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1. Introduction
From 28 to 31 of October, 1991 in Vladivostok (former USSR) first consultative meeting of experts and national focal points on the development of NOWPAP took place (NOWPAP-Action Plan for Protection of Marine Environment in the North-West Pacific). This meeting was organised by UNEP in cooperation with the Center for International Projects (Moscow) and Pacific Oceanographical Institute (Vladivostok). 29 participants from UNEP, China, Japan, Republic of Korea and USSR worked aboard the research vessel "Akaemik Korolev" of Far Eastern Regional Hydrometeorological Research Institute (FERHRI). By March, 1992 National Focal Points will prepare for UNEP National Reports including the information on the state of marine environment, national policy, measures and relevant activities on marine pollution problems in their countries. This overview had been prepared for inclusion in the Russia National Report to UNEP.

It is based on the data of FERHRI and Vladivostok Center for Environmental Pollution Control. It is necessary to intercompare these data with the results of Japanese and Korean researchers on chemical pollution of the Sea of Japan.

Investigations of the NW Pacific chemical pollution have been carried out by FERHRI specialists since 1970-s. Regular expeditions to study chemistry, biology and pollution of the open ocean and its marginal seas are fulfilled aboard FERHRI research vessels. The Sea of Japan, located between USSR, Japan and Korea, attracts maximum attention.

In the coastal zone of the Sea of Japan, in the Peter the Great Bay, chemical pollution studies have been carried out by Vladivostok Center for Environmental Pollution Control as well as by FERHRI specialists. In 1990 about $486 \times 10^4$ m$^3$ of municipal and industrial waste waters were discharged in the Peter the Great Bay (29% - without any treatment). $446 \times 10^4$ m$^3$ were discharged from Vladivostok, $26 \times 10^4$ m$^3$ - from Nakhodka. With these waste waters approximately $19 \times 10^4$ tons of suspended solids, 373 tons of petroleum hydrocarbons, 51 tons of detergents, 54 tons of iron and about 10 tons of other metals were introduced in the Bay in 1990. With the river runoff $36 \times 10^4$ tons of suspended solids, 230 tons of petroleum hydrocarbons and 94 tons of detergents were discharged in 1989. Accidental oil spills were about 30 tons in 1989 and 63 tons in 1990.

2. Materials and methods
Total non-polar petroleum hydrocarbons (PHC) in sea water and bottom sediments were analysed by IR spectrophotometry (Karlberg and Skarstedt, 1972; Orlovsky, 1977; 1979). Aromatic hydrocarbons (AHC) in sea water were measured by modified spectrofluorimetric method in chrysene equivalents (IOC, 1984). Hydrocarbons were extracted from 21 or sea water by n-hexane using magnetic stirrer during 30 min. After column chromatography on Al$_2$O$_3$ fluorescence intensity was measured on JASCO FP-550 spectrofluorometer (Japan). Excitation wavelength - 310 nm, emission -
360 nm.

Synthetic surface-active substances (anionic detergents or surfactants) were analysed by spectrophotometric method with methylene-blue after chloroform extraction (Oradovsky, 1977). Chlorinated hydrocarbons were analysed by gas-liquid chromatography with electron capture detector (Oradovsky, 1977, 1979, 1982). Nutrients were measured by photocolormetric methods (Oradovsky, 1977). Trace metals (TM) in sea water and bottom sediments were analysed by atomic absorption spectrophotometry (Oradovsky, 1979, 1982).

3. Total non-polar petroleum hydrocarbons

Average concentration of petroleum hydrocarbons in the open Sea of Japan was 18 ppb in 1986–1988. In the Sea of Philippines (to the south from 20°N) mean PHC content for the same period was 10 ppb, in the Kuroshio and Oyashio region—12 ppb (Tkalin, 1991a). Elevated PHC concentrations in the Sea of Japan are explained, probably, by its closeness and lower water temperature (in comparison with the Sea of Philippines), which does not promote biochemical degradation of organic pollutants. In 1989–1990 average content of petroleum hydrocarbons in the Sea of Japan was approximately the same.

In the coastal waters of the Sea of Japan PHC concentrations are significantly higher. In 1990 average PHC content in the Golden Horn Bay (Vladivostok is situated around this Bay) exceeded 50 ppb (maximum permissible concentration for the Russia coastal marine waters). In the Amursky Bay and the Bay of Nakhdoka PHC concentrations were also close to this value.

Higher concentrations of petroleum hydrocarbons in bottom sediments are observed near the main ports (Vladivostok, Nakhdoka, Vrangel). In the Golden Horn Bay mean PHC content was about 10 ppt in 1990 (maximum - 40 ppt), in the Amursky Bay and the Bay of Nakhdoka - 0.5–0.8 ppt (maximum - 2–3 ppt). Elevated PHC content was observed also near dredged material dumping sites. For example, in the Amursky Bay concentration of petroleum hydrocarbons in bottom sediments in the dumping area exceeded 4 ppt.

4. Aromatic hydrocarbons

Background level of aromatic hydrocarbons (AHC) in the North Pacific waters is about 0.04 ppb. In 1988 aromatic hydrocarbons content in the Japan Sea surface waters was 0.04–0.07 ppb (Tkalin, 1991b).

In 1989, first USSR-DPRK expedition to study chemical pollution of the Japan Sea coastal waters near the Tumangan River mouth was carried out aboard FERHRI research vessel. Average AHC content outside the area affected by the river runoff influence was 0.06 ppb, near the river mouth concentrations of aromatic hydrocarbons reached 0.96 ppb (Tkalin and Shapovalov 1991). In the same period AHC content in the Korean Strait was 0.03–0.15 ppb. Maximum concentration of aromatic hydrocarbons in surface waters of the Japan Sea in 1989 was 0.33 ppb.

In 1990 second USSR-DPRK expedition to study chemical pollution of the North Korea coastal waters was fulfilled also aboard FERHRI research vessel. In the East-Korean Gulf AHC content varied from 0.03 to 0.15 ppb (Tkalin, 1991b).

5. Synthetic surface-active substances (Anionic detergents)

In 1986–1988 average content of anionic detergents in the Sea of Japan was 25 ppb, in the Kuroshio-Oyashio region - 21 ppb, in the Sea of Philippines (to the south of 20° N) - 17 ppb (Tkalin, 1991a). As in the case of petroleum hydrocarbons, elevated concentrations of detergents in the Sea of Japan are explained by its lower water temperature and relative closeness.

In 1989, during the first USSR-DPRK expedition near the Tumangan River mouth maximum surfactant content reached 30–40 ppb. Concentrations of detergents outside the area affected by the river runoff influence varied from 0.5 to 0.10 ppb (Tkalin and Sh...
In 1990 average content of surfactants in the East-Korean Gulf was 10 ppb, maximum- 29 ppb (Tkalin, 1991b).

In the coastal zone of the Sea of Japan, near Vladivostok and Nakhodka, concentrations of anionic detergents are significantly higher due to discharge of municipal and industrial waste waters. Though average detergent content in the Golden Horn Bay did not exceed maximum permissible concentration (100 ppb), measured concentrations occasionally reached 150-250 ppb.

6. Chlorinated hydrocarbons and nutrients

During the last years, DDT, DDD, DDE, α-HCH and γ-HCH are found in the Peter the Great Bay constantly. In 1989-1990 average concentrations of chlorinated hydrocarbons in sea water near Vladivostok and Nakhodka varied from 0.2 to 4.6 ng/l, maximum concentrations reached 100 ng/l. Organochlorines are discharged in the marine environment directly from agricultural areas as well as with river runoff.

In the bottom sediments of the Peter the Great Bay, concentrations of chlorinated compounds are also considerable. In 1990, average content of DDT and its metabolites in bottom sediments varied from 1 to 25 ng/g, α-HCH and γ-HCH - from “not detected” to 10 ng/g. Maximum concentrations of DDT, DDD and DDE reached 100-150 ng/g, HCH isomers - 50-70 ng/g.

In summer 1989 near the Tumangan River mouth, maximum concentrations of organochlorines were as follows: DDT - 1.4, DDD - 0.9, DDE - 0.6, α-HCH - 3.1, γ-HCH - 0.8 ng/l. Outside the area affected by the river runoff chlorinated compounds were not detected (Tkalin and Shapovalov, 1991).

In the coastal zone of the Sea of Japan, near Vladivostok and Nakhodka, very high concentrations of nutrients were observed in surface waters. In 1990 maximum content of ammonia in the Golden Horn Bay was 273 ppb, in the Nakhodka Bay - 184 ppb, in the Amursky Bay - 132 ppb. Maximum nitrate concentrations in the same areas were 230-290 ppb, maximum phosphate content also exceeded 100 ppb.

7. Trace metals

Dissolved trace metal contents in the open Sea of Japan are less than following figures: Cu - 0.1, Pb - 0.05, Co - 0.02, Ni - 0.02 ppb (Tkalin and Shapovalov, 1991). In the coastal zone, near Vladivostok and Nakhodka, dissolved TM concentrations are significantly higher. For example, in 1990 average TM concentrations in the Golden Horn Bay were as follows: Cu=4.0, Pb - 1.8, Co - 0.4, Ni - 0.6, Cd - 0.3, Hg - 0.02 ppb. Maximum content of zinc was about 200 ppb, iron - 2000 ppb.

Higher concentrations of trace metals in bottom sediments were also observed near Vladivostok and Nakhodka. In 1990 mean copper content in the Golden Horn Bay was 91 ppm, in the Amursky Bay - 19 ppm, in the open Peter the Great Bay - 3 ppm. Concentrations of lead were as follows: 124, 21 and 6 ppm, cadmium - 4.9, 1.4 and 0.5 ppm, mercury - 0.72, 0.06 and 0.02 ppm respectively. Maximum content of lead in the Golden Horn Bay was 380 ppm, cadmium - 15 ppm, mercury - about 2 ppm.

Elevated TM content in bottom sediments was observed also in the dredged material dumping sites. For example, average content of zinc in the Amursky Bay dumping site was 539 ppm, lead - 187 ppm, copper - 136 ppm, cadmium - 2 ppm.

REFERENCES


The environmental conditions of the tunas’ maneuvering sphere in the Bay of Bengal

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and Hisayuki Arakawa**

Abstract: In order to obtain information on the environmental conditions of the maneuvering sphere of tuna in the Bay of Bengal, the Indian Ocean, a series of investigations was conducted on board the T/S Shinyo-maru of the Tokyo University of Fisheries, in February 1987. Simultaneously with measurements of water temperature, salinity, dissolved oxygen, underwater irradiance, and beam attenuation, experimental tuna-longline operations were also carried on in the same area. Regarding the water layer ranged from 38m to 69m, in which the group of tuna were caught, as their maneuvering sphere, its environmental data were obtained through the observations, finding that those were 25.5 to 27.5 °C in temperature, 33.00 to 34.45 % in salinity, 3.0 to 4.6 mL/l in dissolved oxygen content, 8.2 to 2.2 % in relative irradiance (i.e. total light), and 0.11 to 0.22 m⁻¹ in beam attenuation coefficient, respectively. It was also understood that the maneuvering sphere of tuna was located just above the combined layer of thermocline, halocline, and oxycline or its upper part. Moreover, their sphere corresponded to slightly above or just within the high-turbidity water layer. From these results, it can be said that the tunas’ living sphere of the Bay of Bengal is located in the shallowest water compared with any other tuna-fishing grounds all over the world. The reason of such a phenomenon may attribute to the location of the dissolved oxygen minimum layer locating in the subsurface layer of this oceanic water.

1. Introduction

The Bay of Bengal in the Indian Ocean is well-known as one of good fishing grounds of tuna group. The Bay has such an interesting characteristics that its surface-layer current shows, due to effects of seasonal changes of wind directions, a clockwise circulation pattern in spring while it shows a counterclockwise pattern in autumn and the salinity concentration of this layer is extraordinarily low due to enormous volume of water flown into the Bay from huge rivers. (Wyrtki, 1973)

The ecological studies on the tuna group made public in the past are mostly conducted from a viewpoint of their catch distribution in relation to their environmental conditions (UdA, 1960; KawaI, 1969; Sandoval, 1971; Hanamoto, 1975, 1986). For example, UdA (1960) informs that the range of inhabitant temperatures of tuna group is so wide as to be 11.0°C to 32.0°C; Hanamoto (1986) introduces data for inhabitant temperature, salinities, and dissolved oxygen among various ecological factors required for big-eye tuna of the Pacific Ocean indicating that the range of their inhabitant temperatures is so narrow as to be 10°C to 15.0°C, the range of salinities of their inhabitant sphere is from 34.0% to 34.7% in the North Pacific Ocean and 34.5% to 35.5% in the South Pacific Ocean, and the minimum limit of their inhabitant dissolved oxygen is 1.0 mL/l.

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So far the studies mentioned above, the discussions are developed along a very limited number of environmental factors such as water temperatures, salinities, etc. Accordingly, it is afraid that the results of those studies might be fairly deviated from the real state of *in situ* environmental conditions.

In this study, therefore, such optical elements as underwater irradiances and turbidities, which were measured simultaneously with longlining operations in the Bay of Bengal, are added to such conventional items as temperatures, salinities, and dissolved oxygen, so that a step advanced approach to the real state of tunas' environmental conditions can be realized.

2. Method

The surveyed area is a central part of the Bay of Bengal in the Indian Ocean. Fig. 1 shows the distribution of observation stations. At stations numbered 1 to 7, catching experiments and environment measurements were simultaneously conducted, and at Stn. 8, only the latter were carried out.

![Fig. 1. Observation stations in the Bay of Bengal, Indian Ocean](image-url)
The instruments for the measurement of the physical, chemical and optical environment included the CTD with DO sensor, underwater irradiance meter and in situ beam transmittance meter. The measuring accuracy of CTD (Mark IIIB, Neil Brown Co., LTD) was as follows; temperature, ± 0.005°C; conductivity, ± 0.005 mhos; depth, ± 0.1%. In addition, the values of dissolved oxygen were determined from the relationship between the observed and the analyzed values. (Fig. 2)

![Graph showing relationship between observed and analyzed values of dissolved oxygen.](image)

**Fig. 2.** Relationship between the observed and the analyzed values of dissolved oxygen.

The underwater irradiance meter (SR-8 type, Ishikawa Co., LTD) was equipped with eight interference filters with wavelengths of the maximum transmittance: 443, 481, 513, 553, 599, 663, 682 and 709 nm. A beam transmittance meter (XMS type, Martek Co., LTD) with a depth sensor was able to measure beam attenuation (centroid wavelength: 486nm) per meter.

In order to carry out observations of temperature, salinity and dissolved oxygen, a lowering of CTD was continuously made from the surface to a depth of 500 m or 1000 m. To measure irradiance, the meter was lowered at intervals of 10 m, from the surface to 50 m. Also, a beam transmittance meter was simultaneously lowered from the surface to a depth of 100 m. A beam attenuation coefficient was used as an indicator of the turbidity of water.

The tuna longline gear used in the catching experiment was the standard type with six branch lines per basket. As bait for tuna, frozen jack mackerel of which a fork length is 25 cm, was used hooking up a part of the dorsal fin. To evaluate precisely the depth of a branch line hook, the authors used self-recorded depth meter (BS-04 type, Yamauchi Keiki Co., LTD). Each of the three depth meters was hung on the third branch line of the basket, which accounted for an interval of the one quarter of the total number of baskets in the line (Fig. 3). The depth (D) of each hook of a branch line was obtained by the Yoshiwara's expression (1951) as follows:

\[
D = ha + hb + l \left[ 1 + \left( \frac{1}{\cot^2 \phi} \right)^{1/3} \right] - \left( \frac{l}{2} \right)^{1/3} \left( \frac{n}{n} \right)^{1/3} + \left( \frac{\cot^2 \phi}{n} \right)^{1/3}
\]

where ha is length of branch line, hb is length of float line, l is half length of main line per basket, n is number of branch line added to l, j is order of branch line, and \( \phi \) is cross angle between x-axis and tangential line at a supporting point of main line.

The number of baskets used in one operation was 150 at stns. 1 and 2, and 200 at the others. The lines were laid down from 4:00
to 7:30 a.m., and hauled up from 0:30 to 7:00 p.m.

3. Results and Discussion
3-1. Physical and Chemical Factors.

Fig. 4 is a temperature-salinity diagram based on the data collected from stn. 1 to stn. 8. According to the water mass classification of Emery and Meinch (1986), Bengal Bay Water (temperature, 25.0–29.0 °C; salinity, 28.0–35.0‰) is above 500 m in depth, and below that, there is Red Sea Persian Gulf Intermediate Water (temperature, 5.0–14.0 °C; salinity, 35.5–36.8‰). The salinity of the surface seawater of the former water mass changed by the Arabian Sea Water is said to be lower, ranging from 28.0 to 35.0‰.

Figs. 5a and 5b show the vertical distribution of temperature, salinity, and dissolved oxygen at stn. 1 and stn. 8, respectively. The temperature of the surface water at stn. 1 was 28 °C, and decreased sharply with depth between 40 m and 200 m, indicating a form of thermocline. Below the thermocline, the water temperature decreased with depth from 14 °C down to 6 °C at a depth of 1000 m. On the other hand, the surface water temperature at stn. 8 was 26 °C, which was 2 °C lower than that of stn. 1. Under the surface, the vertical distribution of temperature was similar to that of stn. 1.

In terms of the salinity, surface water at stn. 1 was 33.95‰ and increased suddenly at depths from 40 m to 120 m, showing a form of halocline. The depth of halocline coincided roughly with that of the thermocline. Below the halocline, the salinity was 35.0‰, and salinity inversion appeared at a depth of 120 m to 160 m. Below that, it again increased with depth, indicating a value of 36.0 ‰ at a depth of 400 m. Meanwhile, the value of the surface water at stn. 8 was 33.3% less than that of stn. 1. In the vicinity of 40 m deep, halocline was present on a small scale, and below that, it had a tendency to increase with depth the same as that of stn. 1. Yet, the phenomenon of

![Fig. 4. Temperature-salinity diagram. Arrow in the figure means a boundary of each water mass.](image-url)
Fig. 5. Vertical distributions of temperature (T), salinity (S) and dissolved oxygen content (DO) at stn. 1 and stn. 8.

inversion was present at a depth of 150 m.

The dissolved oxygen in the surface water at stn. 1 was about 4.6 ml/l, and at a depth from 40 m to 100 m, changed abruptly in the form of oxycline. At a depth of 120 m, the dissolved oxygen was 1.0 ml/l, and at a depth of 170 m, recorded the minimum value, 0.26 ml/l. Below that depth, the dissolved oxygen increased with depth, and registered 1.3 ml/l at a depth of 1000 m. Such the results of the dissolved oxygen that there are appearance of the minimum layer and an extremely wide range of dissolved oxygen concentration less than 1.0 ml/l correspond to those brought forth by IIIOE (International Indian Ocean Expedition). WYRTKI (1971) reports that this is one of features of dissolved oxygen distribution in the Bay of Bengal. Also, the type of depth distribution at stn. 8 was roughly similar to that of stn. 1. However, one difference was found. It is that the minimum oxygen appeared at a depth of 260 m, which was 100 m deeper than that of stn. 1.

3-2. Optical Factors

Fig. 6 illustrates the depth profiles of downward spectral irradiance at stn. 4 as the representative of measurements. In the figure, the ratio of attenuation became larger according to the band of a short wavelength to a long one. Namely, the percentage of underwater irradiance at a depth of 30 m was 31.9 % for a blue light (481 nm), 22.3% for a green light (553 nm), and 4.03 % for a red light (599 nm), respectively. Also, the values of diffuse attenuation coefficients for downward irradiance were calculated. For instance, at a blue light it was 0.038 m⁻¹, which was about one third of 1.0m⁻¹ (484 nm; HAGA and MATSUKE, 1981) in the northern part of the North Pacific Ocean. According to the optical water mass of JERLOV (1976), this water belongs to the oceanic water type I" and is thought to be very clear.

In next, the depth distribution of water turbidity (beam attenuation coefficient; 486 nm) is shown in Fig. 7. Three stations (stns.
1, 4 and 7) were selected as the representative of measurements. The numerals in the figure increase in proportion to the degrees of turbidity of water. At stn. 1, the values of beam attenuation coefficient was nearly 0.12 m$^{-1}$ at a depth of 0 m to 30 m, and between 40 m and 50 m, it reached the maximum value, 0.19 m$^{-1}$. Below that, it decreased with depth indicating a value of 0.07 m$^{-1}$ at a depth of 100 m. At stn. 4, there was a little variance from the surface to a depth of 80 m, exhibiting ones of 0.13–0.16 m$^{-1}$. At stn. 7, the beam attenuation coefficient was 0.13–0.16 m$^{-1}$ between the surface and a depth of 50 m, which was equivalent to those of stn. 1 above a depth of 40 m. At 70 m deep, it reached the maximum value, 0.18 m$^{-1}$, and below that, it decreased with depth, recording 0.10 m$^{-1}$ at a depth of 90 m. As introduced above, the high-turbidity layer sometimes appears in the turbidity vertical distribution but sometimes does not according to circumstances. Furthermore it is understood that depth of water in which the high turbidity layer is configurated varies with localities.
3-3. Environmental conditions of the tunas’ maneuvering sphere

Prior to discussing the characteristics of tunas’ ecological conditions, it is reasonable to define their maneuvering sphere.

In this sense, a figure of depths in which each tuna was caught by the longlining operations is provided as follows. Fig. 8 represents the catching depths of tuna and billfish by position. Symbols of solid circles, triangles and open circles indicate yellow fin, big-eye and marlin, respectively. From the figure, it can be understood that the range of catching depth is from 38.1 m to 69.0 m. In comparing the catching depth by species, marlin were caught in the shallowest water. Also, Table 1 shows characteristics of catching depth, and the thickness of the catching layer. It is found that the greatest thickness was 24.8 meters at stn. 7, and the least, 8.6 meters at stn. 4. Moreover, thickness of the catching layer changed with operation position, and averaged out to 16.5 meters.

We, authors, assume that the sea layer in which tuna were caught in the Bay of Bengal is a fairly good approximation with the tunas’ maneuvering sphere. Because, as explained in the preceding paragraph, the minimum oxygen layer appears in the surveyed sea regions and the layer of oxygen concentration less than 1.0 ml/l, which is the minimum quantity required for supporting tuna’s life (Hanamoto, 1986), is extended from 120 m to 800 m deep. Judging from these outcomes together with the findings of Wyrtyki (1973), the said assumption can be reasonably justified.

Figs. 9, 10 and 11 show the depth distributions of temperatures, salinity and dissolved oxygen at each station, respectively. The dotted zones in the figures indicate the extent of the maneuvering sphere mentioned above. The temperature of the water within the maneuvering sphere ranged from 25.5 °C to 27.5 °C, and decreased toward the north.

UDA (1960) reported that the water temperature inhabitable for tuna ranged from 11 °C to 32 °C. In the present paper, measurements were in the higher part of temperature range reported by UDA (1960). Moreover, the location of the maneuvering sphere was just above or the upper part of the thermocline. This finding differed from those of Suda et al. (1969) and Hanamoto (1975). They found that the catching depth of tuna was within the thermocline or below that level. Salinity within the maneuvering sphere ranged from 33.00% to 34.45 %, and decreased toward a northerly direction. These values are more smaller than 34.0–34.7% for big-eye tuna in the North Pacific Ocean, which Hanamoto (1986)

![Fig. 8. Catching depth of tuna and billfish.
Open circles, solid ones and triangles mean marlin, yellow fin and big-eye tuna, respectively.](image)

<table>
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<th>Table 1. Characteristics of catching layer.</th>
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obtained from inhabitable water temperature, using T-S curves. Dissolved oxygen in the water of maneuvering sphere varied from 3.0 to 4.6 ml/l. Our values are about three to four times as much as that of Hanamoto (1986). According to Hanamoto (1986),

**Fig. 9.** Vertical distributions of temperature from 0 m to 130 m in depth. Shadow zone denotes the tunas’ maneuvering sphere.

**Fig. 10.** Vertical distributions of salinity from 0 m to 130 m in depth. Shadow zone is shown as in Fig. 9.
in situ measurements of dissolved oxygen inhabitable for tuna have never been conducted before. Therefore, these values are considered to be very important. Also, the maneuvering sphere was positioned just above or at the upper part of oxycline, as was observed at the thermocline and halocline.

With respect to a state of optical environment, Table 2 shows the relative values of downward irradiance by wavelength, and those of total light at the maneuvering sphere. In the table, it can be seen that the energy of the blue light was the greatest of them. On the other hand, the percentage of total light was 8.2 % at a depth of 38 m, and 22.2 % at a depth of 69 m. The ratio of attenuation on total light were almost equivalent to those of green light.

Fig. 12 illustrates the depth profiles of turbidity (beam attenuation coefficient) at each station. The dotted zone in the figure indicates the extent of the maneuvering sphere. Beam attenuation coefficients within that sphere ranged from 0.11 to 0.22 m$^{-1}$ (486 nm). The highest recorded was double that of the Kuroshio area (Matsuike and Morinaga, 1977). In addition, the location of the maneuvering sphere was just above or within the high turbidity layer. This might be related to migratory path for tuna's food-searching.

Finally, let us discuss the maneuvering sphere of tuna in relation to the distribution of dissolved oxygen. Yamazaki (1966) reported that the catching depth of tuna changed according to the location of a fishing ground. For instance, big-eye tuna in the Indian Ocean (except the Bay of Bengal) was
Fig. 12. Vertical distributions of water turbidity. Shadow zone is shown as in Figs. 9, 10 and 11.

Fig. 13. Vertical profile of dissolved oxygen from 0 m to 250 m in depth. Shadow zone is shown as in Figs. 9, 10, 11 and 12.

catched at a depth of 300 m (YAMANAKA, 1966), and as for southern bluefin tuna, at a depth of 350 m (SHIBATA and NISHIMURA, 1969). Also, in the Solomon Islands in the
Pacific, the layer of yellowfin was at a depth of 40 m to 120 m (YAMANAKA and KUROHIJI, 1966), and albacore was at a depth of 90 m to 150 m in the Ogasawara Islands (YAMANAKA, 1966). Compared with the depths mentioned above, it is clear that the maneuvering sphere in the Bay of Bengal generally situated in shallower waters.

The dissolved oxygen in the water is considered to be a very important factor for survival of pelagic fish. For big-eye tuna, the dissolved oxygen minimum content must be 1.0 ml/l for survival (HANAMOTO, 1986), and for skipjack tuna, 3.5 ml/l along a migratory path (INGHAM et al., 1977), and for yellowtail, 3.0 ml/l for swimming in an enclosure (YANAGI, 1986), respectively. Fig. 13 shows the vertical profile of dissolved oxygen content from the surface to a depth of 250 m in the Bay of Bengal. The dotted zone in the figure indicates the maneuvering sphere. As seen in the figure, it is understood that the minimum oxygen (content: <0.25 ml/l) appears at a depth of 150 m to 250 m. Moreover, a value of 1.0 ml/l (HANAMOTO, 1986) is observed at a depth of 100 m, and that of 3.0 ml/l (YANAGI, 1986), at depths from 60 m to 80 m. Accordingly, the vertical situation of the maneuvering sphere is said to be influenced by distribution of dissolved oxygen content. In particular, the reason why the lower part of the layer was shallow is that the dissolved oxygen minimum layer appeared in the subsurface layer of the ocean.

Acknowledgements
The authors express their sincere thanks to Dr. K. Matsuike, Professor of Tokyo Univ. of Fisheries for his valuable comments on this paper. Also, thanks are due to Prof. K. Inoue, Captain of the T/S Shinyo-maru of Tokyo Univ. of Fish., and the crews for their support during the catching experiment.

This study was partially supported by a grant from scientific research of the Ministry of Education, Japan (No. 02454078).

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SUDA, A. S. KUMA, and T. SHIOHAMA (1969): An indicative note on a role of
ベンガル湾におけるまぐろ・かじき類の環境条件

森永 勤・今関昭博・武田誠一・荒川久幸

要旨：インド洋・ベンガル湾のまぐろ・かじき類の環境条件を把握する目的で、1987年2月東京水産大学研究練習船神鷹丸において、従来の環境要素（水温・塩分・溶存酸素）に光学要素（水中照度・観測）を加えた観測を延続観探試験と同時に実施した。

釣獲水深（38mから89mまでの範囲）を生息領域とみなして環境条件を求めると、各値は次の通りであった：水温、25.0～27.5℃；塩分、33.00～34.45％；溶存酸素量、3.0～4.6ml/1；相対照度（全光）、8.2～2.2％；濃度（光束消散係数）、0.11～0.22m⁻¹（486nm）。又、生息領域の船底位置は水温・塩分・溶存酸素の場合では各観測の直上あるいは上層部に、濃度の場合では高濃度層の直上あるいは中層にそれぞれあった。これらの結果に基づくと、ベンガル湾における生息領域では下層部の水深が世界の魚種に比較して最も浅く、酸素極小層の亜表層への出現に影響されていると考えられる。
Oceanic structure in the vicinity of a seamount, the Daini Kinan Kaizan, south of Japan*

Yoshihiko Sekine** and Tatsuya Hayashi**

Abstract: The hydrographic observations in the vicinity of a seamount, the Daini Kinan Kaizan, south of Japan have been carried out three times in summer of 1989 and 1990. It is suggested that a pattern with weak downward shift of isotherms and isohalines in the eastern side above the top of the seamount and upward shift of them just above the top of the seamount are maintained more than ten days. Vertical displacement of isotherms and isohalines at depths below the top of the seamount was always observed over the flank of the seamount. In relation to this water structure, prominent geostrophic flow with large vertical difference existed in the deep water below 1000 m. This suggests that topographic effect of the seamount is confined to depths with large vertical geostrophic shear and to greater depths. Micro-structures were observed over the seamount. In particular, a remarkable vertical temperature inversion with zonally coherent structure over the top of the seamount was observed in the first cruise made in July 1990.

1. Introduction

The interaction of ocean currents with seamounts has been of interest to oceanographers (e.g., Hogg, 1980; Roden, 1987). As oceanic condition of seamounts may be different in localities, hydrographic observations should be made for each of seamounts. The present study is directed toward oceanic conditions in relation to circulation over the Daini Kinan Kaizan south of Japan.

The Daini Kinan Kaizan locates in a central region of the Shikoku Basin (Fig. 1) and has an elliptic shape with a longer axis form southeast to northwest. The top of this seamount is at a depth of 670 m. Up to this time, few observations have been carried out focusing on the topographic effects of the Daini Kinan Kaizan. Konaga et al. (1980) observed that the detached cold eddy from the large meander of the Kuroshio, Harukaze, (cf. Konaga and Nishiyama, 1978) has a tendency to stay over this seamount. As the main axis of the Kuroshio passes over or near the seamount when it meanders, it is suggested that this seamount has a material topographic effect on the dynamics of large meander path of the Kuroshio.

We have observed temperature and salinity fields in the vicinity of the Daini Kinan Kaizan three times in summer (Table 1). In the following, details of the three observations and some noteworthy results are shown.

<table>
<thead>
<tr>
<th>Cruise Name</th>
<th>Periods of observation</th>
<th>Main instruments</th>
<th>Stations</th>
</tr>
</thead>
<tbody>
<tr>
<td>KS-89JUL</td>
<td>17 Jul. 1989</td>
<td>CTD, ADCP</td>
<td>Fig. 2-a</td>
</tr>
<tr>
<td>KS-90JUL</td>
<td>15 Jul. 1990</td>
<td>Mi-com. BT</td>
<td>Fig. 2-b</td>
</tr>
<tr>
<td>KS-90JUL2</td>
<td>24-25 Jul. 1990</td>
<td>CTD, ADCP</td>
<td>Fig. 2-b</td>
</tr>
</tbody>
</table>

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2. Observations

The hydrographic observations by CTD were carried out for three times by use of the Training Vessel Seisui-maru of Mie University (Table 1). The locations of the observational points for each cruise are shown in Fig. 2. Unfortunately, because the trouble of CTD system occurred in the second cruise, the micro-computer BT (mi-com. BT) was used for the stations 1 to 8 shown...
in Fig. 2b. The current measurements by acoustic doppler current profiler (ADCP) were carried out for three depths, 50 m, 100 m, and 150 m. CTD of the upper 700 db layer at station 1 of cruise KS-89JUL1 and ADCP current data at mid-point between stations 7 and 8 of KS-90JUL2 had been lost by miss in data processing.

Here, we refer to the location of the main axis of the Kuroshio during the three cruises. Fig. 3 shows the main axis of the Kuroshio during three observational periods presented by Maritime Safety Agency. For the first cruise made in July 1989, which is hereafter referred to as KS-89JUL, no meander path was formed and the distance of this seamount from the main axis of the Kuroshio was relatively large. However, a large meander path was formed in winter of 1989 and the large meander path existed in the period of last two cruises made in July 1990, in which the main axis of the Kuroshio approached this seamount.

3. Results

The vertical distributions of temperature, salinity and density ($\sigma_z$) along two observational lines of the Cruise KS-89JUL are shown in Fig. 4. A seasonal thermocline with less saline water was formed in a surface layer shallower than 50 m. No remarkable vertical change in isotherms and isohalines are detected over the top of the seamount, of which detailed structure is unclear by the coarse distribution of observational points. However, vertical displacement of the isotherms was observed at depths below the top of the seamount. The vertical displacement has been also detected around other seamounts near the Daini Kinan Kaizan: the Tosa-bae off Shikoku (Yoshiooka et al., 1986; Sekine and Matsuda, 1987) and the Komahashi Daini Kaizan locating at the northern end of the Kyushu-Parau Ridge (Sekine and Sato, 1993). The gradient changes at a depth from 1700–1900 db: upward (downward) shift was observed in southeastward (northwestward) in water shallower than 1700 db, while a definite upward (downward) shift existed in northwestward (southeastward) in water deeper than 1900 db.

The salinity minimum layer was observed at depths just above the top of the seamount. Because of the gradient of
Fig. 4. Temperature, salinity and density ($\sigma_T$) sections of the Cruise KS-89JUL. (a) Meridional section and (b) zonal section. The locations of the observational points are shown on the top.
isohalines, less saline water than 34.5 PSU existed over the flank of the seamount at depths of 800-1500 db. Similar vertical structures to isotherms were observed also for isohalines in deeper layer than 1800 db. The vertical displacement of isopycnal was also found in the greater depths, which suggests the existence of prominent geostrophic flow in the greater depths. Then, a geostrophic flow along the meridional section is displayed in Fig. 5. Here, owing to the difference in depth of each observational point, the reference level is assumed to be 750 db. Although absolute current velocity cannot be obtained from the present analysis, the gradient of isopycnals yields a large vertical difference in geostrophic flow more than 20 cm s$^{-1}$ between 750 db and 1500 db in the south of the seamount. This prominent vertical change in geostrophic flow suggests that a topographic effect of this seamount.

Fig. 5. Geostrophic flow (in cm s$^{-1}$) along the meridional section of KS-89JUL. The reference level is 750 db. Positive (negative) values show eastward (westward) flow. The regions with westward flow are shown by oblique lines.

Fig. 6. Zonal temperature section of KS-90JUL. Sectional areas with vertical inversion of temperature are shown by regions with vertical lines.
is confined to a relatively thin layer below the main thermocline.

The vertical temperature section observed in the Cruise KS-90JUL1 is shown in Fig. 6. As the observations were carried out in closer spacing than the previous one, KS-89JUL1, many vertical unevenness in isotherms were detected: downward shift of the isotherms existed at depths of 450-600 m to the east of the top of the seamount and upward shift was found at depths of 650-800 m to the west. Complex upward and downward shifts were detected below 700 m. The some temperature inversions were observed at depths of 720-830 m. These temperature inversions are considered as micro-structures formed over the seamount. Upward shift of the isotherm of 6°C is found just above the top of seamount.

To examine the temperature fields more closely, vertical profiles at eight stations are shown in Fig. 7. It is shown that noticeable temperature inversions found at depths from 710 m to 750 m have a zonally coherent structure. Below these inversions, other weak inversions are detected at depths of 790-820 m. Zonally coherent temperature inversions are considered to be due to the interleaving of warmer water.

The results of the cruise KS-90JUL2 are shown in Fig. 8. Similar vertical temperature structure to that found during the previous cruise KS-90JUL1 (Fig. 6) was observed over the seamount: deepening of isotherms are found in the east of the seamount at depths 400-650 db. This isotherm deepening, which seems to be the same as during the KS-90JUL1, must be maintained more than ten days, it is rather stable over the seamount. Upward shifts of the isotherm and isohaline just above the top of the seamount are also detected. At depth below the top of the seamount, a distinctive upward displacement of isotherms and isohalines were observed over the eastern flank of the seamount. This vertically coherent displacement may reveal

Fig. 7. Vertical change in temperature of the Cruise KS-90JUL1. Station numbers are given at the bottom.
the upwelling of deep water along the slope. Density fields are quite similar patterns to temperature fields. The geostrophic flow referred to 750 db is shown in Fig. 9. Because of the uplift of isopycnal, a large northward geostrophic flow with vertical velocity difference of 30 cm s\(^{-1}\) between at depths of 1000 db and 1300 db existed between two stations 5 and 6. Furthermore, southward flow between stations 6 and 7 had a vertical flow difference of 60 cm s\(^{-1}\) between at depths of 1100 db and 1800 db. This large vertical geostrophic difference in deeper water agrees with the results of the cruise KS-89JUL. It is suggested that there exists a strong current in the deep water around the seamount.

To make sure of validity of the reference level and to examine the geostrophic balance in the surface layer shallower than 150 db, in which ADCP current data were obtained, correlations between the geostrophic flow and the velocity by ADCP is shown in Fig. 10. Here, vertical differences of the northward velocities between 50 db and 100 db and those between 100 db and 150 db are compared. It is shown that no clear positive correlation is found for both the cases. A weak negative correlation (−0.41) is found for the latter case. Because of a geostrophic flow in the ADCP data, we are not able to estimate the reference level by adjusting the geostrophic velocities to those of ADCP.

4. Summary and discussion
The hydrographic observations in the
The observations are summarized as follows.

1. During the first cruise (KS-89JUL1), a weak undulation of isotherms and isohalines was observed in the upper 500 db layer; however, vertically coherent temperature and salinity gradients were observed over the flank of the seamount.

2. As for the second cruise (KS-90JUL1), weak downward shift of isotherms at depths of 450–600 m in the east of the seamount, upward shift of isotherms just above of the seamount and complicated vertical temperature structure below 800 m were observed. Micro-structures of temperature with zonally coherent inversions were detected at a depth of 730 m.

3. As for the third cruise (KS-90JUL2), similar temperature distribution to that of KS-90JUL1 was observed in depths above 1000 db. So, this temperature pattern must have continued more than 10 days; this temperature structure is considered to be stable near the seamount. Furthermore, a distinct shallowing of the isotherms and isohalines were observed in the east of the seamount.

4. In the east of the seamount, the horizontal gradient of isopycnals suggests that a remarkable geostrophic flow with large vertical shear existed in depths greater than the top of the seamount during cruises of KS-89JUL and KS-90JUL2.

5. The vertical difference in the geostrophic velocity shows no clear correlation with those of the ADCP in the surface water within 150 db. Since this suggests that ageostrophic flow is included in the current obtained by ADCP, the ADCP current data are not useful for estimation of the reference level of the geostrophic calculation.

The oceanic conditions around this seamount must be influenced by the seasonal variation and also by Kuroshio paths. It should be noted that no clear correlation between the geostrophic velocities and those of ADCP offers a serious problem in the current observation: ADCP data do not give the information for reference level of geostrophic calculation. Long term direct
current measurements which are able to exclude ageostrophic component are needed to obtain the real velocity fields around this seamount.

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日本の第二紀南海山周辺の海洋観測

関根 義彦・林 昌哉

要旨：日本南岸にある第二紀南海山周辺の海洋観測を1989年夏、1990年夏に計3回行った。その結果、海山頂以浅では海山東に等温度線と等塩分線の下降があり、海山直上でそれらの上昇を伴うパターンが10日以上維持されることが示唆された。また海山周囲の頂上以深の斜面上では等温度線と等塩分線の鉛直変位が共通して認められた。この鉛直変位により、1000m以深の深層で地衡流が顕著な鉛直シャーを伴い、海山の地形効果による鉛直のシアーが限界深に達すべきが示唆された。また、海山の頂直上では微細な構造が認められた。特に水平方向に同様な構造を持つ水温の逆転付け1990年7月の1回目の航海で観測された。
Characteristics of ciliated protozoa inhabiting colonies of pelagic blue-green algae

Masachika MAEDA**, Miki SUHAMA**, Nobuo TAGA**
and Ryuzo MARUMO**

Abstract: Ciliated protozoa were isolated from the blue green alga Trichodesmium thiebautii which is ubiquitous and often abundant in surface seawater of the pelagic sea. Through protargol impregnation, nuclear staining and observations of the living cells, the morphological characteristics of the protist were determined and this ciliate was identified as Holosticha diademata (Rees, 1884) Kahl, 1932. This ciliate was frequently found in the coastal seawater which suggests the wide distribution of a certain species of protozoa in the coastal and pelagic sea. This species preferentially fed on bacterial strains of Pseudomonas spp. when several genera of bacteria were offered as feed.

1. Introduction

In the course of our research on bacterial biomass in seawater, bacterial carbon was determined to occupy several tens of per cent of particulate organic carbon even within the euphotic zone of the seawater column (Maeda and Taga, 1979; Maeda, 1982). As a result of this research, bacterial carbon is now considered to be one of the largest energy sources in the sea. Williams (1981) also mentioned the significantly large biomass of bacteria in the sea. There have been several reports describing small animals which feed on bacteria (Paffenhöfer and Strickland, 1970; Heinle et al., 1977; King et al., 1980; Maeda, 1989). A large portion of ciliated protozoa are also known to be bacteria feeders (Webb, 1956; Fenichel, 1968; Taylor and Berger, 1976; Alonso et al., 1981; Maeda and Carey, 1985; Maeda, 1986) and the existence of energy transfer from bacteria to animals through ciliates was conclusively established in the laboratory (Seki, 1966; Tezuka, 1974). Thus the role of bacteria as food seems to be substantial and ciliates are probably one of the key animals in the process of food transfer in the marine ecosystem. From this point of view we have been interested in investigating the ecological aspects of ciliates in the marine environment.

In this report we describe the taxonomical characteristics of ciliated protozoa attached to suspended colonies of the blue green alga Trichodesmium thiebautii in the South China Sea. Bacterial strains which coexisted in the ciliate culture were also identified and their availability as feed for the ciliates was determined.

2. Materials and methods

Sampling

Trichodesmium colonies were collected using a plankton net with a mesh size of 330 μm in the southern area of the South China Sea during the cruise of R/V Hakuho-maru...
in November, 1981. Coastal seawater were collected with a small glass bottle at Aburatsubo Inlet, Japan. Trichodesmium colonies were picked up with sterilized pipettes and kept in sterilized seawater for subsequent isolation or examination of the ciliates attached to them.

Isolation of ciliated protozoa

Ciliates attached to Trichodesmium thiebautii were isolated using a micropipette under a binocular microscope (magnification, ×45). Isolated ciliates were placed into a medium which contained the following components (g·l⁻¹ seawater): Proteose peptone (Difco), 0.02; Triptase (Sigma), 0.02; Bacto yeast extract (Difco), 0.02; ribonucleic acid (Sigma), 0.002; Bacto agar (Difco), 15 and extract of cerophyl leaves (Sigma), 2 ml/l (that is, 5 g of cerophyl leaves was boiled with 1 litre of distilled water for 5 min. and the supernatant after filtration with Toyo filter paper (Type 1) was used.). Ten ml of this agar medium was put into a 200 ml of flask and 10 ml of sterilized seawater was placed on top of the agar after solidification. The ciliate cultures were kept at 25 °C.

Identification of ciliates

The species of ciliate was identified by the protargol impregnation technique (Tuffrau, 1967) and the Feulgen nuclear reaction for examining cirri and nuclei, respectively.

Isolation and identification of bacteria

Bacteria were isolated from seawater in situ and from the cultivation bottle for ciliates and were cultured on the same agar medium described above. The isolated bacteria were identified according to the scheme of Shewan et al. (1969). The vibriostatic compound 0/129 (2, 4-diamino-6, 7-diisopropylpteridine) was not used to distinguish Vibrio from Aeromonas. Their discrimination was made on the basis of gas production from glucose. A few Gram-negative, oxidase-negative rods with polar flagella were assigned to Vibrio or Aeromonas but not to Enterobacteriaceae. The mode of glucose metabolism of the isolates was determined using the Hugh-Leifson's medium (Hugh and Leifson, 1953) made with artificial seawater instead of freshwater.

Response of ciliates to bacteria

Ten freshly cultured ciliates were washed three times in sterilized seawater for 24 hrs and placed in a small Petri dishes (27 mm diameter) with seawater. The bacterial strains used as feed for the ciliates were washed with sterilized seawater by centrifugation after cultivating for two days and were added at the concentration of 10⁴ cells/ml to the Petri dishes containing the ciliate. The Petri dishes were placed in the wet chamber at 25 °C and ciliate numbers were determined under the binocular microscope.

3. Results

Fig. 1 shows a colony of Trichodesmium thiebautii. Ciliates of the order Hypotrichida were found among the Trichodesmium colony and these ciliates were isolated and investigated in this work.

Protargol staining shows the arrangement of cirri in the dorsal, ventral and caudal zones of the ciliate cell (Fig. 2). Three frontal cirri and pairs of ventral cirri with zig-zag shape were the characteristic features

Fig. 1. A colony of the blue green algae Trichodesmium thiebautii.
of this ciliate. Nuclear staining revealed two macronuclei and 4 micro-nuclei (Fig. 3). Based on these observations and direct observations of the living cells, taxonomical characteristics of the ciliate are summarized diagrammatically in Fig. 4. Further characteristics of this protist are as follows. Size around 80 × 30 μm. Body flat dorsally, rounded at ends. Membranelles of adoral zone (AZM) 19–26, 2 frontal cirri, about 11 left and 10 right marginal cirri. Transverse cirri around 7 and pairs of ventral cirri with zig-zag shape about 8. Bend of the anterior end of the left marginal cirrus row and a marine habitat. We identified this ciliate as *Holisticha diademata* (Rees, 1884) Kah., 1932, although the number of AZM was slightly different from that reported by Borror (1963). The same species was also found frequently on zooplankton detritus in coastal waters of Japan, such as Aburatsubo Inlet.

Bacterial strains isolated from the agar-seawater medium bottle of *Holisticha diademata* were all *Pseudomonas* spp. Among 9 bacteria isolated, *H. diademata* could be grown with 3 of these bacterial strains as feed, and amongst these strains the Strain No. 7 supported the maximum growth of ciliates during 5 days incubation (Table 1). Among the strains of *Pseudomonas*, *Vibrio*, *Acinetobacter* and *Flavobac-
4. Discussion

The blue green alga *Trichodesmium* is ubiquitous and frequently abundant in sub-equatorial sea areas. It occurs at and/or slightly below the surface water layer and cells (size: 5–10 μm) are linked to each other in strings. The strings form coagulates resulting in colonies which are often large enough to be visible. *Trichodesmium* frequently blooms in the South China Sea and this prominent productive algae which occurs in oligotrophic environments provides a habitat for various microorganisms.

Borrór (1963) reported the distribution of *Holosticha diademata* in the sediment of a salt marsh. We found this species frequently on detritus in coastal seawater in

| Table 1. Bacteria isolated from culture liquid of *Holosticha diademata* and growth of the ciliate in their presence |
| --- | --- | --- |
| Strain No. | Bacterial genus | Growth of *Holosticha* |
| HPP 4 | *Pseudomonas* | + |
| HPP 5 | *Pseudomonas* | ++ |
| HPP 7 | *Pseudomonas* | ++ |
| HPP 8 | *Pseudomonas* | - |
| HPP 13 | *Pseudomonas* | - |
| HPP 15 | *Pseudomonas* | - |
| HPP 20 | *Pseudomonas* | - |

+ : numbers of the ciliate less than 50 cells/cm²
++ : numbers of the ciliate more than 50 cells/cm²
± : little identifiable growth of the ciliate
- : no growth of the ciliate

(*) Numbers of *H. diademata* was expressed as the unit of cells/cm² because this ciliate tended to stay on the bottom of the culture container.

| Table 2. Bacteria isolated from coastal seawater and the growth of *Holosticha diademata* in their presence |
| --- | --- | --- |
| Strain No. | Bacterial genus | Growth of *Holosticha* |
| HPO 1 | *Vibrio* | - |
| HPO 2 | *Vibrio* | - |
| HPO 3 | *Pseudomonas* | - |
| HPO 6 | *Pseudomonas* | + |
| HPO 7 | *Vibrio* | - |
| HPO 8 | *Pseudomonas* | ± |
| HPO 15 | *Pseudomonas* | ++ |
| HPO 16 | *Acinetobacter* | ± |
| HPO 17 | *Acinetobacter* | - |
| HPO 19 | *Pseudomonas* | - |
| HPO 62 | *Flavobacterium* | - |

(Notations are same as those in Table 1.)
eutrophic areas, as well as in pelagic environments. The occurrence of the same species of ciliate in both pelagic and coastal areas seems to suggest that even in oligotrophic areas the potential extent of biological productivity might be high in microbial communities. Thus high productivity of ciliates was attributed by the bloom of *Trichodesmium*.

*H. diademata* fed preferentially on *Pseudomonas* strains of bacteria. Although the reasons for the unsuitability of some bacteria as ciliate food are still not clear from this study, feeding specificity may also provide a mechanism for niche partitioning among cohabiting bactovirous ciliates in the natural environment, as spatial distribution and temporal succession of ciliates can be explained by prey specificity (Noland, 1955; Coler and Gunner, 1969; Taylor and Berger, 1976).

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References


外洋水域の藍藻より分離した原生動物繊毛虫の特徴

前田昌調・洲浜幹雄・多賀信夫・丸茂隆三

南シナ海より採取した藍藻, *Trichodesmium thiebaudii* に付着している原生動物繊毛虫を分離した。プロタール色素, 核染色, および生体観察の結果, この繊毛虫は*Horovista diademata* (Rees, 1884) Kahl, 1932と同定された。この種類は沿岸域海水中にも多く, 今回の分離により, 海洋における原生動物同一種の広範な分布が示唆された。餌料として, いくつかの細菌種を投与したところ, 本繊毛虫は, *Pseudomonas* 属の細菌の存在下において, よく増殖することが明らかとなった。
The 1985 Chilean tsunami around Osaka Bay

Shigeihisa Nakamura

Abstract: The 1985 Chilean tsunami is studied for getting an helpful key of preparedness to a forthcoming coastal hazard. First a notice is given about the specific pattern of the 1985 Chilean tsunami along the Pacific coast of the South America. Its transoceanic pattern, especially around Osaka Bay in the northwestern Pacific, is considered to discuss a possible process at establishing resonant modes in Osaka Bay and Kii Channel after the tsunami arrival.

Energetics of the 1985 tsunami helps to estimate the tsunami energy at the source area and the seismic release of the energy at the event even under a bold assumption. The 1985 event is quite similar to that of the 1960 event in the pattern around Osaka Bay. The 1985 event could be useful at establishing an advanced warning system and protection works for the forthcoming hazardous event.

1. 緒 言
北太平洋西部における1985年チリ津波については、すでに、羽鳥がその状況を記している（羽鳥, 1985）。また、中村（1991）は、南米太平洋沿岸および近畿地方沿岸の検討記録にみられた津波について記している。

過去において、太平洋を横断して日本列島太平洋沿岸に被害をもたらした津波については、たとえば、波辺（1985）の年表がある。なかでも、1960年チリ津波の日本列島沿岸への影響は特に顕著であった（たとえば、高橋, 1961）。このようなことから、1985年チリ津波についての検討とそこから新しくわかったことを本文で述べることとしたい。もちろん、1960年チリ津波との対比も試みてみる。これによって、大阪湾周辺で、チリ津波によって誘起された固定発電のパターンとそこから配分された津波のエネルギーの推定やそれに関連した諸問題についての知見が得られる。

2. チリ津波の危険性
日本列島は、過去において、何回も、南米沖地震津波によって被害をうけている（たとえば、中村, 1988）。その危険度は、東太平洋の津波発生確率としてとらえることも考えられる（NAKAMURA, 1996）。また、地震津波の発生を、惑星地球の問題として検討した例（NAKAMURA, 1990）もある。いずれにしても、南米沖津波は、東太平洋の沿岸域でののみでなく、太平洋北西部の沿岸域でも同様であることはない。

それによって、大阪湾周辺で、チリ津波によって誘起された固定発電のパターンとそこから配分された津波のエネルギーの推定やそれに関連した諸問題についての知見が得られる。

3. 南米における1985年チリ津波の特徴
これまでに、日本では、1960年チリ津波の記録や被害についての詳細な報告がなされている（高橋, 1961）。近年、1990年チリ津波の地震シミュレーションも試みられたようである。しかし、日本国内では、この
1960年チリ津波の南米沿岸における特徴については何も語られていない。

ところで、1985年チリ津波については、チリ海軍の協力によって、南米沿岸の記録や資料が提供されている（中村, 1992）。ちなみに、チリ沿岸のFig.1に示した7検潮所における1985年チリ津波の記録はFig.2のようにになっている。このFig.2の図中の×印は震央の概位を示す。また、津波の最大波高は、Valparaiso（33.0°S, 71.6°W）で1.15m、Talcahuano（36.5°S, 73.0°W）では3mであった。津波伝播の沿岸の特徴は、定性的にみて、中村（1989）が考えたケ

Fig.1. The 1985 Chilean tsunami along the Pacific coast of the South America.
(a) Stations: Arica as ARI, Iquique as IQU, Antofagasta as ANT, Caldera as CAL, Coquimbo as COQ, Valparaiso as VAL and Talcahuano as TAL.
(b) Vertical height scale as a stick of one metre.
(c) Local time (Z+4) at the top and Universal time Z at the bottom.
(d) Each arrow marking the first tsunami crest.

Fig.2．Location of the tide stations along the Chilean coast.

ルビン波型津波としてとらえることができるかもしれない。

ちなみに、1960年チリ津波で、すべての記録で、津波があまりにも巨大で、スケールアウトしたおそらく無事なとは思えない。

4. 近隣地方における1985年チリ津波の特徴

近隣地方で、この1985年チリ津波はとらえられているであろうか。

1960年チリ津波（高橋, 1961）の例などからみれば、チリ沖で発生した地震津波は、ハワイ諸島を経て、地震後約24時間経過した後に日本列島太平洋沿岸に到達するものとみられる。このような過去の資料と記録を参考にして、さらに、1985年チリ津波を含む検潮記録を利用して検討をすすめる。

1985年3月18日のチリ津波についての資料は、当時の神戸海岸気象台の周東健二によって利用可能となったが、近隣地方で津波による被害がなかったことや検潮記録からチリ津波到達の判断が容易でなかったことなどで、とくに、重要視されることなく、現在に至っている。ちなみに、Fig.3に示すような近隣地方の9検潮所における津波の記録は、Fig.4のようにになる。

ここで、簡単のために、線型波として津波をとらえ、
Fig. 3 Location of the tide stations around Osaka Bay in the northwest Pacific.
(a) Stations: Muroto as MUR, Komatsuji as KOM, Sumoto as SUM, Kobe as KOB, Osaka as OSA, Tannowa as TAN, Wakayama as WAK, Shirahama as SIR, and Kushimoto as KUS.
(b) Scales bar for 100 km.
(c) Inset showing the location of Japan, Hawaii and South America with a mark for Valparaíso.

Fig. 4 The 1985 Chilean tsunami recorded at the tide stations around Osaka Bay in the northwest Pacific.
(a) Vertical height scaling by a stick for one metre.
(b) Local time (Z-9) at the top and Universal time Z at the bottom.
期とする振幅約10cmの水位変動が明瞭になる。水位変動の記録を、大阪（OSA）、神戸（KOB）、洲本（SUM）、淡路（TAN）についてみると、この周期的水位変動は、大阪湾口付近を基とし、大阪湾奥を廻るとする固有振動で、いわば、大阪湾の単調湾水振動である。このことから、この単調湾水振動は、チリ津波によって誘起され、振幅最大時には、大阪湾奥では、$E_0$がゼロであるから、概略

$$E = E_0 = 1.2 \times 10^6 \text{erg}$$

(3)

ということになる。大阪湾口付近では、$E_0$がゼロに近い値となり、

$$E = E_0$$

(4)

と考えてよいだろう。

つぎに、紀伊川水によるもの。大阪湾について考えたときと同様にして、和歌山では$E_0 = 1.5 \times 10^6 \text{erg}$程度、小松島では$10^7 \text{erg}$程度と推定される。ここで、Fig.4の水位変動のうち和歌山（WAK）と小松島（KOM）の水位変動は、約30分の周期的変動で、両者互に位相が180°ずれていることがわかる。これは、紀伊川水道内には、単調振動が生じていることを示唆している。同時に、大阪と和歌山とでは振動の位相が互いに位相が180°程度ずれていることもFig.4からわかる。

したがって、和歌山では、$E_0 = 1.5 \times 10^6 \text{erg}$程度と推定される。しかし、白浜（SIR）の水位変動をみると、これは、和歌山に対して位相が180°ずれている。白浜の$E_0$の値は、およそ$8 \times 10^7 \text{erg}$と推定される。これは、日の岬と蒲生田岬とを結ぶ線の近くを基とする紀伊川水のたて振動と解釈することもできる。

中村（1991）は、Fig.5に示すような推定固定点としての白浜海浜観測塔の水温・塩分の連続記録をもあわせて検討した。当時の海上風や海況から判断して、白浜に津波が到達したのは、およそ1985年3月5日8時30分JSTと推定している。白浜（KUS）および室戸岬（MUR）では、地域的な水位変動にまぎれて、津波到達の判別が難しい。

以上のことから、チリ津波が侵入して、大阪湾および紀伊水道での固有振動が誘起され、その判別ができないようなになるまでに、2 - 3時間要していると考えて差支えないとだろう。この2 - 3時間は、津波が反射して、津波のエネルギーが固有振動のエネルギーにおきかえるために要したものと考えられる。しかし、ここで考えたエネルギー変換の力学的機構が現在のところ明らかであるとは考え難い。

5. 津波域の津波エネルギーの推定

ここで、1985年チリ津波の波源域の津波エネルギー
E_rを推定してみる。簡便な方法（たとえば、矢野、1971）として、

\[ E_r = \rho g R C S H T \quad (5) \]

を用いる。概略の値をもとめる目的とするため、

海水密度は近似的に \( \rho = 1 \, \text{g/cm}^3 \) とし、重力加速度

は \( g = 980 \, \text{cm/sec}^2 \) とする。水深 \( h \) ならびに、津波

の速さは \( c = (gh)^{1/2} \) とみてよい。また、\( R \) は津波源

の中心からの半径。\( T \) は波の周期である。

チリ海噴の資料（中村、1991）によれば、1985年3

月3日12時46分54秒GMT（UT）にチリ中部の強い

地震があった。震央は、概略、Valparaiso冲14海里

（約30km）西方であり、地震のマグニチュードは7.7

（リヒターのスケール）であった。

ここで、その付近の水深 \( h \) に対する \( c \) の値を200m

/secとし、\( R \) は約30kmとする。震央と最も近い海岸

域での最大波高を対象として、\( H = 1 \) mとし、波の周

期 \( T = 140 \, \text{m/sec} \) とする。このとき、\( E_r \) の値は、概略、

\[ 3 \times 10^{11} \, \text{erg} \] とみてよいだろう。また、矢野（1971）

の資料を通じて、ここでの、地震のエネルギーの約

\[ 10^{-1} \] 倍が津波のエネルギーになるものと考えることに

すると、1985年チリ津波の最大波高をよりどことす

かが、地震のエネルギー \( -E_r \) はおよそ \( 3 \times 10^{11} \, \text{erg} \)

と推定されることになる。

6. 1985年チリ津波との比較

1985年チリ津波は、大阪湾内では微少なものであっ

た。しかし、清水振動の誘起には、1960年チリ津波の

例に基づき共通点が見られる。すなわち、下

の通り、大阪湾では、湾口を含む平野部であっ

たが、1952年のときは約1.5mであった

のでに対して、1985年のときは約0.1mであった。波のエネ

ルギーは波高の2乗に比例することを考えると、波源

域での津波のエネルギーも同様な割合で評価できるも

のでみてよいであろう。

このことは、地震のマグニチュードについて、195

年では \( M = 7.7 \) （たとえば、中村、1991）とされている

のに対して、1960年では主震に対して \( M = 8.5 \) （東京文

科会編、理科年表）であることと、相互に矛盾してい

ない結果であると言える。

7. 1985年チリ津波の意義

すでに見たように、1985年チリ津波は、大阪湾をは

じめ、近畿地方では微少であった。しかし、関連した

資料を検討してみると、本文で対象とした1985年チリ

津波は、1960年チリ津波の縮小版であったとも考え

ことができる。次の大津波津波の米囊までに、その

特性をとらえ、その成果を、津波警報や対策に有効に

活用できればよい。その検討への鍵が1985年チリ津波

であると言えるであろう。

なお、本文では、津波の指向性（たとえば、Kajiura、

1970；1974）や地震断層パラメータ（たとえば、

Kajiura、1981）についてはとくに考えることはし

なかった。

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（とともに、p. 654）。
Atmospheric eddy induced by a distant decaying typhoon observed at an offshore oceanographic tower" 

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Abstract: At an offshore oceanographic tower station, an eddy induced by a distant decaying typhoon was observed. The tower is located in the northwestern Pacific. A part of the recorded winds at the tower suggests that the typhoon 9015 must surely accompanied or induced a remote atmospheric eddy on 3rd September 1990. A conceptual model is introduced for a dynamical understanding with several assumptions in order to realize the record at the tower. Additional notice is about the suffer which was happened at almost same time just neighbour the tower.

1. 結言

著者は沖合の海洋観測塔記録をよりどころにして、遠隔台風の衰退期に巻巻ともみられる突発的強風を検討した。このような例は、中村（1987）が論じているが、本文の例はこれとは少し視点が異なる。ここでは、1990年の台風9015の影響による地形性の海上小規模渦として、観測塔の風の記録を検討し、思考モデルによって力学的機構の概念的理解に努めた。

なお、この現象は和歌山地方気象台でも解析されており、一部に発表された部分と重複するところがあるかもしれない。当時、気象台関係者と著者との検討を行ったことを記しておきたい。

2. 台風9015号の経路

台風9015号の経路は、台風9113号の経路によく似ている（中村，1987）。すなわち、台風9015号は、1990年2月11日に受理 Received February 11，1992

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Fig. 1. Track of Typhoon 9015 (27th Aug. to 3rd Sep. 1990). Marks T and L mean Typhoon and Low pressure. Encircled dot for the typhoons location at 1800JST on each day with date and pressure (mb or hPa).
Fig. 2. A series of the surface weather map (29th to 4th Sep. 1990). A to G corresponding to the daily weather map on 29th August to 4th September 1990. Each weather map for 1800JST.
年8月27日から9月3日までFig.1に示すような経路をとった。なお図中には、各日18時（ＪＳＴ；日本標準時）について、台風中心位置と台風中心気圧（ミリバール単位；mbあるいはhPa）を示した。ちなみに、新聞天気図（たとえば毎日新聞）では、このFig.1のうち、本文に関係の深いものはFig.2のようになる。

1990年8月29日18時の日本列島付近の地上天気図は、Aのようになっていて、台風9015号が台湾東方にあることがわかる。翌30日18時には、天気図はBのようになり、31日18時にはCのようになる。9月1日18時の地上天気図はD、そして翌2日18時はEとなる。このようなにして、本文の問題とする時刻に近づいていく。図中Fは、9月3日18時の天気図で、この時、すでに本文の対象とした現象は収っている。翌4日18日、日本列島は高気圧におわれている。このように台風9015号、朝鮮半島で強風雨洪水をもたらした後、日本海へ出て低気圧となり、津軽海峡付近を東進した。

3．海洋観測塔の記録

白浜海岸観測塔は、Fig.3の記号Tの位置にある。また、南紀白浜空港は記号Pの位置である。観測塔、海岸線から沖合約30kmにある。また、塔周辺の陸上地形はかならずも単純ではない。便宜的に、その地形の特徴を示す等高線をえらんで示した。

観測塔では、海象・気象の連続観測記録を1分間隔で行っている。ここでは、そのうちの平均風速W_s、平均風向W_dおよび気温T_aを検討の対象とする。とくに、1990年9月3日の16時30分頃、観測塔の北東方約5kmの和歌山県田辺市では、竜巻による被害の通報があった。このようなことから、観測塔の記録をみると、Fig.4のようになっていて、とくに顕著で特徴の

Fig. 3. Location of offshore oceanographic tower station and surrounding profile of coastal zone. Marks T and P mean Tower station and Air Port. Mark of X-X shows the suffered belt by a sporadic gale in Tanabe City.

Fig. 4. Observed result at the offshore tower station. Notation W_s, W_d and T_a are for wind speed, wind direction and air temperature.
ある変動は、16時10分から30分までの間の風の変動である。なお、この9月3日の水温は、15℃～17℃に27.1℃～27.2℃であった。この時の水温は気温より0.5～1.5℃低かったことになる。海面付近の大気は安定であっ
たとみてよいだろう。

観測塔の南方、約3kmの南紀白浜空港の観測によれば、16時11分頃に風が強くなりはじめ、16時15分に
は、最大風速は25m/sとなっている。しかし、この空
港の風の変動が、観測塔の風の変動とどのように対
応しているか、記録のみから判断することは難しか
い。

一方、気象庁が1990年9月3日13時の雲の状態を日
本周辺について図化しているものがあるので、これを
参考にすることとし、その一部をFig.5に示した。こ
の図では、Fig.2のような天気図よりも詳しい気象状
況がわかる。紀伊半島西部に積雲があることが示さ
れ、低気圧となった台風3015号（記号D）は、日本海
中部を20ノットの速さで東北東に進んでいる。山陰
冲（記号G）には小規模ななものがあるが、これは約
3時間後に発生した低気圧となる。これに加えて、
低気圧Dから南へのびた前線が、紀伊水道から紀伊半
島へと広がっている。

このFig.5を指摘することができるか、9月3日の現
象も、中田（1986）の論じた現象とよく似ているよ
うだ。また、Fujita（1981）の例から、トルネー
ドに併発する小さな低気圧性渦に対応すると解釈で
きそうだ。いずれにしても、この現象は和歌山地方気
象台で、いちじるしの気象学的価値にもとづいて検討さ
れた。ここで著者がこの現象を目覚したのは、海上の
小規模風が強いものが沖合の観測塔で記録された点に
ある。これが従来の気象学で知られているものと同等
なもののか、異質なものかは不明とせざるを得ない。上
述の気象データについては、和歌山地方気象台が検討
しているが、現象論としてデータの対比はできても、
その力学的機構をとらえる手がかりとしては満足でき
ない。

4．簡単な渦の思考モデル

これまでに挙げてきた1990年9月3日のFig.4の記
録は、観測塔で得られたもので、観測値や気象ブイの記
録では得ることのできないものである。

ここで、Fig.4の記録の特徴を力学的に理解する一
助とすることにする。渦の規模を模倣するため、海面
上の風線がどのように発生したか、それに基づいて、
その渦が、周辺の風の場で移動するという考えに立脚する。いま、このような渦のモデルとしては、
Fig.6のような例を考える。図の上半分には風速の時間
変化を示す。ランキン渦の発生状態を考慮すると、基
準線Oからの高さは、相対的風速となり、風速の極大はRで、極小はRで
認められるはずである。この渦が周辺の風の場などの
影響により、風速Sで移動しているとすると、風速の
時間変動は基準線OからSへ移動して考えればよい。

地上からみれば、あるいは観測塔からみれば、上の渦
がFig.6の下半分に示すように北東方向に移動し、その
移動は渦の周辺の風の場の状態によるものとすると、
Fig.4を渦の記録として理解できるであろう。渦の移
動に対して観測塔の位置が、時刻t_{1}，t_{2}，t_{3}に点E，
F，Gにあたるとする。このとき対地風速は、点Eおよ
びGでは、RとSとのベクトル和として表わされる。

つまり、定性的には、このよう簡単な渦のモデルで
Fig.4の16時10分～30分の風の変動が、風速そのものに
うまく理解できることになる。この考えは、1990
年9月には、定性的モデルとして、著者が考えていた
ものである。しかし、これ以外のモデルを考えること
ができるかも知れぬ。海上の沖合の観測塔の記録
以外に、総観の資料しか得られていないので、いくつ

Fig. 5. Cloud map at 1500JST on 3rd September 1990. (courtesy of JMA).
5. 災害との関連

本文で対象とした、1990年9月3日の海上規模渦
と田辺市における竜巻による被
害があった。竜巻の記録・測定・被害との相互関係は
はっきりしないが、詳細を述べるには資料が不足して
いる。被害の状況についてみれば、その範囲はFig.3の
上部のX-Xの間で、長さ約2.5km、幅約10mの細
長い帯状地域であった。

折から、1990年12月に、千葉県茂原市を中心とした
竜巻の被害が報じられ（桂, 1991）。本文で述べた問
題は処分なものと位置づけられたようである。ここに
あえて海上規模渦の問題を提起し、諸賢の意を問わ
んとするものである。なお、本文をとりまとめるとあたり、気象庁の関係
諸官、千葉県立長生高校、その他、多数の方々のご協力
をいただいた。本稿は、最初の草稿から18ヶ月後、
査読者の所見を得て、全面的に改稿した。

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Unusual form of *Ecklonia stolonifera* OKAMURA
(Laminariales, Phaeophyta)

Masahiro NOTOYA** and Yusho ARUGA**

Three types of unusual form of *Ecklonia stolonifera* OKAMURA were found by one of the authors (M.N.) during the ecological studies of this species along the Japan Sea coast and the Tsugaru Channel coast in Aomori Prefecture, Japan.

The specimens A and B in Fig. 1 were collected on March 16, 1983 at Tanosawa, Fukaura, on the Japan Sea coast. The specimen A collected from 20 m depth is normal of this species. In *E. stolonifera* the thallus is made up of three parts; holdfast, stipe and blade. In vegetative propagation stipe and blade are produced from stoloniferous haptera. Holdfast is branched and verrucately arises. Stipe is cylindrical, about 5.2 mm in diameter and 10 cm long. Blade is linear or lanceolate with secondary serrulate bladelets.

The specimen B is unusual, having blade-like flattened stipe. It was collected from 20 m depth. Blade is about 30 cm long and 15 cm wide. The flattened stipe is about 1.2 mm thick, 10 cm long and 2 cm wide at the broadest portion, being curved with smooth surface and slightly thicker than the central part of a normal blade. Blade is issued from short stipe-like cylindrical part at the top of the flattened stipe. Blade and holdfast with stoloniferous haptera and newly produced shoots are completely normal in their form. This specimen is three years old judged from holdfast system.

The specimens C and D (Fig. 1) were collected at Ohma, Shimokita Peninsula, on the Tsugaru Channel coast. The specimen C, collected on November 1, 1988 from 8.5 m depth, has two blades; one is 26.5 cm long and 5.4 cm wide and the other 9.8 cm long and 3.5 cm wide. It has a long stipe of 13.6 cm long with a short branched stipe of 0.7 cm long. This specimen is two years old. The blades have no zoosporangial sori.

The specimen D was collected on July 8, 1987 from a community of small thalli in shallow water of 5.2 m. It has a blade with small stipe issued vegetatively from margin of the mother blade at its serrulate portion. The mother blade is 8.6 cm long and 7.3 cm wide with stipe of 1 cm long and the daughter blade is 3.5 cm long and 3.3 cm wide with stipe of 0.5 cm long. The mother thallus is two years old and has two normal young thalli vegetatively produced from stoloniferous haptera.

There have been several reports on unusual forms in many species of Laminariales from Japan (Kinoshita 1933, Hasegawa and Fukuhara 1956, Tokida et al. 1956, 1958, Funano 1974, Yabu and Homura 1981, Kawabata 1959, Kawashima 1987). However, we have not known reports on unusual form of *Ecklonia stolonifera*. Similar types of unusual form have been reported in other species of Laminariales. Kawashima (1987) reported two blades with branched stipe in *Alaria angusta*, *Costaria costata*, *Nereocystis luetkeana* and *Postelsia palmaeformis*. Thallus with second stipe and blade issued from the first blade was reported by Funano (1974) in *Laminaria ochotensis*. Unusual form of blade-like stipe has not been reported yet. The above-mentioned abnormal thalli were found together with normal thalli in the *E. stolonifera* population of

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* Received January 15, 1992
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Fig. 1. *Ecklonia stolonifera* OKAMURA thalli of usual or unusual form collected from the coasts of Aomori Prefecture, Japan. (A) Thallus of usual form collected at a depth of 20 m at Tanosawa, Fukaura on the Japan Sea coast on March 16, 1983. (B) Thallus with flattened stipe collected at a depth of 20 m at Tanosawa on March 16, 1983. (C) Thallus with branched stipe and two blades collected at Ohma, Shimokita Peninsula, on the central part of the Tsugaru Channel coast on November 1, 1988. (D) Thallus with a daughter blade on stipe issued from mother blade margin, collected at Ohma on July 8, 1987. (Scale bar: 10 cm)

several years old. They had normal shoots from stoloniferous haptera. Therefore, it is inferred that the thalli of unusual form might not be under genetic control.

Recently, we have reported in the experiments of tissue culture of Laminariales seaweeds that, in addition to callus, thalli differentiated from the blade tissue collected in the field or from a piece of the juvenile blade of Laminariales (*NOTOYA* 1988, 1990, *NOTOYA* and *ARUGA* 1989, 1990). This suggests the possibility that also in nature thalli of unusual form can be produced from the wounded part of thallus tissue.

References


学 会 記 事

1. 1991年11月22日 東京水産大学において平成4年度学会賞受賞候補者推薦委員会（第1回）が開かれ、委員長に谷口旭氏を選出し、推薦の方法及び次回の日程を決めた。

2. 1991年12月19日 東京水産大学において学会賞受賞候補者推薦委員会（第2回）が開かれ、研究業績について審議の結果、小池勲夫氏（東大・海洋研）が最適格者との結論に達し、この結論を会議に報告することとした。

3. 1992年1月15日 平成4・5年度評議員選挙の公示を行い、投票用紙を平成12年4月現在の全会員に送付した。2月3日までの消印で郵送された用紙を有効とする。

4. 1992年2月6日 東京水産大学において平成4・5年度評議員選挙の開票が行われた。

5. 1992年3月1日 平成4・5年度学会賞受賞候補者について会長より全評議員に推薦理由書を付して賛否の投票を依頼した。

6. 1992年3月22日 平成4・5年度学会賞受賞候補者の賛否について総評議員の投票を締め切り、開票結果は投票総数44（評議員総数53×2/3=36必要票数）
賛否44（有効投票数44×3/4=33決定に必要な得票数）で、受賞者は小池勲夫氏（東京大学）に決定した。

7. 1992年3月24日 東京水産大学において平成4・5年度評議員選挙者による平成4・5年度会長選挙の開票が行われた。

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