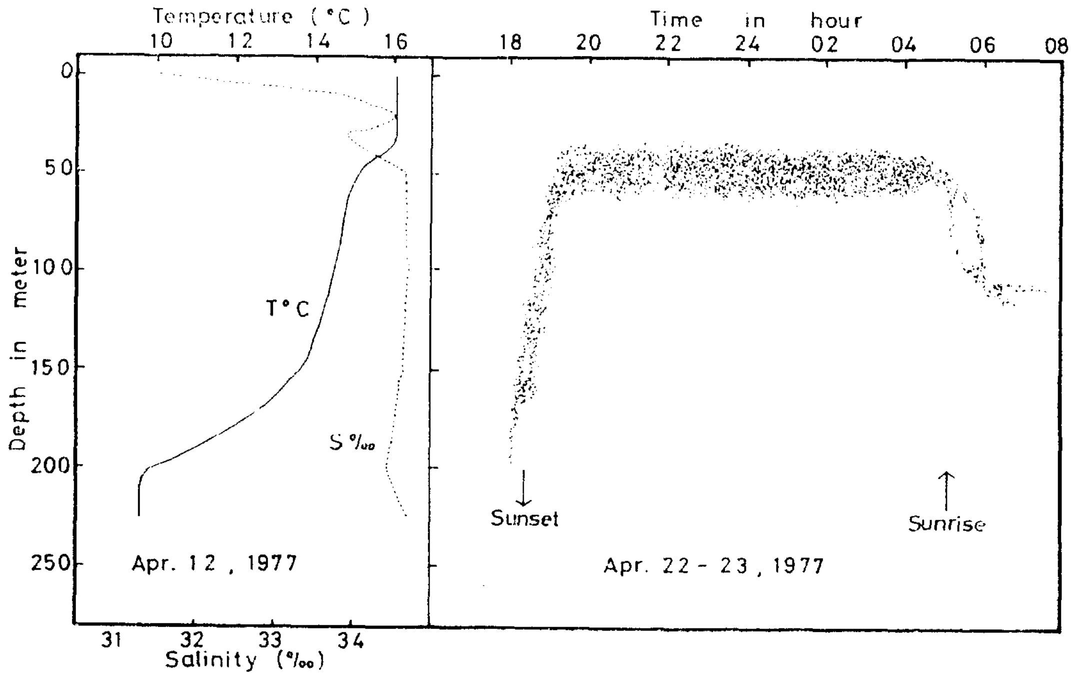


**Fig. 3.** Temperature and salinity profiles in the vicinity of station where *Diaphus suborbitalis* were taken and movement of the sound scattering layer for April 1977 in Suruga Bay.

faintly near the bottom of 200~250m depth off the River Fuji 5 minutes before sunset (1823 hours). This layer started to come up forming a distinct layer at sunset, and the center of the scattering layer (thickness, about 30m) reached 160m depth. This layer continued to ascend, reached 45~60m depth 45 minutes after sunset, and stayed in the upper 60m level until dawn.

One scattering layer began to descend 20 minutes before sunrise (0508 hours) and was faintly recorded at 90m depth 30 minutes after sunrise. Forty minutes after sunrise, another layer which moved downward about 30 minutes after sunrise joined the former layer at 100m level, and they descened continuously. This layer reached 100m depth 1 hour after sunrise, and stayed at the same depth for about 1 hour, This scattering layer, however, became faint about 2 hours after sunrise, and disappeared.

The net sampling was carried out immediately after sunset on April 22, 1977. The first sampling by IKMT was made between 1827 and 2035 hours, and the average catch was 2.0 inds/1,000m$^3$. The second average catch, which was obtained at about 45-60m depth at 2201-0005 hours, was 4.0 inds/1,000m$^3$. The third average catch, which was investigated at 45-60m depth on April 27, 0340-0545 hours, was 0.3 ind/1,000m$^3$.

Although the distribution in the daytime was investigated by IKMT and ORI net, not a single individual was obtained because of sampling difficulty near the sea bottom. A lot of the species, however, were obtained by bottom trawl at 180-280m depth near the bottom between 0815 and 0926 hours. Ohta and Kawaguchi (pers. comm.) also found that the species was observed by submersible camera at 400m depth in the daytime.

These facts show that the species was distributed at about 200-400m depth near the sea bottom of the continental slope in the daytime, and began to ascend around sunset with other organisms forming the sound scattering layer. After that the species was mostly distributed at about 50m depth at night, and began to descend from dawn, and then returned to the habitat of the daytime.

The distribution layer of the species from egg to metamorphosis stage is obscure, because no sample of that early stage has been identified in Suruga Bay. While the juveniles larger than 17mm SL and the adults were sampled at the same depth at night, few were sampled in the daytime. This indicates that the organism after metamorphosis stage of the species is distributed at the same layer as the results, and migrates simultaneously in the same manner as the adults.

## DISCUSSION

It was evident that *Diaphus suborbitalis* are numerously distributed in the waters along the continental slope on the inner and western parts of the Suruga Bay. This character in distribution of the species also appears in other locations as well (Gilbert, 1913; Weber, 1913; Weber and Beaufort, 1913; Kulikova, 1961; Kawaguchi and Shimizu, 1978). Consequently, these reports seem to show that the species is distributed in the waters around islands and coast as shown in Fig. 4.

It has been reported that *Diaphus suborbitalis* is an organism of the sound scattering species off the River Fuji in Suruga Bay by Sakamoto *et al.* (1967). The school of the species observed

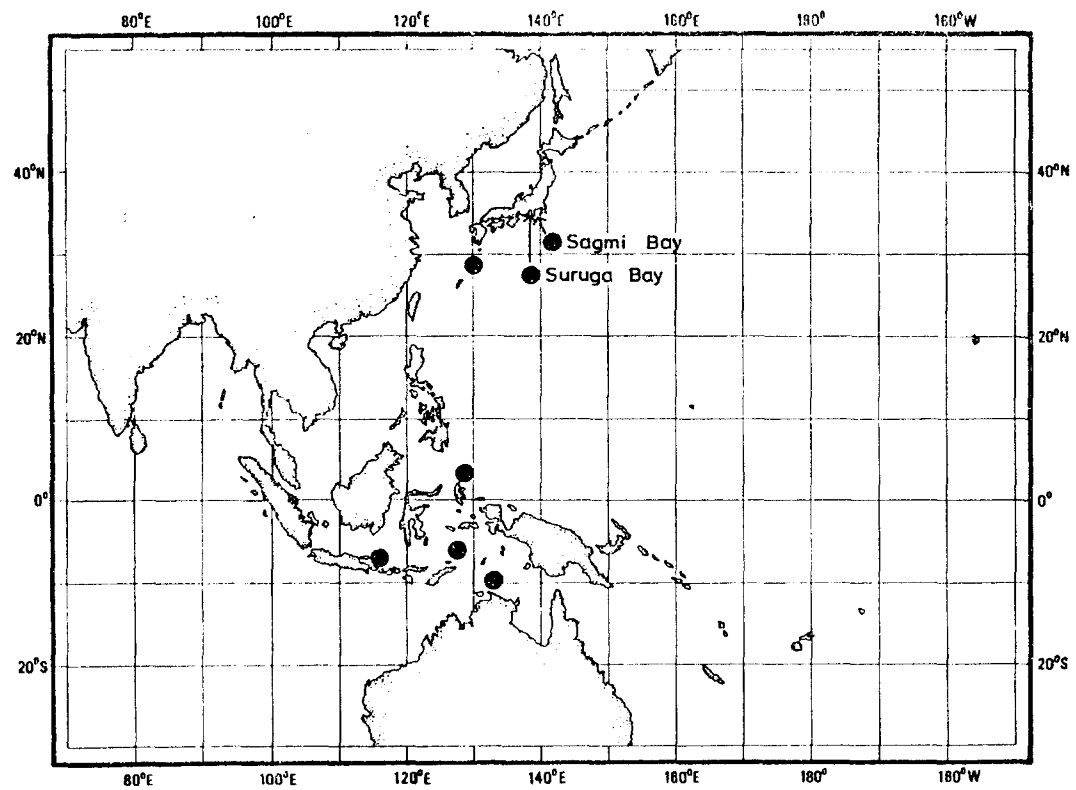


**Fig. 4.** Geographical distribution records of *Diaphus suborbitalis.*

by the fish-finder equipped in the shrimp midwater trawl, was often caught because of misjudging from the school of the sergested shrimp.

The average sampling density of *Diaphus suborbitalis* by IKMT was 1.9 inds (0.2-13.8 inds)/1000m³ at night in Suruga Bay. This value is similar to the sampling density of *Diaphus taaningi* which is known as a principal component of a shallow sound scattering in the Cariaco Trench, Venezuela (Baird *et al.*, 1974). These facts suggest that the combination of net sampling with fish-finder in this study was useful for the investigation of the vertical migration of *Diaphus suborbitalis.*

Though *Diaphus suborbitalis* rises in the upper 100m depth at night, the species does not appear at the uppermost surface ayer. Nafpaktitis (1968) has also reported that the fish of the genera *Diaphus* and *Lobianchia* do not rise near the surface layer on the occasion of diel migration.

In the observation of the sound scattering layer in this study, it was observed that there were two different descending layers, namely, the descending layers before and after sunrise. There was a difference of one hour between the starting time of descent of the two layers. It is uncertain whether the species under study belonged to either of the two descending layers. Judging from the fact that the average catch of the species was 0.3 ind/1000m³ between 0340 and 0545 hours as already described, it is presumed that a great part of the species belonged to the descending layer before sunrise.

The ascending and the descending speed of the vertical migration which was estimated by the fish-finder in Suruga Bay were about 5.6 cm/sec and 1.7cm/sec, respectively. It has been known that the vertical migrating speed of *Lobianchia dofleini* of the similar genus to *Diaphus* is different from season to season, that is, the descending speed is 8cm/sec in late spring, 4cm/sec in late summer, and 3cm/sec in winter (Karnella and Gibbs, 1975).

Many authors have discussed the causes, mechanism, and biological significance of the vertical migrations of the aquatic organisms (Aron, 1962; Clarke and Backus, 1964; Vinogradov, 1970; Pearcy, 1979). These problems are still poorly understood despite the numerous reports. If one of the causes of the diel migration is regarded as an adaptation to feed at the upper layer where food organisms are abundant, it seems that speed variations of the vertical migration of *Diaphus suborbitalis* may be attributable to the changes associated with the time of active feeding in spring to make preparation for spawning (Go, unpublished) with the time of spawning in summer (Go, unpublished), and with the time of the high mortality in winter (Go *et al.*, 1977b).

It has been also considered that the diel change of the light intensity in the sea is one of the main environmental factors influencing the diel migration. Therefore it is expected that the starting time and the migrating speed of the diel migration of *Diaphus suborbitalis* depend on the weather in observation. These points should be considered in further studies.

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## REFERENCES


Anon. 1974. 42nd annual report of the director of sea fisheries for the calendar year 1974. Rep. Div. Sea Fish. Brch. S. Afr. **42**: 1-28.

Anon. 1977. Courageous investigates the distribution and behavior of light fish. Australian Fisheries. **36**(7): 25-27.

Aron, W. 1962. The distribution of animals in the eastern North Pacific and its relationship to physical and chemical conditions. J. Fish. Res. Bd. Can. **19**: 271-314.

Baird, R.C., D.F. Wilson, R.C. Beckett and T.L. Hopkins. 1974. "*Diaphus taaningi*" Norman, the principal component of a shallow sound-scattering layer in the Cariaco Trench, Venezuela. J. Mar. Res. **32**(2): 301-312.

Clarke, G.L. and R.H. Backus. 1964. Interrelations between the vertical migration of deep scattering layers, bioluminescence, and changes in daylight in the sea. Bull. Inst. Oceanogr. Monaco. **64** (1318): 1-36.

Gilbert, C.H. 1913. The lanternfishes of Japan. Mem. Carnegie Mus. **6**(2): 67-107.

Gjösaeter, J. 1978. Life history and ecology of *Maurolicus muelleri* (Gonostomatidae) in Norwegian waters. Dep. Fish. Biol. Univ. Bergen, Norway: 1-30.

Gjösaeter, J. and J. Blindhein. 1978. Observation on mesopelagic fish off Northwest Africa between 16° and 27°N. Bergen Norway: 1-21.

Go, Y.B., K. Kawaguchi and T. Kusaka. 1977a. Ecologic study on *Diaphus suborbitalis* WEBER (Pisces, Myctophidae) in Suruga Bay, Japan—I. Method of aging and its life span. Bull. Jap. Soc. Sci. Fish. **43**(8): 913-919.

Go, Y.B., K. Kawaguchi and T. Kusaka. 1977b. Ecologic study on *Diaphus suborbitalis* WEBER (Pisces, Myctophidae) in Suruga Bay, Japan—II. Growth pattern. Ibid. **43**(12): 1411-1416.

Karnell, C. and R.H. Gibbs, Jr. 1975. The lanternfish *Lobianchia dofleini:* An example of the importance of life history information in prediction of oceanic sound scattering. Pro. ONR Working Symposium on the Prediction of Sound Scattering in the Oceans 11-14, November, Asilomar, Pacific grove, California.

Kawaguchi K. and H. Shimizu. 1978. Taxonomy and distribution of the lantern fishes genus *Diaphus* (Pisces, Myctophidae) in the western Pacific, eastern Indian and the southeast Asian Seas. Bull. Ocean Res. Inst. Univ. Tokyo. **10**: pp. 145.

Kulikova E.B. 1961. Data on the lantern fishes of the genus *Diaphus* (Family Scopelidae) from the western part of the Pacific Ocean. Tr. Inst. Okean., Moscow **43** (In Russian Translation No. 61): 30-31.

Motoda, S. 1971. Devices of simple plankton apparatus V. Bull. Fac. Fish. Hokkaido Univ. 22(2): 101-106.

Nafpaktitis, B.G. 1968. Taxonomy and distribution of the lanternfishes, genera *Lobianchia* and *Diaphus*, in the North Atlantic. Dana-Rep. **73**: 1-131.

Omori, M. 1965. A 160cm opening-closing plankton net—I. Description of the gear. J. Oceanogr. Soc. Japan. **21**(5): 212-220.

Pearcy, W.G., T. Nemoto and M. Okiyama. 1979. Mesopelagic fishes of the Bering Sea and adjacent northern North Pacific Ocean. J. Oceanogr. Soc. Jap. **35**: 127-135.

Sakamoto, I., R. Amano, Y. Okada, and Y. Tominaga. 1967. DSL as biological resources in the southern Sea of Japan—I. A preliminary report through cruise of the "*R/V Tansei Maru.*" J. Fac. Mar. Sci. Technol., Tokai Univ. **30**: 179-196 (In Japanese).

Vinogradov, M.E. 1970. Vertical distribution of the oceanic zooplankton. Moscow Nauka (Israel Program for Scientific Translation): pp. 399.

Weber, M. 1913. Die Fische der Siboga-Expedition. In Siboga-Exped. Brill, Leiden. **57**: 90-91.

Weber, M. and L.F. de Beaufort. 1913. The fishes of the Indo-Australian archipelago. 2. Leiden.

## Plate 1. Movement of sound scattering layer in Suruga Bay

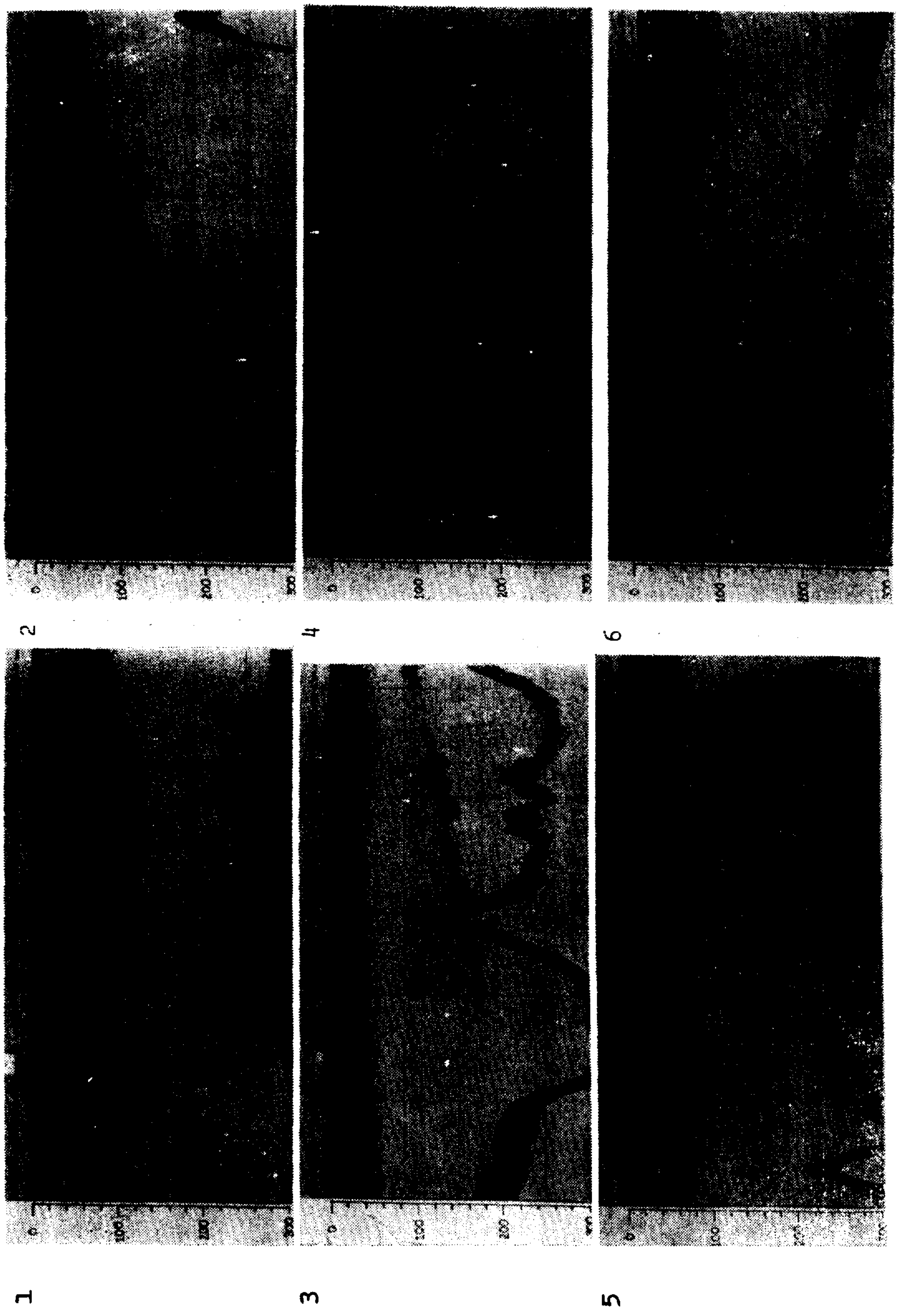
(35°05′N, 138°39′E) during the hours 1703, April 22 and 0705, April 23, 1977. Sunset, 1823; Sunrise, 0508.

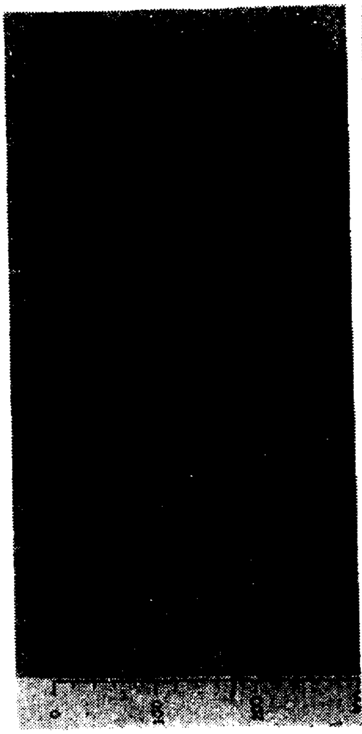
1. 1703-1741, April 22. Some scattering appeared near the bottom of 200-250m depth.
2. 1742-1820. The records of the scattering appeared near the bottom of about 300m depth.
3. 1821-1857. The scattering layer appeared faintly at 200m depth at about sunset, 1823, and the layer became conspicuous at about 160m depth 15 minutes after sunset, and continued to ascend.
4. 1858-1936. The layer ascends continuously to reach about 60m depth at 45 minutes after sunset, and appeared to have remained in the upper 80m depth.

5, 6, 7, and 8. 1936-2015, 2016-2053, 2332-0011, 0127-0206, April 22-23. The scattering layer appears to have remained in the upper 80m layer throughout the night from 1936 to 0206.

9. 0430-0505, April 23. The scattering layer started to sink from the depth of 60m 20 minutes before sunrise, 0508.
10. 0506-0546. The layer continued to sink downward, and is barely recognized at about 90m depth 30 minutes after sunrise.
11. 0547-0624, April 23. The thin layer was sinking and faintly recognizable at about 100m depth 1.5 hours after sunrise.
12. 0625-0705. The layer continued to sink and disappeared 2 hours after sunrise, 0508.

PALTE 1





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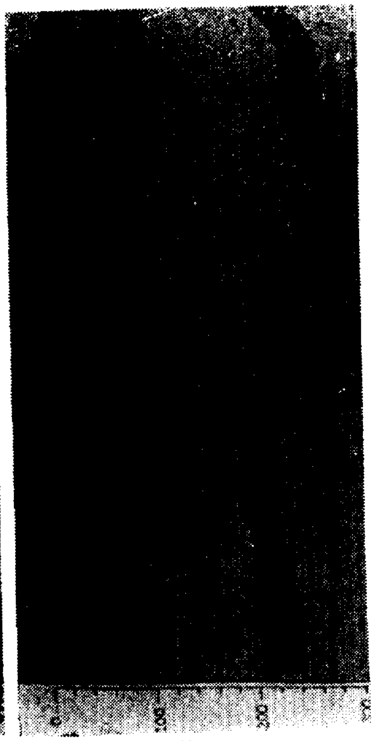

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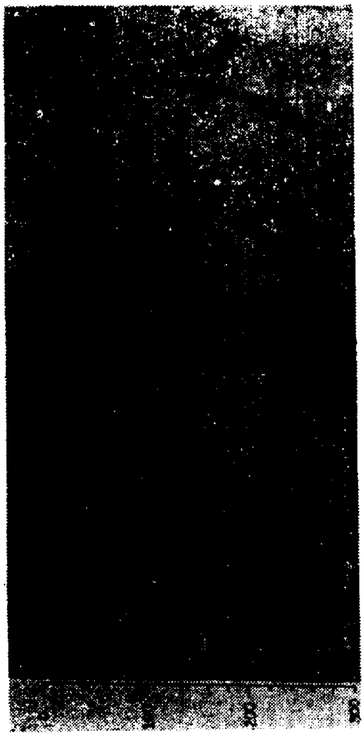

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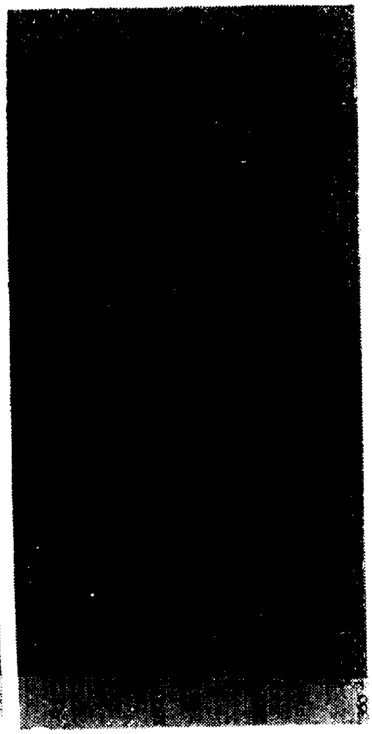

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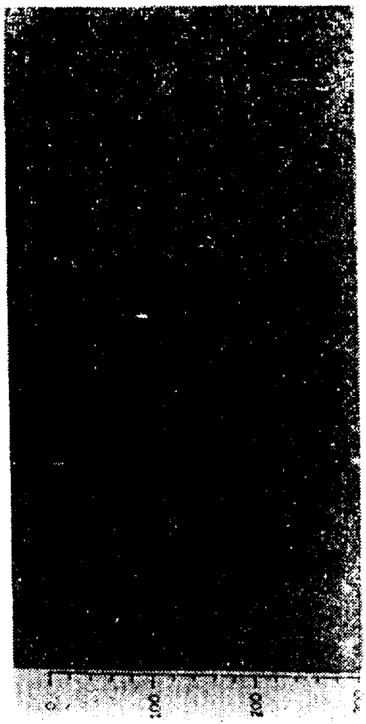

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