ISSN 0503-1540

Tome 37 *Février 2000* Numéro 4

La mer

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2000年2月

日仏海洋学会

La Société franco-japonaise
d'océanographie
Tokyo, Japon

SOCIETE FRÀNCO-JAPONAISE D'OCEANOGRAPHIE

Cimité de Rédaction

(de o'exercice des années de 1998 et 1999)

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La mer 37 : 145–152, 2000
Société franco-japonaise d'océanographie, Tokyo

Observation of tidal and residual circulations in Osaka Bay by HF radar

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Akitsugu NADAI** and Yukiharu HISAKI***

Abstract : Observations of sea surface currents by HF radar were carried out in Okasa Bay in autumn 1995. The overall characteristics of the major tidal currents (M_2, S_2, K_1, O_1) in Osaka Bay are examined. At the same time, variability of current and the clockwise residual circulation is investigated over spring–neap tidal cycle. It is found that magnitude and spatial scale of a clockwise residual circulation in the central part of Osaka Bay at spring tides are larger than that at neap tides. Furthermore, it is sugested that the southward flow at flood tide in the central part of Osaka Bay does not exist during neap tides.

Key words : *HF radar, tidal current, residual current*

1. Introduction

A high frequency ocean radar (HF radar) is a quite useful instrument which enables us to make a long term observation of sea surface current in the wide area. In last decade, a number of observations by HF radar have been made to analyze coastal phenomena such as tidal and residual currents (PRANDLE, 1987), frontal structure (MATTHEWS *et al.*, 1993), upwelling (SHKEDY *et al.*, 1995), and so on.

Okinawa Radio Observatory of Communications Research Laboratory (CRL) developed the first HF ocean radar system in Japan in 1988 (IGUCHI *et al.*, 1989) and the second one in 1991. OHNO (1991, 1993) made several current and sea state observations using HF radars at Tokara Strait, Japan Sea and other places. TAKEOKA *et al.* (1995) utilized the current measurement by HF radars to analyze the Kyucho in the Bungo Channel.

As shown in Fig.1, Osaka Bay is a semi-enclosed basin where the tidal current dominates and the residual flow plays an important role in the long term dispersion of material. Furthermore, it is known that a clockwise residual circulation exists in the central part of Osaka Bay (YANAGI and TAKAHASHI, 1988, 1995 : FUJIWARA *et al.*, 1989 : YUASA, 1994, e.t.c.). In order to obtain the detailed structure of these currents, a long–term observation of currents in wide area is necessary. However, most of the past current observations in Osaka Bay were point-wise measurement by current meter or temporary measurement of vertical section by Acoustic Doppler Current Profiler (ADCP) at best. Therefore, we adopted current measurements by the HF radars to the opbservation of tidal current and residual circulation in Osaka Bay. In the present work, we will illustrate the characteristics of the tidal currents, and variability of current and a clockwise residual circulation over spring–neap tidal cycles in Osaka Bay.

2. Specifications of the HF Radar and Observations

Current measurements by the HF ocean radar system were carried out at the two sites

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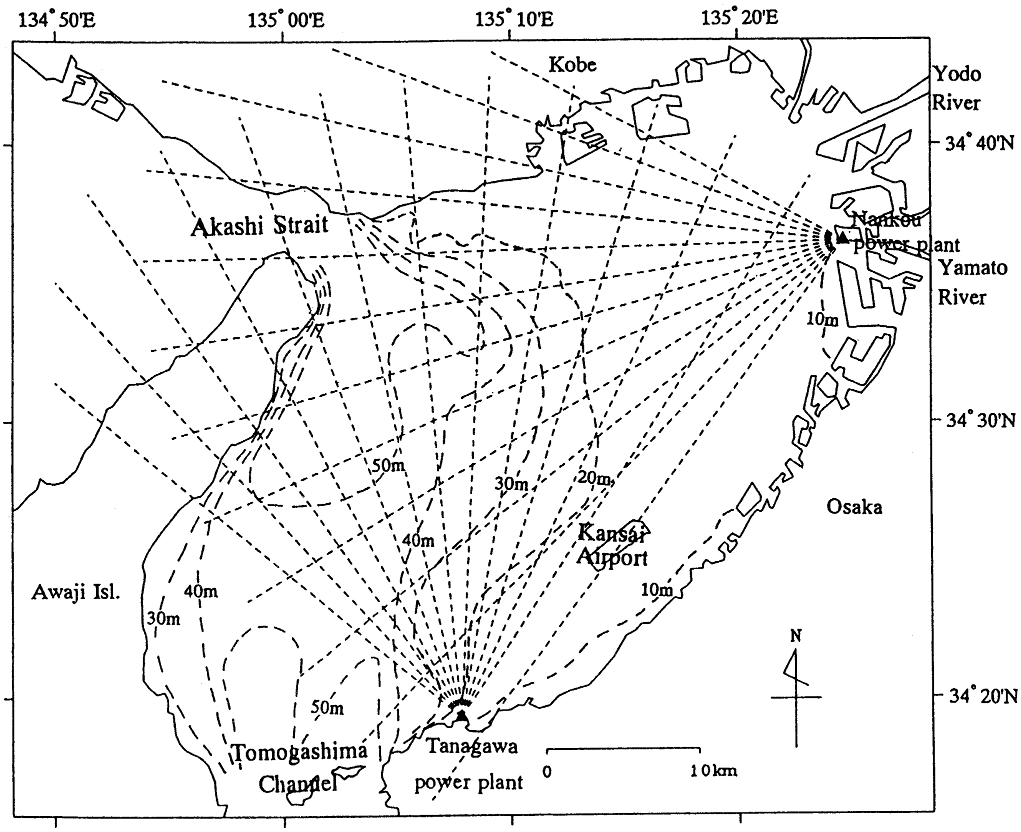


Fig. 1. Map of Osaka Bay. Broken curved lines are depth contours. Numerals are depth in meter. Straight broken lines shows the radar beams.

Table 1. Specifications of the HF ocean radar of CRL. After Takeoka *et al.* (1995)

Radar type	Frequency Modulated Interrupted Continuous Wave (FMICW) radar
Center frequency	24.515 MHz
Range resolution	1.5 km
Transmit power	100 W (peak), 50 W (average)
Antenna type	10-element phased array antenna
Beam width	15°
Beam directions	±45° (13 directions)

shown in Fig. 1, from 11 November to 12 December 1995. Two spring tides (23 Nov. and 7 Dec.) and two neap tides (15 and 29 Nov.) were included in this period. Table 1 shows the specification of the HF ocean radar system of CRL. A phased array antenna of 60 m long is used and the radar beam can be steered electrically in the direction within ±45°. Sea echoes over the range of 90 km can be detected under a favorable condition. Harder the wind blows, shorter the maximum observable range becomes, since sea waves impede the radio wave propagation. The radio wave is backscattered by sea surface waves with half the wave length of the radio wave. The measured current velocity represents the integrated value over the surface layer effective in advecting the surface waves. The thickness of this effective surface layer is said to be about $1/4\pi$ of the surface wave length and hence $1/8\pi$ of the radio wave

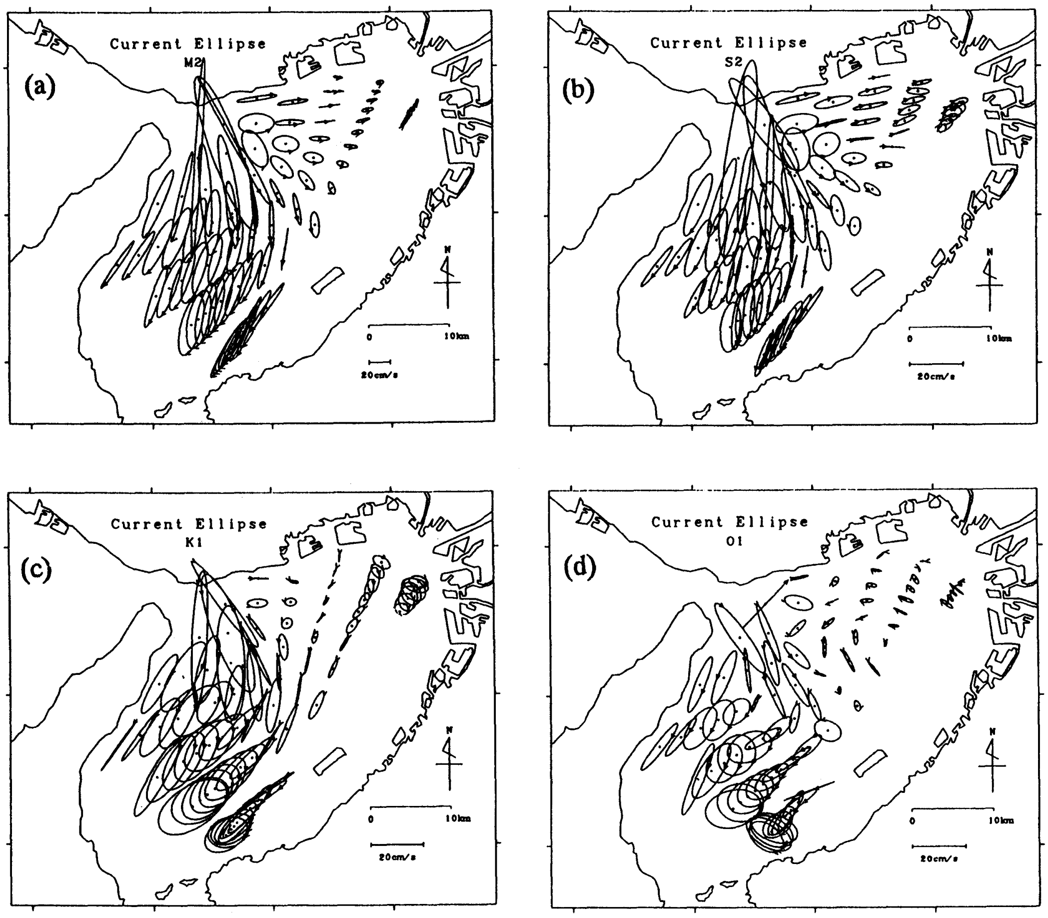


Fig. 2. Tidal current ellipses of major 4 components. (a) is M_2, (b) S_2, (c) K_1 and (d) O_1 tidal current.

length (STEWART and JOY, 1974), and it is about 0.5 m for the radars of CRL since the radio wave length is 12 m. Readers are referred to IGUCHI *et al.* (1989) and OHNO (1991) for more details of the radar hardware.

Backscattered signals along one beam were recorded for 2 minutes, followed by 3 minutes of the interval. This interleaving procedure has 5 minutes intervals, thus measurements along 12 separate beams can be made at hourly intervals.

3. Data Analysis and Observation Results

Obtained signals were spectrally analyzed and radial currents were determined. Here, since data obtained time was different by beam to beam at one site, radial currents were interpolated to the currents at every hour on the hour using linear interpolation method. From these values, hourly current vectors at cross points of radar beams were estimated.

3.1 Harmonic Constants

Harmonic analysis was carried out at each cross points and harmonic constants of 10 major tidal constituents (K_1, O_1, P_1, Q_1, M_2, S_2, K_2, N_2, M_4, MS_4) were obtained with use of the least square method (ODAMAKI : 1981). Tidal ellipses of M_2, S_2, K_1 and O_1 (major 4 components) are shown in Fig. 2(a), (b), (c) and (d), respectively. M_2 tidal current is most dominant component and phase progresses from near coast to central part. Amplitude of M_2 tidal current reaches about 70 cm/s near the Akashi

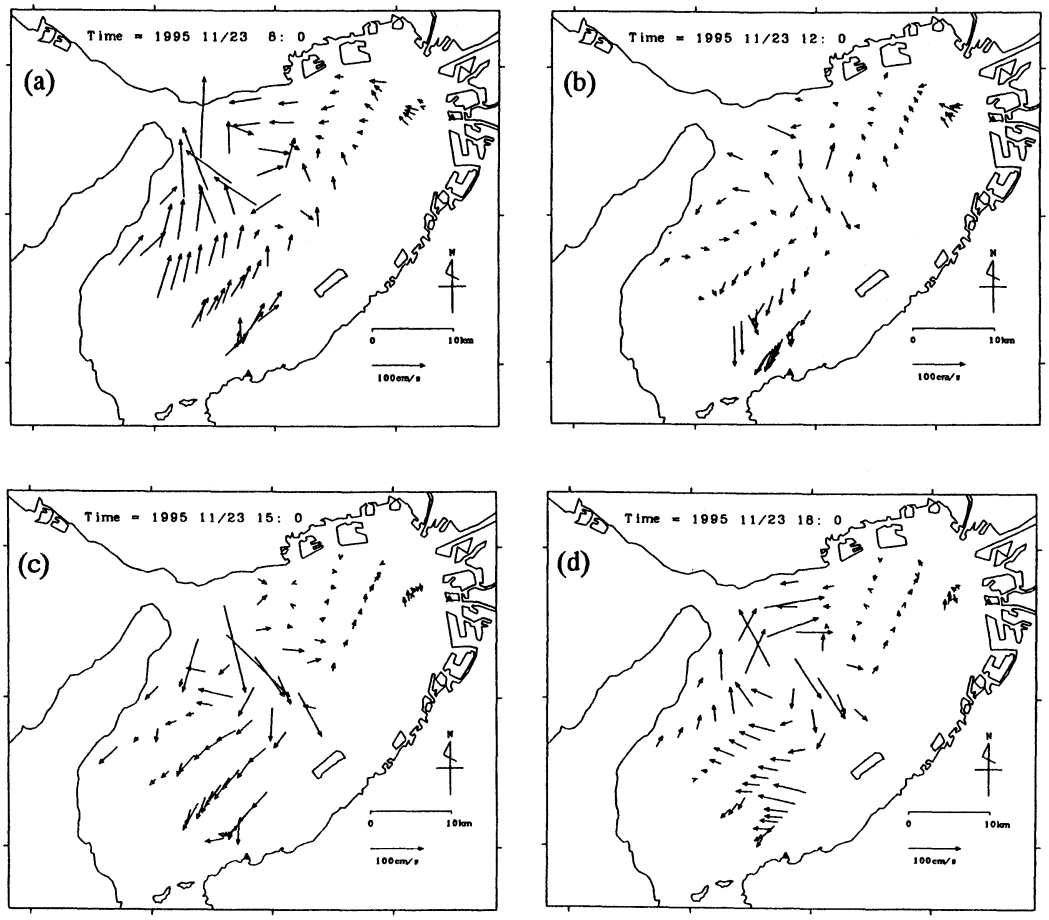


Fig. 3. Time series of the current vectors on 23 November 1995 (spring tide).
(a) flood tide, (b) slack after flood tide, (c) ebb tide, (d) slack after ebb tide.

Strait. Amplitude of S_2 tidal current is about half of that of M_2 tidal current, but flatness, direction of major axia and phase of S_2 tidal current ellipses in the area where depth is more than 20 m (the deeper area, see Fig. 1) are similar to M_2 tidal current. On the other hand, in the area where depth is less than 20 m (the shallower area), S_2 tidal current gradually becomes weak with the approach to the bay head whereas M_2 tidal current rapidly becomes weak. Amplitude of K_1 tidal current is weaker than that of S_2 near the Akashi Strait but stronger near the Tomogashima Channel. Flatness ratio of K_1 tidal ellipses in the shallower area becomes small with the approach to the bay head although that of other components does not change or becomes large. O_1 tidal current is the weakest component among the four major components. Its amplitude reaches about 16 cm/s near the Akashi Strait and about 15cm/s near the Tomogashima Channel. Amplitude of the semi-diurnal tidal currents (M_2 and S_2 components) become weak as approaching from the Akashi Strait to Tomogashima Channel. On the other hand, amplitude of the diurnal tidal currents (K_1 and O_1 components) is not so different between near the Akashi Strait and the Tomogashima Channel, although once that become weak off shore the Kansai Airport.

3.2 Time Series of the Current

In this paper, the time at which westward velocity at the Akashi Strait becomes maximum

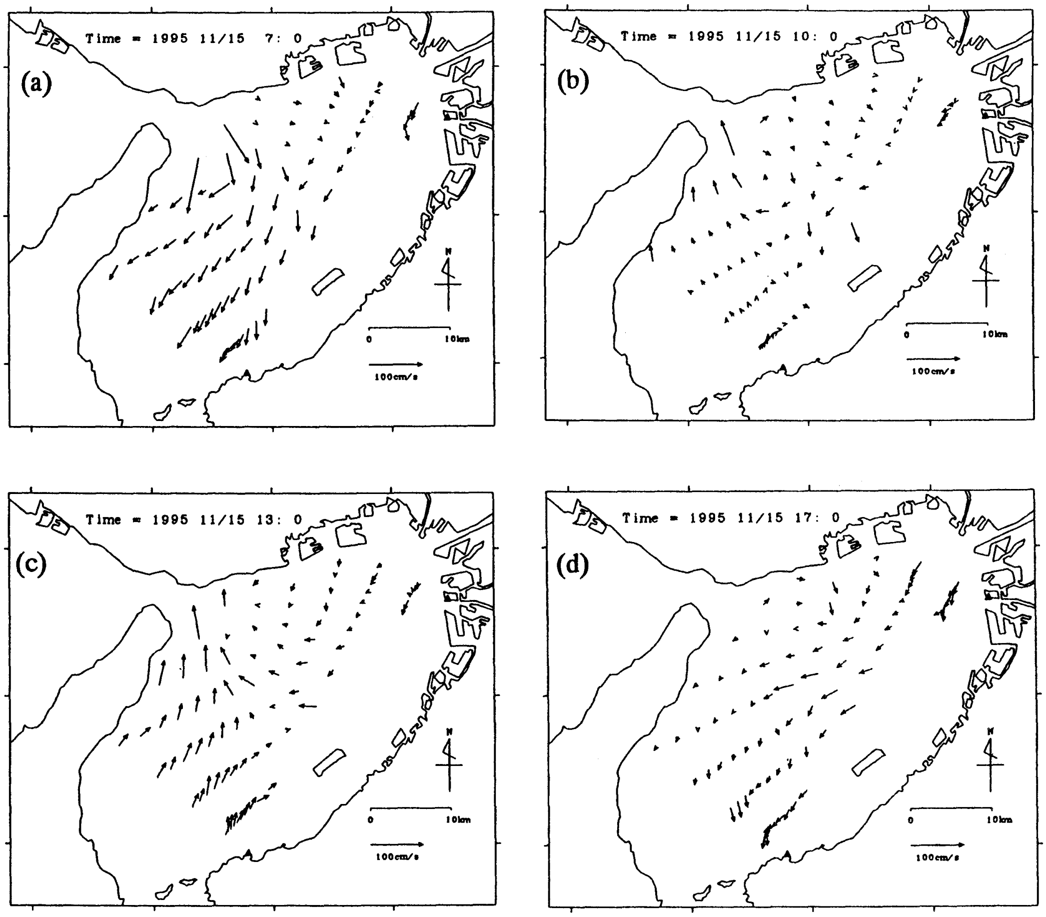
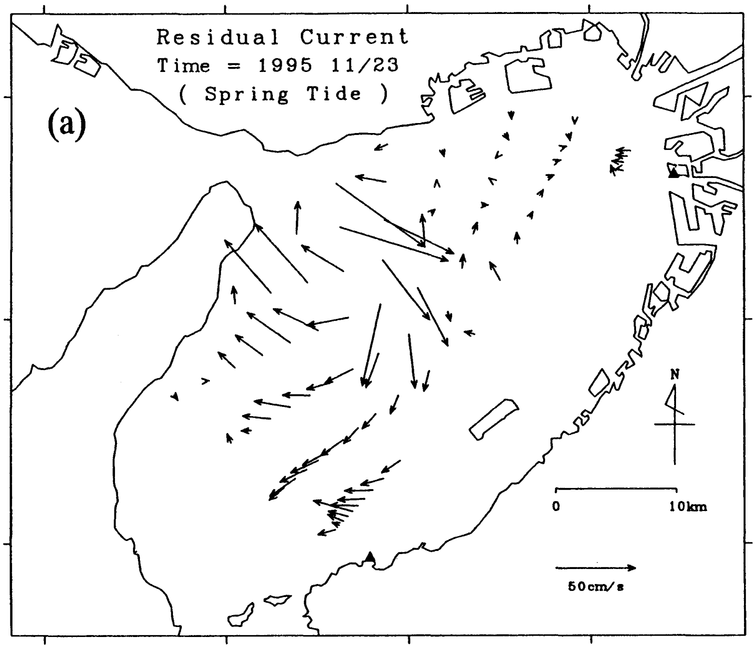


Fig. 4. Time series of the current vectors on 15 November 1995 (neap tide). (a) ebb tide, (b) slack after ebb tide, (c) flood tide, (d) slack after flood tide.

speed is called flood tide and the time at which eastward velocity becomes maximum is called ebb tide.

Figure 3 shows the time series of the surface current vectors at flood tide (a), the slack after flood tide (b), ebb tide (c) and the slack after ebb tide (d) on 23 November 1995 (spring tide). From this time series, we can see how the semi-diurnal current develops in Osaka Bay. Maximum velocity reaches about 155 cm/s at flood tide and about 180 cm/s at ebb tide near the Akashi Strait. The surface current at the deeper area is stronger than that at the shallower area. A clockwise eddy is found in the central part of Osaka Bay at the slack (Fig. 3 (b) and (d)), although the intensity at the slack alfter flood tide is stronger than that at the slack after ebb tide. In spite of flood tide, southward flow has been said to exist at central part of Osaka Bay from the past knowledge (FUJIWARA *et al.*, 1989) and this flow is indeed found in Fig. 3 (a).

Figure 4 shows the time series of the current vectors at ebb tide (a), the slack tide after ebb tide (b), flood tide (c) and the slack tide after flood tide on 15 November 1995 (neap tide). The figure shows that the semi-diurnal current develops in Osaka Bay. Maximum velocity reaches about 110 cm/s at ebb tide and about 70 cm/s at flood tide near the Akashi Strait. Storong surface current is distributed in the deeper area. A clock-wise eddy is found in the central part of Osaka Bay at the slack after ebb tide (Fig. 4 (b)). These results correspond to



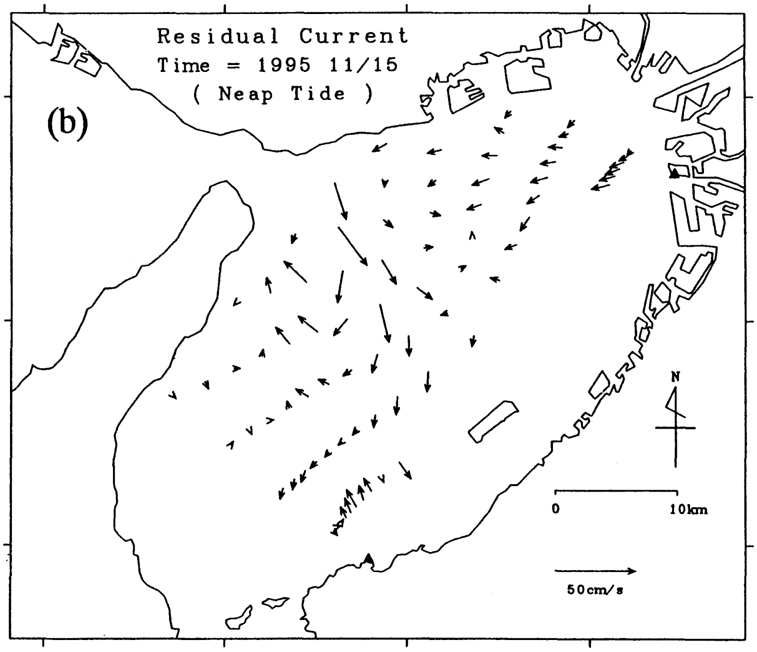


Fig. 5. Distribution of the residual current at spring tides (a) and neap tides (b).

that of spring tides with the intensity of currents put aside. However, southward flow at the flood tide is not found in Fig. 4 (c). Here, most of past observations were carried out during spring tides and the observation during neap tides was rarely made in Osaka Bay. This fact suggests that the southward flow existing at flood tide does not exist during neap tides. Furthermore, at the slack after flood tide of neap tides, we can not find a clockwise eddy in Fig. 4 (d). This clockwise eddy may be a fundamental flow structure of Osaka Bay. Namely, there is a possibility that the residual circulation fluctuates with lunar age period. Thus, we will investigate the variability of the residual circulation in the spring to neap tidal duration in the next section.

3.3 Residual Circulation during Spring Tides and Neap Tides

Figure 5 shows the circulation patterns which are obtained by averaging the current velocities at the beam cross points over 25 hours at spring tide (a) and neap tide (b). A clockwise residual circulation develops in the central part of Osaka Bay at both spring and neap tides. Maximum velocity of the circulation reaches about 70 cm/s during spring tides and about 30cm/s during neap tides near the Akashi Strait and the overall residual velocity during spring tides is 2–3 times stronger than that during neap tides.

The positions of western, northern and eastern edges of a clockwise circulation are not so much different between spring and neap tides. However, during spring tides, a clockwise circulation spreads more to south than that during neap tides. Most likely, this is because the western edge of a clockwise residual circulation is constrained by the northern part of the Awaji Island whereas northern and eastern edges are constrained by the slope which becomes deep rapidly from 20m to 50m depth (refer to Fig. 1), leaving only southern edge free from such topographic constriction. That is, spatial scale of this circulation at spring tides is larger than that at neap tides.

4. Discussions and Conclusions

Variability of current and a clockwise residual circulation are investigated over spring to neap tidal cycles in Osaka Bay using the observation results by HF radar. As a result, it is suggested that the southward flow at flood tide in the central part of Osaka Bay exists during spring tides but not during neap tides. However, this southward flow can be seen during neap tides of 29 November 1995 (not shown). Here, the tidal range at the tide station of Osaka (34°39′N, 135°26′E) is about 61 cm at morning of 15 November and 83 cm at morning of 29 November with a difference of about 22 cm for the same neap tide condition. This fact suggests that, although under the neap tides, there are two cases where the southward flow at flood tide does or does not develop in the central part of Osaka Bay depending on the tidal range at the neap tidal period. This phenomenon will be studies more in the near future using a numerical model.

FUJIWARA *et al.* (1989) investigated the variability of a clockwise residual circulation in the central part of Osaka Bay with use of ADCP observed data. They suggested that intensity of the residual circulation fluctuated according to the fluctuation of the maximum velocity of tidal current at the Akashi Strait. In our results, intensity of a clockwise circulation at apring tides is stronger than that at neap tides. That is, their suggestion corresponds to our result. Furthermore, in our results, intensity of a clockwise eddy at the slack after ebb tide (Fig. 3 (d)) is stronger than that at the slack after flood tide (Fig. 3 (b)) during spring tides. On the other hand, during neap tides, we can find a clockwise eddy at the slack after ebb tide (Fig. 4 (b)), but we cannot find that at the slack after flood tide (Fig. 4(d)). This fact suggests that a clockwise eddy at the slack is caused effectively by the eastward flow at the Akashi Strait and should contribute to compose a clockwise residual circulation in the central part of Osaka Bay.

Acknowledgments

The authors express their sincere thanks to The Kansai Electric Power Co., Inc. for borrowing site to set the radar systems and to Prof. N. HAYAKAWA of Nagaoka Univ. Tech. and Dr. K. ASAI of Yamaguchi Univ. for their helpful

suggestions.

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Received August 17, 1999
Accepted December 24, 1999

La mer 37 : 153–162, 2000
Société franco-japonaise d'océanographie, Tokyo

Ammonium and phosphate pools of *Noctiluca scintillans* and their supplies to the water column in Harima Nada, the Seto Inland Sea, Japan

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Abstract :The contribution of ammonium and phosphate contained in *Noctiluca scintillans* to the water-column nutrient pools were investigated in Harima Nada, the Seto Inland Sea, Japan. Ammonium nitrogen (NH_4^+-N) and phosphate (PO_4^{3-}-P) concentrations varied widely from undetectable to 36.5 μM and to 1.6 μM, respectively. Percentages of NH_4^+-N and PO_4^{3-}-P contributed by *Noctiluca* were estimated based on population densities and the cellular nutrient contents. The NH_4^+-N and PO_4^{3-}-P contained in *Noctiluca* contributed to the water column NH_4^+-N and PO_4^{3-}-P pools ranging from 0 to 119% and to 80%, respectively. The estimated high percentages of both macro-nutrients were usually found in the middle of spring (April to June) where *Noctiluca* red tides were observable, indicating that during this period the nutrient regeneration by *Noctiluca* should not be ignored. The temporary enhancement of nutrients at the sea surface by *Noctiluca* during Spring season when low ambient nutrient concentration is characterized, effectively supports the growth of autotrophs and results in successive phytoplankton blooms.

Key words : *Noctiluca scintillans, nutrient pools, nutrient regeneration, the Seto Inland Sea*

1. Introduction

Noctiluca scintillans is one of the important red tide heterotrophic dinoflagellate which is abundant in tropical and subtropical coastal waters (e. g. HUANG and QI, 1997 ; OKAICHI and NISHIO, 1976 ; TADA *et al.*, 1997, UHLIG and SAHLING 1990). The extraordinary mass development of this organism dyes sea surface with large red streaks when optimum physico-chemical and biological factors are suitable for cell division and accumulation. This phenomena, so-called *Noctiluca* red tide, has been studied in ecological aspects in global to regional level (e. g. ADNAN, 1989 ; OKAICHI and NISHIO, 1976 ; OMORI and HAMNER, 1982 ; PORUMB, 1992 ; SCHAUMANN *et al.*, 1988 ; UHLIG and SAHLING, 1990 ; HUANG and QI, 1997). In the Seto Inland Sea, Japan, seasonal variation in population density and *Noctiluca* biomass have been studied (TADA *et al.*, 1997) together with biophilic cellular carbon and nitrogen contents (TADA *et al.*, 2000). *Noctiluca* has been ecologically considered to be a nutrient regenerator in the coastal seas due to its high cellular contents of ammonium nitrogen (NH_4^+-N) (OKAICHI and NISHIO, 1976 ; SCHAUMANN *et al.*, 1988 ; MONTANI *et al.*, 1998) and phosphate (PO_4^{3-}-P) (SCHAUMANN *et al.*, 1988 ; MONTANI *et al.*, 1998). The high concentrations of NH_4^+-N and PO_4^{3-}-P which contaminate the sea surface after cell lysis, are subsequently utilized by autotrophs. *Noctiluca* ingests particulate organic matter (POM) such as phytoplankton, detritus (FUKUYO *et al.*, 1990) and bacterial size particles (KIRCHNER *et al.*, 1996), and transforms those organic materials into inorganic nutrients inside the cell by metabolic activity. Although protozoan nutrient regeneration has been considered to be less important than that of the microheterotrophs (HARRISON, 1980, 1992 ; CARON and GOLDMAN, 1990), vertical migrating of the species may transport a significant fraction of their regenerated nitrogen(NH_4^+-N) to

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the sea surface where it is easily aaccessible by primary producers (LONGHURST and HARRISON, 1988 ; LONGHURST *et al.*, 1989 ; HARRISON, 1992). In this study, the authors conducted a long-term study of *Noctiluca* abundance in Harima Nada over the period beginning May 1995 an lasting until December 1998. The cellular NH_4^+-N and PO_4^{3-}-P contents had been measured and data were used to estimate the nutrient pools of *Noctiluca* in the study area. The study further examines the role of *Noctiluca* as the nutrient regenerator in the Seto Inland Sea.

2. Materials and methods

Collection of *Noctiluca* and water samples

Seawater samples were collected almost monthly from May 1995 to December 1998 at the depths of 0, 5, 10, 20, and in deeper water 2m from the bottom at Stn. NH (34° 28′ N, 134° 24′E) located in Harima Nada, the Eastern part of the Seto Inland Sea, Japan (Fig.1). A 10-ℓ Vandorn type water bottle was used to collect water samples except the sea surface sample that was collected using a 15-ℓ plastic bucket. Water samples were poured into twice-rinsed 5 ℓ -capacity polyethylene bags and stored in the dark at surface ambient water temperature during transportation to the land laboratory. Within a few hours after collection, samples were filtered using a Whatman GF/F filter. Duplicate filtrate samples were immediately frozen in a freezer (−20℃) for subsequent analysis of NH_4^+-N and PO_4^{3-}-P. *Noctiluca* abundance were estimated from 1 ℓ water filtration through 300 μm-open mesh screen. Cells retained on the screen were fixed with formaldehyde solution (1% final concentration) and counted under a stereomicroscope at 10× magnification. In case of high *Noctiluca* density in the samples, serial dilutions to appropriate cell number were performed before counting.

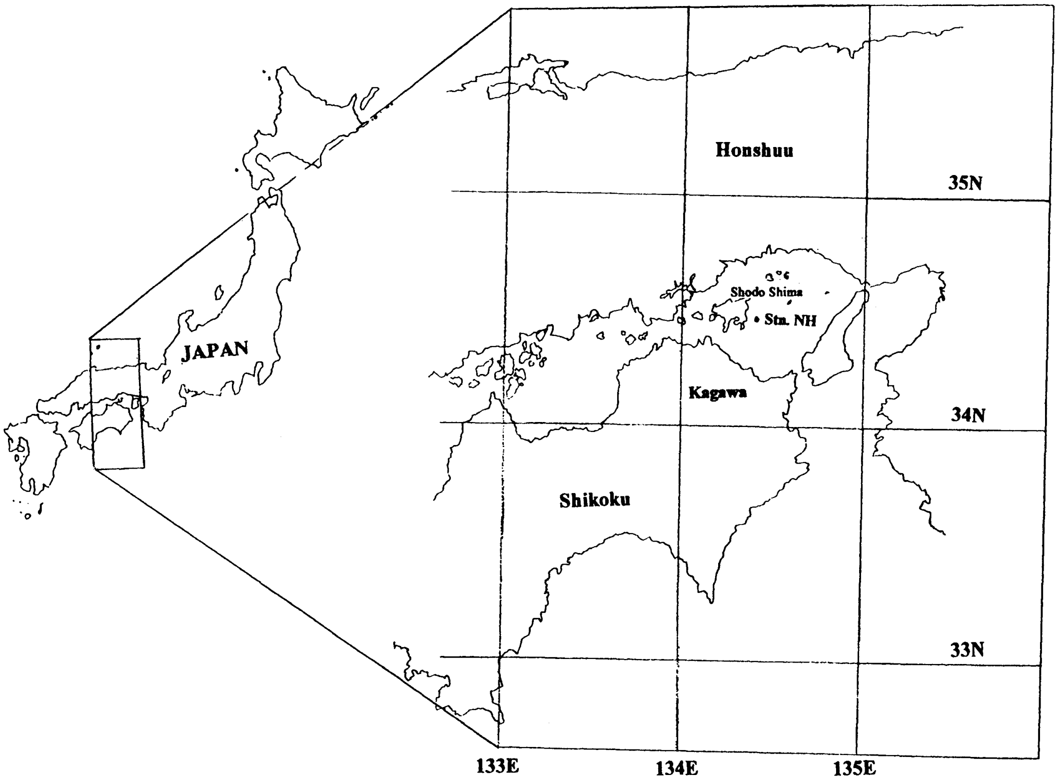

Fig. 1. The location of sampling station, Stn. NH, in Harima Nada, eastern part of the Seto Inland Sea, Japan.

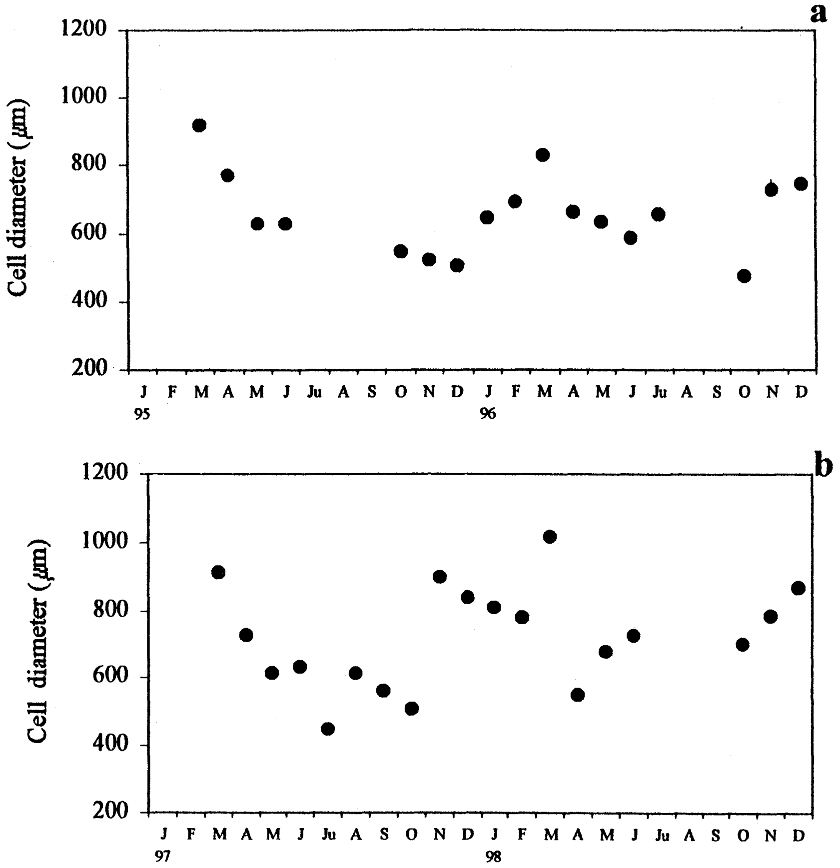

Fig. 2. Monthly changes in *Noctiluca* mean cell diameter during a) 1995–1996. b) 1997–1998.

Noctiluca samples used for determination of cellular nutrient contents were collected by carrying out a vertical tow of a zooplankton net (300μm opening mesh) at a depth of 20m in April, May, June, October, November and December 1996.

Noctiluca cellular content and cell size determination

The details of the method for determining *Noctiluca* cellular nutrient contents are given elsewhere (MONTANI *et al.*, 1998). Buoyant *Noctiluca* cell collected by a zooplankton net were siphoned off the top of net-plankton samples. Cells were washed to eliminate other plankton species with 0.2μm filtered seawater for 3–5 times by repeating the siphon process. *Noctiluca* cell were carefully placed onto a 0.45 μm Milipore filter (cellulose nitrate membrane). *Noctiluca* cells together with the filter were homogenized and sonicated in and ice-cold water bath. Double-distilled water was used to dissolve the inorganic nutrients from the samples. The liquid phase was then filtered using a 0.45 μm disposable disk membrane filter for further analysis of NH_4^+-N and PO_4^{3-}-P using the Technicon Auto-Analyzer II (GRASSHOFF *et al.*, 1983). All samples were prepared in replicates (n=2~6).

Noctiluca cell diameter was measured for different collection period of the year by observing 20 live cells from the plankton net sample under a light microscope with a micrometer at 100 × magnification. No fixing solution was used to fix the cells but we reduced the sea water volume on the Sedgwick-Rafter counting chamber so that the movement of *Noctiluca* was restricted. *Noctiluca* cell volumes were

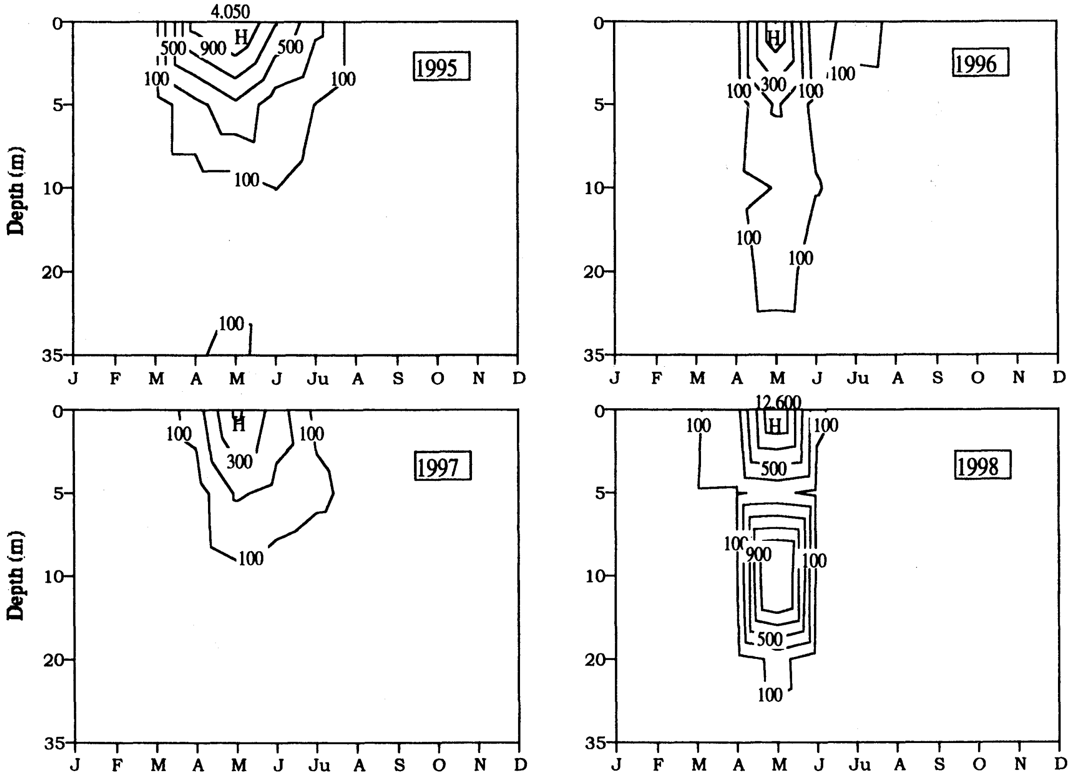

Fig. 3. Vertical profiles and monthly changes in *Noctiluca* population density at Stn. NH during 1995–1998.

calculated assuming spherical shape.

Estimation of ammonium and phosphate pools of *Noctiluca*.

The ammonium and phosphate contents of *Noctiluca* was measured in the 1996 samples and used to estimate the *Noctiluca* inorganic nutrient pools based on its cell volume. We also observed seasonal changes in *Noctiluca* cell diameter during the study period. The largest cells were usually observed in March with diameters decreasing from March to July of October and then increasing toward December (Fig. 2 a, b). For the remaining months that we were not able to measure cellular nutrient contents due either to low cell densities in the water column (in August and September) or due to the difficulty of separating *Noctiluca* from other contaminated zooplankton in the net-samples (in July). We used linear correlation equations between *Noctiluca* cell volume and cellular NH_4^+-N and PO_4^{3-}-P to calculate nutrients content of the cell.

3. Results

The abundance of *Noctiluca scintillans* in the Seto Inland Sea

The high population density of this organism was clearly noticed once or twice every year during the study period (note that our monitoring was carried out at almost monthly intervals). Population densities ranged from 0 to 12,600 cell l^{-1}. The peak cell densities at the sea surface occurred in April to May 1995, and March to May 1998 (Fig. 3). In April 1995 a density of 155 cell l^{-1} was unexpectedly found in the bottom layer. There were small cell density peaks reaching to 500 cell l^{-1} in May 1996 and May 1997 (Fig. 3). No *Noctiluca* density greater than 1,000 cell l^{-1} was found in the 1997 samples. However, a moderately high cell density was counted at that time (426 cell l^{-1}).

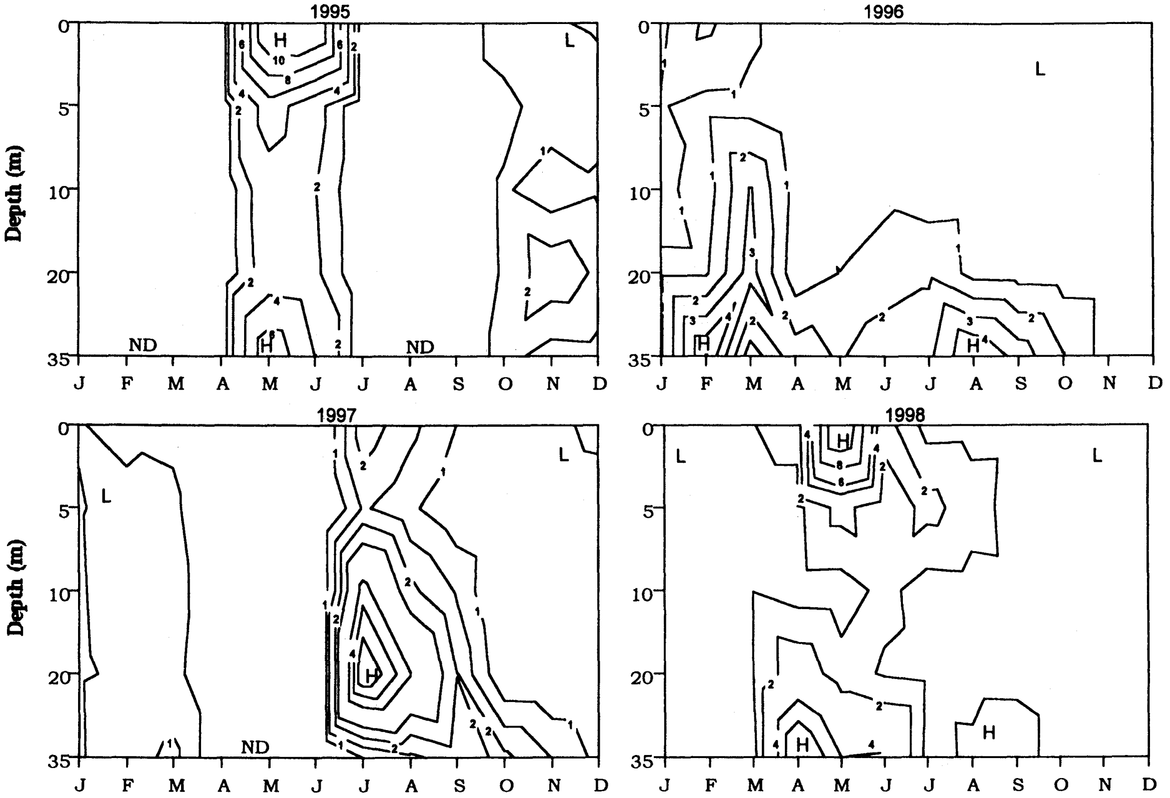

Fig. 4. Vertical profiles and monthly changes in NH_4^+-N concentrations (μM) at Stn. NH during 1995–1998.

The seasonal variation in NH_4^+-N and PO_4^{3-}-P in the study area

The NH_4^+-N and PO_4^{3-}-P concentrations of seawater samples varied widely from undetectable to 36.5μM and to 1.6μM for NH_4^+-N and PO_4^{3-}P, respectively. Ammonium nitrogen concentration usually increased in middle of spring. The highest concentration of 36.5μM was found concurrently with 718 cell l^{-1} *Noctiluca* density in June 1995 (Fig. 4). Low ammonium level spring and summer were found with the exception of samples taken in 1996. Low NH_4^+-N concentrations, however, were measured in autumn and winter waters for most of the samples throughout the monitoring period.

Seasonal changes in PO_4^{3-}-P concentrations experienced the same seasonal trends as the concentrations of NH_4^+-N concentration (Fig. 5). Phosphate and NH_4^+-N concentration increased concurrently with the increase in *Noctiluca* cell density in May 1995 and May 1998. Low PO_4^{3-}-P concentrations were found in early spring and summer as a result of phytoplankton uptake. We observed that nutrient flux from water-sediment interface occasionally induced high concentration of both nutrients found in a bottom layer.

The estimation of ammonium and phosphate provided by *Noctiluca*

The intracellular NH_4^+-N and PO_4^{3-}-P contents of *Noctiluca* were calculated based on the correlation between cell volume and cellular inorganic nutrient contents as :

Noctiluca cellular NH_4^+-N (pmol/cell)

$$=2\times10^{-5}\,v+88.89 \qquad (1)$$

Noctiluca cellular PO_4^{3-}-P (pmol/cell)

$$=3\times10^{6}\,v-129.13 \qquad (2)$$

where v is the *Noctiluca* cell volume(μm^3).

The *Noctiluca* ammonium nitrogen and PO_4^{3-}-

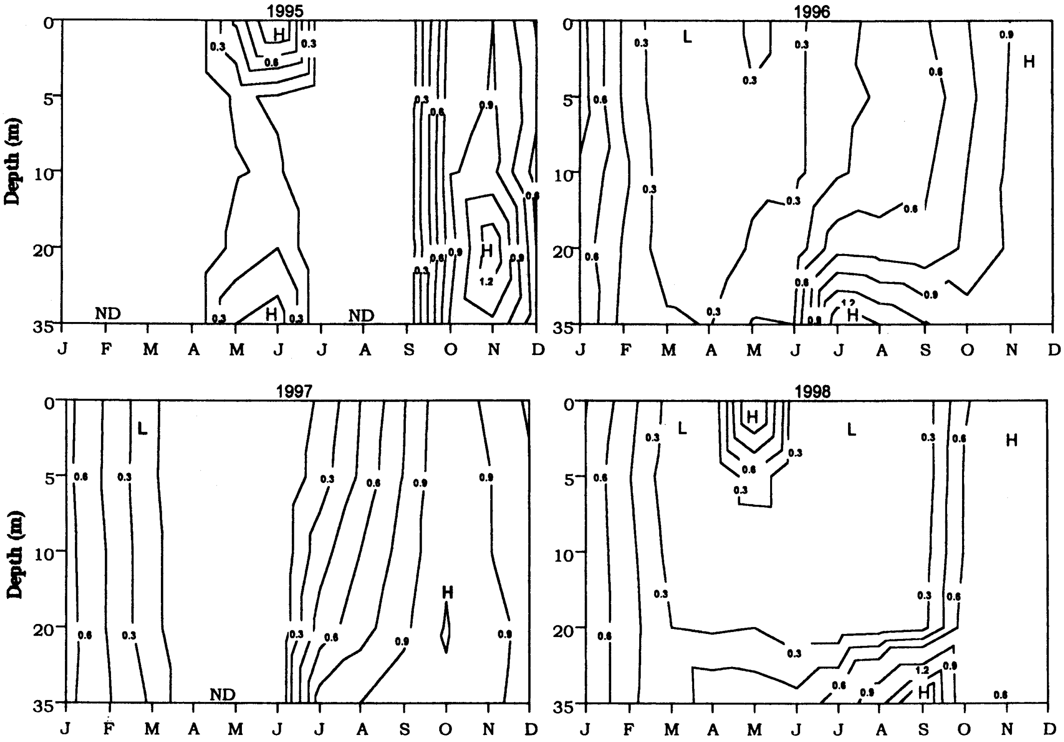

Fig. 5. Vertical profiles and monthly changes in Po_4^{3-}-P concentrations (μM) at Stn. NH during 1995–1998.

P contents of has been reported in a previous study (MONTANI *et al.*, 1998). The estimated seasonal changes in *Noctiluca* cellular nutrient content is shown in Fig. 6. *Noctiluca* cell diameter decreased from the largest cells found in the March sample to the smallest cells found in April, July and October samples. Cell diameters then increased toward December (unpublished data). The same trend in changes in cellular nutrient content was obtained. The highest *Noctiluca* cellular NH_4^+-N and PO_4^{3-}-P contents were found in the March 1998 samples (11.2 and 1.5 nmol $cell^{-1}$ for NH_4^+-N and PO_4^{3-}-P, respectively) when the cell diameter was 1019.2 μm. The lowest cellular nutrient content was found in the July 1997 samples (1.0 and 0.01 nmol $cell^{-1}$ for NH_4^+-N and PO_4^{3-}-P, respectively) when the cell diameter averaged 448 μm (Fig. 6).

Nutrient pools of *Noctiluca* were estimated by the multiplication of intra-cellular nutrient contents and cell standing stocks in 0–33 m depth water-column. High *Noctiluca* NH_4^+-N and PO_4^{3-}-P pools comparing to the ambient nutrient pools were found in May and June 1995, April and May 1996, 1998 and March 1997. These led the percentages of NH_4^+-N and PO_4^{3-}-P contained in *Noctiluca* to the ambient nutrient standing stocks ranged from 6.5–119% and from 5.1–80.0%, respectively. Low percentages of NH_4^+-N and PO_4^{3-}-P pools to the ambient nutrient concentrations were found in other periods of the year (Fig. 7).

4. Discussion

Seasonal variation in *Noctiluca* abundance

Noctiluca abundance has been studied globally (e. g. western coast of Brittany-FÈVRE and GRALL, 1970; German Bight-UHLIG and SAHLING, 1982, 1990; SCHAUMANN *et al.*, 1988; Romanian Black Sea-PORUMB, 1992; Dapeng Bay, the South China Sea-HUANG and QI, 1997; Seto Inland Sea-TADA *et al.*, 1997). HUANG and QI (1997) reported that during the peak period of

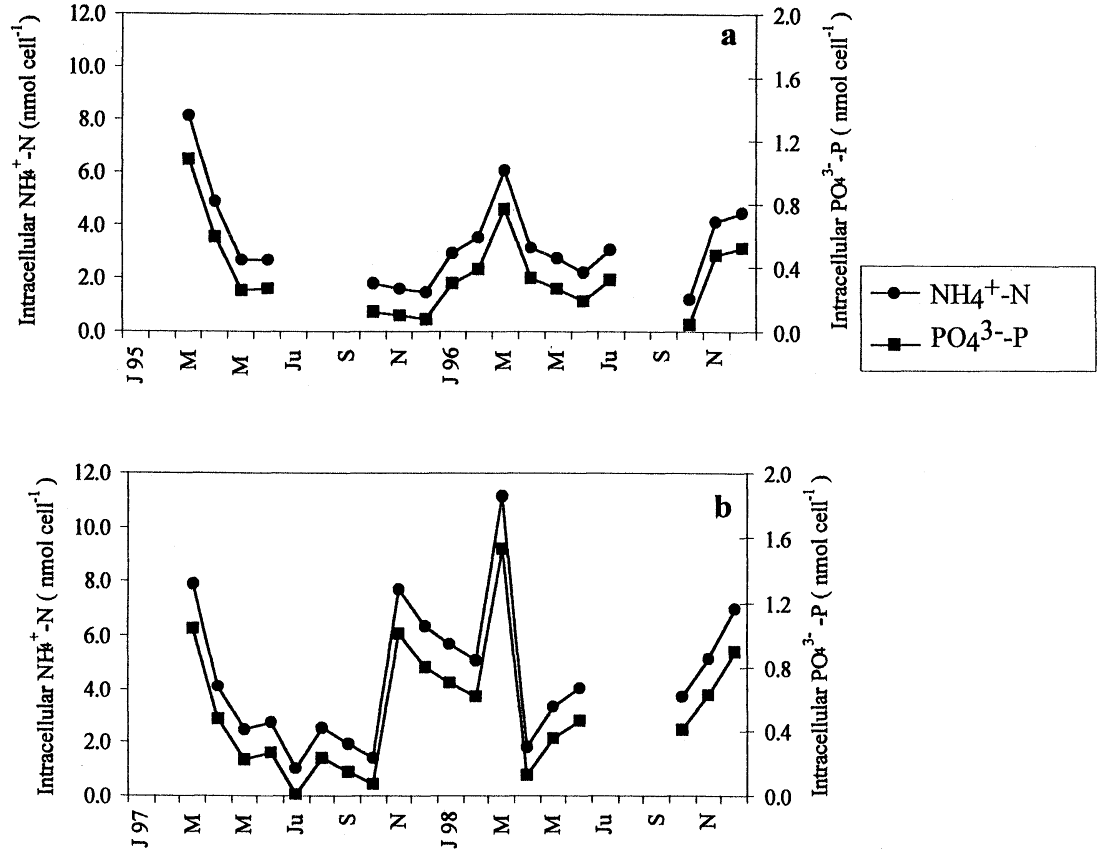

Fig. 6. Monthly changes in *Noctiluca* cellular NH_4^+ and PO_4^{3-}-P contents (nmol $cell^{-1}$) calculated based on the difference in cell volume during a) 1995–1996, b) 1997–1998

abundance between March and May in Dapeng Bay, South China Sea, the average density of *Noctiluca* had a significantly positive relationship with average water temperature. Our study documents the same phenomenon. Other physical factors effecting on the appearance of *Noctiluca* population are wind and tidal current (UHLIG and SAHLING, 1990). UHLIG and SAHLING (1990) also stated that *Noctiluca* growth is influenced by light intensity. Cell growth in nature could be influenced by increasing day length from December toward June (in the German Bight). In spring, water temperature would be the dominating growth parameter. Moreover, hydrographical features, such as fronts, have been postutated as an indicator in outbreaks of the red tide (FÈVRE and GRALL, 1970). The calm weather and weak stratification of the water column with a warm surface layer obviously aids in generating a *Noctiluca* patch (SCHAUMANN *et al.*, 1988). However, PORUMB (1992) reported the most abundance of *Noctiluca* (over 50% of its density) in Romanian Black Sea water was observed between 50 and 75m depth in summer. He suggested that the stratification of water masses and strong heating of the superficial water in August may cause a numerical decrease in the *Noctiluca* population in the surface water. High temperature in the surface layer (over 21℃ was stated by PORUMB, 1992, in Romanian Black Sea waters) modifies the behavior of *Noctiluca* which, by modifying their buoyancy, succees in avoiding layers that are over heated.

Apart from the factors mentioned above, the primary factor in *Noctiluca* multiplication is the presence of food (PORUMB, 1992). *Noctiluca* is well-known for its grazing behavior on a

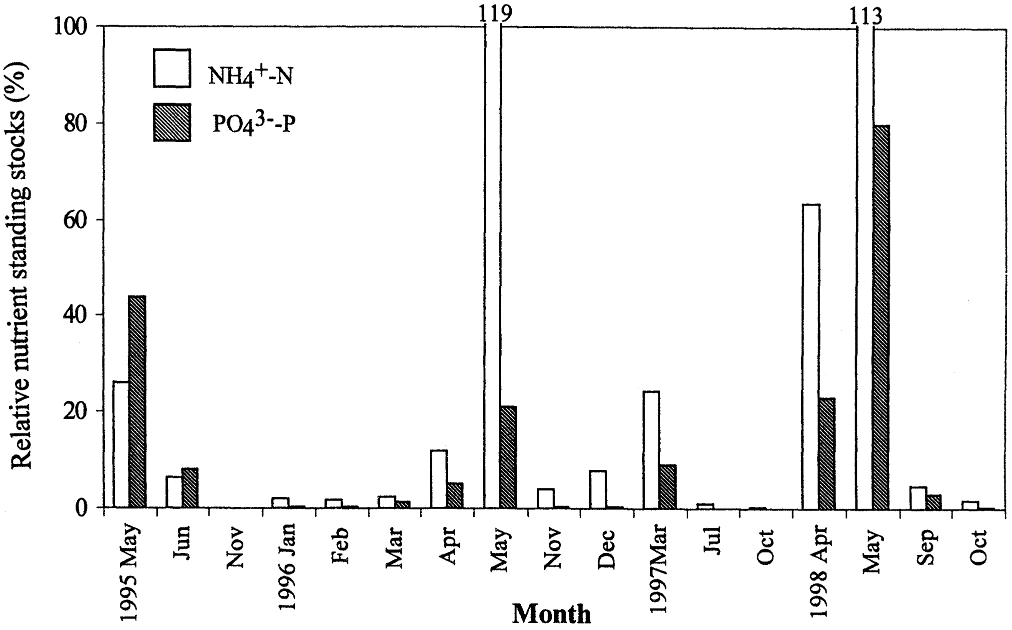

Fig. 7. Percentages of NH_4^+–N and Po_4^{3-}–P pools contained in *Noctiluca* cells to the ambient nutrient concentrations in the water column during 1995–1998

wide variety of foods, including phytoplankton (mainly diatoms and flagellates), zooplankton, fish eggs, detritus (HATTORI, 1962; FUKUYO *et al.*, 1990), and copepods eggs (KIMOR, 1979; DANN, 1987). HUANG and QI (1997) suggested that during the peak period of the *Noctiluca* abundance, the average density of *Noctiluca* at stations in Dapeng Bay showed a significantly negative relationship with average Chlorophyll *a* concentration. This indicated that *Noctiluca* exerts some predation pressure on the phytoplankton. Cyanophytes and bacteria may also serve as a food source for *Noctiluca.* SWEENEY (1970) observed cyanophyte *Trichodesmium* sp. within *Noctiluca* food vacuole. KIRCHNER *et al.* (1996) reported that bacteria and bacterial sized fluorescent latex microspheres can be removed from the water by entrapment in the mucoid web of *Noctiluca.* They also suggested that *Noctiluca* ingests bacteria in the winter when other food source are scarce. In the Seto Inland Sea, we found that a decrease in phytoplankton biomass occurred concurrently with an increase in *Noctiluca* population (TADA *et al.*, 1997).

Ammonium and phosphate provided by *Noctiluca*

The regeneration and supply of limiting nutrients in coastal surface waters are ecologically important especially in temperate regions where there are the high seasonal fluctuations in nutrient concentrations and other physical factors, such as water temperature. Organisms which contribute to nutrient regeneration have been seriously investigated for decades (HARRISON, 1980, 1992). It was suggested that microheterotrophs account for considerably more of the energy tranfer and nutrient cycling within the plankton community than the grazing concept [phytoplankton-zooplankton-fish] held (HARRISON, 1992). The regeneration by micrograzers excretion, for example of heterotrophic bactivorous and herbivorous, however, has also been studied extensively. CARON and GOLDMAN (1990) suggested that protozoans may be important nutrient remineralizers. This ovservation was based on the abundance of protozoa in coastal and oceanic waters, the fact that they are major consumers of bacteria and autotrophic picoplankton, their high biomass-specific metabolism, and field observations that often associated high nutrient regeneration rates with the particle size class in which they fall (CARON and GOLDMAN, 1990; HARRISON, 1992).

Nutrient regeneration contributed by *Noctiluca* has been considered by OKAICHI and NISHIO (1976). Okaichi and Nishnio pointed out that the harmfulness of this dinoflagellate is due to the high NH_4^+-N content in the cell. In adiction ammonium possibly contaminates the surrounding water when cell lysis occurs. This topic has been subsequently discussed by a few additional authors. SCHAUMANN *et al.* (1988) has concluded based on the reports of German scientists that the dense accumulatin of *Noctiluca* cell in the red tide patch heavily influenced the chemical and biological balance of the pelagic ecosystem. Aging *Noctiluca* cells ascend to the water surface which is in part achieved by active intracellular ion exchange and NH_4^+-N accumulation which reduces the specific weight of the cell. Part of this NH_4^+-N is then subsequently secreted together with PO_4^{3-}-P near to at the surface of the water column. This observation has been evidently supported by our findings that patches of *Noctiluca* red tide provided 16- and 25-fold greater concentrations of NH_4^+-N and PO_4^{3-}-P (maximum 86 and 4.6 μM, respectively). Concentrations were greater in the uppermost layer (0–10 cm depth) of the water column compared with concentrations in the ambient sea water (MONTANI *et al.*, 1998). We also reported the intracellular nutrient contents of *Noctiluca* which are used to estimate NH_4^+-N and PO_4^{3-}-P pools in this study.

The increase in *Noctiluca* population density enhances NH_4^+-N and PO_4^{3-}-P concentrations on the sea surface due to its mass nutrient accumulation in the cell which is secreted as waste or released to the water after cell lysis (SCHAUMANN *et al.*, 1988, MONTANI *et al.* 1998). MONTANI *et al.* (1998) reported that the NH_4^+-N concentrations at the center of *Noctiluca* red tide between 0–10cm depth were markedly higher than those of the next 10cm depth layer (10–20cm). In addition to direct nutrient regeneration, a large amount of organic detritus and dissolved organic matter (DOM) produced within the red tide may stimulate microbial activities (SCHAUMANN *et al.*, 1988) which is believed to provide an important fraction of regenerated nutrient. In this study, we can point out that NH_4^+-N and PO_4^{3-}-P pools contained in *Noctiluca* in Harima Nada, the Seto Inland Sea, accounted for 0–119% and 0–80%, of the ambient nutrient pools respectively during spring. These high percentages are important ecologically in relation to the biogeochemical cycles of the biophilic elements, mainly nitrogen and phosphorus, in marine environment.

Acknowledgments

Special recognition for his encouragement is due Prof. Tomotoshi OKAICHI. We are grateful to Prof. Tadashi OCHI for his suggestions in nutrient analysis. Speial thanks go to Dr. Kazuhiko ICHIMI and Ms. Rumiko YANO for their kind assistance. Thanks also to Mr. T. HAMAGAKI, the captain of R.V. Calanus, for his assistance during the field observation.

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Received October 26, 1999
Accepted December 24, 1999

La mer 37 : 163–171, 2000
Société franco-japonaise d'océanographie, Tokyo

Influences of concentration, particle-size and kind of inorganic suspended matter on feed caught by Manila clam, *Ruditapes philippinarum*

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Abstract : The influences of concentration ,particle-size and kind of inorganic suspended matters on the feed caught by of Manila clam, *Ruditapes philippinarum*, were quantitatively analyzed using a Coulter Counter. Total of 250 samples under shell-length 40 mm (±1.0 mm) were examined. Inorganic particles such as porcelain clay, kaolinite (average size 4.2 μm and 15.3 μm) and red-yellow soil (average size 4.5 μm) were suspended in filtered seawater. Phytoplankton, *Pavlova lutheri* (average size 5.6 μm) constituted the simulated feed suspension. The percent catch rate was based on the proportion of feed particles reduced from the initial number. As the particle-size distribution of phytoplankton followed a normal mode, the catch rate's was expressed as the average in the range from 4.0 to 6.3 μm.

When the kaolinite particles of size 4.2 μm were added at the concentration of 2.0×10^5 ml^{-1} to the phytoplankton suspension of 1.0×10^5 cells・ml^{-1} containing one clam, the catch-rate of phytoplankton by the clam was 74.5%・h^{-1}, revealing that the rate remained almost constant, compared to the pre-addition figure of 70.4%・h^{-1}. However, the catch-rate decreased strikingly to 48.7%・h^{-1} when the kaolinite concentration increased to 5.0×10^5 particles・ml^{-1}. In case of the experiment mentioned above, the very fine kaolinite particles were found adhering to the tip of the clam's incurrent siphon. Furthermore, the phytoplankton cell catch-rates were almost constant when kaolinite was replaced with red-yellow soil. When kaolinite particles of sizes 4.2 and 15.3 μm respectively were added at the concentration of 0.5×10^5 particles・ml^{-1} to a feed suspension of identical concentrati wadicating, the cell catch-rates were 77.8%・h^{-1} in the former and 24.1%・h^{-1} in the latter size, indicating a wide variation in the performance of the clam. Thus it is considered that the influence of inorganic suspended matter on the feed caught by Manila clam depends heavily on inorganic particle's concentration and size, but little on its kind.

Key words : *inorganic suspended matter, feeding, Manila clam, catch rate*

1. Introduction

Recently, a great deal of clay and sand are found dispersed in the coastal waters owing to reclamation works, dredging operations and river transports. Thus it is considered that these particles suspended in seawater have a direct influence on tidal flat inhabiting benthic suspension feeders, for instance, the bivalve Manila clam which is one of the important species from the view-point of fishery resources.

GRIZZLE *et al.* (1989) and NUMAGUCHI (1990) reported the profound influence of concentration of particulate organic matter (POM) and suspended solids (SS) on the bivalve's growth and survival rate. With respect to studies on the influence of particle-size on filtration performance, there are the reports of KUWATANI (1965), KUSUNOKI (1977a, b), HANS (1988), and ARAKAWA *et al.* (1997). KUSUNOKI (1977a, b) investigated the quantities of suspended particles caught by oyster according to particle-size. ARAKAWA *et al.* (1997) examined the size of captured particles for different shell-lengths of the

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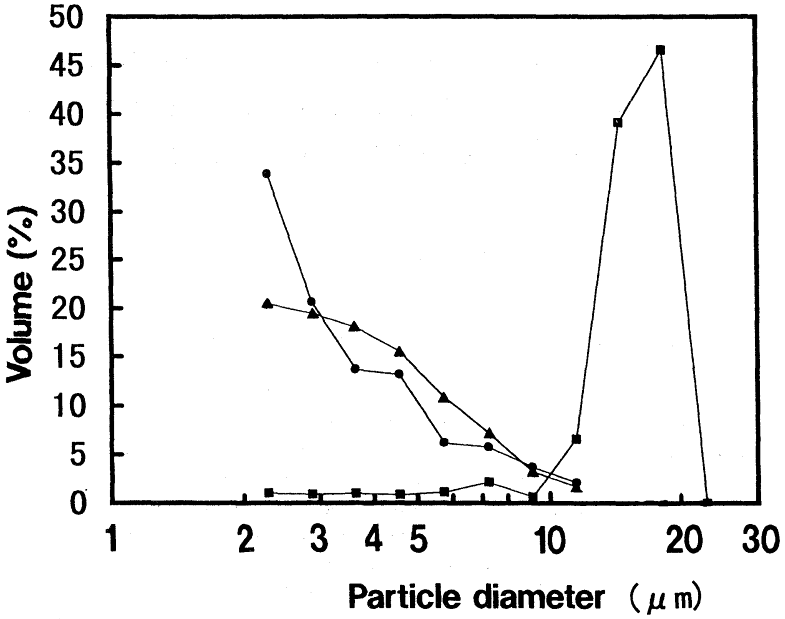

Fig. 1. Particle size distribution of kaolinite and typic red-yellow soil. Symbols ● and ■ indicate kaolinite suspension with average particle-sizes of 4.2 μm and 15.3 μm, respectively, and ▲ indicate red-yellow soil.

clam, supposing that the particle-size of feed greatly influenced the clam's growth in the early stages.

In an earlier related research, FUJIYA *et al.* (1958) studied the influences of waste water and industrial drainage on the feed and filtration of Manila clam with references to their concentrations and the opening and shutting movement of incurrent siphon. CHIBA and OSHIMA (1957) examined the effect of oragnic and inorganic suspended particles on the amount fed and the filtration speed of Manila clam and blue mussel, and found that the speed were approximately constant, irrespective of the quantities of bentonite particles. Apart from this, there is very few information on the influence of inorganic matter suspended in seawater on the feed caught by bivalves.

This study attempts to examine the influences of concentration, particle-size and kind of the inorganic particulate matter on the feed capture of Manila clam.

2. Materials and Method

2.1 Samples and Materials

The bivalve Manila clam, *Raditapes philippinarum* , collected from the tidal flat at Futtsu, Chiba Prefecture were used in this study. A total of 250 clams of shell-length 40 mm (±1.0 mm), were used for the experiment. Each sample was kept from one to eight weeks in basins with filtered seawater maintained at 21±3 ℃.

The inorganic particles employed in this experiment were porcelain clay, kaolinite and typic red-yellow soil. The powdered kaolinite was mixed with seawater filtered through millipore HA (pore-size 0.45 μm), and after one hour, the resulting kaolinite suspension was divided into two kinds; one was the supernatant fluid of suspension, and the other was the suspension filtering through a net of mesh size 20 μm, and not through that of mesh size 10 μm. Fig. 1 shows the particle-size distributions of the supernatant and filterate fractions of the kaolinite suspension obtained. The average particle-size was 4.2 μm for the supernatant and 15.3 μm for the filtrate. Considering the particle range from 2.3 to 11.5 μm in the supernatant suspension, kaolinite particles less than 4.0 μm, constituted nearly 70% of it. On the other hand, the suspension of the filtrate was constituted more than 60% by particles in the range from

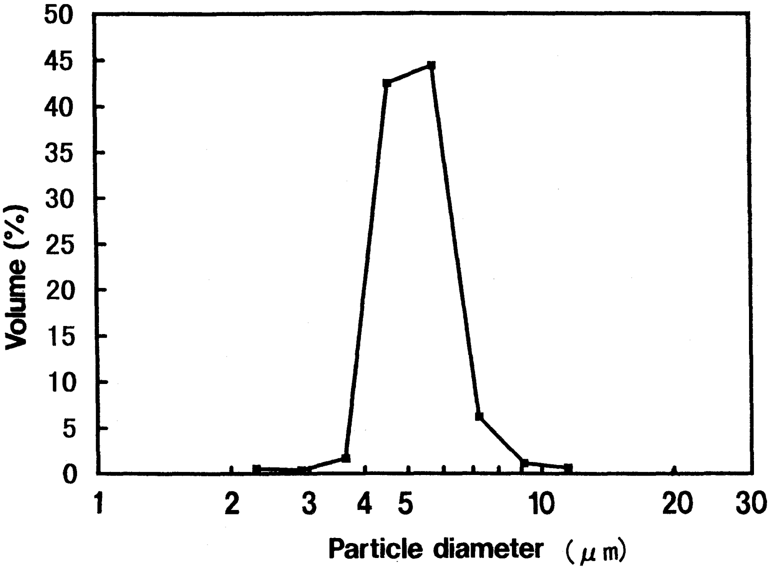

Fig. 2. Particle size distribution of the phytoplankton, *Pavlova lutheri*.

14.5 to 18.3 μm. The red-yellow soil embeded in the Kunigami marge located at Nago, Okinawa Prefecture was also studied. This soil consists of Illite, Halloysite, and etc. (AOKI , 1973) The red-yellow soil was mixed with sea water, filtered through millipore HA (pore-size 0.45 μm), and after one hour, the supernatant fluid of the resulting soil suspension was used as an experimental sample. The particle-size distribution of soil suspension is also shown in Fig. 1, the average size being 4.5 μm. In the case of soil, there were also fewer particles of larger size in the suspension, and those below 4.0 μm, occupied approximately 60% of the total. This distribution is similar to that of the supernatant suspension of kaolinite particles mentioned above.

The feed suspension was the phytoplankton, *Pavlova lutheri* monocultured in a constant temperature room, and it was allowed to emigrate into the seawater. The particle-size distribution of phytoplankton cells is shown in Fig. 2. They ranged in size from 2.3 to 11.5 μm, the maximum numbers (90% of the total) falling in the range from 4.6 to 5.7 μm. The average cell-size of the phytoplankton was 5.6 μm. This value is a little larger than that of ARAKAWA *et al.* (1997).

2.2. Method

The experiments were conducted at the Banda Marine laboratory of Tokyo University of Fisheries during the period from June to December in 1995. An outline of experimental system is illustrated in Fig. 3. The experimental tank was cylindrical in shape and had a diameter of 18 cm, and a depth of 10cm. this tank was set in the constant temperature water-tank. Also, the experimental tank contained yet another cylindrical inner container, 6 cm each in diameter and depth, which retained the experimental bivalve, and a aerator to facilitate water circulation. Such an experimental system enables the pseudo faeces to keep in an inner container, and is similar to that in the previous paper (ARAKAWA *et al.,* 1997).

The experiments intended to examine the effect of, (1) concentration of inorganic particle, (2) it's size, and (3) it's kind on the feed caught by Manila clam. Under the first aspect, kaolinite particles were added to phytoplankton suspension, and the mixture had the concentration of 1.0×10^5 particles · ml^{-1}. At this fixed concentration, we tried four ratios of phytoplankton to kaolinite mix; 10 : 0, 5 : 5, 2 : 8, and 0 : 10. Further, keeping the concenration of phytoplankton at 1.0×10^5 cells · ml^{-1} we added kaolinite at concentrations of 2.0×10^5 particles ·

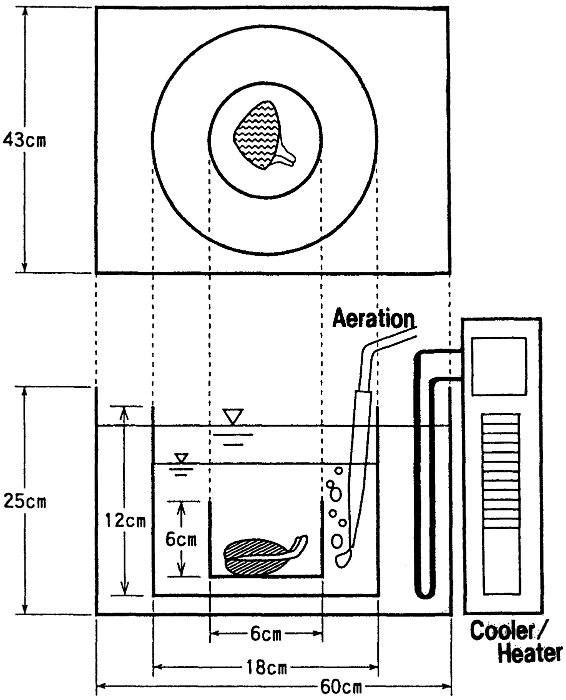

Fig. 3. An outline of experimental system.

ml^{-1} and 5.0×10^5 particles · ml^{-1}. In the second aspect examining the size, kaolinite particles of sizes 4.5 and 15.3 μm, at a concentration of 0.5×10^5 particles · ml^{-1}, was added to the phytoplankton suspension at an identical concentration. In the third study in this series, evaluating the kind of inorganic particle, the red-yellow soil at a concentration of 5.0×10^5 particles · ml^{-1} was added to the phytoplank-ton suspension having the concentration of 1.0×10^5 cells · ml^{-1}. The suspensions mentioned above were maintained in a dispersed state with weak air-pumping in order to avoid sedimentation, thereby producing uniform mixtures.

From about five to ten minutes after introducing a sample clam in the vessel, we observed the vigorous filtration activity with incurrent siphon, and after one hour, we collected 200ml of the water from the vessel with a whole-pipet. The number of particles in the sampled water was measured with a Coulter Counter (Model ZM; aperture size of 100 μm). The objective particles for the study were those in the range from 2.0 to 25 μm. A control was employed simultaneously, using the vessel without the experimental animals, and determining the particle numbers from a similar sample as mentioned earlier.

The catch rate, $C_{r(i)}$ is obtained using the following formula(ARAKAWA *et al.*, 1997);

$$C_{r(i)} = \frac{1}{n \cdot t} \frac{C_{c(i)} - C_{e(i)}}{C_{c(i)}} \cdot 100 \quad (\% \cdot h^{-1}) \quad (1)$$

where, $C_{c(i)}$ is the concentration of particles without the clam, $C_{e(i)}$ denotes the concentration of particles(diameter at i - class: di) contained in the water with the clam, t (hour) stands for the experimental period, and n is the number of clams.

Besides, the average diameter of captured-particle $\bar{D}$ is based on the following formula:

$$\bar{D} = \frac{\Sigma\, d_i \cdot Nd_i}{\Sigma\, Nd_i} \qquad (2)$$

Where, d_i stands for the diameter of particle-size at i-class, and Nd_i stands for the number of particles at the diameter d_i.

In this study, each of the values of n and t mentioned above was one piece and one hour, respectively. Also, the value of catch rate was

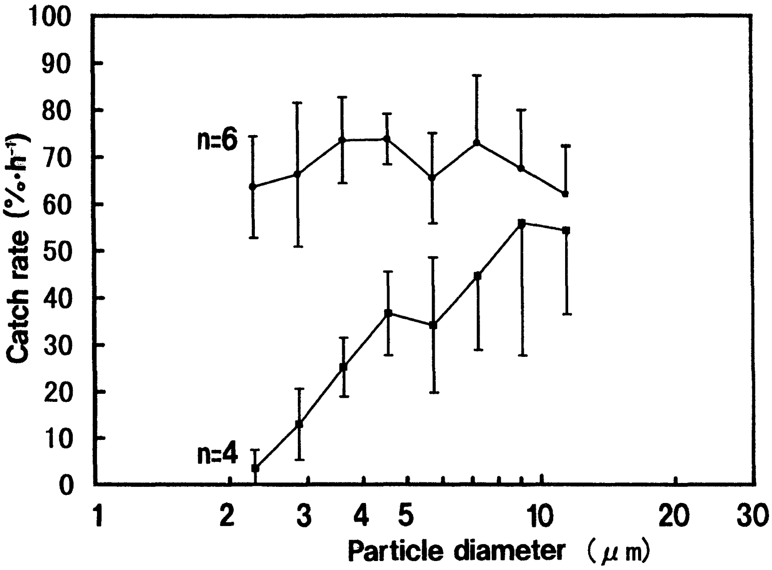

Fig. 4. Changes in the catch-rates of clams when offered two different suspension. Symbols ● and ■ represent phytoplankton and kaolinite with particle-sizes of 4.2 μm, respectively.

expressed as the average for the size range from 4.0 to 6.3 μm as the particle-size of phytoplankton had a normal mode in distribution.

3. Rusults

3.1. Quantity of inorganic matter

3.1.1. Constant concentration

Figure 4 shows the relationship between catch rates of phytoplankton cells and kaolinite particles on the clam and particle-size when it was kept for 60 minutes in filtered seawater. Circle and square symbols denote the phytoplankton, *Pavlova lutheri* and the kaolinite with particle-size of 4.2 μm, respectively. Both had a concentration of 1.0×10^5 particles · ml^{-1}. In the former, the catch rates of phytoplankton cells were 63.6% · h^{-1} corresponding to the particle-size of 2.3 μm, 65.4% · h^{-1} for 5.7 μm, and 62.1% · h^{-1} for 11.5 μm. Accordingly, their catch rates were about 60–70% · h^{-1} for the size range from 2.3 to 11.5 μm. On the other hand, the catch rates of kaolinite were 3.5% · h^{-1} corresponding to 2.3 μm particle-size, 34.1 % · h^{-1} for 5.7 μm, and 54.3% · h^{-1} for 11.5 μm, respectively. The noticeable difference for kaolinite particles was the high catch rates for the size range from 9.1 to 11.5 μm. These facts suggest that the feeding pattern of clam on the phytoplankton cell distinctly differs from that with the kaolinite particle.

The kaolinite with particle-size of 4.2 μm was added to the phytoplankton suspension, and the concentration of resulting suspension was 1.0×10^5 particles · ml^{-1}. Table 1 exhibits the number of particles caught by clam in relation to the phytoplankton: kaolinite ratio. The number of particles was 1.4×10^8 cells · $piece^{-1}$ · h^{-1} corresponding to the ratio 10: 0, 1.6×10^8 particles · $piece^{-1}$ · h^{-1} for 5: 5, 6.2×10^7 particles · $piece^{-1}$ · h^{-1} for 2: 8, and 1.8×10^7 particles · $piece^{-1}$ · h^{-1} for 0: 10, respectively. The efficiency of particle-capture decreased with an increase in the proportion of kaolinite. In particular, when the ratio of phytoplankton to kaolinite was 0 : 10, the capture rate was only 1.8×10^7 particles · $piece^{-1}$ · h^{-1}, and this was just one-tenth that of the suspension containing only phytoplankton cells.

3.1.2. Increase of particle concentration

In the particle-size distribution of phytoplankton cells caught, about 87.9% of the total was constituted by those in the range from 4.0 to 6.3 μm. Table 2 shows the changes in catch

Table 1. Relationships between mix ratio and actual number of particle captured by the clam.

Mix ratio (phytoplankton: kaolinite)	Number of sample	Number of particle (particles・piece^{-1}・h^{-1})
10 : 0	6	1.4 ±0.13×10^8
5 : 5	6	1.6 ±0.08×10^8
2 : 8	8	6.2 ±0.29×10^7
0 : 10	4	1.8 ±0.06×10^7

Table 2. Results of different experimental conditions on the catch-rate of phytoplankton cells by the clam.

Initial condition of experiment	Number of sample	Catch rate(%・h^{-1})
I Kaolinite concentration (particles・ml^{-1})		
0	6	70.4±6.7
2.0 ×10^5	5	74.5±4.2
5.0 ×10^5	5	48.7±4.7
II Kaolinite-size (μm)1		
4.2	6	77.8±4.2
15.3	8	24.1±4.7
III Particle types		
Kaolinite (4.2μm)	5	48.7±5.2
Red-yellow soil	4	48.8±1.5

* Remarks: Phytoplankton concentrations of condition I and III, and condition II are 1.0×10^5 cells・ml^{-1}, and 0.5×10^5 cells・ml^{-1}, respectively.

rate depending on the concentrations of kaolinite particles introduced. Here, the feed suspension of phytoplankton was at a concentration of 1.0×10^5 cells・ml^{-1}. With respect to this suspension, kaolinite particles at the concentrations of 2.0 × 10^5 and 5.0 × 10^5 particles・ml^{-1} were added.

In case of the phytoplankton suspension having no kaolinite, the catch rates of clam was 70.4%・h^{-1} for the size range from 4.0 to 6.3 μm. However when kaolinite particles were added at 2.0×10^5 and 5.0×10^5 particles・ml^{-1}, the catch rates of phytoplankton cell were 74.5%・h^{-1} and 48.7%・h^{-1}, respectively. At the higher kaolinite concentration, the drop in catch rate was quite evident. The fine kaolinite particles were found adhering to the tip of the clam's incurrent siphon.

3.2. Particle-size of inorganic matter

Table 2 expresses the changes in catch rates of phytoplankton cells in the size range from 4.0 to 6.3 μm by the clam when two different sizes of kaolinite were added. The concentration of feed suspension was 0.5 × 10^5 cells・ml^{-1}, and a similar concentration of kaolinite particles at sizes 4.2 and 15.3 μm were introduced. The catch rates of phytoplankton cells were 77.8%・h^{-1} for the particle-size of 4.2 μm and 24.1%・h^{-1} for 15.3 μm, respectively. It is clear throughout the experiments that when the particle-size of the added kaolinite was larger, the catch rate of feed particles was extremely low.

3.3. Kind of inorganic matter

Figure 5 shows the catch rates of clam in relation to particle-size when it was exposed for 60 minutes in seawater containing red-yellow soil at the concentration of 1.0×10^5 particles・ml^{-1}. The catch rate of red-yellow soil was 21.6 %・h^{-1} corresponding to the particle-size of 2.3 μm, 57.8%・h^{-1}for 5.7 μm, and 41.2%・h^{-1} for 11.5 μm. The catch rates(65 to 68%・h^{-1}) were

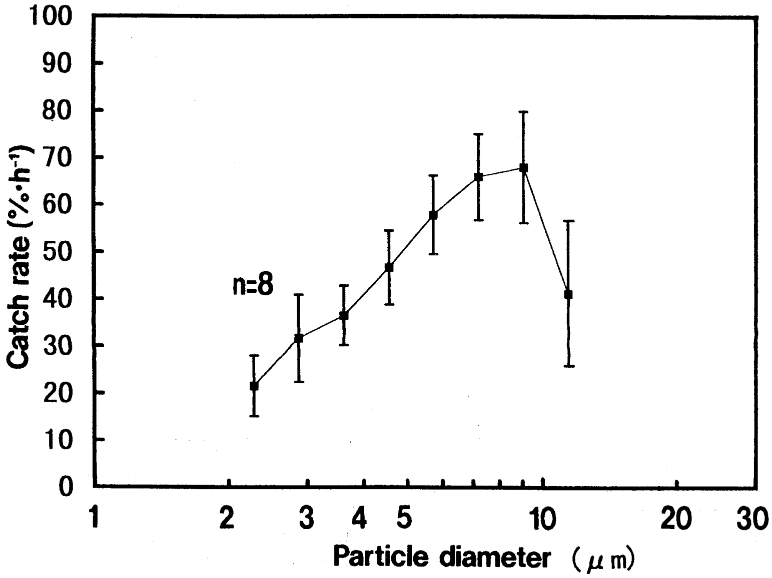

Fig. 5. Changes in the catch-rates of clams exposed to red-yellow soil suspension.

higher for the size range 7.2 to 9.1 μm. Comparing these rates with those for phytoplankton (Fig. 4), we found that the values for the phytoplankton were nearly equal (62 to 74% $\cdot h^{-1}$) for a wide particle size range from 2.3 to 11.5 μm; as against very similar catch rates(65 to 68% $\cdot h^{-1}$) for the soil particles but for a narrower range from 7.2 to 9.1 μm. This result suggests that the capture probability of phytoplankton cells is distinctly different from that of soil and as well as the kaolinite.

Table 2 shows the percent catch rates in the presence of inorganic matter such as kaolinite and red-yellow soil. Here, the value of catch rate was expressed for the size range from 4.0 to 6.3 μm, the concentration of the feed phytoplankton cells being 1.0×10^5 cells $\cdot ml^{-1}$. Also, the concentrations of added inorganic particles were 5.0×10^5 particles $\cdot ml^{-1}$. In case of the soil addition, the catch rate of phytoplankton cells was 48.8% $\cdot h^{-1}$ which was approximately the same as that with the 4.2 μm kaolinite particles. This reveals that the type of the inorganic particle has little influence on the catch rate of the Manila clam.

4. Discussion

In order to fully understand the influence of inorganic particle on the feed caught by Manila clam, it is necessary to have some prior basic information on the filtration performance. Hence, some preliminary experiments: (1) the changes in phytoplankton cell catch rate when the clam were either performing active filtration or not, (2) the changes in phytoplankton cell catch rate with lapse of time, and (3) the influence of the concentration of phytoplankton cell on filtration performance were conducted.

In the first item, the catch rate of clam in a state of motion was about three times of that in a state of rest, corresponding to the particle range from 2.3 to 11.5 μm. The clam used in the present experiment performed active filtration with the end of the incurrent siphon opened. (ARAKAWA *et al.*, 1997)

With respect to the second item, the authors obtained that the number of cells captured was 0.8×10^8 cells $\cdot piece^{-1} \cdot h^{-1}$ in the first half-hour, 1.4×10^8 cells $\cdot piece^{-1} \cdot h^{-1}$ at the end of the first hour and 1.8×10^8 cells $\cdot piece^{-1} \cdot h^{-1}$ by the second hour when the cell concentration was 1.0×10^5 cells $\cdot ml^{-1}$. There was a rapid increase during the first hour and these after the increase was gradual. Throughout these experiments, it is found that the filtration activity of clam continued to an hour.

In case of the third item, the catch rates at different concentrations of phytoplankton cells were 50 to 75% ·h^{-1} for the size range from 2.3 to 11.5 μm. The catch rate of phytoplankton cell is little influenced by the wide range in concentration(0.5 to 6.0×10^5 cells ·ml^{-1}). The catch rates of different particle-sizes and concentrations, in the present study, was almost constant throughout the experiments for cell concentrations between 0.5 to 6.0×10^5 cells ·ml^{-1}. In an earlier study, ARAKAWA *et al.* (1997) experimenting with pellets, reported that with regard to sizes from 2.0 to 10 μm, the catch rates at the concentration of 6.0×10^5 particles·ml^{-1} were extremely lower than those at 1.0×10^5 and 3.0×10^5 particles ·ml^{-1}. This does not coincide with the present findings. It could be attributed to the variations in particle-size distribution, particle's kind and shape between the phytoplankton and pellet.

As to the influence of inorganic particle on the filtration performance of Manila clam, the catch rates of phytoplankton cells(size range from 4.0 to 6.3 μm) abruptly decreased with increase in inorganic particles. JØRGENSEN (1966) has reported that the filtration speed of a bivalve decreased corresponding to an increase in the sediment-particle concentration resulting in closure of the incurrent siphon. In our observations too, we found that the adhension and settlement of inorganic particle in the incurrent siphon of clam occurred in the presence of larger amounts of suspended matter, thereby lowering the phytoplankton cell catch rate. Further experiments are necessary to clarify this point.

With regard to the influence of particle-size of inorganic matter on feeding, the catch rate of phytoplankton cell decreased remarkably as the size increased from 4.2 μm to 15.3 μm. SEMURA (1995) reported that the filtration speed of Adult scallop, *Pecten albicans* changed with kind and quantity of the feed phytoplankton, and found some relationship between the phytoplankton cell size and particle of sizes 5 to 7 μm which were effectively caught with the gill or the filtering organ. The remarkable decrease in catch rate observed in this study when the particle-size of kaolinite is larger, might be because the kaolinite particles of size 4.2 μm are more effectively filtered than those of 15.3 μm.

In the present study, the influence of inorganic suspended matter on the feed caught by Manila clam depended heavily on particles concentration and size of inorganic particles, but little on its kind. These influences could either be fluctuated in the clam of smaller shell-lengths, or different benthic suspension feeders. They have to be examined further.

Acknowledgement

The authors would like to thank to Mr. J. KAKINO , Mr. T. SHIBATA, and Ms. M. SAKAI who are the staffs of the Shellfish Laboratory, Futtse Branch Office of Chiba Prefectural Fisheries Experimental Station for the help presented during the conduct of this study.

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Received August 12, 1998
Accepted January 29, 2000

La mer 37 : 173–181, 2000
Société franco-japonaise d'océanographie, Tokyo

Distribution of underwater irradiances and estimated light attenuation by oil slick in the ROPME Sea area

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Abstract : Classifying seawater in the ROPME Sea area by optical water type (JERLOV, 1964), the water masses of Oceanic Types Ⅱ and Ⅲ were distributed at its centre, and those of Coastal Types 1 and 3, in the coast of UAE and the Arabian side in the vicinity of lat. 27°30′ N, respectively. The depths of water at which PAR attenuated to 1% of its surface value were 26 m and 37 m in the former, and 18 m and more and approximately 18 m in the latter. At the centre of the sea area, the diffuse attenuation coefficients for ultraviolet light A and B were 0.26～0.33 m^{-1} and 0.39～0.53 m^{-1}, respectively. They are several times greater than those of PAR. Based on the experiment about an oil slick on sea surface, the ratio of penetrated light into water became to be smaller as the wavelength was shorter. When the thickness of an oil slick was 0.2 mm, the value of PAR just below that decreased to approximately 1% of the sea surface. The relationship between the thickness of an oil slick and the ratio of PAR attenuation can be expressed by a following formula : $E_{PAR}=100\exp(-23.3\ h)$ $r^2=0.989$, where E_{PAR}, h, and r are relative irradiance (%), thickness of oil slick (mm), and correlation coefficient, respectively. The slicks of crude oil spilled into this Sea area are considered to have an impact on the optical environment underwater.

Key words : *spectral irradiance, optical water type, oil slick, ROPME Sea area*

1. Inyroduction

The ROPME Sea area (hereinafter abbreviated as "RSA") is bounded by seven countries-United Arab Emirates, Qatar, Bahrain, Saudi Arabia, Kuwait, Iraq and Iran, and it has traditionally been called the Persian Gulf or the Arabian Gulf. This sea area is connected to the Arabian Sea through the Strait of Hormuz and the outer Gulf of Oman. The mean depth of water is approximately 35 m with the utter absence of water depths over 100 m. The shape of this sea area is rectangular with a length of approximately 960 km and a width of approximately 250 km, and the total area is 240,000 km^2 which is nearly equal to the area of Honshu Island, Japan.

During the Gulf War in 1990, 1.08×10^7 barrels of crude oil spilled into the RSA, and there were enormous impacts upon diverse marine animals and plants (FAYAD and OVERTON, 1995; READMAN *et al.*, 1996). Oils spilled into oceans are considered to have impacts on not only aquatic animals and plants but also their habitat conditions. Detailed studies are available on physiology and ecology of fish and algae ; e. g. HOLT *et al.*, 1978; PROFFITTE *et al.*, 1995 ; WATANABE *et al.*, 1998. Also, studies on water quality, sea bottom sediments and the effects upon sand shoals are conducted ; OTSUKI *et al.*, 1998 ; I. ALAM *et al.*, 1998. We anticipate that oil slicks hamper the penetration of sun light, with consequential degradation of the optical environment underwater.

Historical studies were more papers, e.g. SCOTT, 1908; SCHULY, 1914; BLEGVAD, 1944; EMERY, 1956. For example, EMERY (1956) provided the first detailed map of the surface salinity distribution, together with some vertical profiles, from data obtained on board the RV Meteor. After that, a joint research by Tokyo University of Fisheries and Kuwait Oceanographic Institute was conducted on board the RT/V Umitaka-Maru in 1968 (Tokyo Univ. of Fish., 1974). OSHITE (1974), one of investigators on board, reported that the values of

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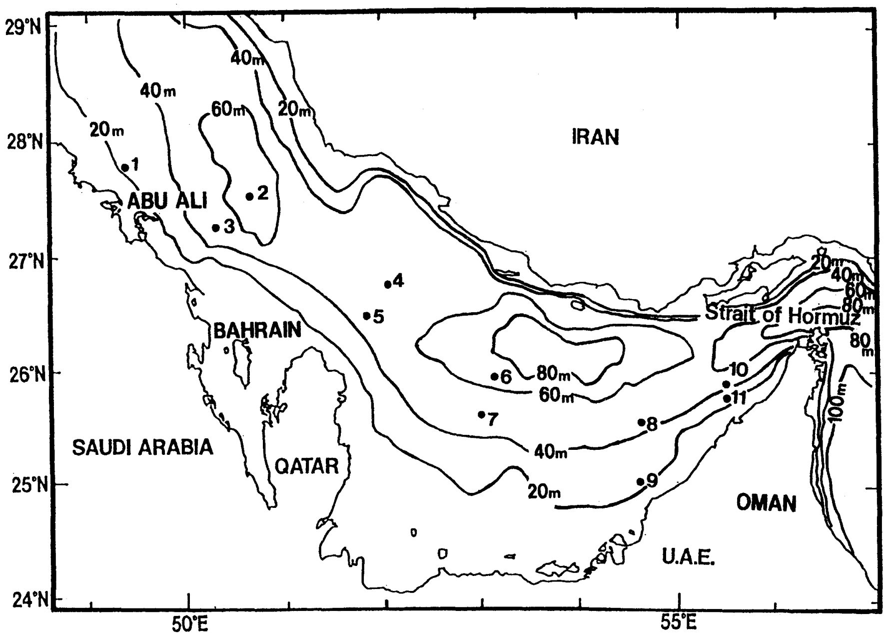

Fig. 1. Map showing the observation Stations in Dec. 1994. The numerals are Station numbers from 1 to 11.

transparency and SS in the Gulf ranged from 8 to 16 m and 0.2 to 1.8 mg/l, respectively. From a recent survey by the RV Mt. Mitchell of NOAA, USA, Reynolds (1993) found out that the low salinity water near the mouth of the Gulf might be associated with an inflow of water from the Gulf of Oman through the Strait of Hormuz. However, none made the optical oceanographic study.

This study was conducted as an integral part of the International Scientific Research Programme "An Integrated Study on the Effects of Crude Oil Spills in the ROPME Sea Area" In the study, relative irradiance of visible light by wavelength, photosynthetically available radiation (PAR) and ultraviolet light in lat. 28° N and further south of the RSA was observed concurrently, assessing how far light in what wavelength penetrates sea water, whereby the effects of slicks caused by crude oil spills in this sea area on light attenuation were investigated.

2. Observation Method

Oceanographic observations were carried out aboard the RT/V Umitaka-Maru (1,828 G/T) of Tokyo University of Fisheries from 15 to 17 December, 1994. A total of eleven observation stations were arranged in the RSA on lat. 28° N and further south (Fig. 1). Conventional oceanographic observation elements such as visible light, PAR, and ultraviolet light (A and B) were taken up in this study. Observations of visible light were made at all stations, PAR at Stations 1, 3, 5, 6, 7, 8, 9, 10 and 11, and ultraviolet (A and B) at Stations 5, 7, 8, and 10, respectively. An irradiance meter, PRR-600 (Biospherical Instruments Inc.) provided with a depth sensor was used to measure the relative irradiance of visible light by wavelength 412, 443, 490, 510, 555, 665 nm and PAR, 400–700 nm. An another meter, IL-1700 (International Light Inc.) was also used with the ultraviolet light A, 326–380 nm (the maximum transmittance: 355 nm, hereinafter called "UV-A"), and B, 270–306 nm (the maximum transmittance : 288 nm, hereinafter called "UV-B"). The observation method was such that the each instrument was lowered from the ship's sunny side, whereby observations were carried out on the sea surface and the bottom or continueously down to the limit of observations by pre-set water

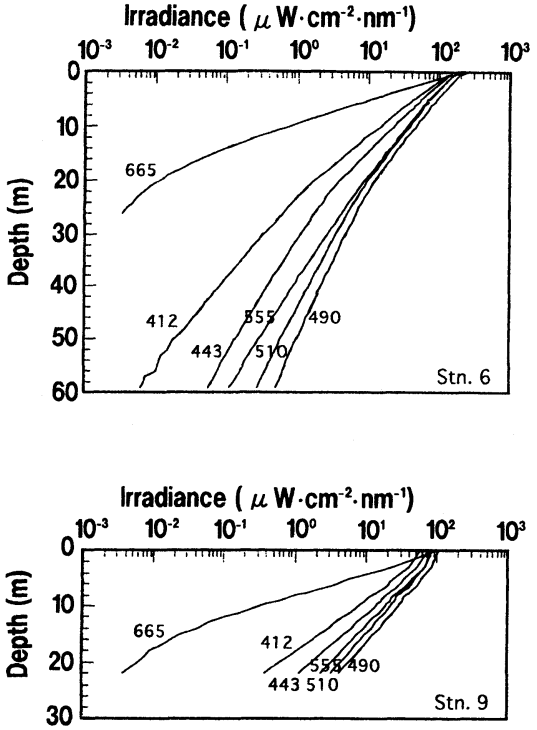

Fig. 2. Depth profiles of downward irradiance at Stn. 6 (upper) and at Stn. 9 (lower). The numerals in the figures indicate wavelength (nm) of visible light.

depth.

The effects of oil slicks on submarine irradiance distribution were experimentally investigated in the following method. At culmination on a fine day, measurements were taken with an instrument, PRR-600, which was used in field observations, soaked near the surface of distilled water contained in a cylindrical tank coated black inside (70cm both in dia. and depth) placed on the rooftop of our laboratory. The Iranian heavy crude oil was used with a specific gravity of 0.87 g/cm^3.

3. Results and Discussions

3-1 Irradiance distribution of visible light by wavelength

Figure 2 shows measurements of irradiance of visible light by wavelength taken at Station 6 in the central region of the Sea area and at Station 9 on the coast of UAE. At Station 6, the wavelengths in descending order of light penetration were 490, 510, 555, 443, and 412 nm, and the reading of 665 nm was assumed to be below the measuring limit at the depth of 25 m. On each the wavelengths given, the inclination of attenuation was approximately the same from the sea surface down to the vicinity of bottom. It follows that the water mass under investigation is optically uniform. At Station 9, it was observed that the irradiance decreased as a function of water depth tended to be steeper than that at Station 6. However, the sequential order of wavelengths with good light penetration was identical. Light attenuation of each wavelength is approximately linear, indicating that the water mass is optically homogeneous, even in the coastal waters, except at the bottom layer.

Figure 3 illustrates the relative irradiance distribution of visible light by wavelength at the depth of 10 m at all stations. It could be seen from the figure that the value of relative irradiance was lower on the shorter wavelength side, with peaks at 490 or 510 nm, and registered sharp falls on the longer wavelength side. This distribution pattern was commonly

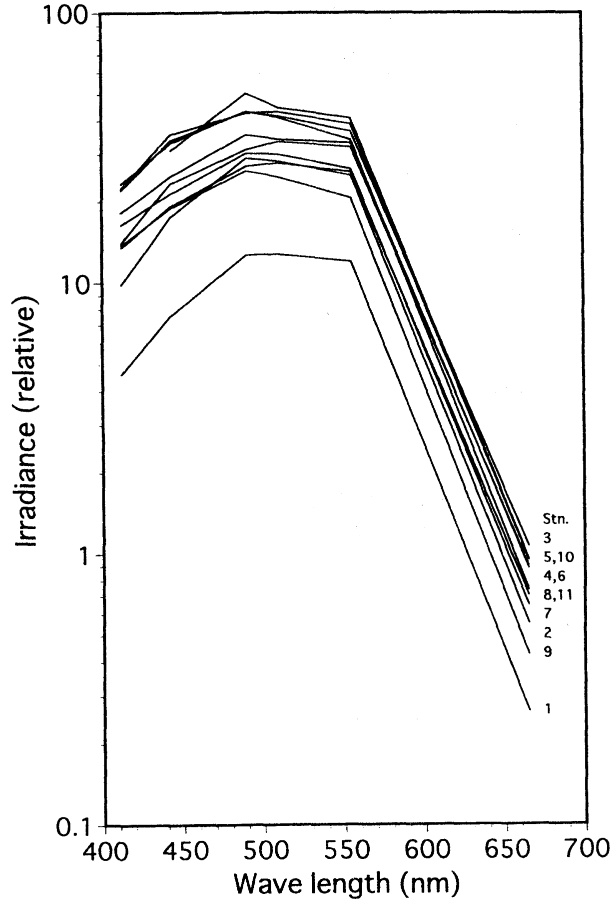

Fig. 3. Spectral distributions of downward irradiance at the depth of 10m.

seen at all stations within the Sea area. When arranged in descending order, the magnitude of light penetration took the following order: Stations 3, 5, 10, 4, 6, 8, 11, 7, 2, 9, and 1. The relative values of irradiance at Station 1 to that at Station 3 for the range of wavelength from 412 to 665 nm are within 10 to 40%. In other words, there are optically different water masses in this Sea area. According to JERLOV's optical water mass classification (1964), the Oceanic Types II and III are widely distributed in waters at the central part of the Sea area from the Strait of Hormuz to off Qatar Peninsula. The coast of UAE (Station 9) corresponds to Coastal Type 1, and water area in the vicinity of 27°30′ N correspond to the Coastal Types 1 to 3.

ARAKAWA *et al.* (1998) carried out the observations of irradiance and turbidity concurrently in this Sea area, and they clarified that there was a clean water mass at the central part of RSA with increasing turbidity in waters closer to the coasts ; and consistent turbidity from the surface to the bottom layer. There results are in good agreement with the results of the present study on relative irradiance distribution.

3-2 Distribution of PAR

Figure 4 shows the depth profile of relative irradiance of PAR at each station. PAR on the sea surface at Station 10 (17 December, 1994, noon, fine) was approximately $1.8 \times 10^3 \mu$ mol · m^{-2} · s^{-1}. The attenuation trends of PAR were

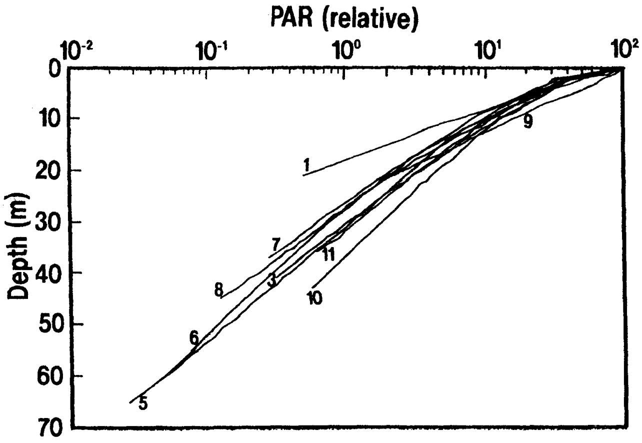

Fig. 4. Depth profiles of PAR at each station.

approximately linear at all stations from the sea surface to the vicinity of bottom. The stations in descending order of good irradiance of PAR were Stations 10, 11, 5, 3, 6, 8, 7, 9 and 1. The relative values at the depth of 10 m were 16% at Station 10, and 8% at Station 1, and the latter was approximately half of the former. The water depth at which PAR assumed 1% of the sea surface was in the range from 26 to 37 m for generous areas of waters, except for approximately 18 m in the Gulf water at Station 1, and greater in other areas of Gulf water. Furthermore, the diffuse attenuation coefficient for PAR was between 0.20 and 0.29 m^{-1}, which was smaller at the center of the Gulf water and greater in the coasts and peripheral waters. This is in close agreement with the results of the distribution of optical water mass types.

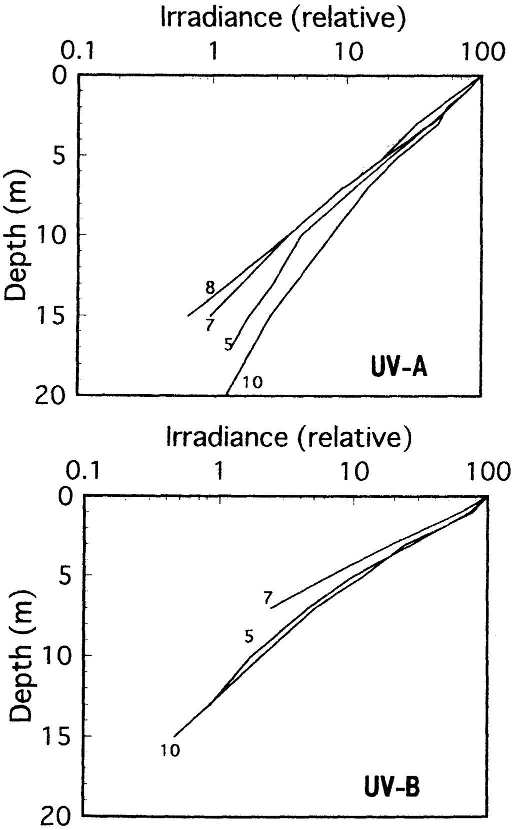

Fig. 5. Depth profiles of UV-A (upper) and UV-B (lower) at each station.

3-3 Distribution of Ultraviolet Light (A, B)

When PAR on the sea surface at Station 10 was approximately $1.8 \times 10^{3}\ \mu\mathrm{mol} \cdot \mathrm{m}^{-2} \cdot \mathrm{s}^{-1}$, irradiance of UV-A and UV-B were about $1.4 \times 10^{-4}\mathrm{W} \cdot \mathrm{m}^{-2}$, and $1.3 \times 10^{-4}\mathrm{W} \cdot \mathrm{m}^{-2}$, respectively.

Figure 5 shows the relative irradiance of UV-A and UV-B. Supposing that UV-A just beneath the sea surface is 100%, UV-A at Station 10 assumed 24.3% at the depth of 5 m, 7.6% at 10 m, and it reached the limit of measurement at the depth of 20 m. The trend for the attenuation of UV-A at each station was linear. The diffuse attenuation coefficients for UV-A ranged from 0.26 to 0.33 m^{-1}, and there were slight dispersions.

The attenuation trends of UV-B were also

Table 1. Each value of the diffuse attenuation coefficients for visible light, PAR and ultraviolet light under different optical water types. Unit is indicated as m^{-1}.

Stn.	1	2	3	4	5	6	7	8	9	10	11
Water Type	3	1	Ⅲ	Ⅲ	Ⅱ	Ⅲ	Ⅲ	Ⅲ	1	Ⅲ	Ⅲ
$K_{MAX.\ TRANS.}$	0.19	0.12	0.11	0.11	0.06	0.11	0.11	0.11	0.12	0.11	0.11
K_{PAR}	0.290	—	0.208	—	0.234	0.224	0.252	0.239	—	0.207	0.226
K_{UV-A}	—	—	—	—	0.310	—	0.332	0.333	—	0.258	—
K_{UV-B}	—	—	—	—	0.406	—	0.531	—	—	0.389	—

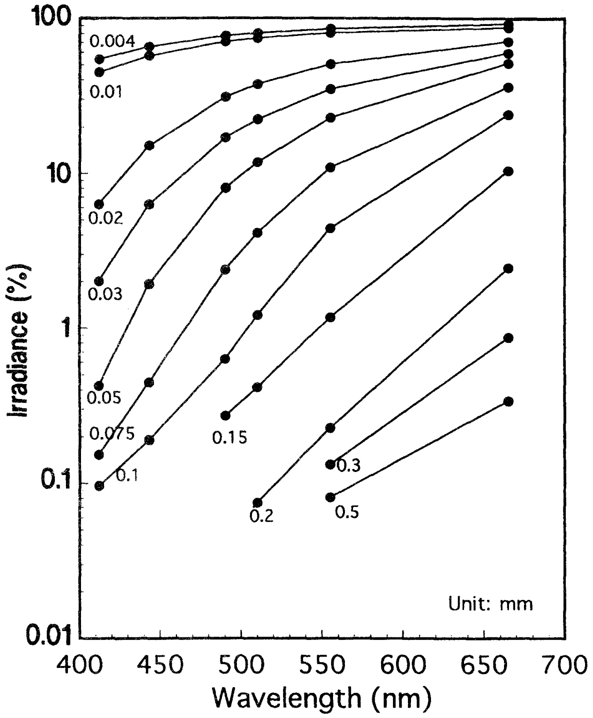

Fig. 6. Spectral distributions of relative downward irradiance just under oil slick. The numerals are thickness of oil slick on water surface.

linear. Due to significant attenuation, the limit of measurement was ranged from 7 to 15 m. The diffuse attenuation coefficients for UV-B were between 0.39 and 0.53 m^{-1}, which were greater than those for UV-A. It follows that UV-A at the central part of the Gulf featuring clear water is such that approximately 1% or more of the ultraviolet light on the sea surface penetrates 15 m or more.

3-4 Relationships between Optical Water Type, PAR and Ultraviolet Light (A, B)

Table 1 shows the relationships between the optical water mass type at each station and the diffuse attenuation coefficients for PAR and ultraviolet light (A, B). $K_{MAX.TRANS.}$ in the table indicates the diffuse attenuation coefficient for the wavelength at which light penetration is highest. Concerning the relationship between the optical water mass type and the diffuse attenuation coefficient for PAR (K_{PAR}), to begin with, K_{PAR} of 0.21–0.25 m^{-1} corresponds to the Oceanic Types Ⅱ and Ⅲ (K_{475}: 0.06 m^{-1}, K_{500}: 0.11 m^{-1}) and K_{PAR} of 0.29m^{-1} corresponds to the Coastal Type 3 (K_{550}: 0.19m^{-1}), respectively. Therefore, values of K_{PAR} correspond to

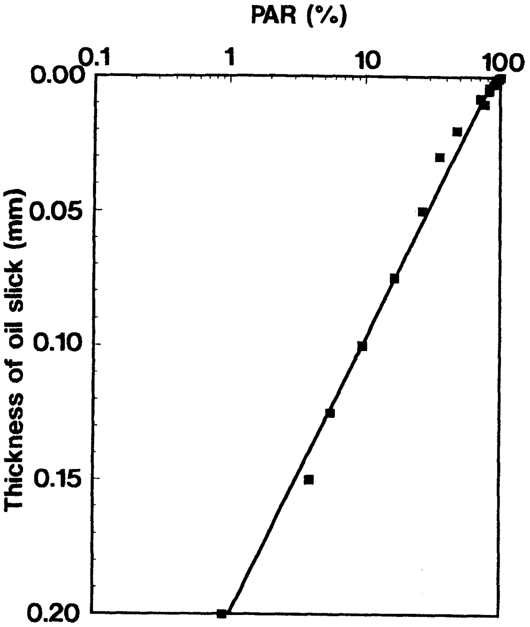

Fig. 7. Correlation between the thickness of oil slick and the ratio of PAR attenuation.

approximately 1.5 to 4.0 times the diffuse attenuation coefficients (K_{475}, K_{500}, K_{550}) of each water mass, which are slightly larger than the theoretical results of OKAMI (1978) ; i. e., 1.6 to 2.1. In the next attempt to obtain similar relationships as those above on the relation between the diffuse attenuation coefficients for UV (K_{UV-A} and K_{UV-B}) and K_{PAR}, we found that K_{UV-A} was approximately 2.5 to 5.0 times K_{PAR}, and K_{UV-B} was approximately 4.0 to 6.0 times K_{PAR}. From the discussion above, it can be found that the ultraviolet lights (A, B) attenuate most violently.

3-5 Effects of Oil Slicks on Underwater Irradiance Distribution

Crude oil spilled into the sea immediately propagetes over wide areas of water under the effects of wind and waves, and forms oil slicks. Fig.6 shows the relative irradiance distribution of visible light just below oil slicks by thickness. Relative irradiance is shown taking the value in the absence of oil slicks as 100. When the thickness of an oil slick is 0.02 mm, submarine irradiance just below that is 6.3, 37.5 and 71.1% at wavelengths of 412, 510 and 665 nm. When the thickness of an oil slick is 0.1 mm, 0.10% at 412 nm, 1.22 % at 510 nm and 24.1 % at 655 nm, respectively. Namely, greater attenuation of irradiance is caused by oil slicks on the sea surface at shorter wavelengths. Besides, the diffuse attenuation coefficients due to slicks were 6.9×10^3 m^{-1} at a wavelength of 412 nm, and 1.4×10^3 m^{-1} at a wavelength of 665 nm.

Figure 7 shows the relationship between PAR just below the sea surface and the thickness of an oil slick. If the irradiance in the absence of oil slicks is taken as 100, irradiance was 47.8% when the thickness of an oil slick is 0.02 mm, 9.62% to 0.1 mm, and 0.91% to 0.2 mm. The relationship between the thickness of an oil slick and the ratio of PAR attenuation is expressed by the formula below.

$$E_{par} = 100 \cdot \exp(-23.3 \cdot h), \quad r^2 = 0.989$$

where,

E_{par} : relative value of PAR,
h : thickness of crude oil slick (mm)
r : correlation coefficient

From the above discussion, we can see that the value of PAR sharply drops as the thickness of an oil slick increases, and the irradiance just below that when the thickness of slick is even with only 0.2 mm assuming approximately 1% of the case without slick. At this time, the value of diffuse attenuation coefficient for PAR is 2.3 $\times 10^3 m^{-1}$.

Concerning with UV, the attenuation of irradiance due to oil slick is quite violent at shorter wavelengths, thus penetration of UV into sea water is considered to become almost nil if there are oil slicks.

On the basis of the investigation stated above, the effects of crude oil spills in the RSA on submarine irradiance are examined. The quantities of crude oil spilled as a consequence of the Gulf War were reported to be 1.08×10^7 barrels (1.7×10^6 kl). The spilled crude oil ran along the coast of Saudi Arabia, reaching near the Abu Ali Peninsula, fouling 640 km of the coasts (HAYES *et al.*, 1993). The scope of crude oil propageted at this time was reportedly 35 linear miles (64.8 km), with a width of 10 miles (18.5km) (Peter, 1991), and the area was approximately 1,200km^2. Assuming that the crude oil propageted at an uniform thickness, the thickness of an oil slick is calculated to be 0.14 mm or more. This suggests that the submarine space at the time of the crude oil spills is a black world.

In this study, the effects of crude oil slicks on the submarine optical environment were investigated. Several tens percent of the spilled oil is said to solve into the sea. In future, it is therefore necessary to investigate the effects of emulsified oil in the sea for assessing precisely the influences of spilled oil on the changes of underwater irradiance.

Acknowledgments

The authors are pleased to acknowledge the considerable assistance of Prof. and Dr. A. OTSUKI who was a representative of International Scientific Research Programme, and also would like to thank Prof. K. KASUGA, captain of the RT/V Umitaka-Maru of Tokyo Univ. of Fish., and their staff. Besides, we wish to thank Mr. T. TOUMA of "MITSU UROKO" company for offering us experimental sample of crude oil.

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Recieved December 9. 1998
Accepted February 8. 2000

La mer 37 : 183-184, 2000
Société franco-japonaise d'océanographie, Tokyo

資　料

日仏海洋学会うみ（La mer）第37巻第 4 号掲載欧文論文要旨

高橋　暁[*]・湯浅一郎[*]・宝田盛康[*]・灘井章嗣[**]・久木幸治[***]：HFレーダーによる大阪湾の潮流・残差流観測

1995年11月11日から12月12日までの約１か月間，大阪湾において短波海洋レーダー（HFレーダー）による表層流の観測を行った。得られたデータを調和分析することにより，主要潮流（M_2，S_2，K_1，O_1）の特性を示した。また，大潮時と小潮時のそれぞれにおいてデータを解析した結果，大阪湾中央部に卓越する時計回りの残差循環流の大潮時の流速は，小潮時に比べ２～３倍大きいことがわかった。また，大潮時の残差循環流は小潮時よりも南へ拡がることも明らかとなった。さらに，上げ潮時においてさえも南下する湾中央部の流れは，小潮時には存在しない場合もあることが示唆された。（[*]中国工業研究所海洋環境制御部　〒737-0197　広島県呉市広末広2-2-2，[**]通信調査研究所　〒184-8795　小金井市井北町4-2-1，[***]通信調査研究所沖縄電波観測所　〒901-2400　沖縄県中上郡中城村829-3）

サンチワット ピタクポル[*]・多田邦尚[*]・門谷　茂[*]：瀬戸内海播磨灘における夜光虫体内のアンモニウム塩およびリン酸塩濃度と水柱への供給

瀬戸内海播磨灘において，３年半におよぶ長期観測により，夜光虫体内に含まれているアンモニウム塩およびリン酸塩が水柱の栄養塩プールに対する寄与について見積もった。夜光虫が観察された海水中のアンモニウム塩およびリン酸塩濃度は，極めて広範囲に分布しており，それぞれ０～36.5μMおよび０～1.6μMであった。細胞内の栄養塩濃度と細胞数から，水柱への栄養塩供給寄与の程度を見積もったところ，アンモニウム塩では０～119%，リン酸塩では０～80%であった。夜光虫が頻度高く観察される春季（４～６月）には，高い寄与割合であることがわかり，この時期の夜光虫の存在は，沿岸海域における生物生産，物質循環過程に大きな影響を与えていることが予想される。（[*]香川大学農学部　〒761-0795　香川県木田郡三木町池戸2393）

田畑彰久[*]・森永　勤[**]・荒川久幸[**]：懸濁無機粒子の濃度，粒径および種類がアサリの餌捕捉へ与える影響

無機懸濁粒子の濃度，粒径および種類がアサリの餌捕捉へ及ぼす影響を，コールターカウンターで定量的に調べた。アサリの殻長は40mm（±１mm）で，使用総数は約250個体である。無機粒子は粘土鉱物カオリナイト（平均粒径：4.2μmと15.3μm）と国頭礫層の砂壌土（平均粒径：4.5μm）を濾過海水にそれぞれ懸濁させ用いた。餌には植物プランクトンの*Pavlova lutheri*（平均細胞径：5.6μm）を用い，餌の捕捉率は植物プランクトンの細胞径分布の90%以上が細胞径4.0μm～15.3μmまでの範囲にあるため，懸濁水中のこのサイズ範囲の粒子が１時間に減少する割合として求めた。アサリ１個体の入った，植物プランクトンの細胞密度1.0×10^5cells ml^{-1}の懸濁水中へ粒径4.2μmのカオリナイトの濃度が2.0×10^5particles ml^{-1}である懸濁水を添加した場合の捕捉率は74.5%h^{-1}であり，添加前の捕捉率70.4%h^{-1}とほとんど変わらなかった。しかし，カオリナイトの濃度を5.0×0^5particles ml^{-1}に増加させた場合は，捕捉率は著しく減少し48.7%h^{-1}であった。この場合，アサリの水管の先端部にはカオリナイト粒子の付着が観察された。また，カオリナイトを砂壌土に取り替えた場合，捕捉率はカオリナイトの場合と比較して大きな差は見られなかった。植物プランクトンの細胞密度5.0×0^5cells ml^{-1}の懸濁水へ粒径4.2μmおよび15.3μmのカオリナイト懸濁水を餌と同濃度で添加した場合，捕捉率は前者で77.8%h^{-1}，後者の場合は24.7%h^{-1}であり，大きく異なった。以上から，アサリの餌捕捉への無機懸濁粒子の影響は，粒子濃度および粒径に依存し，種類にはあまり依存しないと考えられる。（[*]北海道大学大学院工学研究科　〒060-8628　札幌市北区北13条西８丁目　[**]東京水産大学海洋環境学科　〒108-8477　港区港南4-5-7）

森永　勤*・荒川久幸*：ROPME海域における海中照度分布およびオイルスリックによる光減衰

ROPME海域を光学的水型（JERLOV，1968）で分類すると，その中央部では外洋型ⅡとⅢがUAEの沿岸部および北緯27度30分付近のアラビア側では沿岸型1と3がそれぞれ分布していた。光合成有効光（PAR）が海面の値の1％となる水深では，前者で26 mおよび37 m，後者では18 m以上と18 m程度であった。紫外線AおよびBの消散係数は，海域の中央部ではそれぞれ0.26～0.33 m^{-1}および0.39～0.53 m^{-1}を示し，PARの消散係数より概ね数倍の大きさであった。海面に油膜があるときの水中透過光を実験により調べると，その割合は短波長側ほど小さく，油膜の厚さが0.2 ㎜の場合，油膜直下のPARは海面の約1％に低下することがわかった。また，海面油膜の厚さとPARの減少の割合との関係は$E_{PAR}=100\cdot\exp(-23.3h)$，$r^2=0.989$［$E_{PAR}$：PARの相対照度（％）；h：油膜の厚さ（㎜）；r：相関係数］で表すことができる。当海域へ流失した原油のスリックは，海中の光環境に重大な影響を及ぼしていると考えられる。（*東京水産大学海洋環境学科　〒108-8477　港区港南4-5-7）

La mer 37: 185-188, 2000
Société franco-japonaise d'océanographie, Tokyo

学 会 記 事

1. 平成12年度科学研究費補助金（学術定期刊行物）の申請を行った。
2. 1999年12月15日（水） 東京水産大学において，1999年度学会賞受賞候補者推薦委員会（第2回）が開かれ，評議員より推薦のあった候補者について審議の結果，関　文威会員（筑波大）を受賞候補者と決定し，会長へ報告することとした。
3. 平成12・13年度評議員選挙が行われた（公示11月27日，投票締め切り1月5日，開票1月14日）。開票結果は下記の通り。

1）投票総数59通，1,803通

2）有効票数1,798票（無効票数5票）

3）得票結果（43位までは同得票順位，45位以下は抽選による）

（（　）内は得票数）

1	（45）	松山優治
2	（37）	石丸　隆
3	（36）	有賀祐勝
4	（34）	柳　哲雄
5	（32）	森永　勤，山口征矢
7	（31）	村野正昭，関　文威
9	（29）	今脇資郎，松生　洽
11	（27）	長島秀樹，平　啓介
13	（26）	門谷　茂，中田英昭，高橋正征，谷口　旭
17	（25）	関根義彦
18	（24）	有元貴文
19	（23）	永田　豊，寺崎　誠
21	（22）	前田明夫
22	（21）	小池勲夫，須藤英雄
24	（20）	奥田邦明，和田　明，渡邊精一
27	（19）	福田雅明，平野敏行，前田　勝，鳥羽良明
31	（18）	青木三郎，鎌谷明善
33	（17）	岸野元彰，黒田一紀，佐藤博雄
36	（16）	磯田　豊，糸洌長敬，岩田静夫，小池　隆，小池康之，中田喜三郎，千手智晴
43	（15）	前田昌調，隆島史夫
45	（14）	梶浦欣二郎
46	（14）	山崎秀勝
47	（14）	高野健三
48	（14）	岡市友利
49	（14）	八木宏樹
50	（14）	大塚一志
51	（14）	斉藤誠一
52	（13）	佐伯和昭
53	（13）	高木和徳

（54位以下省略，大塚一志会員は辞退のため51位斉藤誠一会員まで当選）

4. 第18期学術会議会員候補者，同推薦人および推薦予備人について評議員の投票の結果，会員候補者として有賀祐勝会員，推薦人として松山優治会員，推薦予備人として山口征矢会員が選出され，学術会議へ届け出た。
5. 評議員宛に「2000年度日仏学者交換公募」の推薦依頼を行った。
6. 退会（正会員・届出順）

花本栄二，徳田擴士，島津仁一，今関昭博，武田恵二，森実庸男，中村　充

7. 受贈図書（受付順）

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駿河湾海底地質図
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Journal of the Korean Society of Oceanography 34(4)
Revista Cubana de Investigaciones Pesqueros 18 (1-7), 19(1, 2), 20(1, 2)

日仏会館シンポジウム
科学の進歩と人間の未来
Le Progres scientifique et l'avenir de l'homme

生物学は最近目覚ましい進歩を示しています。私達は，専門の如何を問わず，「人間の本質」を改めて見直し，認識を深める必要を痛感します。理系日仏諸学会は1998年末の諸学会総合シンポジウムで提起されたこの課題を継承して，医学，生命倫理，植物学それぞれの先達者を迎えて，このシンポジウムを企画しました。理系，文系にこだわることなく，多数の方の御参加を念願しております。

日時　2000年3月11日（土）
会場　日仏会館ホール・入場無料
10：00　開会の辞　飯山敏通（日仏会館常務理事）
10：10　経過報告　中村廣明（日仏農学会）
10：20　講演（1）　森　亘氏（日本医学会会長）
これからの医学に想う
司会　飯山敏通（日仏理工科会）
12：00　昼休み
13：30　講演（2）　青木　清氏（上智大学生命科学研究所所長）
生命科学の進歩と人間の生存を考える
司会　水野丈夫（日仏生物学会）
15：00　講演（3）　駒嶺　穆氏（日本植物学会会長）
植物バイオテクノロジーは21世紀の地球生命圏の危機を救えるか
司会　大山勝夫（日仏農学会）
16：30　閉会の辞　小林善彦（日仏会館常務理事）
閉会後　ワインパーティー

主催：日仏会館（東京都渋谷区恵比寿3-9-5
TEL. 03-5424-1141）
日仏医学会，日仏獣医学会，日仏海洋学会，日仏工業技術会，日仏農学会，日仏理工科会，日仏生物学会，日仏薬学会

第17期学術会議水産学研連の活動

学術会議水産学研究連絡委員会は，1999年度中2回の委員会が開催された。

第17期第6回　開催日：1999年5月17日（月）

1．学術会議総会・部会の概要について隆島委員長より報告された。

2．科学研究費補助金審査員候補者の推薦法について平成12年度の推薦法を下記のように決定し，各学会へ候補者の推薦を依頼することとなった。

1）第一段

A．水産学一般

（1）12年度の推薦委員数は15名とする。

（2）水産学会より推薦された8名を候補者とする。残りの7名は他の学会から推薦された候補者の中から水研連で連記式の投票により選出する。ただし水産学会から選出された者を除く。平成12年度は第1位を水産学会で第1位に推薦された者を充て，次に水研連で最多得票を得た他学会推薦の者を充て，これを順次15位まで順位を付ける。各学会から推薦できる人数は以下の通りとする。

会員数1000人以上の学会	2名
1001-2000名の学会	4名
2001-3000名の学会	6名
3001-4000名の学会	8名

B．水産化学

（1）推薦人数は10名とする。

（2）水産学会から推薦された5名を候補者とする。残りの5名は全ての学会から推薦された候補者の中から水研連で連記式の投票により選出する。

2）第二段

（1）推薦人数は4名とする。

（2）選出法は前回に決定した通りとし，推薦の意志のある学会は各1名の候補者を推薦し，水研連で投票により候補者を1名選出す。

3）選挙事務担当として，日本水産学会，日本海洋学会，漁業経済学会から選出されている委員があたることとした。

4）開票集計は以下の基準により行う。

（1）継続者と無資格者を除外し，得票の多い順に整理する。

（2）同一機関に属する者は上位2名とする。

（3）得票数が同じ場合は，女性，若齢者，会員数の多い学会から推薦された者の順にする。

5）各学会はそれぞれの推薦者の過去5年の業績，専門分野とそのキーワード，審査委員の経験を委員長宛に送付することとする。

3．第17期第2回シンポジウムについて

「水と環境」（仮題）を平成12年５月ころに開催することとし，準備を進めることとした。各学会からテーマを提示することとなった。演者との折衝は各委員に委嘱する。

第17期第７回：1999年７月13日（火）

１． 平成12年度科学研究費補助金審査委員候補者の選出を行った。

１）選出に先立ち，委員長から提案された選出の手順について審議し，細則を決定した。

２）委員の投票により，第２段審査委員候補者４名，第一段（水産学一般）審査委員候補者15名，第一段（水産化学）審査委員候補者10名を選出した。

２． 第18期研究連絡委員会登録学会について，委員長より登録状況が報告された。

３． シンポジウムの開催について

１）第17期第２回シンポジウムについて原案を了承した。

２）「次世紀へつなぐ水産研究」：水産・海洋科学が取り組んでいる食糧保証と環境保全に関する諸課題のうちから，今日的トピックスを選び，やさしく解説する。

開催日：平成12年５月20日（土）
09：50-17：00
場　所：東京水産大学資源育成学科棟
Ｂ100（１階）
日本水産学会，日本海洋学会，漁業経済学会，日本魚病学会，日本魚類学会，水産海洋学会，日仏海洋学会，日本プランクトン学会，日本水産工学会，日本水産増殖学会，地域漁業学会，日本付着生物学会（12学会）

（山口征矢）

お知らせ

公益信託ミキモト海洋生態研究助成基金
平成１２年度研究助成候補者募集

平成４年７月に発足した「公益信託ミキモト海洋生態研究助成基金」（受託者三井信託銀行株式会社）では、潮間帯から浅海にわたる海域に関する研究に対し、次の要領で助成します。

①対象となる研究

（１）潮間帯から浅海にわたる海域に生息する生物に関する調査・研究
（２）潮間帯から浅海にわたる海域に生息する生物の生息環境に関する調査・研究
（３）潮間帯から浅海にわたる海域における生態の保全のあり方に関する調査・研究

②応募資格

大学または研究機関の研究者や研究グループ、中・高等学校の教諭、生物クラブなど。なお当該研究について当方から問い合わせのできる方の推薦が必要です。

③助成金と件数

助成金額は１５０万円で、この範囲内で複数の研究に助成します。申請に当たってはそれぞれの研究の所要額を助成希望金額として申請してください。ただし、５０万円を上限とします。なお、より優れた研究に助成するため、上記いずれかのテーマの研究を複数助成する場合もあり、必ずしも３テーマの研究それぞれに助成するとは限りません。

④助成金の使途及び結果の報告

旅費、労務費、消耗品費などを主とすること。なお、助成金の使用期間は助成金交付後２年以内です。その範囲であれば研究スケジュールにそって使用できます。研究終了時に、研究結果と会計について報告いただきます。

⑤申請書等の請求先

〒113-0034　東京都文京区湯島２－２９－３
財団法人自然環境研究センター内
公益信託ミキモト海洋生態研究助成基金　事務局
電話　０３－３８１２－０８１１　担当：掘田

⑥審査方法

当公益信託に設置されている運営委員会において、厳正に審査・選考いたします。選考結果は、申請者全員に書面で通知いたします。

⑦助成金支給時期：平成１２年７月中旬

⑧募集締め切り　：平成１２年５月１０日（水）（当日消印有効）

La mer (Bulletin de la Société franco-japonaise d'océanographie)

Tome 37 (1999–2000)

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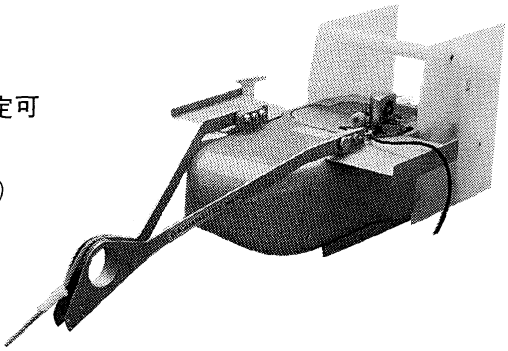

日仏海洋学会入会申込書

（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

2000年2月25日印刷
2000年2月28日発行
うみ
第37巻
第4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

本雑誌に関する問合せ　電話番号：03（5463）0462

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