ISSN 0503-1540

Tome 37 *Juin 1999* Numéro 1

La mer

うみ

1999 年 6 月

日 仏 海 洋 学 会

La Société franco-japonaise d'océanographie

Tokyo, Japon

Note pour la présentation des manuscrits

La mer, organe de la Sociét franco-japonaise d'océanographie, publie des articles et notes originaux, des articles de synthèse, des analyses d'ouvrages et des informations intéressant les membres de la société. Les sujets traités doivent avoir un rapport direct avec l'océanographie générale, ainsi qu'avec les sciences halieutiques.

Les manuscrits doivent étre présentés avec un double, et dactylographiés, en *double interligne*, et au recto exclusivement, sur du papier blanc de format A4 (21×29.7 cm). Les tableaux et les légendes des figures serount regroupés respectivement sur des feuilles séparées à la fin du manuscrit.

Le manuscrit devra étre présenté sous la forme suivante:

1° Il sera écrit en japonais, français ou anglais. Dans le cadre des articles originaux, il comprendra toujours le résumé en anglais ou français de *200 mots* environs. Pour les textes en langues européennes. il faudra joindre en plus le résumé en japonais de *500 letters* environs. Si le manuscrit est envoyé par un non-japonophone, le comité sera responsable de la rédaction de ce résumé.

2° La présentation des articles devra étre la méme que dans les numéros récents; le nom de l'auteur précédé du prénom *en entier*, en minuscules; les symboles et abréviations standards autorisés par le cometé; les citations bibliographiques seront faites selon le mode de publication: article dans une revue, partie d'un livre, livre entier, etc.

3° Les figures ou dessins originaux devront étre parfaitement nettes en vue de la réduction nécessaire. La réduction sera faite dans le format 14.5×20.0 cm.

La premiére épreuve seule sera envoyée à L'auteur pour la correction.

Les membres de la Société peuvent publier 7 pages imprimées sans frais d'impression dans la mesure à leur manuscrit qui ne demande pas de frais d'impression excessift (pour des photos couleurs, par exemple). Dans les autres cas, y compris la présentation d'un non-membre, tous les frais seront à la charge de l'auteur.

Cinquante tirés-à-part peuvent étre fournis par article aux auteurs à titre gratuit. On peut en fournir aussi un plus grand nombre sur demande, par 50 exemplaires.

Les manuscrits devront étre adressés directement au directeur de publication de la Société: Y. YAMAGUCHI, Université des Péches de Tokyo, Konan 4-5-7, Minato-ku, Tokyo, 108 Japon; ou bien au rédacteur étranger le plus proche: H. J. CECCALDI, EPHE, Station marine d'Endoume, rue Batterie-des-Lions, 13007 Marseille, France; E. D. GOLDBERG, Scripps Institution of Oceanography, La Jolla, California 92093, Etats-Unis; ou T. R. PARSONS, Institute of Ocean Sciences, P.O.Box 6000, 986OW, Saanich Rd., Sidney, B. C., V8L 4B2, Canada.

La mer 37 : 1–10, 1999
Sociétě franco-japonaise d'océanographie, Tokyo

Distribution of low saline water near the mouth of Tokyo Bay

I Wayan NURJAYA*, Yujiro KITADE*,
Masaji MATSUYAMA* and Sachio MATSUI*

Abstract : Detailed CTD measurements were made in two lines in Sagami Bay to investigate a behavior of low saline water flowed out from Tokyo Bay near the bay mouth in May, September and November 1997. The low saline and high turbidity water were found near the tip of Miura Peninsula in Sagami Bay in all three observations. The low saline water distributed along the southern coast of the peninsula, and extended toward the center of Sagami Bay. Then the area occupied by the low saline water at the southern observation line was smaller than at the western one. ADCP measurements made in November 1997 shows the existence of the northwestward current in the southern line and west-northwestward current in the western line. The distribution of the low saline water flowed out from Tokyo Bay is strongly affected by the external force, i. e., the current circulation in Sagami Bay.

Key words : *Tokyo Bay, Low saline water (LSW), Density current, Sagami Bay, Intrusion, CTD measurement, ADCP measurement, Internal radius of deformation*

1. Introduction

Low saline water (LSW) discharged from rivers is usually found in coastal zone of world's ocean and leads to formation of sharp density gradient, i.e., density front. Its behavior is often affected by external forcing, i.e., wind effect, ambient flow, bottom and coastal topography, and inflow properties. Existence of the buoyant's sources along the coastline represents one of the principle forcing mechanisms for coastal and shelf currents (YANKOVSKY and CAHAPMAN, 1997). When the width of LSW is equal to or larger than the internal radius of deformation in the coastal region, LSW has a characteristic of density current in the rotating fluid without external forces, that is, moving right on the coast in the northern hemisphere (e.g., GRIFFITHS, 1986). This characteristic is usually observed in coastal water in the world.

Tokyo Bay is a semi-enclosed bay with lots of river discharges. LSW discharged from Tokyo Bay is expected to flow out through the bay mouth into Sagami Bay to have a characteristic of density current in a rotating fluid. UNOKI and KISHINO (1977) reported from the long-term mean data that the low salinity and low transparency water distributes along the western coast of Tokyo Bay. MATSUIKE *et al.* (1986) also observed the high turbidity waters concentrated along Miura Peninsula, i. e., at the western side of the bay. But, the discharged water from the western side of the bay mouth is not clarified by the observation in detail. Both studies of field observation and numerical modeling are required to understand the behavior of LSW discharged from Tokyo Bay.

The present study was firstly focussed on the distribution of LSW in the vicinity of Miura Peninsula, i.e., western sides of the bay's entrance. The main purpose of this study is to obtain spatial and temporal scales of LSW distribution as a guide to build a gravity current model.

2. Observations

Figure 1 shows bottom topography of Tokyo and Sagami Bays, and the two observation

* Department of Ocean Sciences, Tokyo University of Fisheries, 4–5–7, Konan, Minato-ku, Tokyo 108–8477

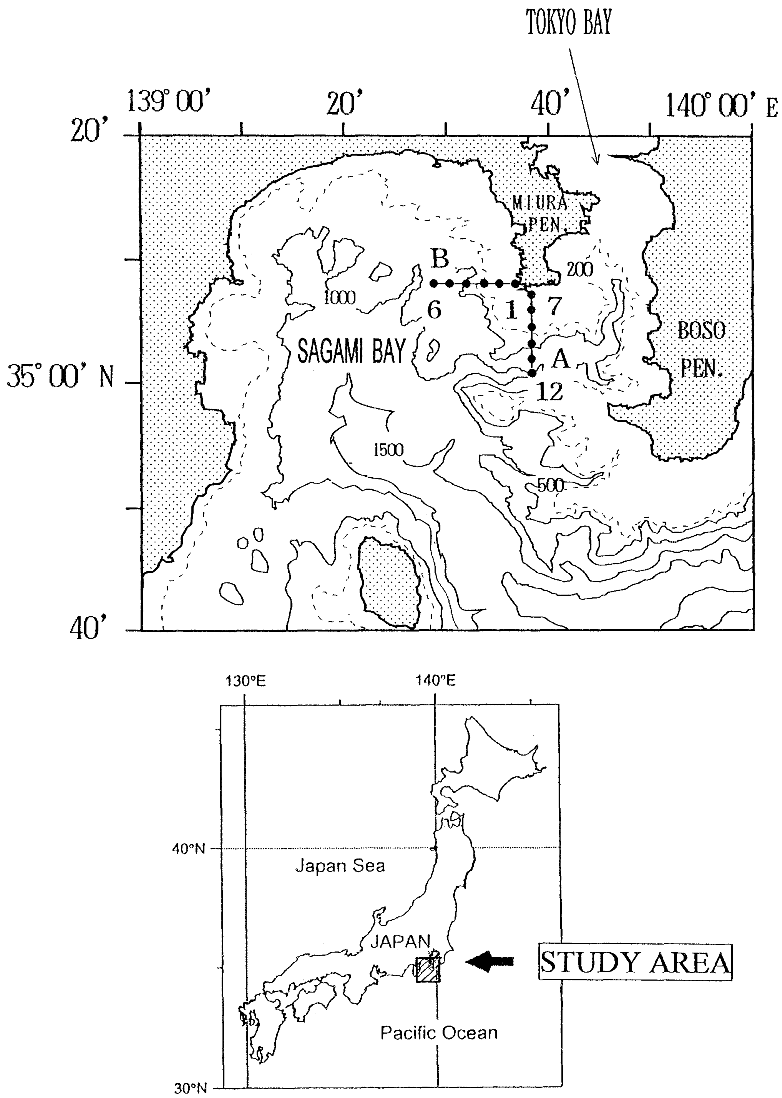

Fig. 1. Location of study area and bottom topography of Tokyo and Sagami Bays. A and B are CTD observation lines. Bottom contours are in meters.

lines (Line A and Line B) and each observational position. Each line consists of six stations. Line A faces to the south of the tip of Miura Peninsula in Sagami Bay, while Line B faces to the west. The distance between station and station is 1 miles (about 1.85 km) to 1.5 miles (about 2.8 km) and the nearest station to the coast is 0.9 km from shoreline in Line A and 1.2 km in Line B. The observations were made by T/V Seiyo-maru, belonging to Tokyo University of Fisheries. The CTD observations were made in May, September and November 1997 and the ADCP measurements were made in November, 1997.

3. Results

Figures 2 to 4 show temperature, salinity and density distributions on May 10, September 11, and November 15, 1997, respectively. The temperature and density distributions indicate the existence of the stratification due to the seasonal thermocline (e.g., IWATA, 1979; KAWABE

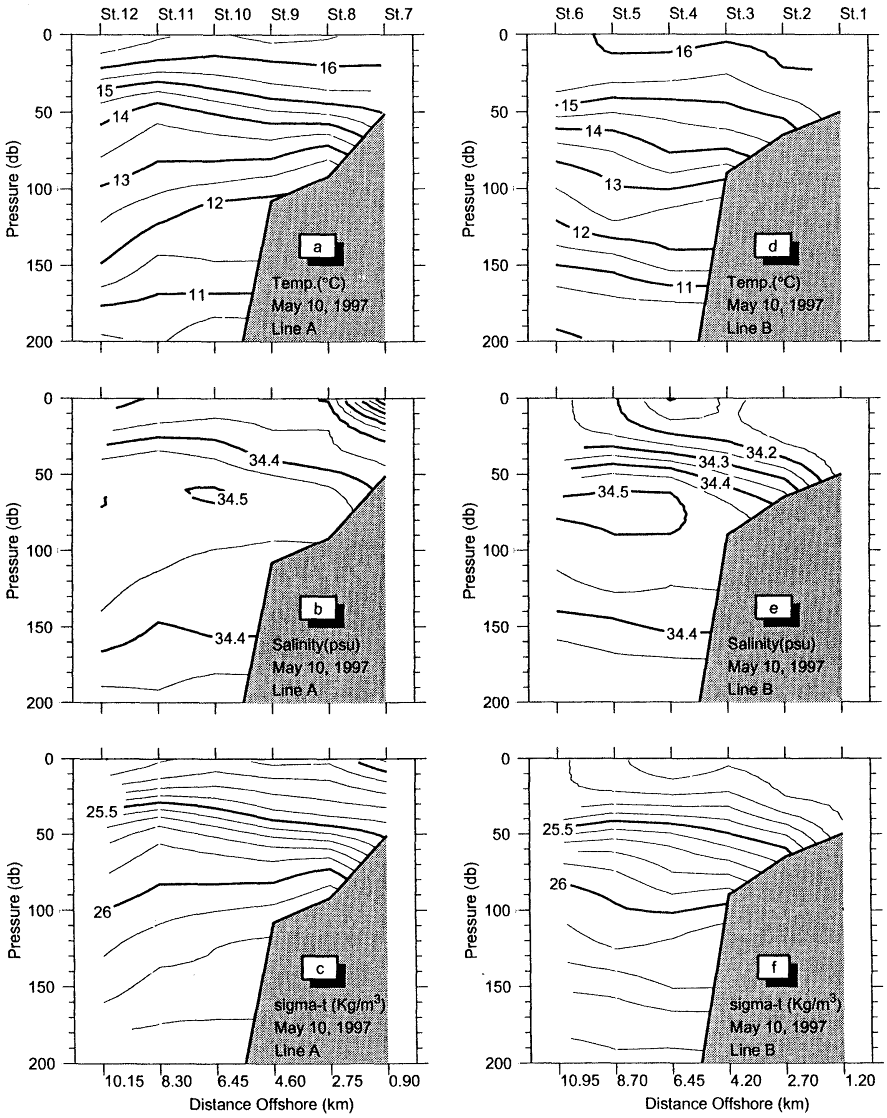

Fig. 2. Distributions of (a) water temperature in Line A, (b) salinity in Line A, (c) sigma-t in Line A, (d) water temperature in Line B, (e) salinity in Line B, and (f) sigma-t in Line B on May 10, 1997

and YONENO, 1987). In May (Fig. 2), the contours of the temperature and density in both Line A and Line B gradually decline toward the coast from the sea surface to about 100m depth. This indicates the existence of westward current in Line A and northward in Line B. The same feature is not found except near the coast in Line B in September (Fig. 3). In November (Fig. 4), the temperature and density distributions are complicated by the coastal water intrusion into the subsurface layer. The contour-line declination toward the coast is also recognized in the density distributions.

Salinity is variable in each observation, especially in the surface layer. The lowest value was observed at the sea surface in September among three observations. The subsurface layer is occupied by the higher salinity water of 34.5, originating from the Kuroshio water in

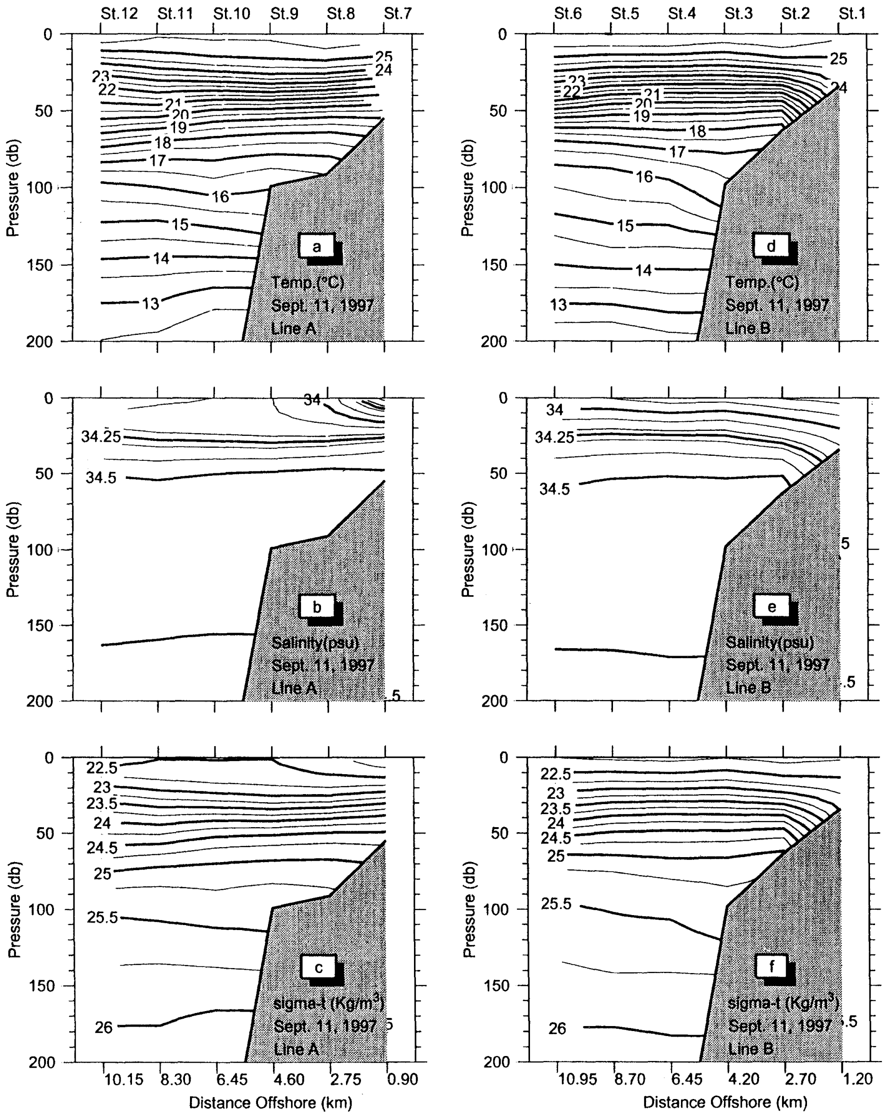

Fig. 3. The same as Fig. (2) except on September 11, 1997

every observation. The two common features are found from the comparison of Line A and Line B as follows. (1) The low salinity water concentrated in the surface layer near the coast in Line A. (2) The width of LSW was in Line B larger than in Line A. Then, LSW is trapped in the coast in Line A, while it extended offshore at Line B by the external forc. In November, the interesting feature is also found in the intrusion of the coastal water into the subsurface layer, i.e., the core depth of the intrusion is 30 m in Line A and 35m in Line B. The intrusion occurred along the density contour line. The separation of the temperature and density contour lines in Line A is due to the intrusion (Fig. 4). The intrusion into the subsurface layer observed in November is remarkably different from the dispersion at the sea surface in May and September.

LSW flowed out from Tokyo Bay into Sagami Bay is considered to be high turbidity water as well (MATSUIKE *et al.*, 1986, UNOKI and KISHINO, 1977). Figure 5 shows the salinity-transparency relation at every line in each

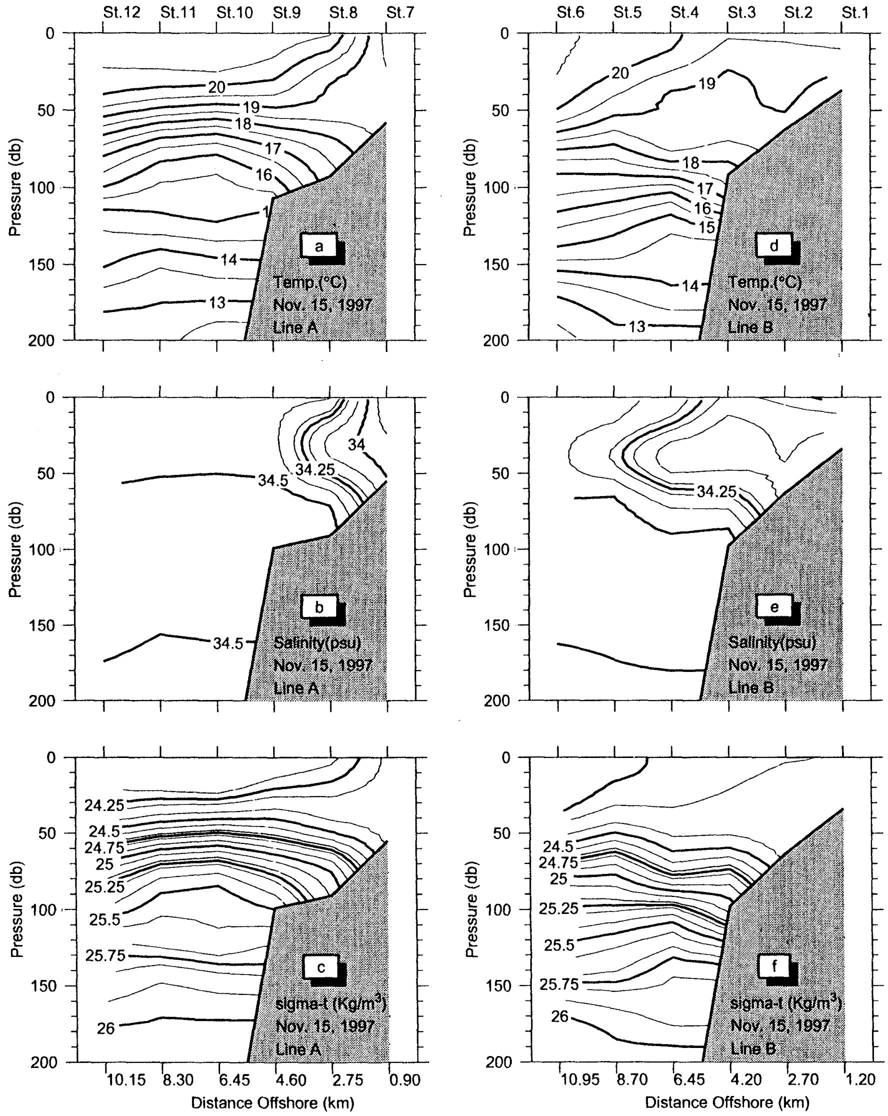

Fig. 4. The same as Fig. (2) except on November 15, 1997

observation. The value of transparency in May is relatively low in comparison with that in September and November. As the reason is not sufficiently explained, we treat as the relative relation of the salinity-transparency. The transparency is basically positive relation to the salinity except some data. The low salinity water indicates the low transparency water, i. e., highly turbidity water. The high salinity and low transparence water is found at St. 10 and at St. 4 in May, and at St. 4 and at St. 6 in November. The boundary mixing is possibly occurred near the sea bottom because the swift current in relation to the semidiurnal internal tide exists in this region (MATSUYAMA and IWATA, 1985, KITADE and MATSUYAMA, 1997). The detailed observations near the sea bottom will be required to clarify this phenomenon in future.

The ADCP measurements were made along Line A and Line B in November 15, 1997. Figure 6 shows the current distributions of 15m, 45m and 100 m depths, as the typical distributions in the surface, subsurface and middle

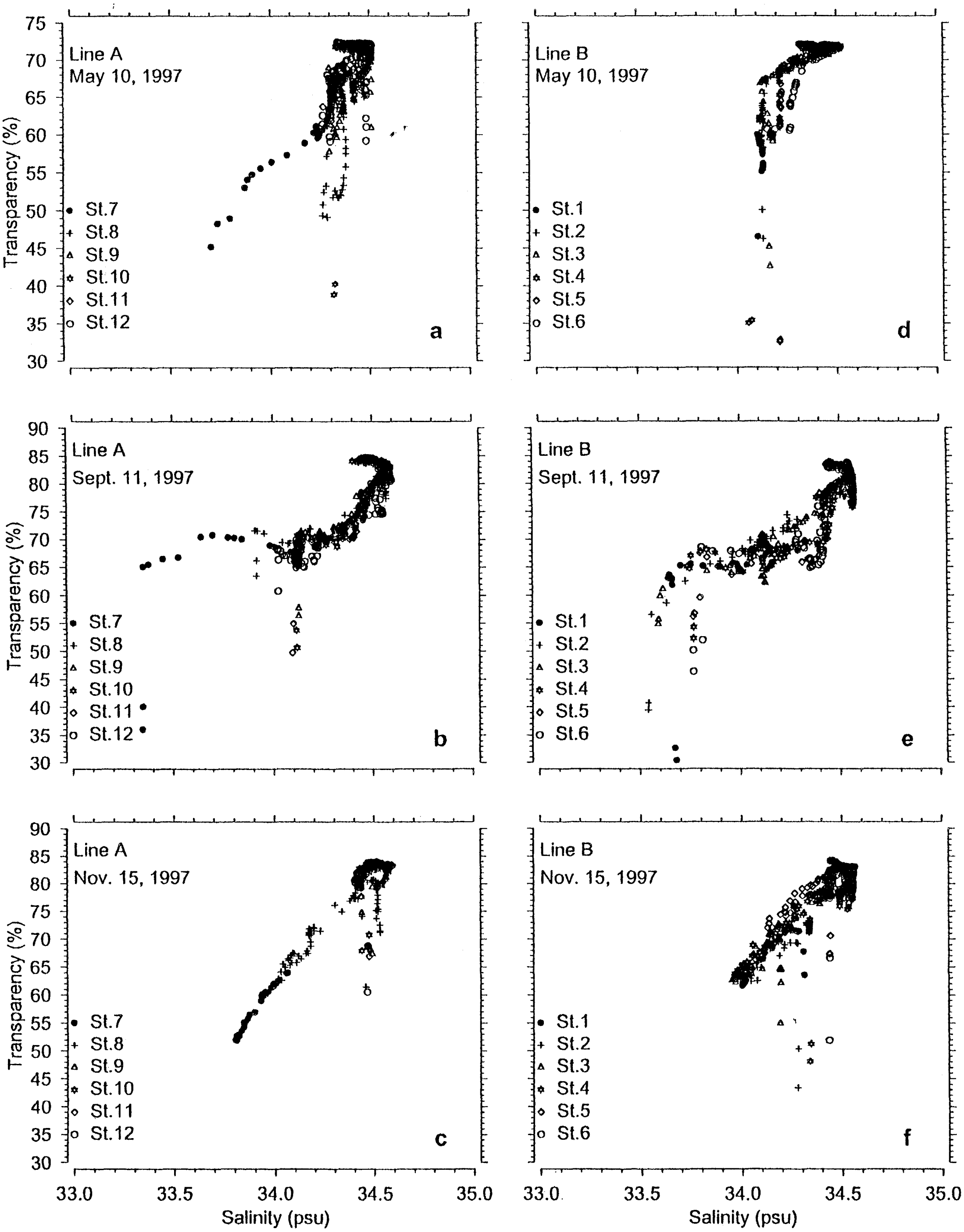

Fig. 5. Transparency - Salinity diagram of Line A and Line B in on May 10, September 11, and November 15, 1997

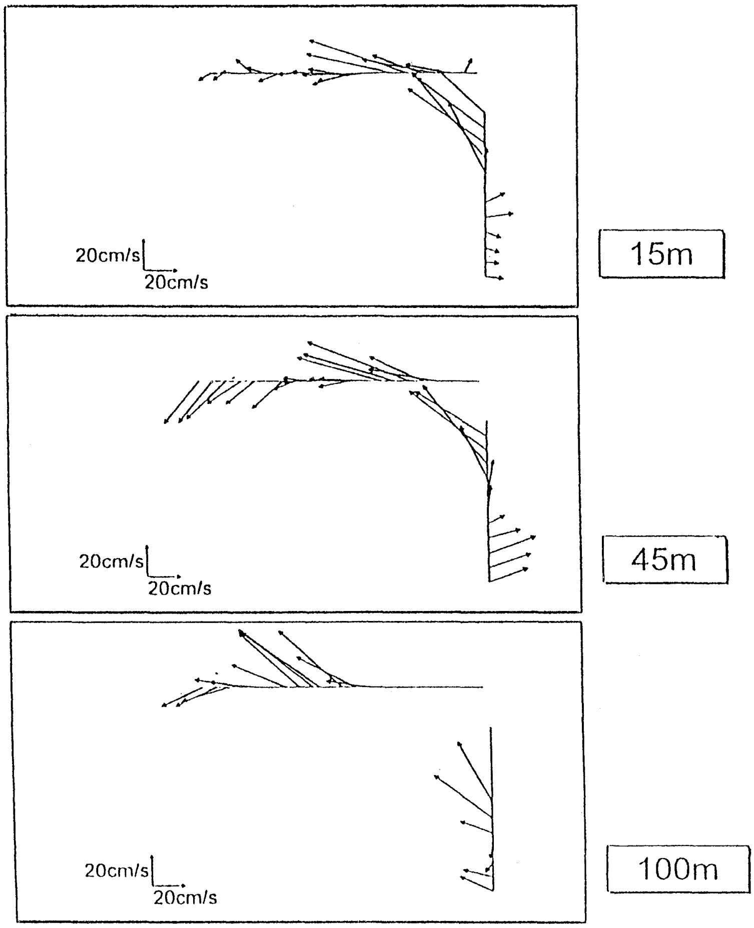

Fig. 6. Current at 15 m, 45 m and 100 m depths of Line A and Line B on November 15, 1997

layers, respectively. The strong current existed in the 15m and 45 m depths near the coast, i. e., the northwestward to west-northwestward direction in Line A and west-northwestward direction at Line B. The direction agrees with the current deduced from the density distributions (Fig. 4). The discharged low saline and high turbidity water moves westward through Line A and along Line B. As a result, the low saline water did not move northward along the eastern coast of Sagami Bay, but was dispersed toward the center of Sagami Bay. The current direction observed near the coast agrees with that obtained from the long-term current measurements on the shelf off Miura Peninsula by Iwata and MATSUYAMA (1989). They showed the mean current direction through 315° to 340° on the shelf west off Jogashima (the tip of Miura Peninsula). As a result, the low saline and high turbidity water flowed out from Tokyo Bay into Sagami Bay, trapping the coast of the tip of Miura Peninsula as a density current in a rotating fluid. After passing this area, the low saline water was extended to the westward to be affected by the external force in the field. The reason is speed of density current to be much less than that of the current in Sagami Bay.

4. Structure of LSW

Coastal Trapped Structure

LSW was trapped along the coast at the southward line (Line A) from the tip of Miura Peninsula in all three observations. The observation shows the coastal-trapped structure in a rotating fluid (e. g., GRIFFITHS, 1986). So, we

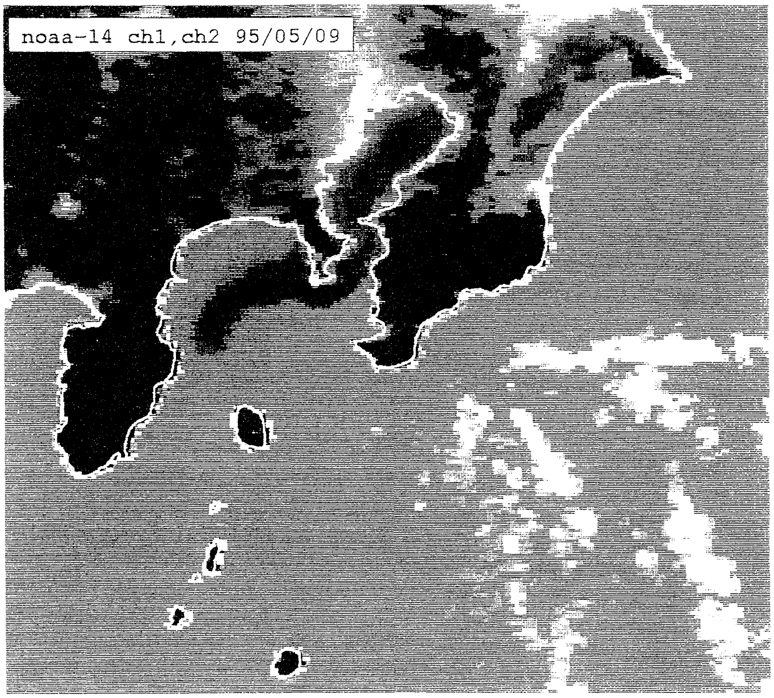

Fig. 7. Satellite image of the sea-surface chlorophyll of Tokyo and Sagami Bays on May 9, 1995 by NOAA-14.

examine to grasp a characteristic of the coastal-trapped mode by solving the basic equations under the hydrostatic and Boussinesq approximations in non-viscous fluid, following KUNDU *et al.* (1975). A rectangular coordinate system consists of x eastward, y northward with the origin at the coast and z upward from the mean sea level. The fundamental equations are obtained as follows;

$$\begin{aligned} &\frac{\partial u}{\partial t} - fv = -\frac{1}{\rho_0}\frac{\partial p}{\partial x} \\ &fu = -\frac{1}{\rho_0}\frac{\partial p}{\partial y} \\ &\frac{\partial p}{\partial z} + \rho g = 0 \\ &\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial x} = 0 \\ &\frac{\partial \rho}{\partial t} + w\frac{\partial \bar{\rho}}{\partial z} = 0 \end{aligned} \tag{1}$$

where u, v, and w are the x-, y- and z-components of the velocity, respectively, g the gravitational acceleration, ρ_0 the vertical mean density, $\bar{\rho}$ the equilibrium stable density, ρ the perturbation density, p the perturbation pressure, and f the Coriolis parameter. The potential vorticity equation is derived from the set of fundamental equations (1) as

$$\frac{\partial}{\partial t}\left\{\frac{1}{f^2}\frac{\partial^2 p}{\partial y^2} + \frac{\partial}{\partial z}\left(\frac{1}{N^2}\frac{\partial p}{\partial z}\right)\right\} = 0 \tag{2}$$

where $N^2 = -\frac{g}{\rho_0}\frac{\partial \bar{\rho}}{\partial z}$ is the square of the buoyancy frequency. Assuming that N is constant and initial potential vorticity is zero, Eq. (2) is written as

$$\frac{\partial^2 p}{\partial y^2} + \left(\frac{f^2}{N^2}\right)\frac{\partial^2 p}{\partial z^2} = 0\,. \tag{3}$$

The vertical and horizontal modes can be separated from Eq. (3) as follow;

$$\begin{aligned} &\frac{d^2 Z_n}{dz^2} + \left(\frac{N^2}{f^2}\right)\alpha_n^2 Z_n = 0 \\ &\frac{d^2 Y_n}{dy^2} - \alpha_n^2 Y_n = 0 \end{aligned} \tag{4}$$

where α is separation constant, and n the vertical mode number. We assume the dominant of the first mode from the distribution of the low salinity water at Line A (Figs. 2 to 4). The appropriate solution of the lower part of Eq. (4) is $Y_1 = A_1 \exp(\alpha_1 y)$ and of the upper part of Eq. (4) can be obtained as

$$Z_1 = B_1 \cos\left(\frac{N\alpha_1}{f} z\right)$$

under the boundary conditions at the sea surface and bottom, i. e., $w=0$ at $z=0$ and $z=-H$ (KUNDU *et al.*, 1975). A_1 and B_1 are unknown constant. The internal radius of deformation is obtained as $\alpha_1^{-1} = \frac{NH}{f\pi}$. When we adapt $H=70$ m, $f=8.34 \times 10^{-5} s^{-1}$, the internal radius of deformation is estimated as 3.0 km in May, 4.9 km in September and 3.1 km in November.

On the other hand, if the salinity distributes as the coastal-trapped structure, the salinity is expressed as $S(y)=S_0-S' \exp(ay)$ where a is the scale of the salinity variation, S_0 the salinity in open sea, and (S_0-S') the salinity at the coast $(y=0)$. So, we estimate the radius of deformation as 3.2 km in May and 3.4km in September. In November, the estimation is not easy for the intrusion into the subsurface layer.

The internal radius of deformation is little difference from the scale of the salinity variation defined in this study, that is, there is little difference between the both values obtained from the different method. The radius of deformation ranged 3 km to 5 km in three observations.

Intrusion of LWS into the subsurface layer

The salinity distributions are variable in time and space. The outflow mechanism may be different from each observation. The core of the low salinity was found at the sea surface in May and September, but at about 30m depth in November. As mentioned above, the density current is affected by the earth rotation (e. g., GRIFFTHS, 1986). Therefore, the core of low salinity at the sea surface can be explained as the outflow of low-density water moving southward along the western coast of Tokyo Bay. When the core of salinity minimum is 30 m depth, how can be explained the mechanism ? As shown in Fig. 6, the current distribution near the coast is nearly uniform in vertical. The distribution of the salinity minimum at about 30 m depth is speculated having already formed inside the mouth of Tokyo Bay. Recently KOIKE *et al.* (1997) reported the outflow in the subsurface layer through the bay mouth and the core of the coastal water at about 30 m depth. They explained the phenomenon due to the vertical circulation induced by the fairly strong northward wind during a few days. The salinity inversion in the surface layer is possible to occur by external forcing in Tokyo Bay, especially in late fall and winter when the density stratification is weaker than in summer. But, in future, we will continue the detailed observation in order to clarify whether or not the intrusion phenomenon is frequently found in weak density stratification and to grasp its formation.

5. Summary and Discussion

In order to investigate a behavior of low saline water flowed out from Tokyo Bay, the CTD observations were carried out in two lines, i. e., the southward and westward from tip of Miura Peninsula, in May, September and November 1997. The low saline water flowed out along the tip of Miura Peninsula into Sagami Bay in all three observations. The low saline water distributed along the southern coast of the peninsula, and extended toward the center of Sagami Bay. Therefore the area occupied by the low saline water at the southern observation line was smaller than at the western one. The ADCP measurements in November support the existence of the northwestward current at the southern line and west-northwestward current at the western line. Then, the low saline water flowed out from Tokyo Bay is strongly affected by the circulation in Sagami Bay. In November, the low saline water intruded into the subsurface layer in Sagami Bay. The internal radius of deformation, i. e., width of LSW, is estimated as 3–5 km from density stratification.

The coastal water flowed out from Tokyo Bay did not move along the western coast of Miura Peninsula, but extended toward the center of Sagami Bay, in all three observations. The west-northwestward current is clarified to be the most important role on behavior of the discharged water. Figure 7 shows a satellite image of the sea surface chlorophyll in Tokyo and Sagami Bay obtained on May 9, 1995. The distribution of the chlorophyll shows the pathway of the discharged water from Tokyo Bay and supports the above explanation.

The observed distributions of LSW near the tip of Miura Peninsula may be possible to be affected by tidal currents, especially semidiurnal internal tidal current (MATSUYAMA and IWATA, 1985; KITADE and MATSUYAMA, 1997). We examine the influence of the tidal current to the salinity distributions in Lines A and B. The first-mode internal tide is considered to dominate over higher modes ones, so the upper layer water moves with the same velocity. The tidal current excursion, η, is estimated as follows,

$$\eta = \int_0^{\frac{T}{2}} v_0 \sin\left(\frac{1\pi t}{T}\right) dt$$

where T is the semidiurnal period, and v_0 the current amplitude. When typical current amplitude is 0.2 m/s (MATSUYAMA and IWATA, 1985), the excursion, η, is estimated as 2.9 km. The current direction is mostly parallel to the coastline, so the tidal current effect should be considered to include the observation plan. It took about 4 hours to make CTD observations in the both lines; we will be required to shorten the observation time.

Acknowledgement

We wish to thank Captain Y. KOIKE and the crew of T/V Seiyo-maru, Tokyo University of Fisheries, and the member of physical oceanography laboratory for their support during the field observations. Thanks are also due to Dr. Shizuo IWATA for his kind offering of the Satellite Image data. This study was partially supported by a Grant-in-Aid defrayed by the Ministry of Education, Science, and Culture of Japan (10640420).

References

GRIFFITHS, R. W (1986) : Gravity currents in rotating systems. An. Rev. of Fluid Mech., **18** : 59–89.

IWATA, S. (1979) : Seasonal variation of the sea surface water in Sagami Bay. Rep. of Fisheries Resources in Sagami Bay. Kanagawa Prefecture Fisheries Station, 27–34 (in Japanese).

IWATA, S. and M. MATSUYAMA (1989) : Surface circulation in Sagami Bay : the response to variations of the Kuroshio axis. J. Oceanogr. Soc. Japan, **45** (5) : 310–320.

KAWABE, M. and M. YONENO (1987) : Water and flow variations in Sagami Bay under the Influence of the Kuroshio Path. J. Oceanogr. Soc. Japan, **43** : 283–294.

KITADE, Y. and M. MATSUYAMA (1997) : Characteristic of internal tides in upper layer of Sagami Bay. J. Oceanogr., **53** : 143–159.

KOIKE, Y., M. MATSUYAMA, T. HAYASHI, Y. KITADE, A. KITAZAWA and J. YOSHIDA (1997) : Distribution and behavior of bottom water in Tokyo Bay in summer – Role of wind on outflow of poor oxygen water–. J. Tokyo Univ. Fish., **82**(2) : 43–51 (in Japanese with English abstract).

KUNDU, P. K., ALLEN, J. S. and R. L., SMITH (1975) : Modal decomposition of velocity fields near the Oregon Coast. J. Phys. Oceanogr., **5**, 683–704.

MATSUIKE, K., T. MORINAGA and T. HIRAOKA (1986) : Turbidity distribution in Tokyo Bay and movement of the turbid water. J. Tokyo Univ. Fish., **73(2)** : 97–114.

MATSUYAMA, M. and S. IWATA (1985) : Semidiurnal internal tides observed over the continental shelf off Jyogashima in Sagami Bay. J. Tokyo Univ. Fish., **72**: 43–49. (in Japanese with English abstract)

UNOKI S. and M. KISHINO (1977) : Average oceanic condition and water exchange in Tokyo Bay. Rep. of Physical Oceanography Laboratory in Physical Chemical Institute, No.1, 89pp. (in Japanese).

UNOKI S. (1993) : Coastal Physical Oceanography. Tokai University Press. 672 pp. Tokyo.

YANKONVSKY, A. E. and D. C. CHAPMAN (1997) : A simple theory for the fate of buoyant coastal discharges. J. Phys. Oceanogr., **27** : 1386–1401.

Received January 5, 1999
Accepted May 24, 1999

La mer 37 : 11–19, 1999
Société franco-japonaise d'océanographie, Tokyo

Long-term effect of massive crude oil spill during the Gulf War on intertidal invertabrates

Hiroo SATOH*, Kotaro TSHUCHIYA*, Ryo TSUJIMOTO**†, Toshiyuki HIRANO*, Ryusuke KADO** and Hiroshi TOKUDA***

Abstract : A massive oil spilled during the Gulf War of 1991 covered ashore from the southern area of Kuwait to the west side of the Abu Ali Island in the western Arabian Gulf, and a large amount of oil is still left along the intertidal level of these beaches. Surveys were carried out at three times during the period from February 1992 to November 1994, and collected oiled sediment samples on the Gulf coast. This paper reports on the information as the follows ; 1) oil contents of sediment samples in intertidal zone, 2) changes of chemical composition in n-alkanes and identification of polycyclic aromatic hydrocarbon in sediment samples at Munifah Beach 3) influence of oil spilled on intertidal invertabrates, on the bassis of biological data obtained at each sites in western Arabian Gulf coast. The contamination by polycyclic aromatic hydrocarbon in an inner layer of sand still persisted and so the infauna at habitat of a deeper layer in sandy beach, such as *Umbonium vestiarium* and *Dosinia* sp., was not yet found in Manifah Beach, which was the most oil-polluted site on early November 1994.

Key words : *Crude oil spill, Gulf War, Infauna, n-alkane, PAH (Polycyclic aromatic hydrocarbon)*

1. Introduction

From late January and early April in 1991, crude oil more than 160 million gallons was spilt into the seawater of Arabian Gulf (IOC, 1991). The oil slicks moved toward the southeast, staying ashore under the influence of northerneast winds. As a result, the spilt oil was trapped by Abu Ali Island near Al-Jubail. Most of the Saudi Arabia shoreline from Kuwait to Abu Ali Island ranging over more than 500 km, were covered heavily by oil (Fig.1). According to Saudi Arabian Officials, the amount of the light fraction in the spilt oil lost by evaporation have been estimated as high as 50 percent, and approximately 38 million gallons were stranded along the Saudi shoreline (IOC, 1991). The remained oil penetrated into and persisted in the sediments throughout the intertidal zone (HAYES *et al*., 1993). The purpose of the present studies is to clearfy the duration of the persistent contamination of oil and its long-term effects on invertabrates in intertidal the zone sediments.

* Tokyo University of Fisheries, 4-5-7 Konan, Minato-ku, Tokyo, 108-8477 Japan
** Kitasato University, Sanriku, Iwate, 022-0100 Japan
*** Aikokugakuen Junior College, 5-7-1 Nishikoiwa, Edogawa-ku, Tokyo, 133-0057 Japan
† Present address: Toyama Prefecture Fisheries Institute, 363 Takatsuka, Namerikawa-shi, Toyama, 936-0011 Japan

2. Materials and methods

The survey sites was selected on basis of IOC report (1991). According to this report, the spilt oil covered most of shore from Abu Ail Island to southern area in Kuwait City. On the first survey, sampling was carried out at eight sites on mid-February 1992, which were Al Khobar Beach near Dhahran and eastern side of Abu Ali Island as non-polluted area, and the western side of Abu Ali Island, Munifah, Safaniya, Grummah Island and other points as polluted area. Second survey was conducted on late August 1993 at six sites, which were along Manifah Beach, the western and eastern sides of Abu Ali Island as polluted sites, and

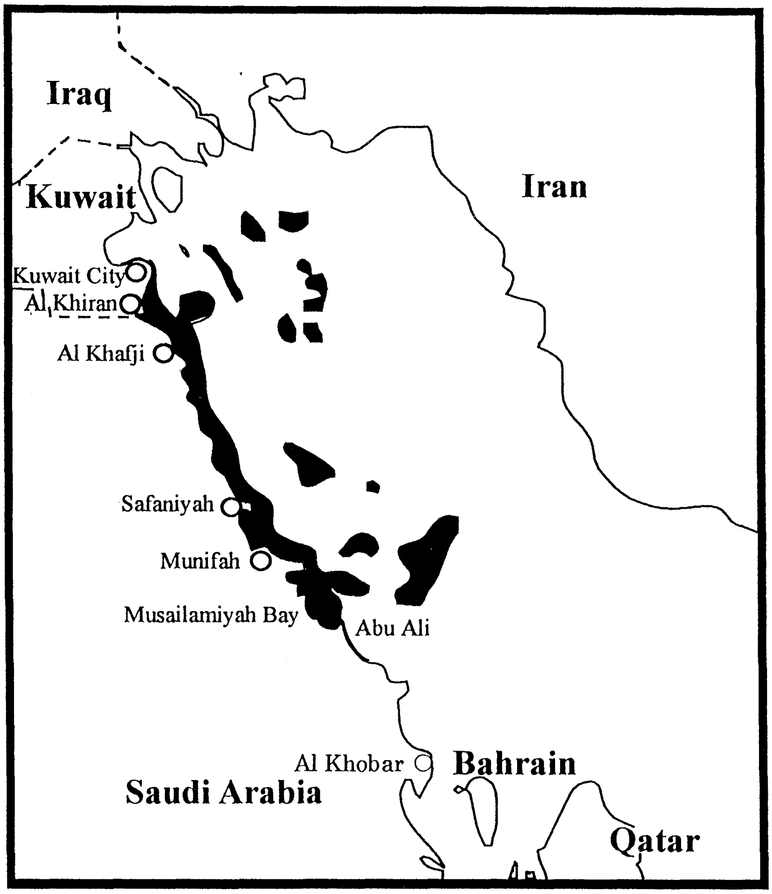

Fig. 1. Extent of the oil spill during the Gulf War and sampling sites for three time survey. A black part indicates the oil polluted area as monitored on March 6, 1991 (cited by GERGES, 1993)

along Al Khafji and Al Khiran where was located between Al Khafuji and Kuwait City. The third survey was carried out on early November 1994 at the same six sampling sites as ones conducted in the second survey and additional at Al Khober also.

Sediment samples were all collected at mid-tide levels of intertidal sandy beaches and salt marshes in each sites. The sediment-core samples for chemical analysis were collected manually with plastic tubes, which were 40 cm in length and 3 cm in diameter. The core sample were cut into several centimeter with a knife, and was analyzed for determination of oil content.

The analytical procedure of oil content in the core samples is shown in Fig. 2. The extracted fraction by n-hexane and by dichlorometane were analyzed according to American National Standard Test Method D-893 (1992). Each sample was prepared by the homogenizing the oil and/or sand mixture with a spatula in 50-ml vial. Sample of 10 gram was extracted by n-hexane of 10ml and made dry up after three time extractions (n-hexane-soluble fraction). The residue of sediment was extracted at three time by dichloromethane (dichlorometane-soluble fraction), and the fraction was mainly extracted for asphaltic components. Extraction efficiency was enhanced by using ultrasonic wave, and allowed to sit for one hour. After the extracted sample reached equilibrium, the vial was centrifuged at 3000 rpm for 10 minutes. An aliquot of the n-hexane-soluble fraction was

Fig. 2. Photograph of a core sediment sample collected at Munifah beach on early November 1994.

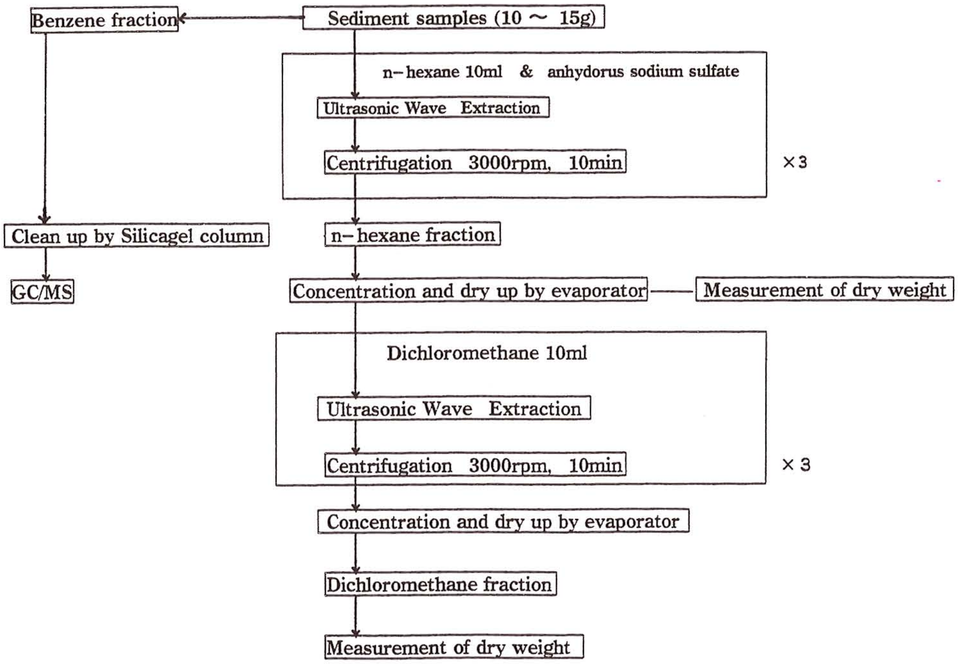

Fig. 3. Flow chart of analytical method of sediment samples collected at each sites. GC/MS operating parameters is following as TSUJIMOTO *et al.* (1998).

purified by silicate gel column, and then injected into a Gaschromatograph (Varian 3400)-Massspectrometer (Quadrupole 710, Finnigan MAT Inst. Co.). The component of n-alkane in the n-hexane-soluble fraction and of polycyclic aromatic hydrocarbons in benzene-soluble fraction were detected by single ion monitoring method of GC/MS (modified by FARRINGTON *et al*, 1982).

The benthic organisms in mid-tidal sediment

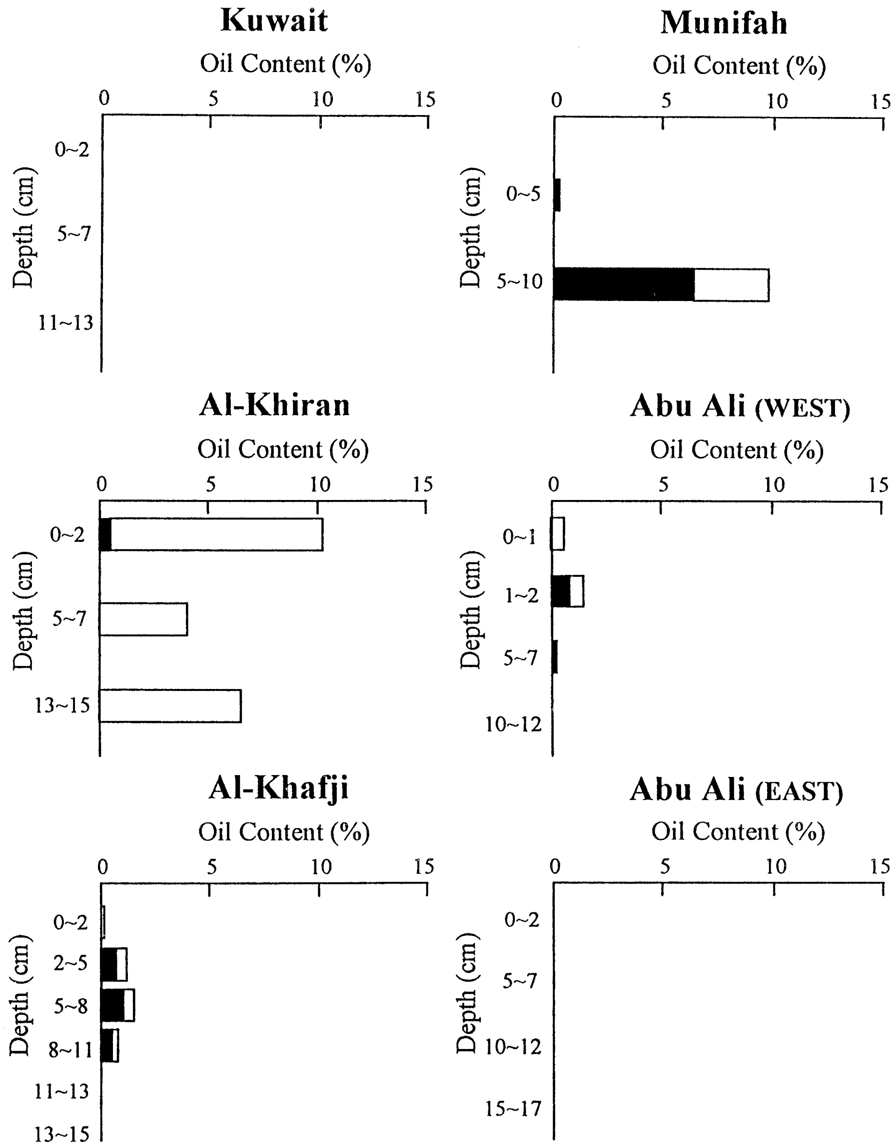

Fig. 4. Vertical distribution of oil content (%) in the sediment samples collected at each sites on late August 1993. Black and white bars indicate the n-hexane soluble fraction and the dichlorometane soluble fraction, respectively.

samples were collected in a quadrat of $10cm^2$ up to the depth of 10 cm and sieved with 2 mm mesh at each survey sites. Retained invertebrates were sorted their individual number live and dead animals.

3. Results and Discussion

In a core sample collected at Munifah Beach on November 1994, sedimented oil still found heavily remaining from surface to 10 cm depth layer (Fig. 3). As shown in Fig. 4, the analytical results of sediment samples collected on late August 1993 indicate that spilt oil at the southern area of Kuwait City and the eastern side of Abu Ail Island was not found clearly. That is, the polluted areas were restricted between Al Khiran coast and the west of Abu Ali Sand Bank, as almost same result by GERGES

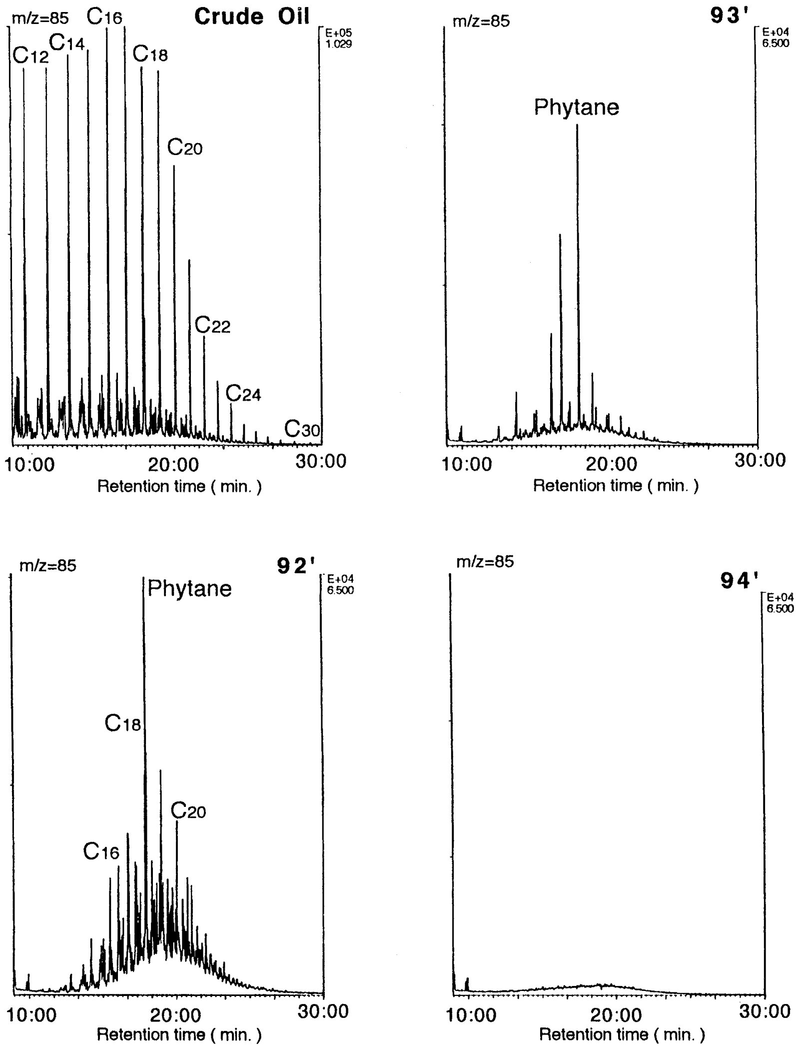

Fig. 5. Chromatograms of the n-hexane soluble fraction in sediment samples collected at Munifah beach. Numbers of peaks indicate chain length of n-alkanes.

(1993). The surface of sediments at several sites on mid-February 1992 was still covered 220 cm thick with weathered oil which was already changed to asphalt. And, as this result is shown, oil content of the sand at the depth between 5 and 10 cm of Munifah Beach on late August 1993 was 98.3 g/kg at the maximum which was occupied by 67% of n-hexane-soluble fraction, and the rest was composed of dichlorometane-soluble fraction. The oil content of surface sand layer was less than that of layer ranging from 5 to 10 cm depth. The percentage of dichlorometane-soluble fraction at Al Khiran Beach was considerably high. It was assumed that the sedimental oil in the surface layer of these areas was weathered to the asphaltic component.

From the result of the crude oil by Single Ion Monitor of GC-MS of sediment samples from 1992 to 1994 at Munifah Beach (Fig. 5), showed that the sample mainly contains n-alkanes ranging from C_{12} to C_{24}. Phytane and UCM (unresolved complex mixture) in the sediment samples of 1992 were clearly detected, and phytane was dominat in the samples of 1993, but no peak of n-alkanes were detected in the

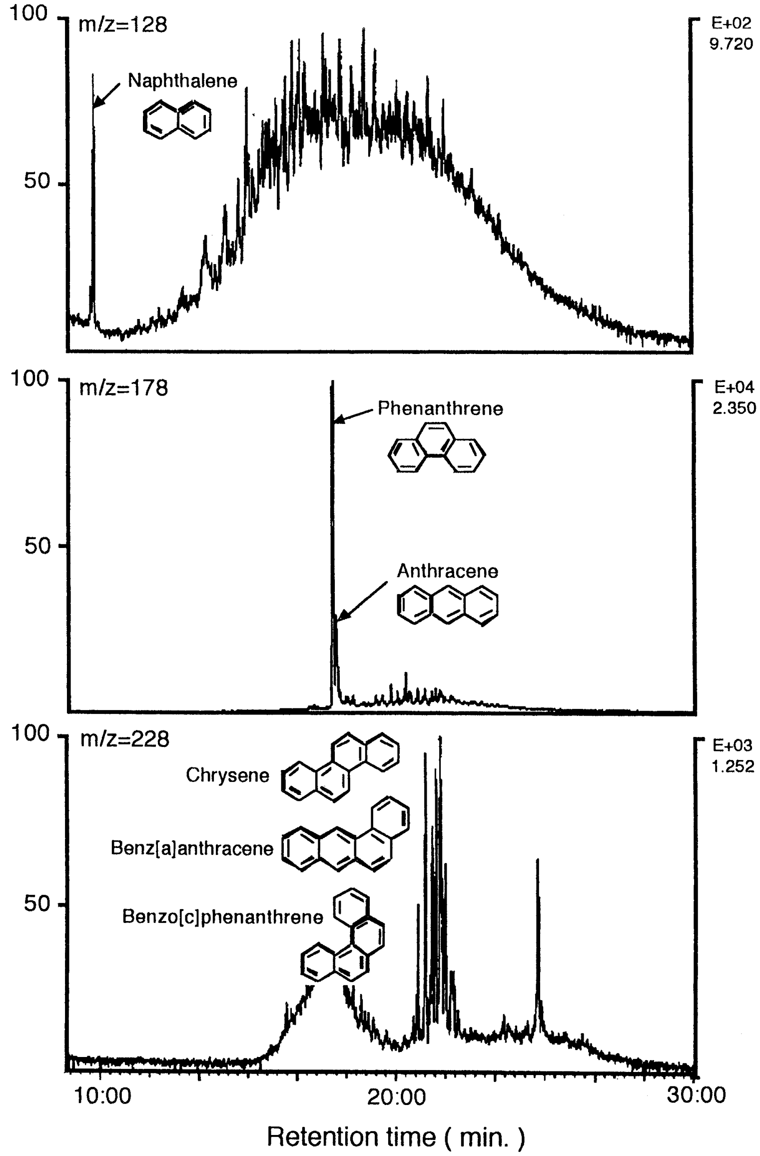

Fig. 6. Chromatograms of benzene soluble fraction in sediment samples collected at Munifah beach on early November 1994.

samples of 1994, which were fifteen months old after spilt out. This result suggests that the decomposition rate *in situ* was extremely lower than that in culture media (NELSON-SMITH, 1970), because the oil absorbed by sand invaded inner layer of the days go on, and then the decomposition of remaining oil is interrupted by newly covered sand which gave rise to anaerobic environment in an oily sand layer.

Figure 6 shows the mass-chromatogram of benzene-soluble fraction in sediment at Munifah Beach at the third survey of 1994. Polycyclic aromatic hydrocarbons, such as naphthalene, phenanthrene, anthracene and chrysence, still remained for long term after the Gulf War, as shown similarly to the result of the barge Florida spilt No. 2 fuel oil into Buzzzard Bay, Massachusetts on 29 September

Table 1. Species abundance and change of benthic organisms (>2mm) at the main sampling sites in the intertidal zone of southeastern coast of Arabian Gulf area

Locality	Al Khafji				Munifah			Abu Ali					Al Khobar	
	polluted		Non-polluted					polluted			Non-polluted			
year	93	94	93	94	92	93	94	92	93	94	93	94	92	94
ANNELLIDA														
Polychaeta														
unidentified spp.				++/		+/					+/	+/		
MOLLUSCA														
Gastropoda														+/
Umbonium vestiarum		/+		/+	/++		/+						/++	
Pseudomonilia gradata	/+	/+			/+	/+						/+		
Ocilinus kotschyi			++/+				/+							
Nodilittorina arabica		/+		+/			/+						+/	++/+
Cerithiopsidella cingulata		/+++	/+	+/++				++/++	/++	++/++	++/++	+/+		
Potamides conicus				/++	+/+++		+/++						++/+++	/+
Cerithium scabridium	/++	+/+	/+	/+										
Cerithium sp.	/+	/+		/+	/++	/+	/+		/+		/+	/+	++/++	+/
Clypeomorus b. persicus		/+		/+	/++		/+	/+	/+	+/+	/+	+/+	+/++	
Mitrella blanda	/+													
Atys cylindrica	/+													
Bivalvia*														
Brachydontes variabilis							/+						/+	
Modiolus sp.					/+			/+						/++
Pillucina fischeriana		+/+++												+/
Tellina arcinoensis					/+						/+		+/+	+/
Tellina (?*Arcopella*) sp.		/+		+/+										
Dosinia spp.	/+	/++	+/+	/+	+/++	/+	/+	/+	/++	/+	/++		+/++	+/+
Meretrix sp.														+/
ARTHROPODA														
Crustacea														
Balanus amphitrite											/+		+/+	

Abundance are shown in "plus" character as follows: +, <10 ind.; ++, <100 ind.; +++, <1,000> ind., arranged living/dead abundances.

*Abundance of dead bivalve shell was calculated as all valve number/2.

1969 reported by TEAL *et al.* (1992). The decomposition of these persistent components and their long-term effect to marine ecosystem should be pursued in the furture.

Taxobiogeological data collected at each sites for three time surveys are summerized in Table 1. Species names and abundance of invertebrates collected in each sample are listed up, and the fauna was mostly composed of molluscs, among which the dominant species were gastropods, *Cerithiopsidella cingulata* and *Cerithium scabridum*, and bivalves also. Total number of species at each site was less than fifteen at most. The diversity of biological communities in the intertidal zones of the Arabian Gulf was very low for three time surveys, even in non-oil-polluted sites. Seasonal changes of these communities in three seasons, that is, February, August and November were not clearly observed. This low diversity and narrow fluctuation throughout the year is due to the stressful environment, such as high salinity and high water temperature, as reported by KADO *et al.* (1992).

Percentages of live and dead individuals of littoral animal at each sites is shown in Fig 7. At the heavily polluted sites of Munifah and Al Khafuji, living organisms were not found at all, while plently of living organisms were found at non-polluted site of Al Khobar Beach. In any case, percentages of live individuals were clearly low in the oil-polluted sites as compared with those of non-polluted sites. This fact appears to be a proof that oil-polluted areas in 1994 were still suffered from the adverse effects of the oil and was delayed recovery of marine

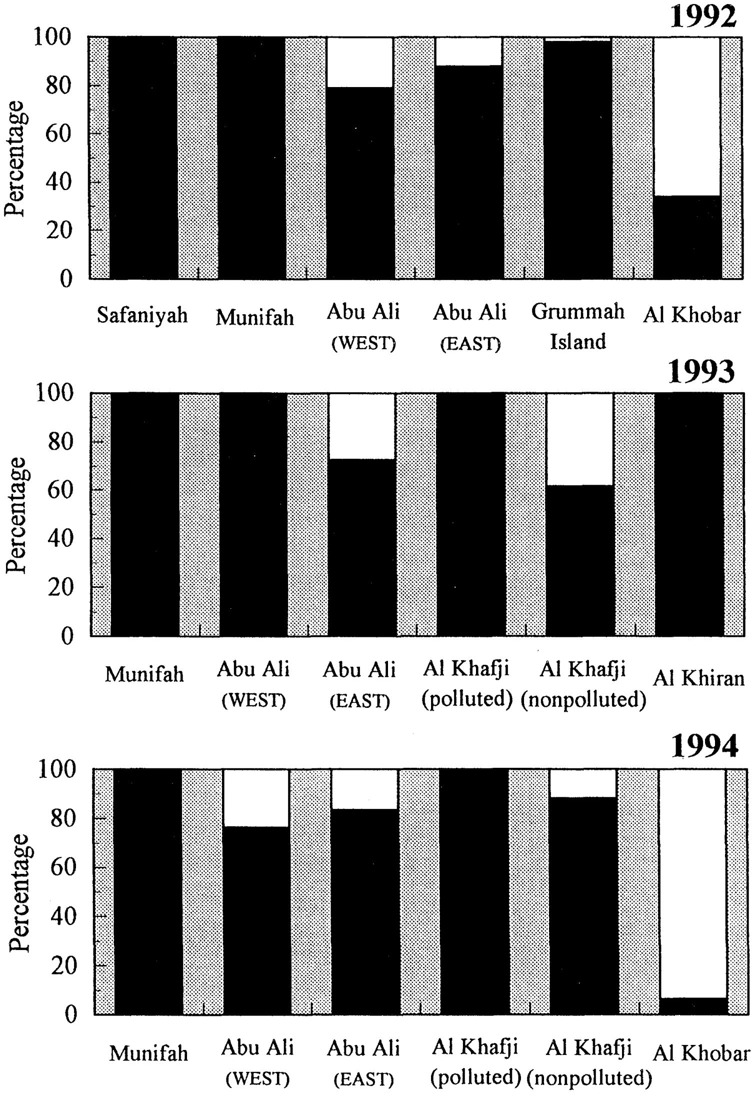

Fig. 7. Percentages of live and dead individuals at each site in mid-February 1992, late August 1993 and early November 1994. Black and white bars indicate dead and living organisms, respectively.

life. The infauna which organisms was living at habitat of a deeper layer in sandy beach, such as *Umbonium vestiarium* and *Dosinia* sp., were not yet found in Manifah Beach of the most oil-polluted site on early November 1994. It suggests that the remaining oil, both weathered and absorbed by sediments, is not only taking the favorite substrata away from inhabitants like sandhoppers and crabs, but also oxygen supply is reduced at to a deeper layer and consequently infaunal invertabrates are prevented from recovering. In addition, oozing oil may be discouraging invertebrate larvae from settling on sand.

The most polluted area at Munifah Beach is still contaminated by polycyclic aromatic hydrocarbons. The long-term monitoring on oil and organisms in oily beach urgently needed, and the favorable coastal environment should be recovered as soon as possible.

Acknowledgments

The authors are grateful to ROPME, MEPA, KISR, AOÇ and WWF-Japan for encouragement of science to serve humanity. This study was supported by research grant from Monbusho International Scientific Program and from the Centennial Anniversary of the Founding of Tokyo University of Fisheries.

Referrence

AMERICAN NATIONAL STANDARD (1992): Standard Test Method for Insoluble in Used Lubricating Oils. D 893–92, pp. 261–265.

FARRINGTON, J. W., B. W. TRIPP, J. TEAL, K., TJESSEN, A. C. DAVIS, J. B. LIVRAMENTO, N. W. HEYWAR and N. M. FREW (1982): Biogeochemistry of Aromatic Hydrocarbons in the Benthos of Microcosms. Toxicology Environ. Chem., **5**, 331–349.

GERGES, M. A. (1993): On the Impacts of the 1991 Gulf War on the Environment of the Region: General Observations. Mar. Pollut. Bull., **27**, 305–314.

HAYES, M. O., J. MICHEL, T. M. MONTELLO, A. M. AL-MANSI, J. R. JENSEN, S. NARUMALANI, D. V. AURAND, A. H. AL-MOMEN and G. W. THAYER (1993): Distribution of Oil from the Gulf War Spill within Intertidal Habitats–One Year Later. Proceedings of the 1993 International Oil Spill Conference, American Petroleum Institute, Washington D. C. pp. 373–381.

IOC (1991): Working Group on Oceanographic Cooperation in the ROPME Sea Area, First meeting, 12–14 June 1991. UNESCO, IOC/WGOCR–1–3, Reports of Meetings of Experts and Equivalent Bodies. pp. 10.

KADO, R., H. TOKUDA, H.SATOH, S.HANAWA and Y. MURATA (1993): Influence of a Big Oil Spill the Gulf War on Intertidal Invertabrates. Proceedings of the 1993 International Oil Spill Conference, American Petroleum Institute, Washington D. C. pp. 859–862.

NELSON-SMITH, A. (1970). The Problem of Oil Pollution of the Sea. In Advances in Marine Biology Vol.8, Academic Press, Yew York, pp.215–306.

TEAL, J. M., J. W. FARRINGTON, K. A. BURNS, J. J. STEGEMAN, B. W. TRIPP, B. WOODIN and C. PINNEY (1992). The West Falmouth Oil Spill After 20 Years: Fate of Fuel Oil Compounds and Effects on Animals. Mar. Pollut. Bull., **24**, 607–614.

TSUJIMOTO, R, S. HASHIMOTO, and A. OTSUKI, (1998): Distribution of n-alkanes and heterocyclic sulfur compounds in open seawaters in the central region of the ROPME sea area. *In* Offshore Environment of the ROPME Sea Area after the War Related Oil Spill. Otsuki, A. M. Y. ABDULRAHEEN and R. M. REYNOLDS (EDS.) pp. 215–230.

Received December 17, 1998
Accepted May 21, 1999

La mer 37 : 21–28, 1999
Société franco-japonaise d'océanographie, Tokyo

Standing crops of planktonic ciliates and their prey organisms, picoplankton and nanoplankton, around the continental shelf break in the East China Sea

Toshikazu SUZUKI*

Abstract : Standing crops of planktonic ciliates, nanoplankton and picoplankton were investigated around the continental shelf break in the East China Sea. They were 1.0×10^1–2.08×10^3, 2.15×10^5–6.45×10^6 and 6.14×10^7–1.01×10^9 cells/l, respectively. Vertical profile of planktonic ciliates was almost parallel to that of autotrophic nanoplankton. On the other hand, the profiles of heterotrophic nanoplankton and picoplankton, though similar to each other, were different from that of ciliates. These results might indicate that energy and carbon flux flowing into ciliate plankton is mainly from the production of autotrophic nanoplankton in this area. Picoplankton and heterotrophic nanoplankton might be less influential on ciliate production.

Key words : *Planktonic ciliates, Picoplankton, Nanoplankton, East China Sea*

1. Introduction

Planktonic ciliates, nanoplankton and picoplankton are essential components in marine microbial food webs. Ciliates are known to ingest nanoplankton (GIFFORD, 1985; VERITY, 1985) and picoplankton (SHERR and SHERR 1987; BERNARD and RASSOULZADEGAN, 1990). Nanoplankton, especially heterotroph, is also an important predator on picoplankton (TANAKA and TANIGUCHI, 1996; TANAKA *et al.*, 1997). Relationships between the two plankton out of these three have been quantitatively investigated. Picoplankton abundance correlates to heterotrophic nanoplankton abundance (SANDERS *et al.*, 1992), while in some case the relationship is weak though statistically significant (GASOL and VAQUÉ, 1993). Furthermore, standing crops of nanoplankton correlates well to ciliate plankton in the western Pacific Ocean (SUZUKI *et al.*, 1998). LYNN and MONTAGNES (1991) however report that the correlation between picoplankton biomass and planktonic ciliate biomass is poor. An entire figure composed of these three groups is not easily obtained from these relationships because these reports were obtained individually on space and time. A simultaneous investigation on these three plankton groups is indispensable for prevailing their trophic structure.

In this study, standing crops of planktonic ciliates, nanoplankton and picoplankton were simultaneously investigated around the continental shelf break in the East China Sea. There is a boundary between the water of continental shelf and that of the Kuroshio current in this region. The shelf water is rich in nutrients from large river, Changjiang River, and sometimes productive, e. g. 1570 mg C/m^2/d (HAMA, 1995). On the other hand, the Kuroshio water is poor in nutrient and less productive, e. g. 60 mg C/m^2/d (TANIGUCHI, 1972) and 209–290 mg C/m^2/d (HAMA, 1995). Various substances in the shelf water are mixed and conveyed out by the Kuroshio current flowing to north-east along the continental slope. To estimate the transportation of particulate organic carbon and other biogenic substances, the investigation of microbial components as well as organisms in the classical food chain is essential.

2. Method

On May 29, 1996, three stations around the continental shelf break in the East China Sea

* Faculty of Fisheries, Nagasaki University, Nagasaki 852-8521, Japan

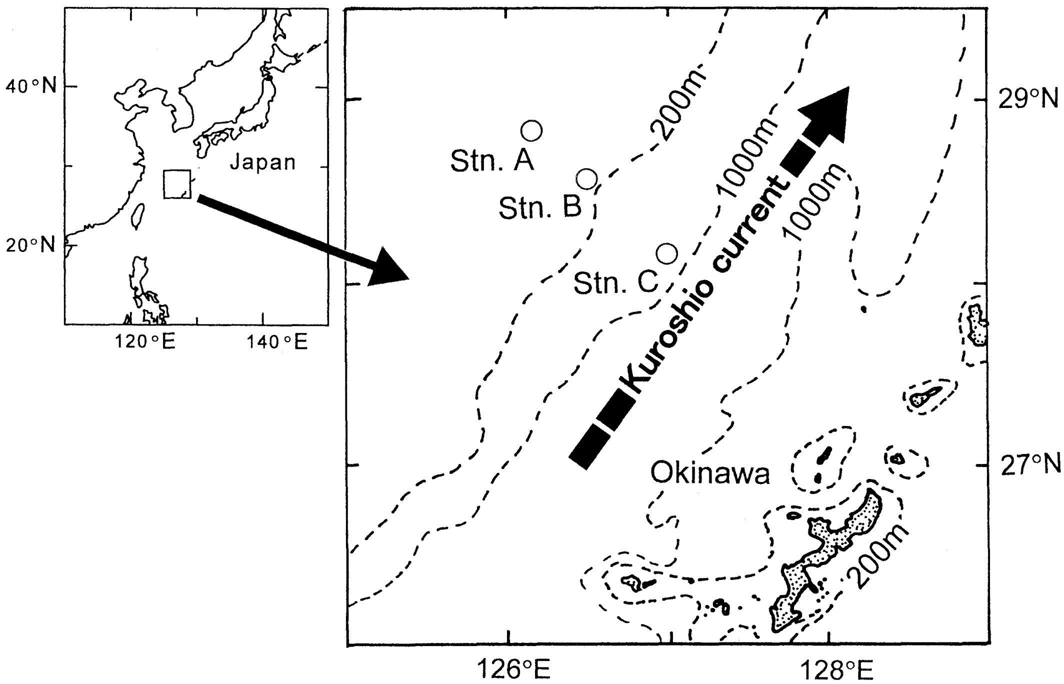

Fig. 1. Location of stations in the East China Sea occupied on the cruise of the T/S Kakuyo Maru in early summer of 1996. Position of the Kuroshio current is cited from the Quick Bulletin of Ocean Condition, No. 11 (1996).

(Fig. 1) were investigated by T/S Kakuyo-Maru, Nagasaki University. Temperature and salinity were measured with a CTD. Thirty three water samples from upper 110 to 400 m were taken with a rosette multisampler equipped with the CTD. Bottom depth at Stns. A, B and C were 113, 134 and 910 m, respectively.

Preparation for picoplankton (0.2 to 2 μm in equivalent spherical diameter) and nanoplankton (2 to 20 μm in ESD) counting was carried out on board immediately after sampling. An aliquot of 40 ml water was fixed with glutaraldehyde at final concentrations of 0.5 %. Ten ml of the fixed sample was stained with DAPI for picoplankton counting and filtered through a 0.2 μm pore size and black pre-stained Nuclepore filter (SHERR *et al.*, 1993). Another 20 ml was stained with proflavin for nanoplankton and filtered through a 0.6 μm pore and black pre-stained Nuclepore filter (SHERR *et al.*, 1993). The prepared filters were stored in a freezer (−20 ℃) until microscopic observation in laboratory.

Within one month after sampling, picoplankton and nanoplankton were observed under an epifluorescence microscope (Nikon BHC) at 1000× magnification using UV and Blue excitation, respectively. Twenty fields for picoplankton equivalent to 1.38×10^{-3} ml and 1690 fields for nanoplankton equivalent to 2.34×10^{-1} ml were examined. Their detection limit were 7.52×10^{5} cells/l and 4270 cells/l, respectively. Although small-sized ciliates, less than 20 μm in ESD, occurred occasionally, such ciliates were not counted in nanoplankton category. Autotrophic nanoplankton were separately counted from heterotrophic one according to the red emission of chlorophyll pigments.

For the examination of planktonic ciliates, 200 ml of water aliquot was fixed on board with Bouin's solution at final concentration of 5 % (JEROME *et al.*, 1993). Fixed water samples were stored in cool and dark place. After returning to laboratory, samples were concentrated with a sedimentation cylinder and observed under biological microscope (Nikon BHC) using a Sedgwick-Rafter slide. Detection limit of

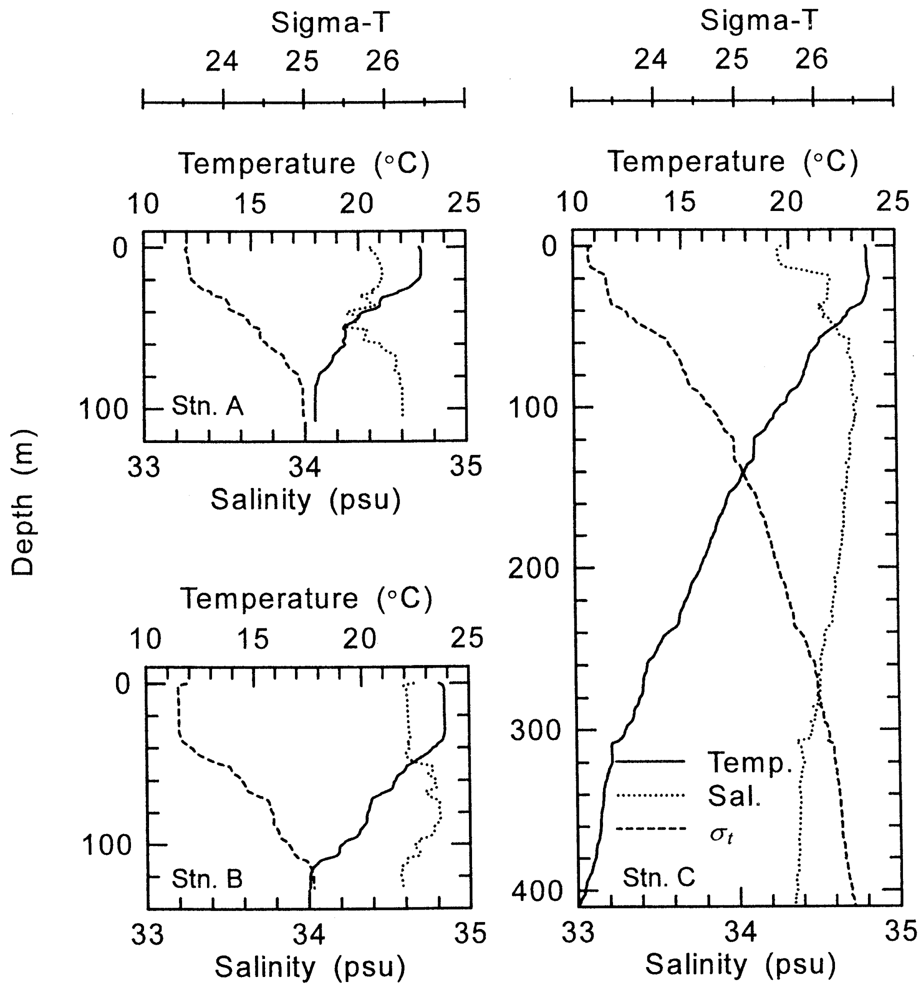

Fig. 2. Vertical profiles of water temperature, salinity and sigma-T.

ciliate counting was 5 cells/l. *Mesodinium* spp., other naked ciliates and loricated ciliates were separately counted by their morphological features.

3. Result and Discussion

Sampling stations were located on the boundary between the shelf water and the Kuroshio water (Fig. 1) according to the report of the Quick Bulletin of Ocean Condition (1996). Stn. A was more influenced by the shelf water and Stn. C was by the Kuroshio water.

Mixing layer was observed in the surface at every station (20–40 m in thickness) (Fig. 2). Water temperature and salinity at 0 m depth was 22.8 – 23.6 ℃ and 34.29 – 34.66 psu, respectively. Below this layer, water temperature decreased with depth, salinity however did not show conspicuous change while it fluctuated in fine scale around 40–100 m depth, and sigma–T resulted in increasing with depth. At Stns. A and B, undeveloped picnocline occurred also near the bottom (10–20 m in thickness).

Picoplankton abundance at Stns. A and B was 4.31×10^8–9.93×10^8 cells/l and did not show noticeable change throughout the water column (Fig. 3). On the other hand, the abundance at Stn. C decreased gradually with depth, especially in the deeper layer, i. e. from 1.01×10^9 cells/l at 0 m depth to 6.14×10^7 cells/l at 400 m. These abundances are comparable to those

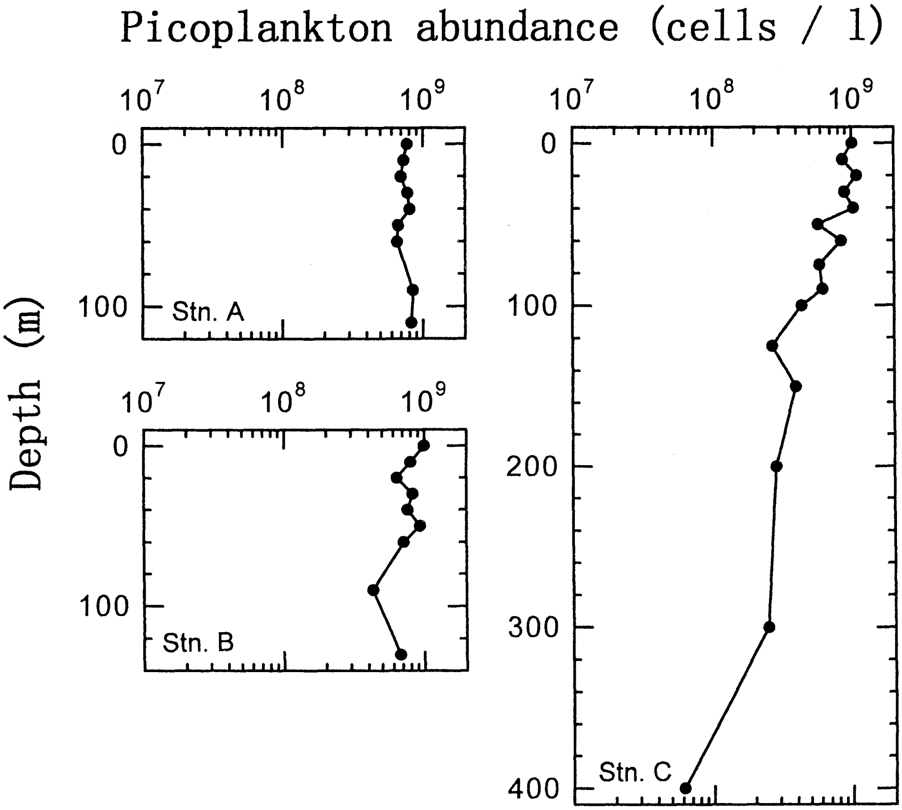

Fig. 3. Vertical profiles of picoplankton abundance.

of coastal and offshore waters, e.g. 0.5 – 3.0 $\times 10^9$ cells/l in summer of Onagawa Bay, the northeastern Pacific coast of Japan (TANAKA and TANIGUCHI, 1996) and 10^8 cells/l order of magnitude in Kashima-Nada, the lower reach of the Kuroshio current (ISHIGAKI *et al.*, 1997).

Abundances of total nanoplankton, autotrophic nanoplankton and heterotrophic nanoplankton were 2.15×10^5–6.45×10^6, 1.73×10^4–5.65×10^6 and 1.85×10^5–1.69×10^6 cells/l, respectively (Fig. 4). Although autotrophic nanoplankton dominated over heterotrophic one in the surface at every station, it became subordinate below 150 m depth at Stn. C. These standing crops were comparable to those of other oceanic waters, e. g. 6.9×10^5–1.38×10^6 cells/l of total one, 1.44×10^5–5.25×10^5 of autotrophic one and 3.76×10^5–1.17×10^6 of heterotrophic one in Sargasso Sea (CARON, 1983) and 1.45×10^5–3.18×10^6 cells/l of total one in off eastern Australia (SUZUKI *et al.*, 1998). They were however slightly smaller than that of eutrophic coastal sea water, e. g. 1.0×10^6–8.8×10^6 cells/l of heterotrophic one in northern Hiroshima Bay, Seto Inland Sea, Japan (IMAI and YAMAGUCHI, 1996).

Total ciliate abundance was 1.0×10^1–2.08×10^3 cells/l (Fig. 5). It was also comparable to other warm waters around Japan, e. g. 30–3040 cells/l in the East China Sea in August (OTA, 1995), 40–1760 cells/l in Toyama Bay in August (SUZUKI and TANIGUCHI, 1997). The decrease of ciliate abundance with depth was stronger than those of picoplankton and nanoplankton especially at Stn. C.

Among the three ciliate groups, *Mesodinium* spp. were hardly observed. They occurred at only three layers of Stn. A and their abundances were less than 85 cells/l. Even if they were all autotrophic one, i.e. *M. rubrum*, their contribution to primary production might be trivial in the continental shelf edge of the

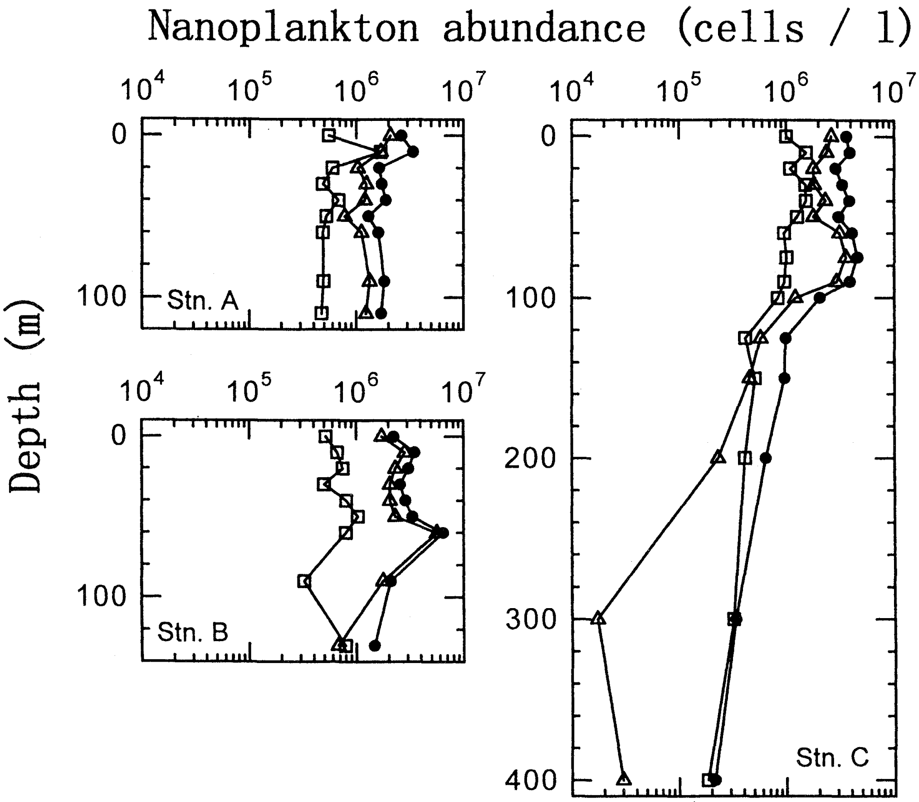

Fig. 4. Vertical profiles of nanoplankton abundance. ●: total nanoplankton, △: autotrophic nanoplankton, □: heterotrophic nanoplankton.

East China Sea.

Loricated ciliates occupied small proportion to total ciliates. Its ratio to total ciliates was less than 0.14. Naked ciliates except *Mesodinium* spp., on the other hand, dominated throughout the water column at every station. Such small proportion of loricated ciliates was also reported in oligotrophic and open sea areas (SUZUKI and TANIGUCHI, 1998).

Abundance ratio of picoplankton to heterotrophic nanoplankton ($3.33 \times 10^2 - 1.91 \times 10^3$) was stable, while it slightly decreased with depth (Fig. 6B). The vertical profile of picoplankton was parallel to that of heterotrophic nanoplankton. Picoplankton might have a close relationship with heterotrophic nanoplankton, as is usually reported in various sea areas (e. g. SANDERS *et al.*, 1992). On the other hand, the ratio to autotrophic nanoplankton ($1.27 \times 10^2 – 1.43 \times 10^4$) and that to ciliate plankton ($4.13 \times 10^5 – 7.07 \times 10^6$) increased substantially with depth (Figs. 6A and C). The vertical profiles of autotrophic nanoplankton and ciliates showed stronger decrease with depth rather than that of picoplankton. The relationship between picoplankton and autotrophic nanoplankton and that between picoplankton and ciliates might be trivial in this area. The contributions of autotrophic nanoplankton and ciliate plankton toward the microbial food webs were relatively large in the shallow layer and small in the deep layer.

The ratio of autotrophic nanoplankton to ciliates ($1.92 \times 10^2 – 1.90 \times 10^4$) did not show a significant change throughout the water column, while it varied widely (Fig. 7A). Autotrophic nanoplankton showed nearly parallel profile to ciliates. It might have a close relationship with ciliates and sustain the standing crop of ciliates. On the other hand, the ratio of heterotrophic nanoplankton to ciliates ($2.85 \times 10^2 – 1.85 \times 10^4$) increased with depth (Fig. 7B). Heterot-

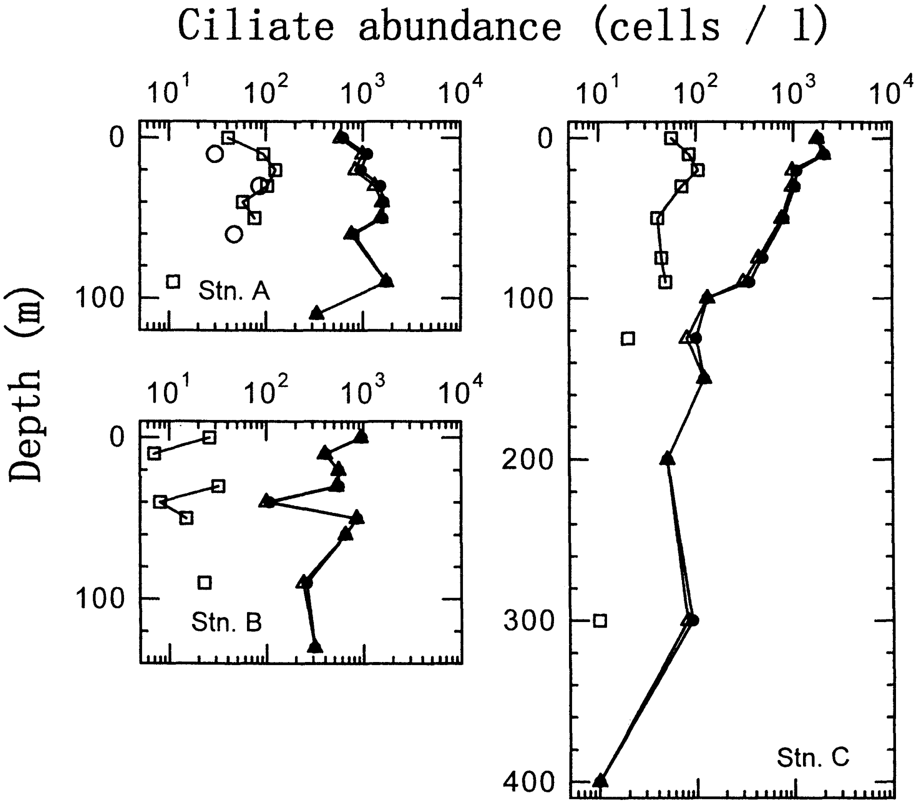

Fig. 5. Vertical profiles of ciliate abundance. ● : total ciliates, △ : naked ciliates except *Mesodinium* spp., □ : loricated ciliates, ○ : *Mesodinium* spp.

rophic nanoplankton showed dissimilar profile to ciliates, i.e. the former decreased more weakly with depth. The relationship between heterotrophic nanoplankton and ciliates might not be so substantial as that between autotrophic nanoplankton and ciliates.

From these abundance ratios, it is considered that there are two independent routes of energy flux in the microbial components; one is from picoplankton to heterotrophic nanoplankton and the other is from autotrophic nanoplankton to ciliate plankton. The former is relatively important in the deep layer and the latter is in the shallow layer. These scheme is different from the original microbial loop that the bacterial production is the primary energy source for ciliate production (AZAM *et al.*, 1983). Considering the microbial processes integrated through an entire water column, the shelf break zone in the East China Sea might be the boundary of microbial energy route, i. e. the link from autotrophic nanoplankton to ciliates is important in the continental shelf area and that from picoplankton to heterotrophic nanoplankton is in the Kuroshio current area.

Acknowledgments

I would like to thank the captain H. AKISHIGE, the chief officer H. YOSHIMURA and other officers and the crews of T/S Kakuyo-Maru, Nagasaki Univ. for their generous assistance in water samplings. This research was partially supported by grants from the Ministry of Education (no. 10660185) and from Sumitomo Foundation (no. 973048).

References

AZAM, F., T. FENCHEL, J. G. FIELD, J. S. GRAY, L. A. MEYER-REIL and F. THINGSTAD (1983) : The ecological role of water-column microbes in the sea. Mar. Ecol. Prog. Ser., **10**, 257–263.

BERNARD, C and F. RASSOULZADEGAN (1990) : Bacteria

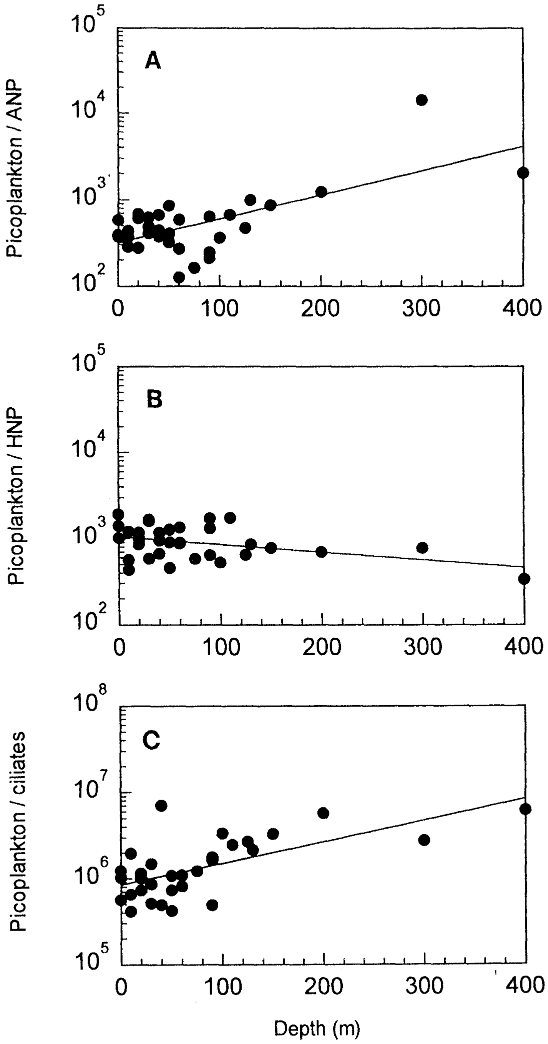

Fig. 6. Relationship between depth and abundance ratio of picoplankton to other plankton groups. Linear lines are drawn by the least square mehod on semilogarithmic scale. A : picoplankton / autotrophic nanoplankton (ANP), B : picoplankton / heterotrophic nanoplankton (HNP), C : picoplankton/ciliate plankton

on microflagellates as a major food source for marine ciliates: possible implications for the microzooplankton. Mar. Ecol. Prog. Ser., **64**, 147–155.

CARON, D. A. (1983) : Technique for enumeration of heterotrophic and phototrophic nanoplankton, using epifluorescence microscopy, and comparison with other procedures. Appl. Environ.

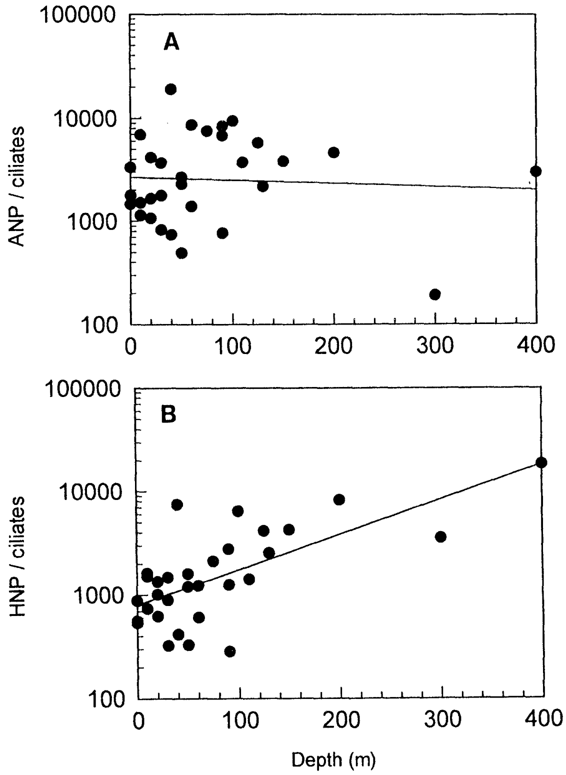

Fig. 7. Relationship between depth and abundance ratio of nanoplankton to ciliate plankton. Linear lines are drawn by the least square method on semilogarithmic scale. A : autotrophic nanoplankton (ANP) / ciliate plankton, B : heterotrophic nanoplankton (HNP)/ciliate plankton

Microbiol., **46**, 491–498.

GASOL, J. M., and D. VAQUÉ (1993) : Lack of coupling between heterotrophic nanoflagellates and bacteria : a general phenomenon across aquatic systems? Limnol. Oceanogr., **38**, 657–665.

GIFFORD, D. J. (1985) : Laboratory culture of marine planktonic oligotrichs (Ciliophora, Oligotrichida). Mar. Ecol. Prog. Ser., **23**, 257–267.

HAMA, T. (1995) : Seasonal change of the primary productivity in the East China Sea. Proceedings of the 1994 Sapporo IGBP Symposium, 74–79.

IMAI, I. and M. YAMAGUCHI (1996) : Seasonal fluctuations in abundance and production of bacteria and quantitative relation with heterotrophic microflagellates in northern Hiroshima Bay, Seto Inland Sea. Bull. Nansei Natl. Fish. Res. Inst., **29**, 75–86 (In Japanese with English abstract).

ISHIGAKI, T., J. NISHIKAWA, A. TSUDA and M. TERAZAKI

(1997) : Distribution of nanoplankton around a warm water tongue in the Kashima-Nada Sea in July 1993. La mer, **35**, 69–80 (In Japanese with English abstract).

JEROME, C. A., D. J. S. MONTAGNES and F. J. R. TAYLOR (1993) : The effect of the quantitative protargol stain and Lugol's and Bouin's fixatives on cell size : A more accurate estimate of ciliate species biomass. J. Euk. Microbiol., **40**, 254–259.

LYNN, D. H. and D. J. S. MONTAGNES (1991) : Global production of heterotrophic marine planktonic ciliates. *In* : "Protozoa and Their Role in Marine Processes", P. C. REID, M. TURLEY and P. H. BURKILL (eds.), Springer–Verlag, Berlin Heidelberg, pp. 281–307.

OTA, T. (1995) : Biomass and production of microzooplankton in the East China Sea with special reference to planktonic ciliates. Master's Thesis, Tohoku Univ., Sendai. (In Japanese with English abstract).

Quick Bulletin of Ocean Condition, No.11, July 7 (1996) : Hydrographic Department, Maritime Safety Agency, Japan.

SANDERS, R. W., D. A. CARON and U. –G. BERNINGER (1992) : Relationships between bacteria and heterotrophic nanoplankton in marine and fresh waters : and inter–ecosystem comparison. Mar. Ecol. Prog. Ser., **86**, 1–14.

SHERR, E. B. and B. F. SHERR (1987) : High rates of consumption of bacteria by pelagic ciliates. Nature, **325**, 710–711.

SHERR, E. B., D. A. CARON and B. F. SHERR (1993) : Staining of heterotrophic protists for visualization via epifluorescence microscopy. *In* : "Handbook of Methods in Aquatic Microbial Ecology", P. F. KEMP, B. F. SHERR, E. B. SHERR and J. J. COLE (eds.), Lewis, Boca Raton, pp. 213–227.

SUZUKI, T. and A. TANIGUCHI (1997) : Temporal change of clustered distribution of planktonic ciliates in Toyama Bay in summers of 1989 and 1990. J. Oceanogr., **53**, 35–40.

SUZUKI, T. and A. TANIGUCHI (1998) : Standing crops and vertical distribution of four groups of marine planktonic ciliates in relation to phytoplankton chlorophyll *a*. Mar. Biol., **132**, 375–382.

SUZUKI, T., N. YAMADA and A. TANIGUCHI (1998) : Standing crops of planktonic ciliates and nanoplankton in oceanic waters of the western Pacific. Aquat. Microb. Ecol., **14**, 49–58.

TANAKA, T. and A. TANIGUCHI (1996) : Short–term variation in abundance of bacteria and heterotrophic nanoflagellates in summer observed in Onagawa Bay, Japan. Bull. Plankton Soc. Japan, **43**, 21–29.

TANAKA, T., N. FUJITA and A. TANIGUCHI (1997) : Predator–prey eddy in heterotrophic nanoflagellate bacteria relationships in a coastal marine environment : a new scheme for predator–prey associations. Aquat. Microb. Ecol., **13**, 249–256.

TANIGUCHI, A. (1972) : Geographical variation of primary production in the western pacific ocean and adjacent seas with reference to the inter–relations between various parameters of primary production. Mem. Fac. Fish., Hokkaido Univ., **19**, 1–33.

VERITY, P. G. (1985) : Grazing respiration, excretion, and growth rates of tintinnids. Limnol. Oceanogr., **30**, 1268–1282.

Received January 26, 1999
Accepted May 24, 1999

La mer 37 : 29–37, 1999
Société franco-japonaise d'océanographie, Tokyo

Optical characteristics of hook line in tuna longline fishing

Yoshihiko NAKAMURA*, Siriraksophon SOMBOON**, Fumie SUZUKI* and Yoshinori MIYAMOTO*

Abstract : The in-water apparent contrast of different materials used for hook line in tuna longline fishing was estimated by using their in-water video image. The materials were consisted of three types of wire and nylon monofilament and one fluorocarbon monofilament. Each material was prepared for three operated history in the fishing; a new (no used), 1 day-operated and 7 days-operated hook line samples, respectively.

The apparent contrasts of all kinds of wire hook lines are higher than that of the nylon and fluorocarbon monofilaments. The apparent contrasts of 1 day-operated hook lines are rather lower than that of new hook line materials. The apparent contrasts of 7 days-operated hook lines are rather higher than that of 1 day-operated hook lines.

The nylon and fluorocarbon monofilament hook lines and the 1 day to 3 days-operated hook lines being effective for tuna longline fishing, it is considered that fish are caught by the hook line materials of lower apparent contrast.

Key words : *Visibility, Contrast, Video image, Brightness value, Tuna longline fishing*

1. Introduction

In tuna longline fishing, the book line is generally made of wire or nylon monofilament materials. The catch rate of nylon monofilament hook line is reported to be higher than that of wire hook line (KASUGA, 1990). This higher catch rate is considered to be due to the elasticity characteristic and poor visible range of nylon monofilament; these bring about difficulty for fish both to get free from hook and to detect nylon monofilament hook line, respectively. Moreover some works have been investigated on the optical characteristics of wire and nylon monofilament used as the hook line in tuna longline fishing (NAKAMURA *et al*., 1990 a, b; WARDLE *et al*., 1991). However, why nylon monofilament is suitable for the hook line is not clear yet. In the meantime, it is reported that fish use no other sense except the visual sense to detect fishing gear in its vicinity (BLAXTER *et al*., 1964). From this point of view, the apparent contrast of the hook line with its surr ounding background is considered.

The apparent contrast of an object in the water has been calculated from its luminance with its background which are measured using a luminance meter, but this is difficult to do with a small object in the water. Then luminance measurement of an underwater object can be carried in the laboratory for setting the various optical conditions.

This study proposed a simple investigation method both to estimate the underwater apparent contrast with different materials used for hook line in tuna longline fishing by using an underwater video image, and also to characterize their optical performance.

* Tokyo University of Fisheries, 4–5–7 Konan, Minato-ku, Tokyo 108–8477 Japan
** Southeast Asian Fisheries Development Center, Training Department, P. O. Box 97, Phrasamutchedee Samutprakan 10290, Thailand

2. Materials and Methods

1) Materials

Samples of hook line were collected from tuna longline operation during the cruise of the T/S Shinyo Maru of the Tokyo University of Fisheries in 1996. Table 1 shows the samples of

Table 1. Materails, size, number of sample with different history of using age and the catch

Material	Type	Size		Number of samplee (line)			
		Number*	dia. (mm)	New	1 day	7 days	Catch
Wire	Zinc-alumi-plated	30 (3+9)	1.4	1	2	2	1
Wire	Zinc-plated	30 (3+9)	1.4	1	2	2	0
Wire	Red colour-coated	30 (3+9)	1.4	1	2	2	1
Nylon monofilament	Common White-colored	120	1.95	1	2	2	1
Nylon monofilament	Flexible White-coloured	120	1.95	1	2	2	2
Nylon monofilament	Light grey-coloured	120	1.95	1	2	2	2
Fluorocarbon monofilament	Fluorocarbon	120	1.95	1	2	2	4

*Standardized size of wire and monofilament material in Japan

seven different hook line materials with four different historical hook line materials used in the tuna longline operation and their characteristics. The materials were consisted of three types of wire and nylon monofilament and one fluorocarbon monofilament. Each material was prepared for three operated history in the fishing; "a new" (no use), "1 day-operated" and "7 days-operated" hook line samples, and the hook lines which caught fish hereinafter called "catch line", respectively. A number of the new sample line was only one line for each material compared to two used sample lines because optical characteristics of the new sample lines are about constant. For the catch line, only the good condition lines without twisting or bending were used in the experiments.

2) Methods

The tuna longline fishing operations were carried out by T/S Shinyo-Maru in the Bay of Bengal during the 13–19th of Feb., 1996. Fig. 1 shows seven fishing grounds for the tuna longline operation. In each operation, one hundred baskets were used including seven materials of hook line; six hook lines per basket. The arrangement of the seven materials of hook line is shown in Fig. 2; each material was set for two baskets continuously. After the first tuna longline operation, two hook lines from each materials were collected as "1 day-

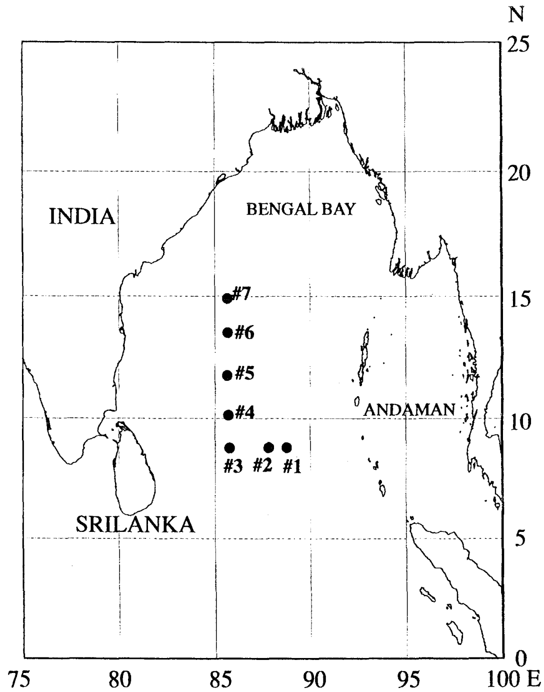

Fig. 1. The fishing grounds for tuna longline fishing operation; figures from #1 to #7 denote seven fishing operations, respectively.

operated" experimental samples. They were rinsed materials were collected as "1 day-operated" experimental samples. They were rinsed with freshwater and dried in shade before being kept in cool conditions. By the same

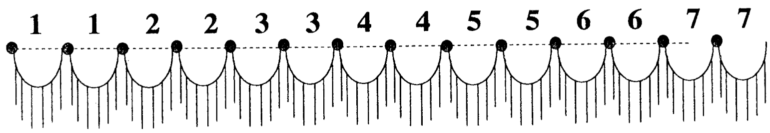

Fig. 2. Diagram of structure in tuna longline fishing gear used. The number 1, 2, 3, 4, 5, 6 and 7 represent seven hook line materials of zinc-alumi-plated wire, zinc-plated wire, red color-coated wire, common white-colored nylon monofilament, flexible white-colored nylon monofilament, light gray-colored nylon monofilament, and fluorocarbon monofilament, respectively.

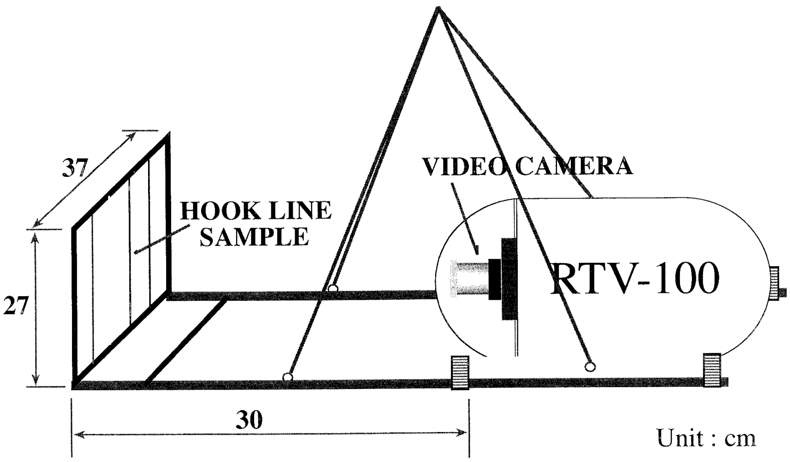

Fig. 3. Instrument for taking an underwater image of hook line samples.

method used in fishing, after seven days the other two lines from each material were collected as "7 days-operated" samples. Furthermore, the hook lines, which caught fish in each fishing operation, were also kept as "catch line" samples; length, weight and species of fish were recorded for every "catch line". These used-line samples were kept for measuring of their apparent contrast.

3) Underwater video image

An underwater video image of the samples was taken during the cruise of T/S Seiyo-Maru of the Tokyo University of Fisheries in the Sagami Bay on the 23rd of May, 1996. The video camera (Nikon Type−5) was set inside the water-proofed case of the Remotely Operated Vehicle (ROV) model "RTV100". Fig. 3 shows arrangement and method to measure the underwater video image of the samples. Due to the visibility of video camera and the small size of the samples diameter being less than 1.95 mm, the distance between the samples and the ROV-video camera was fixed as short as possible at 30 cm. The interval distances between each sample were 7cm apart. The light transmittance (%) in the waters during the experiment was measured by using the STD transmissometer (wavelength 540 nm). As shown in Fig. 4, the profile of light transmittance (%) in the waters of the Sagami Bay clearly shows that the transmittance 85.57% (beam attenuation coefficient; 0.16 m^{-1}) at the depth of 10m reduced to 76.96% (beam attenuation coefficient; 0.26 m^{-1}) at the depth of 17 m. It was overcast sky where the direct light was hardly observed and the irradiance was ranged from 30,000 lx to 50,000 lx on deck. From a forementioned circumstances, the video image was taken up to the depth of 20 m.

The sea conditions such as wave level measured at 3, and wind forces measured at 4 on the

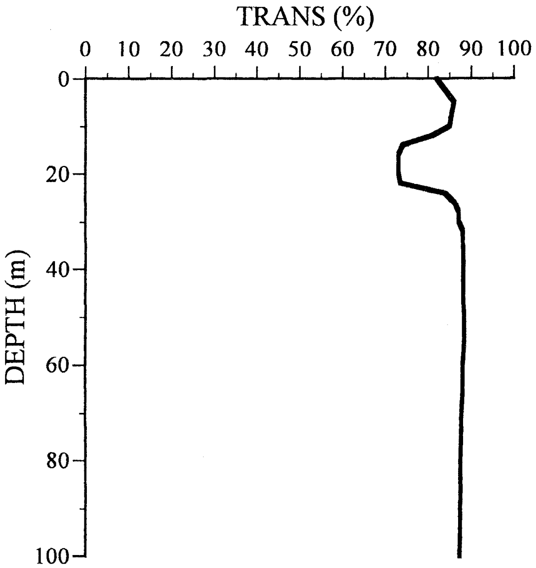

Fig. 4. The profile of light transmittance (%) in the waters of the Sagami Bay.

Beaufort scale were also observed, respectively. In order to prevent bubbles from occurring on the sample line during the experiment, all of the sample lines were soaked in sea water for about 3h.

4) Underwater video image with different distances

An underwater video image of all seven materials with different distances was also taken by two divers in the waters off the Banda Marine Laboratory of the Tokyo University of Fisheries on the 28th of May, 1996. The distances of hook line apart from video camera were changed five steps at 30, 60, 90, 120, and 150 cm, and each step of recording time was 10 s. The vedeo image measurement of these materials was made by an underwater video camera (CCDTR 850, SONY) at the depth of 6m from surface where the water bottom depth was about 10 m. It was cloudy weather where the direct light was hardly observed and the irradiance was 50,000lx on deck. The beam attenuation coefficient α (m^{-1}) was calculated to be 0.28m^{-1}, which was defined as shown in the equation (1) (DUNTLEY, 1963)

$$C_{(r_2)} = C_{(r_1)} e^{-\alpha(r_2 - r_1)} \qquad (1)$$

where C denote the contrast value at different distances between r_1 and r_2.

5) Underwater apparent contrast

Video image of all materials were captured by video capture soft ware and saved as document file as shown in Fig. 5. The NIF IMAGE 1.55 software was used to measure the brightness value of the sample T_g against its surrounding background B_g. Five positions on each sample were measured to calculate an average value.

In this study, the apparent contrast C_l of sample can be defined as shown in the equation (2) (HIOKI, 1981).

$$C_\ell = \frac{T_l - B_\ell}{T_\ell - B_\ell} \qquad (2)$$

where T_l and B_l represent the luminance of sample and surrounding background, respectively.

Then, the video image contrast C_g can also be defined as the function of the brightness value of sample T_g and its background B_g as shown in the equation (3) (NAKAMURA *et al.*, 1995a).

$$C_g = \frac{T_g - B_g}{T_g - B_g} \qquad (3)$$

The coefficient of correlation between apparent contrast C_l and video image contrast C_g being high to be 0.95 under the illmination intensities of 40lx and over, the relationship between them can be defined as shown in the equation (4) (NAKAMURA *et al.*, 1995 b).

$$C_l = 0.134 \ln C_g + 0.933 \qquad (4)$$

According to aforementioned methods, the underwater apparent contrast of each material was estimated.

3. Results

1) Apparent contrasts of hook line material at different conditions

Figure 6 show the apparent contrasts of all hook line materials for the new line in comparison with the 1 day-operated, the 7 days-operated and the catchlines.

Figure 6–a shows the apparent contrasts of the new hook lines. The apparent contrasts of the new wire materials are higher than new

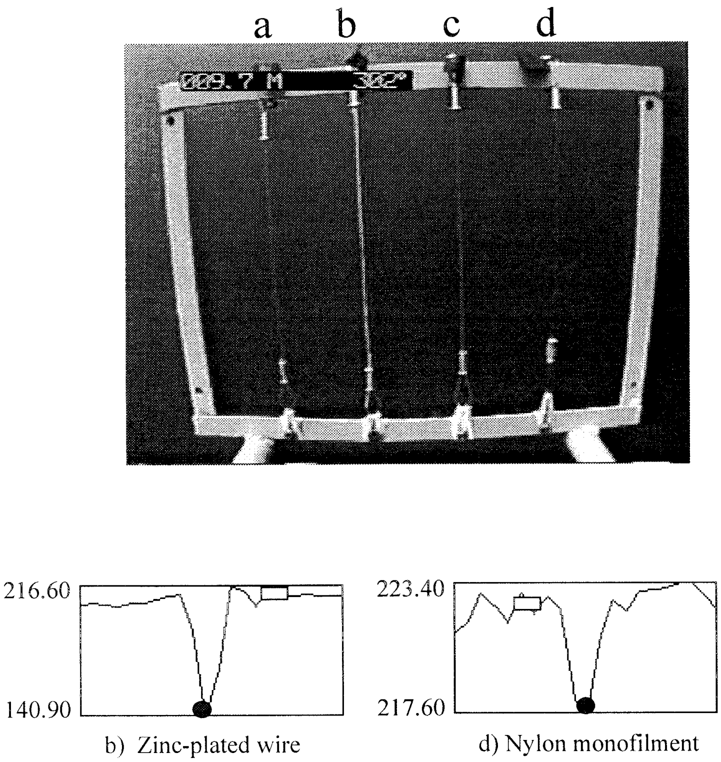

Fig. 5. The image of hook line samples (upper) and measurement of their brightness value with their background (lower).
Symbols a, b, c and d represent hook line samples.
Sumbols ● and □ denote measuring point of hook line sample and background, respectively.

nylon monofilament and fluorocarbon monofilament. Among the wire materials, the apparent contrast of zinc-plated wire is the highest and that of zinc-alumi-plated wire is the lowest. Among the nylon and fluorocarbon monofilament, the apparent contrast of the common nylon monofilament being the highest, that of light gray-colored nylon monofilament is the lowest.

Figure 6–b shows the apparent contrast of 1 day-operated hook line materials. The apparent contrast of 1 day-operated materials is rather lower than that of new materials. The apparent contrasts of 1 day-operated wire materials are distinctly higher than that of the nylon and fluorocarbon monofilament compared with that of new materials. The apparent contrast of the fluorocarbon monofilament is the lowest among all of them. In addition the apparent contrast of the light gray-colored nylon monofilament is two times higher compared to that of the new material.

Figure 6–c shows the apparent contrasts of 7 days-operated hook line materials. The apparent contrast of 7 days-operated material is rather higher than that of 1 day-operated materials. The apparent contrasts of wires are still higher than that of the nylon and fluorocarbon monofilaments.

Figure 6–d shows the apparent contrasts of catch line; the apparent contrasts of all wire materials and the common white nylon monofilament could not be measured due to the bending and twisting which occurred in the fishing operation. The apparent contrasts of the remaining nylon and fluorocarbon

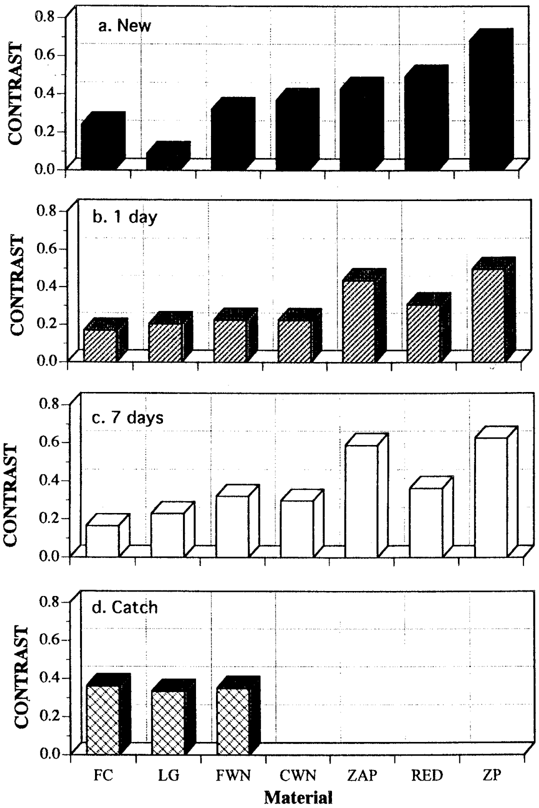

Fig. 6. Apparent contrasts of all materials of sample for the new (a), 1 day-operated (b), 7 days-operated (c) and the catch lines (d).
Symbols FC, LG, FWN, CWN, ZAP, RED and ZP denote hook line materials of fluorocarbon monofilament, light gray-colored nylon monofilament, flexible white-colored nylon monofilament, common white-colored nylon monofilament, zinc-alumi-plated wire, red color-coated wire and zinc-plated wire, respectively.

monofilament catch lines are distinctly higher than that of new, 1 day-and 7 days-operated materials.

These show very clearly that the apparent contrasts of all kinds of wire material are higher than that of the nylon and fluorocarbon monofilaments. Among new hook line materials, the apparent contrast of the light gray-colored is the lowest but it increases when the history is changed to 1 day and 7 days operations. This is the contrary result of the fluorocarbon monofilament whose apparent contrast of new material is higher than that of 1 day-and 7 days-operated materials.

2) Influence of the light transmittance in the water to the apparent contrast

Figure 7 shows the apparent contrasts of all hook line materials for different transmittances of 85.57% and 76.96%, respectively. Regarding this decreasing of the transmittance, it is understood that the apparent contrasts of the hook line materials were also affected. Especially the apparent contrast of wire materials decreases in proportion to decreasing the transmittance. In the case of 1 day-and 7 days-operated nylon and fluorocarbon monofilament, their apparent contrasts seem to be hardly changed with different levels of the transmittance.

3) Apparent contrast with different distances

From the visual observation by two divers it was found that the new fluorocarbon monofilament was poorly visible in the water when compared with the new zinc-alumi-plated wire. Fig.8 shows an example of the apparent contrasts of new zinc-alumi-plated wire

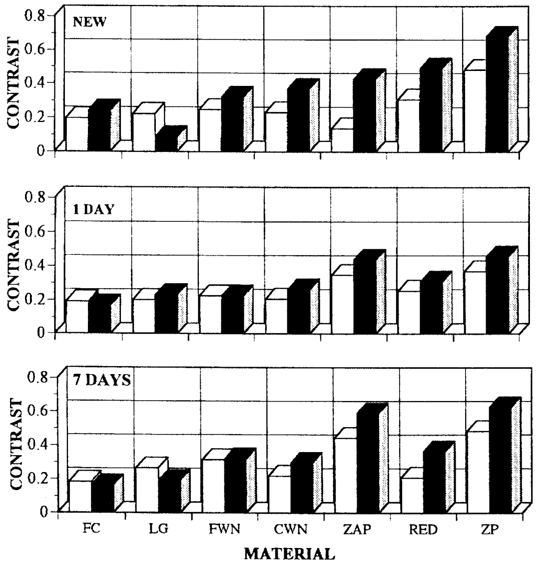

Fig. 7. Apparent contrasts of all materials for the new, 1 day used, 7 days used with different level of transmittance at the depth of 10m and 17m, respectively. Symbols FC, LG, FWN, CWN, ZAP, RED and ZP are same as in Fig. 6.
Symbols ■ and □ denote the transmittance of 85.57% (10m) and 76.96% (17m), respectively.

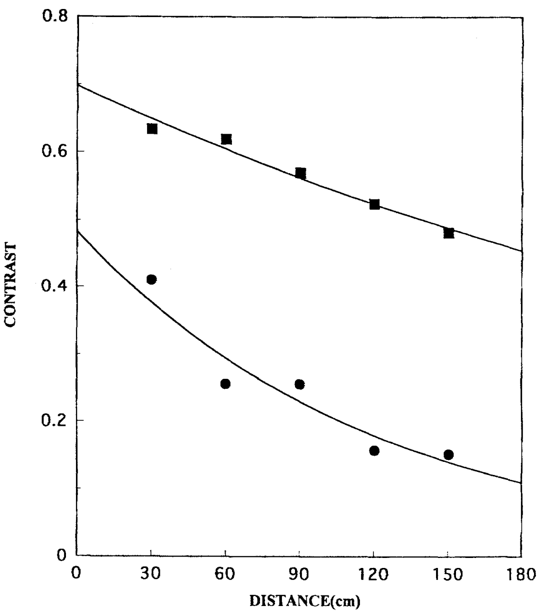

Fig. 8. Relation between the apparent contrast of hook line and the video recording distance. Symbols ■ and ● denote hook line materials of the new zinc-alumi plated wire and fluorocarbon monofilament, respectively.

and fluorocarbon monofilament according to the video recording distance. The beam attenuation coefficient was calculated to be 0.28 m^{-1} by the equation (1). From the figure, the apparent contrasts of zinc-alumi-plated wire are larger than that of fluorocarbon monofilament materials, which seems to support the result from visual observation. The apparent contrast of both materials also decreases as the distance increases. In addition the apparent contrast of the zinc-alumi-plated wire steadily decreases by the distance.

4. Discussion

1) Apparent contrast of 1 day-operated hook line materials

In the squid jigging operation nylon monofilament being used as jigging line, its luminance value (cd/m^2) increased for 3 days-operated; with higher increased for 7 days-operated material (NAKAMURA *et al.*, 1990 b). It is understood that the apparent contrast increases as luminance value increases, in case of the constant background luminance.

From the results in Fig. 6, it is shown that the apparent contrasts of the 1 day-operated hook line materials are lower than that of the new hook line materials in tuna longline. This is a different result from the results on the squid jigging lines. In order to clarify the apparent contrast of the 1 day-operated hook line, its standard deviation is studied. As shown in Table 2, the standard deviations of the apparent contrast are two times larger in the 1 day-operated hook line material than that in the new one; also larger than that in the 7 days-operated one. In this case we understands the mean value of apparent contrast to be small, even though the apparent contrast value varies largely. This large standard deviation of materials means that they stimulate the vision of fishes.

2) Catch analysis related to hook line materials

Figure 9 shows the number and fish species caught related to the materials used as hook lines during seven days operations. Due to the catch result it is clear that the nylon and fluorocarbon monofilament hook lines are better than wire ones. It is also noted that tunas are caught by nylon and fluorocarbon monofilament hook line only. As shown in Fig. 6, with the apparent contrast of the nylon and

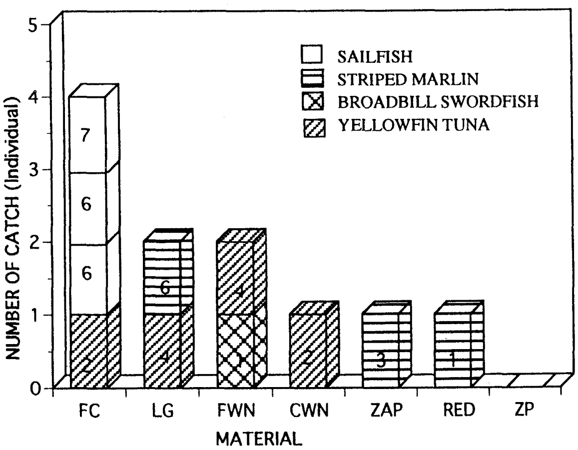

Fig. 9. Number of catch related to hook line materials. A numerical number inside the bar represents the used days of hook line in tuna long line fishing operation. Symbols FC, LG, FWN, CWN, ZP, RED and ZAP are same as in Fig. 6.

Table 2. The mean apparent contrast and standard diviation (SD) of all materials for the new, 1 day used, 7 days used and the catch.

SAMPLES	NEW		1 DAY		7 DAYS		Catch	
	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD
Zinc-alumi-plated wire	0.426	0.030	0.437	0.062	0.588	0.034		
Zinc-plated wire	0.682	0.032	0.497	0.060	0.625	0.033		
Red color-coated wire	0.491	0.045	0.308	0.105	0.363	0.043		
Common white-colored nylon	0.367	0.071	0.224	0.112	0.296	0.013		
Flexble white-colored nylon	0.319	0.032	0.225	0.086	0.320	0.060	0.347	0.097
Light grey-colored nylon	0.088	0.021	0.205	0.056	0.229	0.101	0.333	0.027
Fluorocarbon	0.240	0.113	0.169	0.069	0.164	0.050	0.361	0.054

fluorocarbon monofilament hook line being smaller than that of wire one, it is considered that fish are caught by the hook line materials having poor apparent contrast.

Besides, only the 5 and 6 days-operated hook line of fluorocarbon monofilament still could be utilized to catch other species but not for the 4 days-or longer days-operated wire one. With respect to these aforementioned it can be said that the fluorocarbon monofilament is a highly effective material used for the hook line in tuna longline fishing.

3) Sighting range of tunas on the hook line

The value of visual contrast threshold for tuna is not informed, so the value for cod *Gadus morhua* L is applied to tuna; it is reported to be 0.02 (ANTHONY, 1981) which is defined as shown in the equation (5).

$$C=\frac{T_l-B_l}{B_l} \quad \cdots\cdots(5)$$

where C, T_l and B_l represent the apparent contrast, luminance value of sample and surrounding background, respectively.

These are changed by increasing the distance between target and fish eyes. The apparent contrast is decreased by increasing the distance and reaches the visual contrast The relationship between C and C_l from the equation (2) can be defined as shown in the equation (6).

$$C_l=\frac{C}{C+2} \quad \cdots\cdots(6)$$

According to the equation (6), C being 0.02, C_l is calculated to be about 0.01. As shown in Fig. 8, the apparent contrast value is decreased with the increasing of distance; apparent contrast reaches to 0.01 at the distance which is defined as the sighting range of the tuna. For example, the sighting rages of tuna on the new fluorocarbon monofilament and zinc-alumi-plated wire are calculated to be about 5m and 2m in the $0.28\mathrm{m}^{-1}$ of turbid water, respectively.

Acknowledgement

We are most grateful to the Captain Mr. Y. TAKASU and Boatswain Mr. Y. SAITO of Shinyo-maru for their most generous cooperation. We also express our thanks to Misses. N. HANAMURA and K. MORI for their cooperation.

Reference

ANTHONY, P. D. (1981): Visual contrast thresholds in the cod *Gadus morhua* L., J. Fish Biol., **19**, 87–103.

BLAXTER, J. H. S., B. B. PARRISH and W. DICKSON (1964): The importance of vision of fish to drift nets and trawls. *In*: Modern Fishing Gear of the World 2, London, pp. 529–536.

DUNTLEY, S. Q. (1963): Underwater visibility. *In*: The Sea. HILL, M. N. (ed.), John Wiley & Sons, New York, pp. 452–455.

HIOKI, R. (1981): Light term encyclopedia. Ohmu-sha, Tokyo, p. 87 (in Japanese).

KASUGA, I. (1990): On experimental operation using monofilament nylon gut un tuna longline fishing. Suisangijutu to Keiei, **200**, 55–62 (in Japanese).

NAKAMURA, Y., Y. KURITA, Y. MATSUNAGA and S. YANAGAWA (1990 a): Optial characteristics of snood in tuna longline fishing. Nippon Suisan Gakkaishi, **57**, 1–7 (in Japanese).

NAKAMURA, Y., T. MIYAZAKI and K. MATSUIKE (1990 b): Optical characteristics of monofilament nylon gut in squid angling fisheries. La mer, **28**, 105–110 (in Japanese).

NAKAMURA, Y., E. FU and S. SOMBOON (1995 a): Estimation of in-water image contrast using photograph. Fisheries Engineering, **32**(1), 1–5 (in Japanese).

NAKAMURA, Y., E. FU and S. AKIYAMA (1995 b): Estimation of underwater image contrast using televised image from videotape. Fisheries Engineering, **32**(2), 89–94 (in Japanese).

WARDLE, C.S., G. CUI, W. R. MOJSEIWICZ and C. W. GLASS (1991): The effect of color on the appearance of monofilament nylon under water. Fish. Res., **10**, 243–253.

Received December 4, 1998
Accepted June 10, 1999

La mer 37 : 39, 1999
Société franco-japonaise d'océanographie, Tokyo

資　料

日仏海洋学会誌　うみ（La mer）第37巻1号掲載欧文論文要旨

イワヤン・ヌルジャヤ*・北出裕二郎*・松山優治*・岩井祥夫*：東京湾口近傍における低塩分水の分布

1998年5月，9月，11月の3回にわたり，東京湾から流出する低塩分水の分布を詳細なCTD観測により調べた。観測線は三浦半島の先端から真南と真西に設けられた。高濁度の低塩分水は半島の南端では陸岸に補足されるように相模湾に流出している様子は3回の観測でいずれも見られた。しかし流出後三浦半島西岸を北上せず，相模湾中央に向かって広がっていった。したがって，東京湾口に近い南北観測線よりも，遠い東西線のほうが低塩分水の占める割合が大きくなった。11月に同じ観測線でADCP観測を行ったが，流れは北西あるいは西北西向きで低塩分水の分布をうまく説明していた。湾口から流出後の低塩分水の分布に相模湾の循環流が支配的であることが分かった（*〒108-8477　港区港南4-5-7　東京水産大学）

佐藤博雄*・土屋光太郎*・辻本　亮*+・平野敏行*・加戸隆介・徳田　博***：湾岸戦争に伴う流失油が潮間帯無脊椎動物に及ぼす長期的影響**

1991年の湾岸戦争にともなった流失油は，西部アラビア湾のアブアリ島からクウェートの南部沿岸域を汚染し，いまだに潮間帯に残存している。1992年2月，1993年8月および1994年12月の計3回の現地調査により採取された，油汚染砂および潮間帯生物について，1）汚染された海岸の堆積砂中の油含量，2）油汚染域（マニファ海岸）の砂中に含まれるn-アルカンの時系列的な変動および多環芳香族系炭化水素の同定，および3）採取した潮間帯無脊椎動物（貝類，多毛類など）への影響について解析を行った。汚染砂中のn-アルカンは，1994年の調査試料からは検出されなかったが，その試料中には多環芳香族系化合物のナフタレン，フェナンスレン，アントラセンなどが検出された。マニファ海岸の潮間帯では，サラサキサゴ，カガミガイのような埋在性の貝類が未だに見られないことが明らかになった。（*〒108-8477　港区港南4-5-7　東京水産大学，**〒022-0100　岩手県三陸町北里大学，***〒133-0057　江戸川区西小岩5-7-1　愛国学園短期大学，+現所属：〒936-0011　富山県滑川市高塚363，富山県水産試験場）

鈴木利一*：東シナ海陸棚縁辺部における織毛虫プランクトンと餌生物（ピコプランクトンおよびナノプランクトン）の現在量

東シナ海陸棚縁辺部において，織毛虫プランクトン，ピコプランクトンおよびナノプランクトンの現在量を調査した。それらは各々$1.0\times10^1-2.08\times10^3$，$2.15\times10^5-6.45\times10^6$ および $6.14\times10^7-1.01\times10^9$ cells／1であった。織毛虫プランクトンの鉛直分布型は独立栄養ナノプランクトンのものとよく似ていた。一方，ピコプランクトンと従属栄養ナノプランクトンではお互いに似た鉛直分布型を示したが，それは織毛虫プランクトンのものとは異なっていた。これらの結果により，織毛虫プランクトンに至る物質やエネルギーのフラックスは，主に独立栄養ナノプランクトン由来のものであると考えられる。ピコプランクトンや従属栄養ナノプランクトンの生産は，織毛虫プランクトンの生産に対してあまり寄与していないと思われる。（*〒852-8521　長崎市文京町1-14　長崎大学水産学部）

中村善彦*・シリラクソフォン　ソンブン*・鈴木文枝*・宮本佳則*：鮪延縄漁業に用いられる針元の光学的特性

鮪延縄漁業に用いられる針元のコントラストを，海中で撮影したヴィデオ映像から求めた。供試材料にはワイヤー3種類，ナイロンモノフィラメント3種類およびフルロカーボンモノフィラメント1種類で，それぞれについて未使用，1日の操業に使用，および7日間の連続操業に使用した釣元を用意した。ナイロンおよびフルロカーボンモノフィラメントのコントラストは未使用，1日使用および7日間使用のいずれの場合も，ワイヤーよりも小さい。1日使用した材料は未使用の材料よりコントラストが減少するが，7日間使用のあとでは増大する。フルロカーボンモノフィラメント系の釣元，および1日から3日使用した釣元で釣獲が良いことから，コントラストの小さい材料の釣元で釣獲が良いものと推定される。（*〒108-8477　港区港南4-5-7　東京水産大学）

La mer 36: 40, 1999
Société franco-japonaise d'océanographie, Tokyo

学 会 記 事

1. 1999年5月19日（水）東京水産大学において，1999年度評議員会が開かれた。主な議事は下記の通り。

1）平成10年度事業報告
2）平成11年度学会賞受賞候補者選考経過報告
3）平成10年度収支決算報告ならびに監査報告
4）平成11年度事業報告（案）審議
5）平成11年度収支予算（案）審議
6）その他

ア）前会長宇野　寛氏を名誉会員に推挙することが諮られ了承された。

イ）文部省科学研究費補助金審議員候補者の推薦について，学会に選出のための選挙管理委員会を設置し，庶務担当幹事を中心に事務処理を行う事とした。これにともない，委員会規定の文案，選挙人等は今後検討することとした。

ウ）2000年10月31日より11月3日まで，北京で開催される第3回世界水産会議の案内があった。

エ）第18期学術会議の団体登録を行う事を決定した。

オ）1999年度日仏学者交換事業による派遣希望者について，4月30日を締め切りとして評議員宛に照会したが，特に応募者はなかった。

2. 新入会員（正会員・学生会員*）

氏　名	所属・住所	紹介者
長谷川一幸*	日本大学生産工学研究科 〒275-8575　習志野市泉町1-2-1	和田　明
鷲見　浩一*	日本大学生産工学研究科 〒275-8575　習志野市泉町1-2-1	和田　明
田中　祐志	東京水産大学海洋環境学科 〒108-8477　港区港南4-5-7	石丸　隆

3. 受贈図書（受付順）

養殖研究所ニュース 31
養殖研究所研究報告 28
NTT R&D 48(3, 4, 5)
なつしま 158, 160
Bulletin of the National Science Museum 25(1)
日本海区低魚資源研究連絡会議報告39
東海大学海洋学部業績集 28
東海大学紀要（海洋学部）47
東海大学紀要（海洋学部一般教養）24
勇魚 20
東北区水産研究所研究報告 16
サイエンスボランティア名簿
なつしま 159
東海大学海洋研究所年報 20
東海大学海洋研究所研究報告 20
農業工学研究所年報 10
農業工学研究所報告 38
神奈川県立博物館研究報告（自然科学）28
日本海区水産研究所研究報告 49
Journal of the Korean Society of Oceanography 34(1)
Meereswissencshaftliche Berichte 32, 33, 34
Israel Oceanographic & Limmological Research 20

日仏海洋学会会則

昭和35年４月７日　制定
昭和60年４月27日　改正
平成４年６月１日　改正

第１条　本会は日仏海洋学会と称する。

第２条　本会の目的は日仏海洋および水産学者の連絡を密にし，両国のこの分野の科学の協力を促進するものとする。

第３条　上記の目的を実現するため本会は次の事業を行なう。

(1)　講演会の開催
(2)　両国の海洋学および水産学に関する著書，論文等の相互の翻訳，出版および普及
(3)　両国の海洋，水産機器の技術の導入および普及
(4)　日仏海洋，水産学者共同の研究およびその成果の論文，映画などによる発表
(5)　両国間の学者の交流促進
(6)　日仏海洋，水産学者の相互の親睦のために集会を開くこと
(7)　会報の発行および出版
(8)　その他本会の目的を達するために必要な事業

第４条　本会には，海洋，水産学の分野に応じて分科会を設けることができる。

分科会は評議員会の決議によって作るものとする。

第５条　本会の事務所は日仏会館（〒150　東京都渋谷区恵比寿３丁目９番25号）に置く。

第６条　本会に地方支部を置くことができる。

第７条　本会会員は本会の目的に賛成し，所定の会費を納めるものとする。

会員は正会員，学生会員および賛助会員とする。

第８条　正会員会費は年額6,000円，学生会員会費は年額4,000円，賛助会員会費は一口年額10,000円とする。

第９条　本会は評議員会によって運営される。

評議員の定数は50名とし，正会員の投票によって選出される。選挙事務は別に定める選出規定による。

会長は評議員会の同意を得て５名までの評議員を追加することができる。

評議員の任期は２年とする。ただし，重任を妨げない。

第10条　評議員はその内より次の役員を選ぶ。ただし，監事は評議員以外からも選ぶことができる。

会長　１名，副会長　２名，幹事　10名，監事　２名

役員の任期は２年とする。ただし，重任を妨げない。

役員の選出方法は別に定める選出規定による。

第11条　本会に名誉会長，顧問および名誉会員を置くことができる。名誉会長，顧問および名誉会員は評議員会の決議により会長これを委嘱または推薦する。

日仏会館フランス人学長を本会の名誉会長に推薦する。

第12条　会長は本会を代表し，総会および評議員会の議長となる。会長事故あるときは副会長がこれに代わる。

会長，副会長および幹事は幹事会を構成し，本会の庶務，会計，編集，研究発表，渉外などの会務を行う。

監事は本会の会計を監督する。

第13条　年に１回総会を開く。総会では評議員会の報告を開き，会の重要問題を審議する。会員は委任状または通信によって決議に参加することができる。

会長は必要に応じて評議員会の決議を経て臨時総会を招集することができる。

第14条　本会則の変更は総会の決議による。

日仏海洋学会評議員・役員選出規定

1．本規定は日仏海洋学会会則第９条および第10条に基づき本会の評議員および役員の選出方法について規定するものである。
2．評議員は正会員の50名連記無記名投票により選出する。
評議員の選挙事務は庶務幹事が行う。ただし，開票にあたっては本会役員以外の会員２名に立会人を委嘱するものとする。
3．会長は評議員の単記無記名投票により選出する。
会員選挙の事務は庶務幹事が行う。ただし，開票にあたっては本会役員以外の会員２名に立会人を委嘱するものとする。
4．副会長，幹事，および監事は，会長の推薦に基づき評議員会で決定する。
5．本規定の改正は評議員会の議を経て行う。

日仏海洋学会賞規定

1．日仏海洋学会賞（以下「学会賞」という）を本学会に設ける。学会賞は本学会員で，原則として本学会誌に発表した論文の中で，海洋学および水産学において顕著な学術業績を挙げた者の中から，以下に述べる選考を経て選ばれた者に授ける。
2．学会賞受賞候補者を選考するため学会賞受賞候補者推薦委員会（以下「委員会」という）を設ける。
3．委員会の委員は13名とする。
委員は毎年春の評議員会で選出し，委員長は委員の互選により定める。
会長は委員会が必要と認めた場合，評議員会の同意を得て２名まで委員を追加委嘱することができる。
4．委員会は受賞候補１件を選び，12月末までに選定理由をつけて会長に報告する。
5．会長は委員会が推薦した候補者につき無記名投票の形式により評議員会にはかる。投票数は評議員総数の３分の２以上を必要とし，有効投票のうち４分の３以上の賛成がある場合，これを受賞者として決定する。
6．授賞式は翌年春の学会総会において行い，賞状，メダルおよび賞金を贈呈する。賞金は５万円とする。
7．本規定の改正は評議員会の議を経て行う。

覚　書

1．委員は各専門分野から選出されるよう十分配慮すること。
2．受賞者は原則として順次各専門分野にわたるよう十分配慮すること。

日仏海洋学会誌「うみ」投稿規定

1. 「うみ」(日仏海洋学会の機関誌；欧文誌名 **La mer**）は，日仏海洋学会正会員およびそれに準ずる非会員からの投稿（依頼原稿を含む）を，委員会の審査により掲載する。
2. 原稿は海洋学および水産学両分野の原著論文，原著短報，総説，書評，資料などとする。すべての投稿は，本文・原図とも正副２通とする。副本は複写でよい。本文原稿はすべてA4判とし，400字詰め原稿用紙（和文）に，または厚手白紙にダブル・スペース（和文ワープロでは相当間隔）で記入する。表原稿および図説明原稿は，それぞれ本文原稿とは別紙とする。
3. 用語は日，仏，英３か国後の何れかとする。ただし，表および図説明の用語は仏文または英文に限る。原著論文（前項）には約200語の英文または仏文の要旨を，別紙として必ず添える。なお，欧文論文には上記要旨の外に，約500字の和文要旨をも添える。ただし，日本語圏外からの投稿の和文要旨については編集委員会の責任とする。
4. 投稿原稿の体裁形式は最近号掲載記事のそれに従う。著者名は略記しない。記号略号の標記は委員会の基準に従う。引用文献の提示形式は，雑誌論文，単行本分載論文（単行本の一部引用も含む），単行本などの別による基準に従う。
5. 原図は版下用として鮮明で，縮尺（版幅または1／2版幅）に耐えられるものとする。
6. 初校に限り著者の校正を受ける。
7. 正会員に対しては７印刷頁までの掲載を無料とする。ただし，この範囲内であっても色彩印刷を含む場合などには，別に所定の費用を著者負担とすることがある。正会員の投項で上記限度を越える分および非会員投稿の印刷実費はすべて著者負担（10,000円／頁）とする。
8. すべての投稿原稿について，１篇あたり別刷り50部を無料で請求できる。50部を越える分は請求により50部単位で有料で作製される。別刷り請求用紙は初校と同時に配布される。
9. 原稿の送り先は下記の通り

〒108-8477　港区港南4-5-7　東京水産大学海洋環境学科（山口征矢気付）
　　　　　日仏海洋学会編集委員会

執　筆　要　領

1. 原稿

(1) 和文原稿の場合：A4判，400字詰横書き原稿用紙に，新かな遣い，常用漢字を用いて楷書体で読みやすく書き，数字は原則としてアラビア数字を使用する。和文ワープロを用いる場合はA4判の用紙におよそ横30字，縦25行で書くこと。

(2) 欧文原稿の場合：A4判の上質の白色用紙に，ダブルスペース約25行にタイプライトし（ワープロの場合も同様)，十分な英文添削を経て提出すること。

(3) 和文原稿，欧文原稿いずれの場合も，要旨，表原稿および図版説明原稿はそれぞれ本文原稿とは別紙とする。

(4) 最終原稿とともに，原稿が入力されたフロッピーディスクの提出を歓迎する。この場合ファイルはテキスト形式で保存すること。

2. 論文記載の順序

(1) 原著（和文原稿）：原稿の第１ページ目に表題，著者名と住所（所属機関およびその郵便番号と所在地など）を和文と欧文で記す。またキーワード（４語程度）およびランニングヘッドを添える。第２ページ目に欧文要旨（Abstract，200語以内）を記す，本文は第３ページ目から，「緒言」「方法」「結果」「考察」（あるいは「はじめに」「材料と方法」「結果と考察」など)，謝辞，文献，図版の説明の順に記す。なお，原稿には通し番号のページを記入すること。

(2) 原著（欧文原稿）：原稿の第１ページ目に表題，著者名と住所（所属機関およびその郵便番号と所在地など)，キーワード（４語程度）およびランニングヘッドを記す。第２ページ目に要旨（Abstract，200語以内）を記す，本文は第３ページ目から，「緒言（Introduction)」「材料と方法（Materials and method)」「結果（Results)」

「考察（Discussion）」「謝辞（Aknowledgement）」「文献（Reference）」「図版の説明（Figure Legends）の順とする。最終ページに，和文の表題，著者名と住所および約500字以内の和文要旨を添える。なお，原稿には通し番号のページを記入すること。

(3) 総説，短報：和文ならびに欧文原稿とも原著に準じる。

(4) 資料，学術情報：特に記載に関する規定はないが，すでに発行されている雑誌を参考にすること。

3. 活字指定

オリジナル原稿の文中で次の活字はそれぞれ朱で指定すること。イタリック指定は下線（＿＿），ボールドあるいはゴシック指定は波下線（〰），スモールキャピタル指定は二重下線（＝＝），中点は・を四角（□）で囲む。上付きおよび下付き文字は∨および∧を入れる。和文原稿での動植物名はカタカナを用い，学名はイタリック指定のこと。なお句読点は（。）および（,）とする。その他の活字指定は編集委員会に一任する。

4. 文　献

文献は本文および図表に引用されたものの全てを記載しなければならない。本文の最後にアルファベット順にまとめ，各文献は下記の例に従って記載する。

(1) 論文の場合

有賀祐勝・前川行幸・横浜康継（1996）：下田湾におけるアラメ群落構造の経年変化．うみ，**34**，45–52.

YANAGI, T., T. TAKAO and A. MORIMOTO (1997): Co-tidal and co-range charts in the South China Sea delived from satellite altimetry data. La mer, **35**, 85–93.

(2) 単行本分載論文（単行本の一部引用）の場合

有賀祐勝（1981）：海洋植物プランクトンの生産生態．藻類の生態（秋山　優・有賀優勝・坂本　充・横浜康継編），内田老鶴圃，東京，p.81–121.

WYNNE, M. J. (1981): Phaeophyta: Morphology and classification. *In* The Biology of Seeweeds. LOBBAN, C. S. and M. J. WYNNE (eds.), Blackwell Science, Oxford, p.52–85.

(3) 単行本の場合

柳　哲雄（1989）：沿岸海洋学—海の中でものはどう動くか—．恒星社厚生閣，東京，154pp.

SVERDRUP, H. U., M. W. JOHNSON and R. H. FLEMING (1942): The Oceans: Their Physics, Chemistry and General Biology. Prentice-Hall, Englewood Cliffs, New York, 1087pp.

5. 図，表および写真

(1) 図，表および写真とその説明はすべて英文または仏文を用いる。

(2) 図は黒インキで明瞭に描き，そのまま印刷できるもののみ受け付ける。図中の線や記号，文字，数字はレンタリング器具などを使用して鮮明に描くこと。原図は原則としてＡ４判以下のサイズにして投稿すること。なおコンピュータのグラフィックソフトを用いて鮮明に描かれた図も受け付ける。この場合プリントアウトはレーザープリンター等を用いて鮮明に打ち出すこと。

(3) 表は別紙にタイプライトすること。

(4) 写真は光沢平滑印画紙（黒白）に鮮明に焼き付け，白地の厚手台紙に貼り付けること。カラー印刷を希望する場合はその旨明記すること。

(5) 図，表，写真は刷り上がり時に最大横が14cm，縦が20cm（説明文を含む）以内であることを考慮して作成すること。

(6) 図，表，写真にはそれぞれ通し番号を付け，１枚ごとに著者名，縮尺ならびに天地を記しておく。図および写真の説明文は別紙にまとめて書き，添付すること。

(7) 図，表，写真の挿入箇所は，本文中に置きたいおよその位置の原稿右欄外に Fig. 1 や Table 1 のように朱書すること。

(8) 地図には方位とスケールを入れること。

6. 単位

時間，濃度，速度，重量，長さ，束（flusx）を表す場合には基本的に SI 単位を用い，本文，図表とも sec, min, hr, d, yr, $\mu g\ l^{-1}$，mg $O_2\ l^{-1}$，cm sec^{-1}，gC $m^{-2}\ d^{-1}$ のような表現を用いること。日付の表示は西暦を用いる。

賛　助　会　員

阿部嘉方	東京都練馬区春日町２－１５－６
アレック電子株式会社	兵庫県神戸市西区井吹台東町７－２－３
株式会社　イーエムエス	兵庫県神戸市中央区多聞通３－２－９
株式会社　内田老鶴圃　内田　悟	東京都文京区大塚３－３４－３
有限会社　英和出版印刷社	東京都文京区千駄木４－２０－６
株式会社　カイジョウ	東京都西多摩郡羽村町栄町３－１－５
(財)　海洋生物環境研究所	東京都千代田区内神田１－１８－１２　北原ビル内
株式会社　川合海苔店	東京都太田区大森本町２－３１－８
ケー・エンジニアリング株式会社	東京都台東区浅草橋５－１４－１０
三洋測器株式会社	東京都渋谷区恵比寿南１－２－８
株式会社　自然・情報環境研究所	横浜市栄区桂町１－１，３－４０１
新日本気象海洋株式会社	東京都世田谷区玉川３－１４－５
全日本爬虫類皮革産業連合会	東京都足立区梅田４－３－１８
株式会社　高岡屋	東京都台東区上野６－７－２２
テラ株式会社	東京都世田谷区代田３－４１－８　代田ウェスト５Ｆ
株式会社　東京久栄技術センター	埼玉県川口市芝鶴ケ丸６９０６－１０
株式会社　西日本流体技研	長崎県佐世保市棚方町２８３
日本アクアラング株式会社	神奈川県厚木市温水２２２９－４
(株)　三菱総合研究所 (社会情報システム部)	東京都千代田区大手町２－３－６
日本海洋株式会社	東京都千代田区神田須田町２－２－４　須田町藤和ビル７Ｆ
株式会社　読売広告社	東京都中央区銀座１－８－１４
渡辺機開工業株式会社	愛知県渥美郡田原町神戸大坪２３０
株式会社　渡部計器製作所	東京都文京区向丘１－７－１７

日仏海洋学会入会申込書

（正会員・学生会員）

	年度より入会	年　　月　　日申込
氏　　名 ローマ時		年　　月　　日　生
勤務先	住　所　〒 機関名 電　話	
自　宅	住　所　〒 電　話	
紹介会員氏名		
送付金額　　　　円	送金方法	
会誌の送り先（希望する方に○をつける）	勤務先　　　自　宅	

（以下は学会事務局用）

受付	名簿 原簿	会費 原簿	あて名 カード	学会 記事

入会申込書送付先：〒150-0013 東京都渋谷区恵比寿 3-9-25

（財）日仏会館内

日　仏　海　洋　学　会

郵便振替番号：00150−7−96503

1999年6月25日印刷
1999年6月28日発行
う　み
第37巻
第1号

定価　¥ 1,600

編集者　山口征矢
発行所　日仏海洋学会
財団法人　日仏会館内
東京都渋谷区恵比寿 3-9-25
郵便番号：150-0013
電　話：03（5421）7641
振替番号：00150-7-96503
印刷者　佐藤一二
印刷所　㈲英和出版印刷社
東京都文京区千駄木 4-20-6
郵便番号：113-0022
電　話：03（5685）0621

Tome 37　　N° 1

SOMMAIRE

第 37 巻　第 1 号

目　　次