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Quantification of microphytobenthos biomass in intertidal sediments: layer-dependent variation of chlorophyll *a* content determined by spectrophotometric and HPLC methods

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Abstract : We assessed the difference between chlorophyll *a* (Chl. *a*) values estimated by spectrophotometer using either 90% aceton or N,N-dimethylformamide (DMF) as an extractant, and by HPLC using DMF, in intertidal sediment samples from the Seto Inland Sea, Japan. This was conducted both at the surface(0–0.5 cm) and subsurface(0.5–2 cm) layers and through the vertical profile of the sediments (each next cm to 10 cm depth). The Chl. *a* content determined using the three different procedures gave similar results at the surface. In contrast, the Chl. *a* content at the subsurface layer was 94.5±13.7 and 70.1±19.4% that found at the surface when spect ophotometrically determined using 90% aceton and DMF, respectively, while it was 47.7 ±16.9% when determined by HPLC. Such difference between procedures was consistent with depth. At the 6–7, 8–9 and 9–10 cm layers, Chl. *a* determined spectrophotometrically varied from 1.1 to 2.1 μg g^{-1}, while it was not detected by HPLC. These results indicate that the more practical spectrophotometric method can be reasonably employed to quantify the living fraction of microphytobenthic biomass in the surface layer of these sediments. At lower layers, only relying on either aceton or DMF extraction of pigments and spectrophotometric determination is likely to lead to an overestimation of the Chl. *a* content up to >50%. This can be related to the progressive increase and interference with depth of photosynthetic degradation products whose reliable estimates can only be obtained by chromatographic quantification.

Key words : *Microphytobenthos, biomass, chlorophyll a, methods, HPLC, spectrophotometer, tidal flat, Seto Inland Sea*

1. Introduction

During the last decade, major interest has arised on the role of intertidal microphytobenthos as a primary carbon source for estuarine food webs and on its implications in the cycling of nutrients (SULLIVAN and MONCREIFF, 1990; DE JONG and DE JONGE, 1995; HEIP *et al.*, 1995; MACINTYRE *et al.*, 1996; GUARINI *et al.*, 1998). It is therefore important that the determination of chlorophyll *a* (Chl. *a*) content in sediments could give a reliable estimate of the living fraction of microphytobenthic biomass. This is particularly critical for the top few mm of sediments where microphytobenthic photosynthetic activity occurs (REVSBECH *et al.*, 1983; KROMKAMP *et al.*, 1998) and primary production is calculated (PINCKNEY and ZINGMARK, 1993; BARRANGUET *et al.*, 1998). The HPLC-technique has been earlier indicated as the most reliable one, particularly in sediment samples containing a mixture of pigments (DAEMEN, 1986). MACINTYRE *et al.*(1996) indicated that there may be negligible to large (40%) error due to interference of degradation products where Chl. *a* is measured by spectrophotometer. Other works showed either good agreement between spectrophotometric and HPLC measurements (PLANTE-CUNY *et al.*, 1993) or a slight overestimation of Chl. *a* content determined by spectrophotometer of 2 to 5% (BARLOW *et al.*, 1990). Such controversy in results obtained using different methods suggests that possible discrepancies should be

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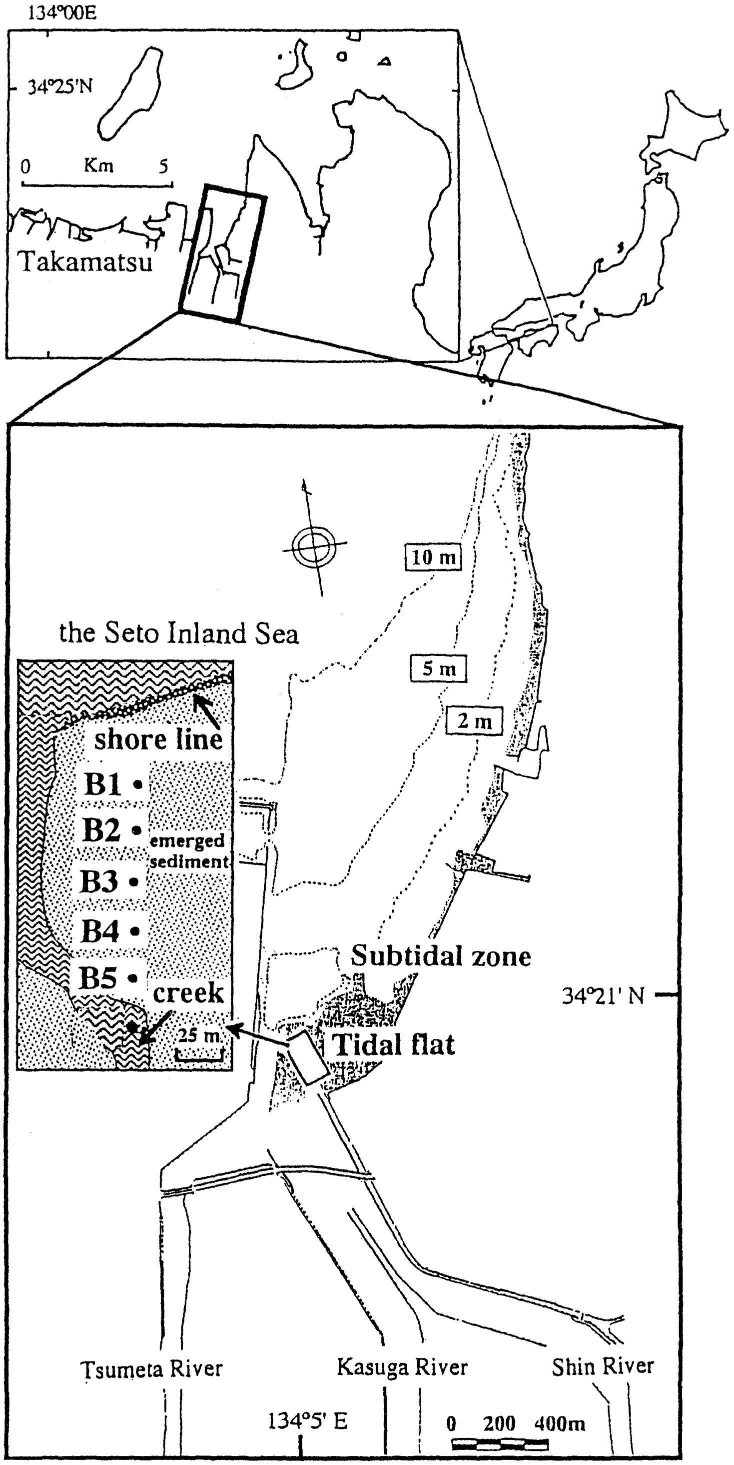

Fig. 1. Study area and location of the sampling stations.

checked in each relevant study area. It can be inferred that the more practical spectrophotometric method can be suitable for long-term and intensive survey schemes, provided that concurrent spectrophotometric and HPLC estimates either show a reasonable approximation or are normalized (DE JONG and DE JONGE, 1995). Until now, an evaluation of possible discrepancies between methods has been restricted to the upper 1 cm layer of sediments (DAEMEN, 1986; BARLOW *et al.*, 1990; PLANTE-CUNY *et al.*, 1993; MACINTYRE *et al.*, 1996). In the present work, we additionally tested whether there can be a layer-dependent variability in the Chl. *a* content determined by spectrophotometer and HPLC, due to the increasing fraction of degradation products with depth (SUN *et al.*, 1994; CARIOU-LEGALL and BLANCHARD, 1995; LUCAS and HOLLIGAN, 1999) which may concurrently cause decreasing reliability of the spectrophotometric method (DAEMEN, 1986; BARLOW *et al.*, 1990). In the spectrophotometric method, we employed two different extractants for Chl. *a*, such as 90% aceton and N,N-dimethylformamide (DMF), the latter also used for HPLC measurements.

2. Materials and methods

2.1. Study area and sampling procedure

We collected the sediment samples for chlorophyll *a*(Chl. *a*) measurements at five stations located on a sandflat of a tidal estuary in the Seto Inland Sea (Fig. 1), where a multidisciplinary project is in progress on the cycling biophilic elements (MONTANI *et al.*, 1998; MAGNI and MONTANI, 1997; 1998; 2000; MAGNI *et al.*, 2000). Sampling occured on 3 different dates, during a spring low tide: October 20 (Stn. B4), November 19 (Stns. B5 to B1) and December 18, 1997 (Stn. B4). On each occasion, we randomly collected emerged sediment samples at 7 to 8 spots of a station, using an acrylic core tube (3 cm i.d.) gently pushed by hand into the sediment. Both the surface (0–0.5 cm) and subsurface (0.5–2 cm) layers were carefully extruded and sliced off the sediment. Sediment samples from the same layer were pooled together and brought to the laboratory within 2 h for further treatment and analysis. Additionally at Stn. B4, we collected sediment samples at lower layers (each next cm to a 10 cm depth), on October 20, 1997.

2.2. Sediment treatment and analysis

In the laboratory, chlorophyll *a* (Chl. *a*) and phytopigment degradation products (i.e. total pheopigments) were extracted from duplicate subsamples of wet sediment (ca. 1 g) using either 90% acetone of N,N-dimethylformamide (DMF). After 24 h of darkness at 4℃, the samples were sonicated for 5 min, centrifuged at 3000 rpm (1000 × g) for 10 min, and extracts were spectrophotometrically analysed for Chl. *a* and pheopigment content. Chl. *a* and pheopigment values were obtained, using either extractants, before and after acidification with 1 N HCl, respectively, according to LORENZEN's (1967) method, as described in PARSONS *et al.* (1984), where the volume of water is substituted by the dry weight (DW) of the sediment expressed in gram. Values were expressed as $\mu g\ g^{-1}$ and corrected for porosity, as measured by the water content. This was obtained after drying duplicate sediment subsamples at 105 ℃ for 20 h. Concurrently on each occasion and station, we determined, from the same sample, the Chl. *a* content by HPLC using DMF as an extractant, according to SUZUKI and ISHIMARU (1990). The apparatus used for the HPLC pigment analysis consisted of 2 pumps (Jasco 880-PU intelligent HPLC pump) driven by a gradient programmer (Shimadzu C-R5A), an injection valve with a 200 μl loop (Rheodine 7125) and a fluorescent detector (Jasco 870-UV intelligent UV-VIS) with a 8 μl flow cell. Cromatographic separation was carried out with a Toso TSK gel ODS-80 TM, ϕ 4.6 mm, 250 mm column. Absorbance for Chl. *a* was set at 440 nm. The solvents for the HPLC gradient used were as follows: solvent A was methanol: water:ion pair solution (7:2:1, v/v/v); the ion pair solution consisted of 0.75 g tetrabutyl ammonium acetate and 3.5 g of ammonium acetate dissolved in 50 ml redistilled water. Solvent B was methanol and ethylen acetate (4:1, v:v). The flow rate was 0.8 ml min^{-1} and the gradient was linear. The program utilized was 30 min long. It started with 50% of solvents A and B, reached 100% solvent B in 10 min and stayed with 100% of solvent B until the end. Standard solutions of Chl. *a* were obtained from Wako pure chemical.

3. Results and discussion

The chlorophyll *a* (Chl. *a*) content determined using the three different procedures gave similar results at the surface layer (0–0.5 cm), irrespective ot the station and the sampling occasion, with mean values of 7.0 and 7.2 $\mu g\ g^{-1}$ for the spectrophotometric and HPLC methods, respectively (Table 1). In contrast at the subsurface layer (0.5–2 cm), the mean Chl. *a* varied remarkably from 6.6±0.9 to 3.5±1.3 $\mu g\ g^{-1}$, as determined by spectrophotometer using 90% aceton and by HPLC, respectively (Table 1). At this layer, the former procedure gave Chl. *a* estimates significantly higher than those obtained using both the spectrophotometric and HPLC technique and DMF as an extractant($p<0.05$ and $p<0.001$, respectively; Table 1).

Accordingly, the Chl. *a* content at the subsurface layer resulted to be 94.5±13.7 and 70.1±19.4% that found at the surface when spectrophotometrically determined using 90% aceton and DMF, respectively, and 47.7±16.9% when determined by HPLC (Table 1). Such difference in Chl. *a* estimates among procedures was consistent through the vertical profile, being remarkably higher those determined spectrophotometrically and extracted by 90% aceton down to the 4–5 cm layer (Fig. 2). At the 6–7, 8–9 and 9–10 cm layers, Chl. *a* determined spectrophotometrically varied from 1.1 to 2.1 $\mu g\ g^{-1}$, while it was not detected by HPLC (Fig. 2).

The study by DAEMEN (1986) indicated that the difference between Chl. *a* values estimated by spectrophotometer or by HPLC in surface sediments samples from the Oosterschelde Estuary (the Netherlands) was not likely to be more than 20% on average. In a subsequent work carried out in intertidal areas of the same estuary, DE JONG and DE JONGE (1995) adopted a conversion factor of 0.7 to make spectrophotometer and HPLC estimates of Chl. *a* in surface sediments comparable, where spectrophotometer value, 0.7=HPLC value. The results of the present study show that in our study area the Chl. *a* in the uppermost layer (0–0.5 cm) of the sediments estimated by the llceoser spectrophotometric method is reasonably similar to that estimated by HPLC. This in a agreement with the results of earlier studies by BARLOW *et al.* (1990) and by PLANTE-CUNY *et al.* (1993). In contrast, at lower layers a strong overestimation occurred when the Chl. *a* content was estimated by spectrophometer, most remarkably using 90% aceton as an extractant.

Table 1. Chlorophyll *a* (Chl. *a*) estimates at the surface (0–0.5%) and subsurface (0.5–2cm) layers of intertidal sediments and the ratio between layers, using the spectrophotometer method and either 90% aceton or N,N-dimethylformamide(DMF) as an extractant, and the HPLC method (DMF as an extractant). ANOVA: single factor; *: $p<0.05$; * * *: $p<0.001$; * * * *: $p<0.0001$; ns; not significant)

Sampling date	Station	Surface (0–0.5cm)			Subsurface (0.5–2cm)			Subsurface/Surface		
		Spectrophotometer		HPLC	Spectrophotometer		HPLC	Spectrophotometer		HPLC
		Aceton	DMF	DMF	Aceton	DMF	DMF	Aceton	DMF	DMF
		($\mu g\ g^{-1}$)	($\mu g\ g^{-1}$)	($\mu g\ g^{-1}$)	($\mu g\ g^{-1}$)	($\mu g\ g^{-1}$)	($\mu g\ g^{-1}$)	ratio (%)	ratio (%)	ratio (%)
20 Oct 1997	B4	5.9	5.4	5.8	5.2	2.5	1.0	88.1	46.3	17.2
19 Nov 1997	B5	6.6	7.2	7.0	7.2	4.0	3.4	108.1	55.6	48.6
	B4	6.7	5.7	6.1	7.1	5.7	3.5	106.0	100.0	57.4
	B3	6.9	7.7	8.1	5.4	7.1	5.2	78.3	92.2	64.2
	B2	6.5	6.5	7.3	7.2	4.5	4.5	110.8	69.2	61.6
	B1	8.2	8.3	7.4	6.7	5.4	3.8	81.7	65.1	51.4
18 Dec 1997	B4	8.2	7.9	8.4	7.2	4.9	2.8	87.8	62.0	33.3
	AVG	7.0	7.0	7.2	6.6	4.9	3.5	94.5	70.1	47.7
	SD	0.9	1.1	1.0	0.9	1.4	1.3	13.7	19.4	16.9
Anova: Single Factor										
Spectrophotometer (aceton)				ns			* * *			* * * *
Spectrophotometer (DMF)			ns			*		*	*	*
		ns		ns	*		ns			

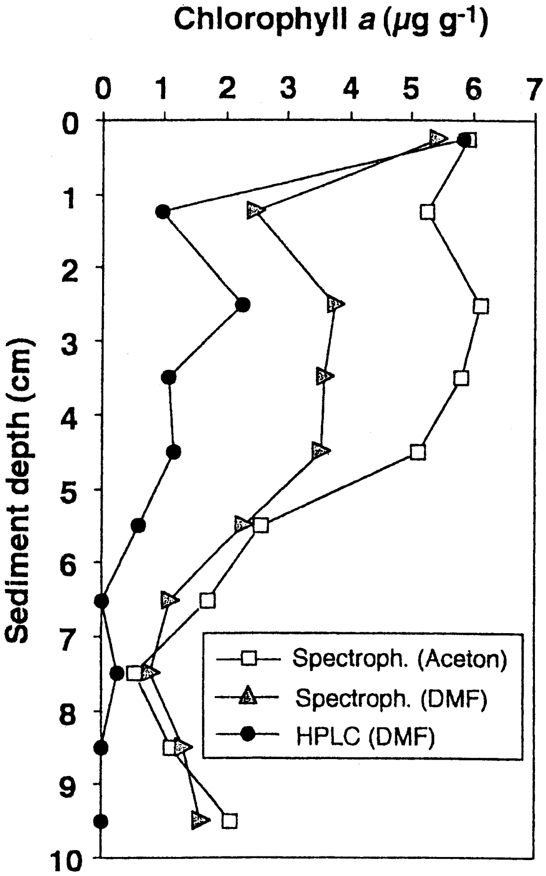

Fig. 2. Vertical distribution of chlorophyll *a* (Chl *a*) content using the spectrophotometer method and either 90% aceton or N,N-dimethyl-form amide (DMF) as an extractant, and the HPLC method (DMF as an extractant)(20 Oct. 1997).

Our HPLC measurements indicated the presence of living microphytobenthos in the non-photosynthetic active layers of the sediments down to 7–8 cm layer (Fig. 2). Several studies indicated that microphytobenthos can growth heterotrophically if light is not available (CADEE and HAGEMAN, 1974; HELLEBUST and LEWIN, 1977; DARLEY *et al.*, 1979; PELETIER, 1979), even surviving for many months (GARGAS and GARGAS, 1982). Vertical migration by epipelic benthic diatoms may be related to the effect of tidal waves and currents (STEVENSON, 1983; KINGSTON, 1999) and tidal cycle (PINCKNEY and ZINGMARK, 1991). Sediment reworking by macrozobenthos, abundant on this flat (MAGNI and MONTANI, 1998; MAGNI *et al.*, 2000), may also represent an important factor of microphytobenthos transport in the sediments (BRANCH and PRINGLE, 1987; ALLER, 1988). However, the decrease of the living fraction of microphytobenthos occurred rapidly with depth (Fig. 2). This was consistent with previous studies conducted in intertidal sediments (BARLOW *et al.*, 1990; SUN *et al.*, 1994; CARIOU-LEGALL and BLANCHARD, 1995; DE JONG and DE JONGE, 1995), suggesting a progressive increase with depth of photosynthetic degradation products (LUCAS and HOLLIGAN, 1999) whose reliable estimates can only be obtained by chromatographic quantification (BARLOW *et al.*, 1990). We conclude that the more practical and rapid spectrophotometric method can be reasonably employed to quantify the living fraction of microphytobenthos in the surface sediments of the flat under investigation. At lower layer, only relying on either aceton or DMF extraction of pigments and spectrophotometric determination is likely to lead to an overestimation of the Chl *a* content up to >50%.

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Seasonal variation in sea surface temperature around Java derived from NOAA AVHRR

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Abstract : An observation of Sea Surface Temperature (SST) by using NOAA AVHRR data was conducted in the Java Sea and the Indian Ocean around Java in order to understand the seasonal variation and its spatial distribution during the period of 1995–1997. SST characteristic in the Java Sea was found to be significantly different from that in the Indian Ocean. Semi annual variation is dominant in the Java Sea, while in the Indian Ocean, annual variation is more dominant. Mean SST in the Java Sea is higher by 1–2℃ than that in the Indian Ocean, while SST maximum and minimum is higher by 1–4 ℃. SST in the Java Sea is mainly affected by net heat flux through the sea surface, while that in the Indian Ocean is influenced by the upwelling related to monsoon.

Key words : *SST, NOAA AHVRR, around Java*

1. Introduction

The Java Sea and the Indian Ocean around Java is the most important area for the economical activities in the western Indonesia. Both areas are characterized by different situation in terms of the economical activities and the environmental condition. The Java Sea existing between Java and Kalimantan is a shallow water. In this area, the activities are various from heavy industry, off-shore gas drilling, agriculture, coastal fishing to the transportation as a consequence of the urban concentrations in the northern coast of Java and southern coast of Kalimantan. While the Indian Ocean is an open sea and deep water. The main activity in this area is coastal and open sea fishing due to high productivity generated by the upwelling.

To understand the oceanographic and the environmental condition within these regions, some expeditions and investigations have been conducted by using expensive conventional methods with research vessels to derive a numerous oceanic parameters including sea surface temperature (SST). In the Java Sea, some expeditions to obtain a series of physical, chemical and biological data at some areas along the northern coast of Java have been conducted to reveal a basic knowledge of the environmental condition (LIPI, 1980 and 1981). While in the Indian Ocean, some observations have also been carried out to understand the upwelling processes (WYRTKI, 1962; RACHFORD, 1962; PURBA, 1995; SOERIATMADJA, 1957; PARIWONO *et al*, 1988) and water productivity from chlorophyll *a* concentration (NONTJI, 1977 and SETIAPERMANA *et al*, 1992). However, the knowledge of the temporal and spatial distributions of SST were still limited. SST is well known as a key parameter for detecting current, front, eddies and upwelling. Since SST data are needed for integrated study of the marine environment within these regions, a reasonable cost to retrieve a regular and continuous data should be selected. Satellite remote sensing data from NOAA (National Oceanic and Atmospheric Administration) AVHRR (Advanced Very High Resolution Radiometer) can now offer an effective aid to solve such demand. Hence, the utilization of a synoptic time series SST data derived from NOAA AVHRR in our study is expected to complete the lack of information on the marine

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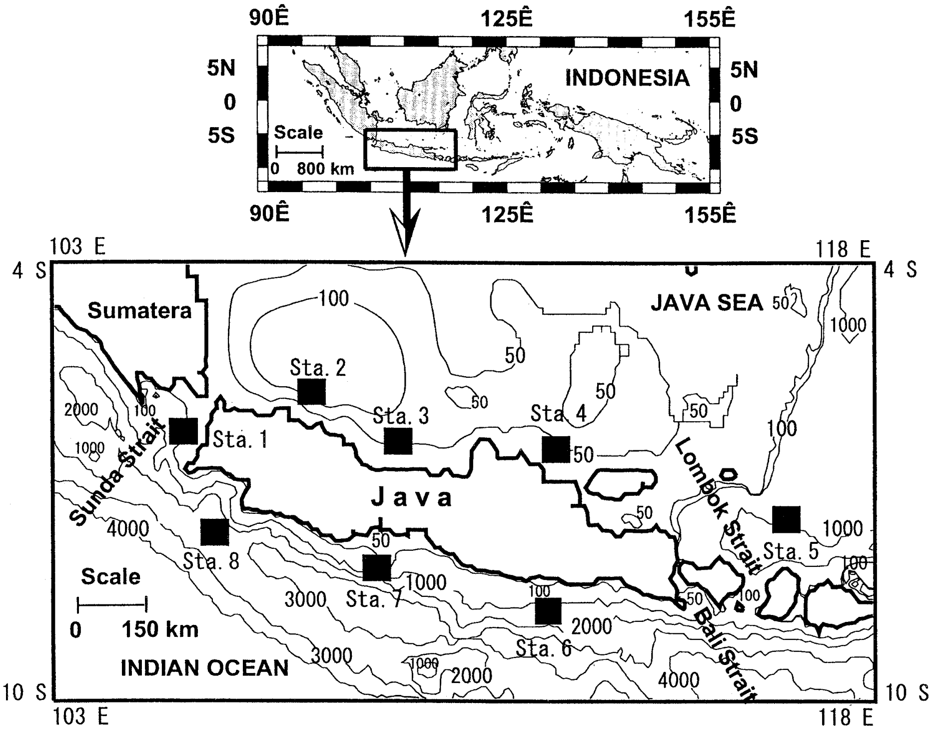


Fig. 1. Study area, bathymetry (meter) and SST sampling point in the Java Sea and the Indian Ocean.

environment condition within these regions. In this study, SST variation of the Java Sea and the Indian Ocean around Java will be described by analyzing the monthly mean SST variability. The upwelling phenomenon in relation with marine fish production will also be discussed.

2. Study area

Study area between 103–113°E and 4–10°S covers the Java Sea in the northern part and the Indian Ocean in the southern part. While in the western part and eastern part, the area is bounded by Sunda Strait and Bali Strait, respectively. These straits connect the Java Sea to the Indian Ocean and vice versa. Bathymetry of the Java Sea is less than 200 m and that of the Indian Ocean is more than 1000 m (Fig. 1).

3. Data collection and analysis

A time series of mean monthly SST of NOAA AVHRR satellite data derived from 1995–1997 in Version 4.1 with resolution of 9 km were obtained from NOAA Pathfinder to study SST variation in the Java Sea and the Indian Ocean. The AVHRR data are obtained by using a non-linear Sea Surface Temperature (NLSST) algorithm of Version 4.1. The data were validated and calibrated by match up of the AVHRR data and the in-situ observation data derived from TOGA (Tropical Ocean Global Atmosphere) and TAO (Tropical Atmosphere Ocean) buoys and it provides a high accuracy data with a negative bias of 0.1–0.2℃ (VAZQUEZ *et al.*, 1998). HELLERMAN and ROSENSTEIN (1983) monthly wind stress data with resolution of $2° \times 2°$, bathymetry data of the National Geophysical Data Center (NGDC) with resolution of $5' \times 5'$ were also collected to support this study. To understand the characteristic of SST variation in the Java Sea and the Indian Ocean, the mean monthly SST during 1995–1997 were mapped. To obtain a specific information of SST variation, SST at some points in northern and southern coasts of Java were also sampled from the mean monthly SST of each year. SST data of the Java Sea and the Indian Ocean were then analyzed by Fourier analysis to obtain an average, amplitude and phase of SST variation during 1995–1997. The equation of Fourier analysis is described on the below:

$$T_t = A_o + A_1 \sin wt + B_1 \cos wt + A_2 \sin 2wt + B_2 \cos 2wt \cdots\cdots\cdots\cdots (1)$$

Where:

T_t : SST at time t

A_o: Average SST

w : Angular frequency with the period of 1 year

A_1 and B_1 : Constants for annual variation

A_2 and B_2 : Constants for semi annual variation

The amplitude and phase of the annual and semi annual variations were then obtained by the equations :

Amplitude of annual variation (Ap1) :
$(A_1^2+B_1^2)^{1/2} \cdots\cdots\cdots\cdots (2)$

Phase of annual variation (Ph1) :
$\tan^{-1}(B_1/A_1) \cdots\cdots\cdots\cdots (3)$

Semi annual amplitude (Ap2) :
$(A_2^2+B_2^2)^{1/2} \cdots\cdots\cdots\cdots (4)$

Semi annual phase (Ph2) :
$\tan^{-1}(B_2/A_2) \cdots\cdots\cdots\cdots (5)$

To support this study, sea surface heat flux was also calculated on the basis meteorological data at Jakarta, oceanographic data at Jakarta Bay and equations of KIM and KIMURA (1995), EFIMOVA (1961) and KONDO (1975). While to understand correlation of the upwelling existence on the marine productivity within these regions, a series of fish production data at some places in northern and southern coasts of Java as well as their SST variability were also analyzed.

4. Results

Temporal and spatial variations of the monthly mean SST in the period of 1995–1997 around Java are shown in Fig. 2. During the northwest monsoon from January to March, SST in the Java Sea and the Indian Ocean show almost the similar range, that is within 28–29 ℃. Entering to the transition period of April to May, SST in the eastern part of the Indian Ocean begins to decrease from 28 to 27℃. During the southeast monsoon from June to September, SST gradually decreases and reaches to the lowest level less than 25℃ in the Indian Ocean in August and September, and low SST spatially propagates to the western part. In the southeast monsoon, SST in the Indian Ocean is lower by 1–4℃ than that in the Java Sea. On the other hand, SST in the Java Sea during the transition period of April to May slightly increases from 28–29℃ to 29–30℃ and decreases to 27–28℃ during the southeast monsoon. In the transition period of October to November, SST in the eastern part of the Java Sea gradually increases to 28–30℃ and SST in the eastern part of the Indian Ocean to 27–28℃. During the transition periods of April to May and October to November, SST in the Indian Ocean is lower by 1–2℃ than that in the Java Sea.

Temporal variations of SST at representative stations are shown in Fig. 3. Stas. 2–4 represent the SST variability in the Java Sea and Stas. 6–8 in the Indian Ocean. SST variation in the Java Sea shows the different character from that in the Indian Ocean. Semi annual variation is dominant in the Java Sea, while annual variation is dominant in the Indian Ocean. SST in the Java Sea is slightly fluctuated within the range of 27–30℃ with semi annual oscillation during 1995–1997. While in the Indian Ocean, SST variability is larger and fluctuated within 24–30℃ with annual oscillation in 1995, 26–30 ℃ in 1996 and 23–29℃ in 1997. Moreover, SST maximum in the Java Sea ranged 29–30℃ and occurred twice a year in April and November. While SST minimum in the Java Sea ranged 27 –28 ℃ and occurred in January and August. In the Indian Ocean, SST maximum ranged 28–29℃ and occurred once a year in April. While SST minimum in the Indian Ocean ranged 23–27℃ and occurred in September.

The average SST from 1995–1997, the amplitude and phase of annual and semi annual SST variations in the Java Sea and the Indian Ocean, which were obtained by Fourier analysis, are shown in Fig. 4. The results show that the average SST in the Java Sea is higher by 1 –2℃ than that in the Indian Ocean. The amplitude of SST in the Java Sea shows the semi annual variation with range of 0.5 to 1.0℃. This

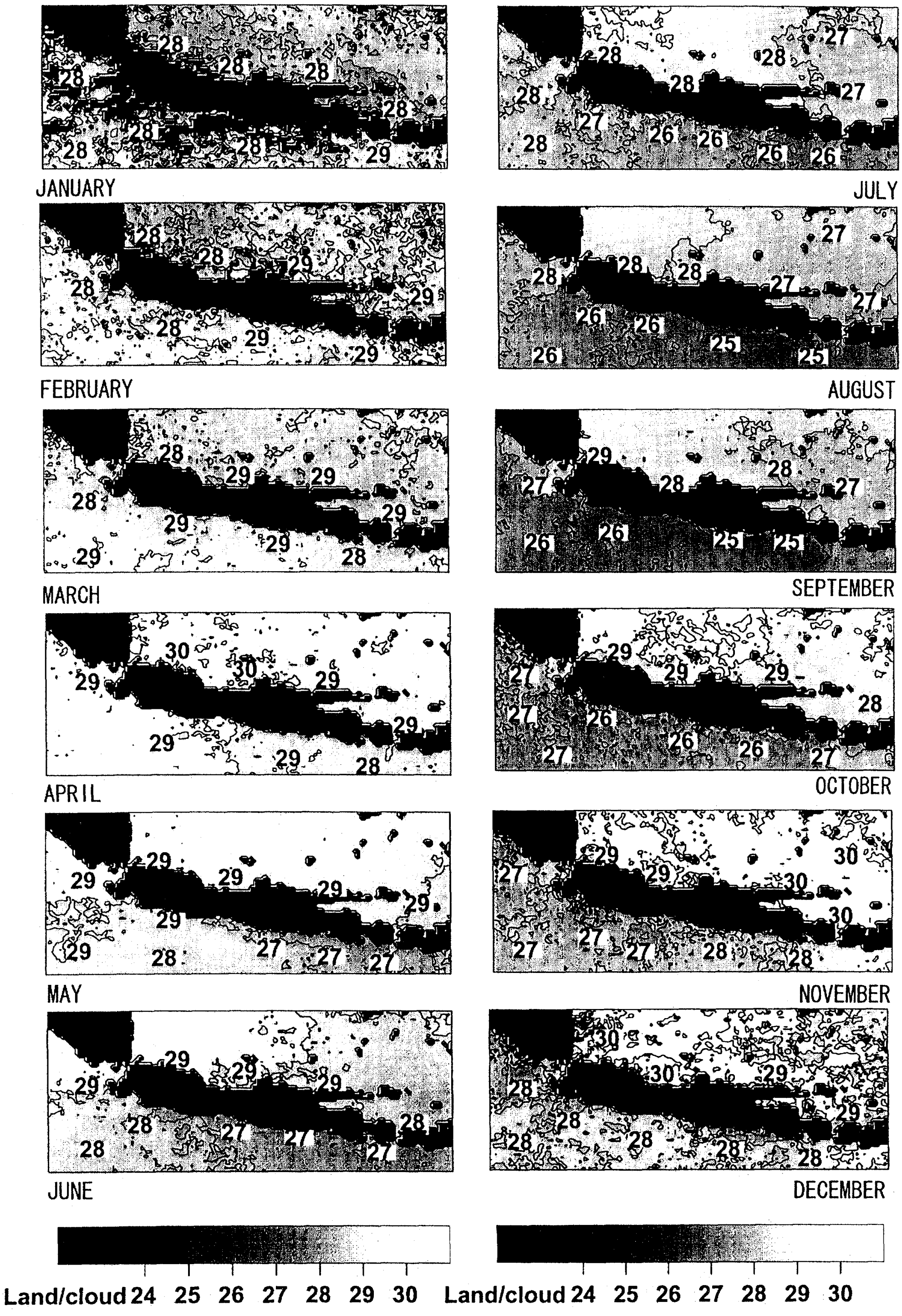
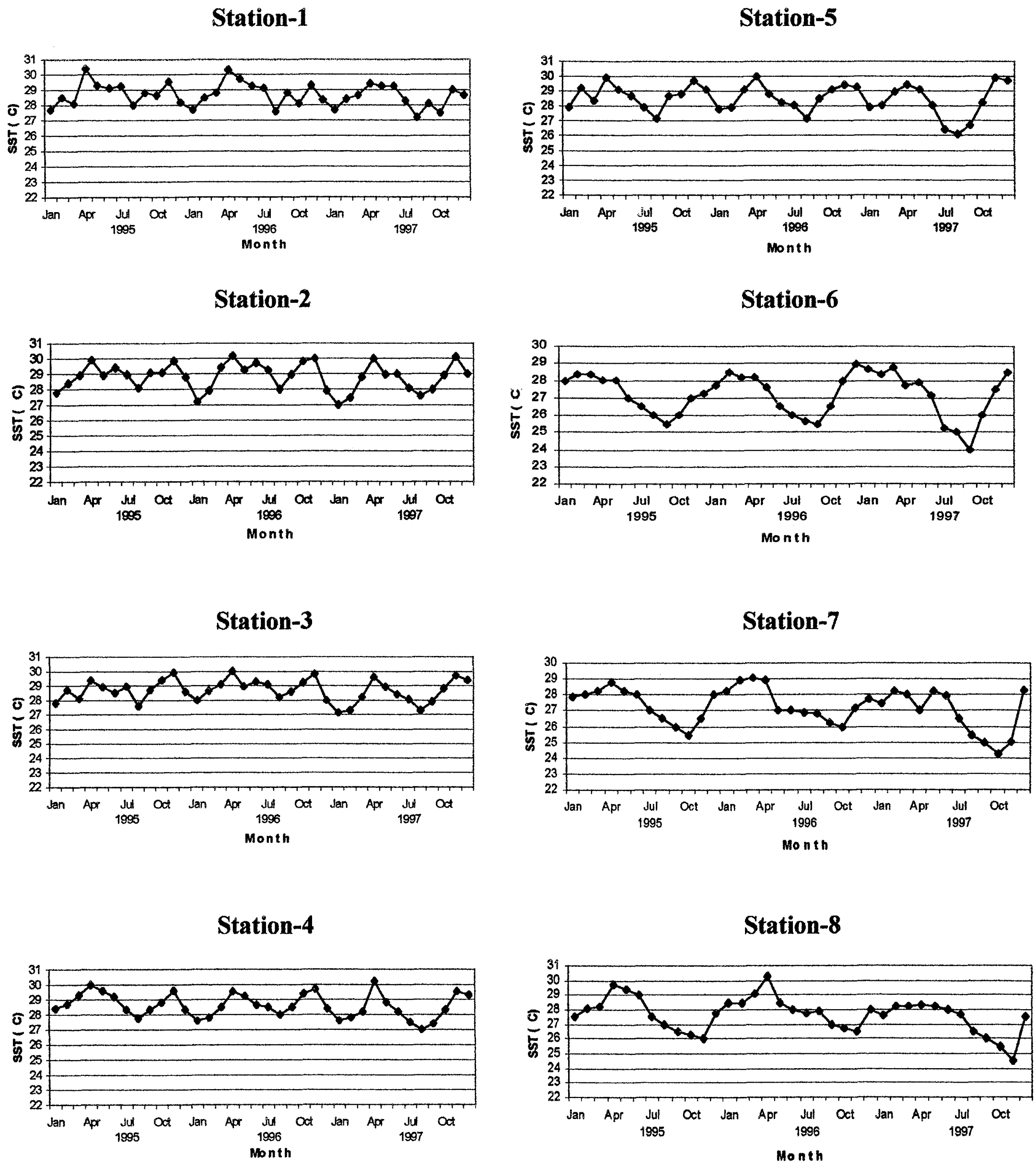


Fig. 2. Average monthly SST (°C) variation during 1995–1997.



Station-1

Station-5

Station-2

Station-6

Station-3

Station-7

Station-4

Station-8

Fig. 3. Monthly mean SST variations during 1995–1997 at some sampling points in the Java Sea and the Indian Ocean.

value is smaller than that of the annual variation of SST in the Indian Ocean with range of 1.0 to 1.5℃.

Temporal and spatial variations of wind stress are shown in Fig. 5. During the northwest monsoon from January to March, the northwesterly wind over the Java Sea is weak. Entering to the transition period of April to May, the southeasterly wind gradually increases and reaches to the strongest level in August and September. During such period, the northwesterly wind is disappeared. The southeasterly wind is then weakened entering to the transition period of October to

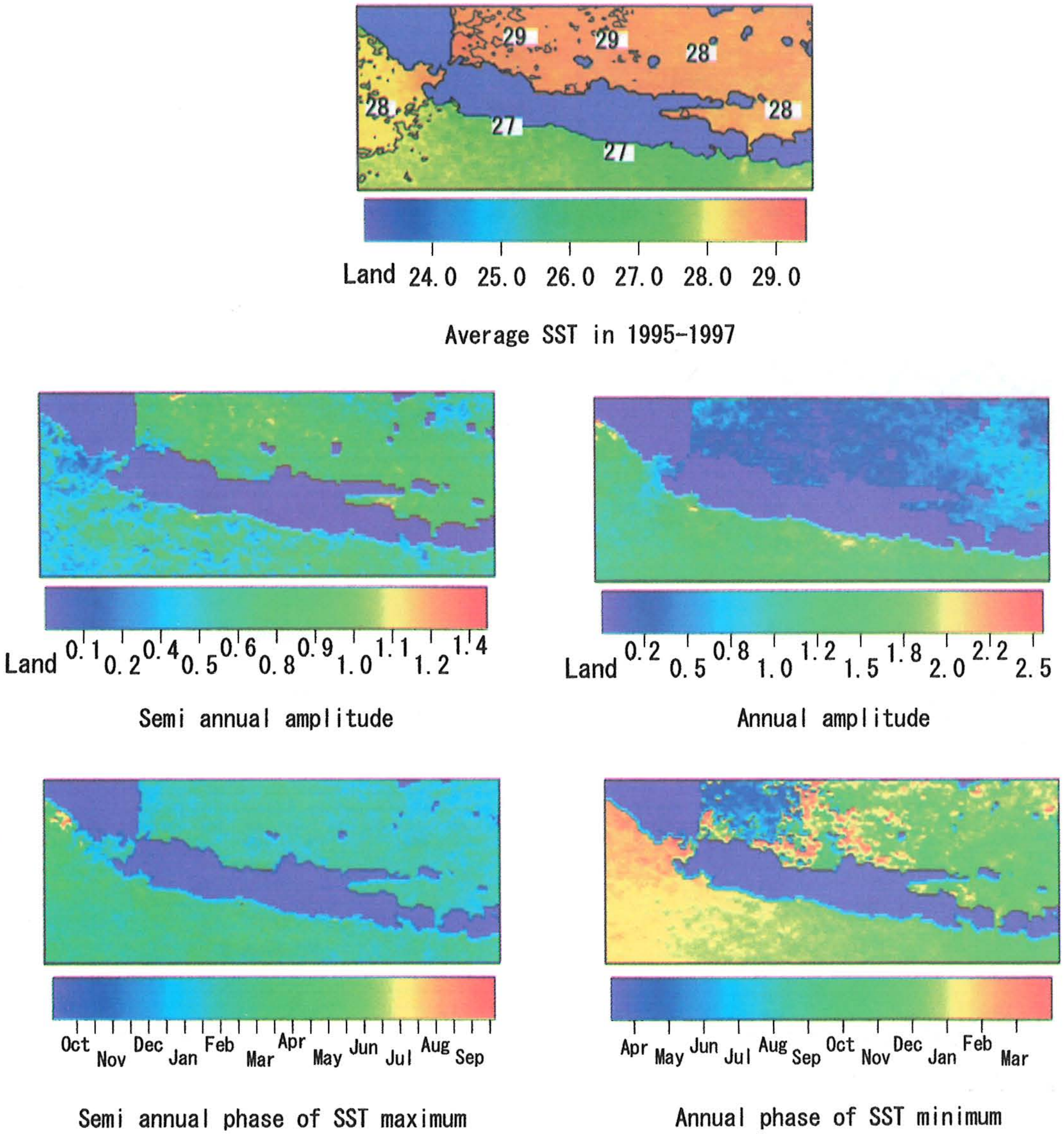


Fig. 4. Average SST, amplitude and phase of semi annual and annual variations in the Java Sea and the Indian Ocean.

November.

5. Discussion

Bathymetries of the Java Sea and the Indian Ocean are significantly different and such condition reflects on the difference of SST characteristics between these areas. The Java Sea is shallow water where the depth is less than 200 m, while the Indian Ocean is a deep water where the depth is more than 1000 m. This situation obviously affects on the characteristic of SST variation.

Mean monthly SST in the Java Sea is relatively higher by 1–2℃ than that in the Indian Ocean. It is due to the effect of subsurface cold water in the Indian Ocean. SST variability in the Java Sea may be mainly governed by the net heat flux (Qnet) variability which shows a

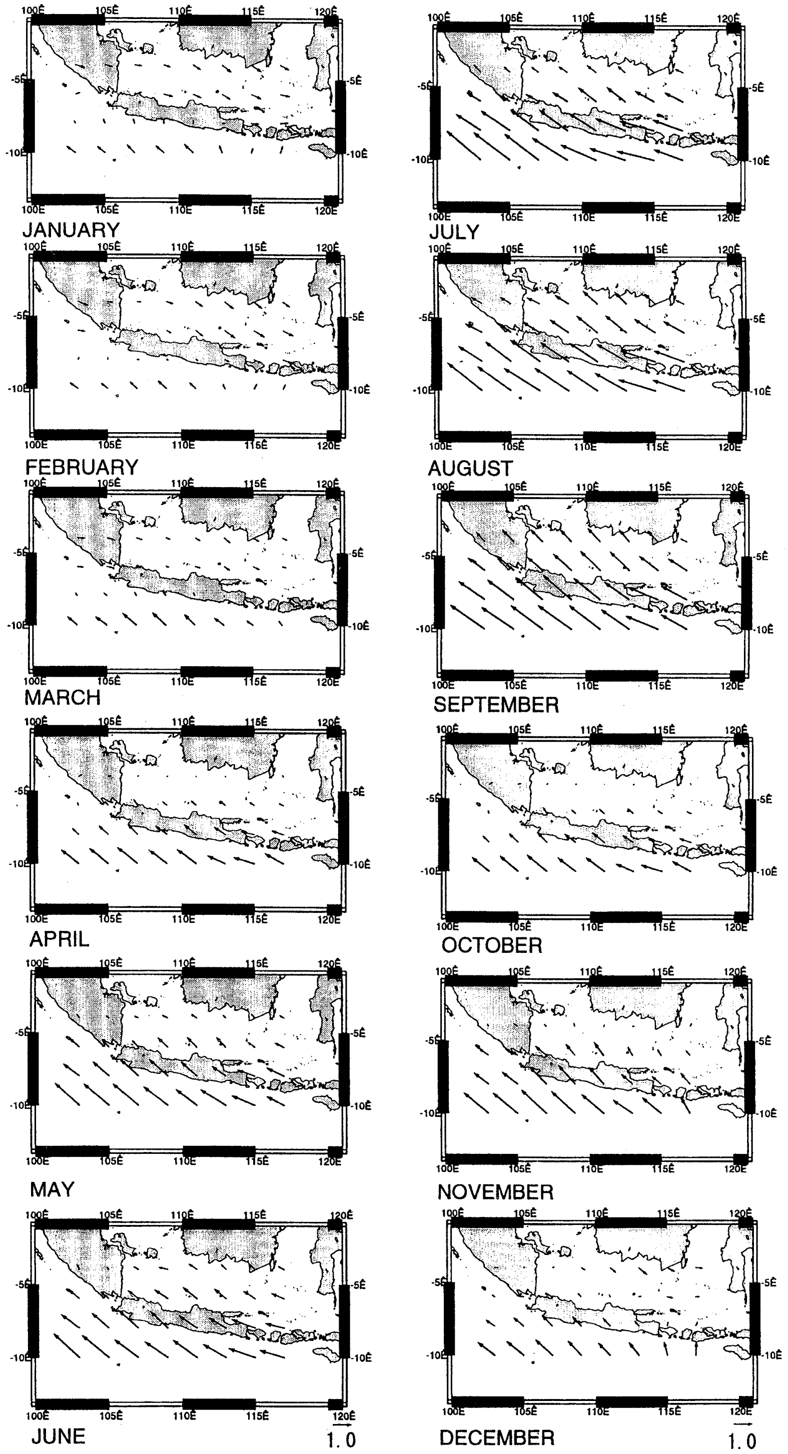


Fig. 5. Monthly mean wind direction and stress (dyne/cm^2) over the Java Sea and the Indian Ocean.

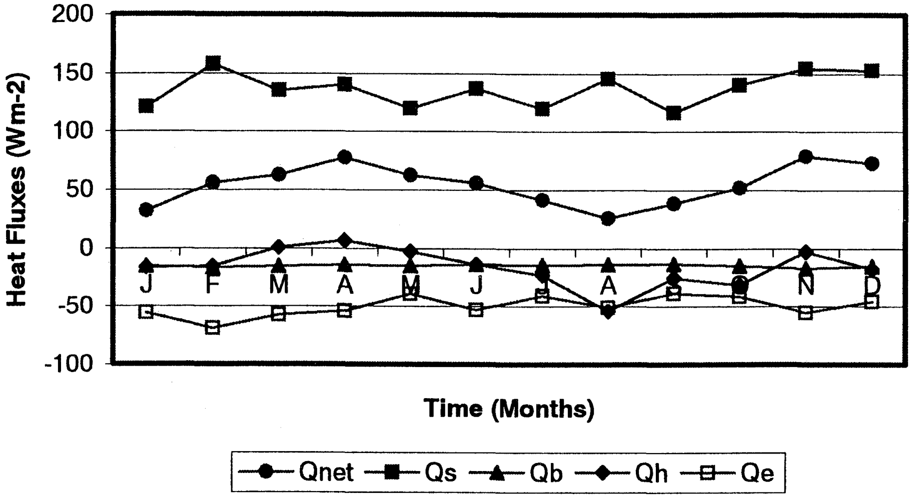


Fig. 6. Mean annual heat flux (Wm^{-2}) around the Java on the basis of the data from Meteorological Agency, Indonesia, during period of 1931–1960. Q_{net}, Q_s, Q_b, Q_h and Q_e are net heat flux, short-wave, long-wave, sensible and latent heat fluxes, respectively.

semi annual variation as shown in Fig. 6. While in the Indian Ocean, SST variability mainly influenced by the monsoon where annual variation becomes more dominant. SST maximum in the Java Sea occurs in the transition period of April and November when the sun crosses the equator and the net heat flux (Qnet) is large. While SST minimum in the Java Sea occurred in January due to the small net heat through the sea surface. Also in August, SST minimum occurred due to another small net heat flux. On the other hand, SST minimum in the Indian Ocean occurred in September in the eastern part due the strongest upwelling that is generated by the sea surface Ekman transport as response to the strongest southeasterly wind. This situation has been occurred from June with the westward propagation of low SST minimum and reaches to the peak of the upwelling with minimum SST in September. This situation was confirmed by the result of spatial distribution of the lower SST in time function during the upwelling period of the southeast monsoon and the effect of the southeasterly wind speed on the SST at the same period as shown in Fig. 7.

Previous study (WYRTKI, 1962 and PURBA, 1995) described that the upwelling in the southern coast of Java, the Indian Ocean, was developed during the southeast monsoon (July –September). But our results shown in Fig. 2, denotes that the upwelling begins in May and ends in November. Figure 2 and 3 also show that the occurrence of upwelling within this region is different between the eastern part and the western part. In the eastern part, the upwelling developed earlier than that in the western part as well as for the ending. This situation is supported by the wind stress shown in Fig. 5, that is, the southeasterly wind begins to develop in April and still exists in November in the western part. Though the upwelling has already ended in the eastern part in November, the upwelling process is still occurred in the western part. It is obviously seen on the SST status in November where SST in the eastern part was higher than that in the western part following the weakening of the southeasterly wind entering to the transition period, while in the western part, the southeasterly wind was still strong. Nevertheless, more detail investigation through the comprehensive field observation should be conducted to confirm that situation. Our result also noticed that the strongest upwelling was occurred in September in the eastern part. It is shown by the appearance of the coldest water along the coast spreading offshore up to 100

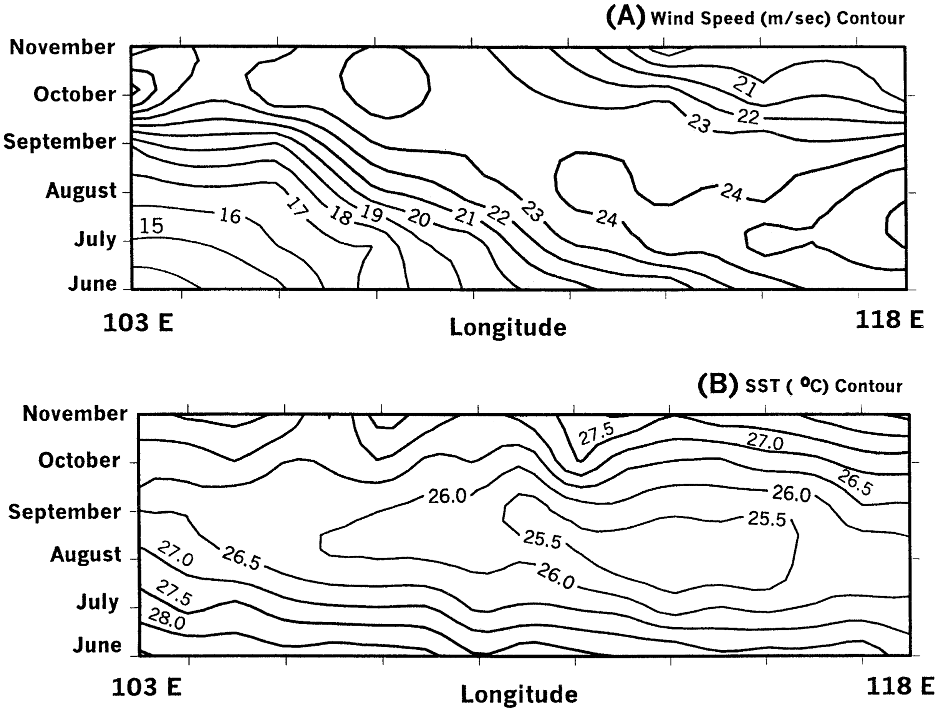


Fig. 7. Wind speed (A) and SST (B) distributions along the southern coast of Java, Indian Ocean during the upwelling period of June–November.

km as shown in Fig. 2.

The existence of the upwelling along the southern coast of Java has provided a good impact on fish production as shown in Fig. 8. Fish production in the Southern Coast of Java during the period of 1995–1997 was significantly higher than that in the Java Sea. Moreover fish production during the upwelling season from June to November was greater and regularly reach more than 900 ton month^{-1} through the year. This situation indicated that the upwelling area in the southern coast of Java is more productive than that in the Java Sea where the upwelling was not occurred. The fish catch mostly composes of skipjack, blue fin tuna and yellow fin tuna, an oceanic and seasonal migratory fish that has strong correlation to the seasonal upwelling in the southern coast of Java.

6. Summary and Conclusion

SST variabilities in the Java Sea and the Indian Ocean show the different characters, that is, semi annual variation is dominant in the Java Sea, while an annual variation is dominant in the Indian Ocean. Average, maximum and minimum SST in the Java Sea is higher by 1–2℃ than those in the Indian Ocean due to the effect of the upwelling. In general, SST variability around Java is controlled by bathymetry, net heat flux (Qnet) and monsoon. SST in the Java Sea is mainly controlled by the net heat flux, while that in the Indian Ocean is strongly influenced by the monsoon. SST in the Java Sea slightly changes throughout the year but in the Indian Ocean, SST dramatically changes through the seasons. The existence of the prevailing southeasterly wind during the southeast monsoon is a main factor causing the upwelling phenomenon in the southern coast of Java and it promotes fishing activity due to the increasing of marine productivity. To reveal more detailed upwelling processes in relation to the marine productivity within this region, the utilization of ocean color images is strongly recommended for the future study.

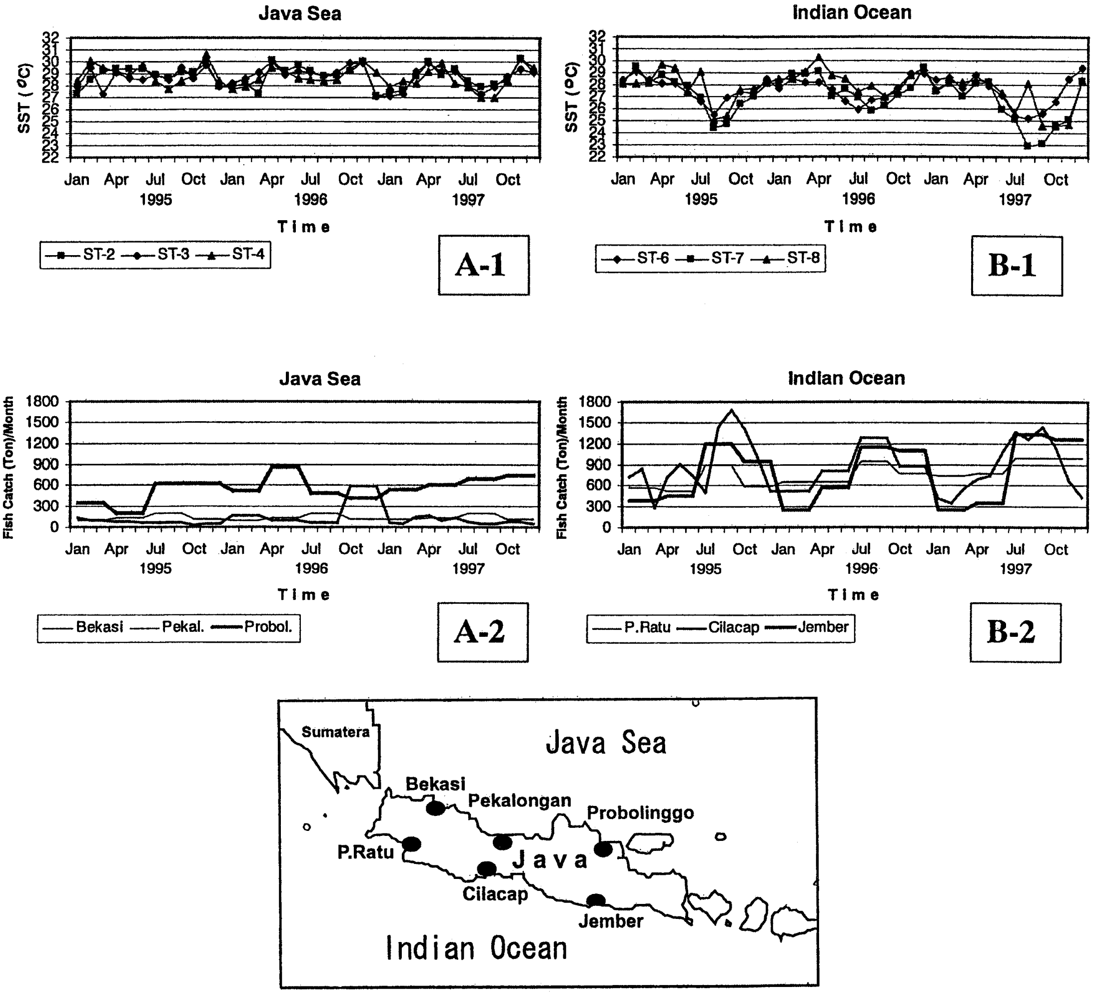


Fig. 8. Year to year variations of SST (A-1) and fish production (A-2) in the Java Sea; year to year variations of SST (B-1) and fish production (B-2) in the Indian Ocean obtained from some places in the northern coast of Java (Java Sea) and southern coast of Java (Indian Ocean) from 1995-1997.

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遊泳と摂餌に関する形質の発達に基づいた クジメ仔稚魚の発育段階

河野　博*・栗田　豊**・青海忠久***

Ontogenetic intervals based on the development of swimming- and feeding-related characters in the hexagrammid, *Hexagrammos agrammus,* larvae and juveniles

Hiroshi KOHNO*, Yutaka KURITA** and Tadahisa SEIKAI***

Abstract : Based on the development of swimming-and feeding-related characters, ontogenetic intervals of larvae and juveniles were established for *Hexagrammos agrammus.* Consequently, the following four and three phases were recognized by the development of each function. Swimming: 1) the phase in which the larvae swim by using the whole body (from hatching to five days after hatching, D-5); 2) the phase in which the larvae swim by using both the whole body and caudal fin (D-5–D-15); 3) the phase in which the propulsion force generated by the caudal fin is effectively used by using the whole body (D-15–D-25/30 : the former period being recognized as a sub-phase in which a more or less complete swimming ability being attained); 4) the functional juvenile phase with complete swimming ability (beyond D-30). Feeding : 1) the phase with the feeding mode of sucking (from hatching to D-10); 2) the phase in which the sucking ability increases (D-10–D-25/30: the former period being recognized as a sub-phase in which dharacters associated with biting develop; 3) the functional juvenile phase with complete feeding ability (beyond D-30). Relationships between these morphological changes and ecological changes under artificial rearing and natural waters were discussed.

Key words : Hexagrammos agrammus, *larvae, juveniles, functional development*

1.　はじめに

カサゴ目アイナメ科に属するクジメ（*Hexagrammos agrammus*）は，日本沿岸の各地や朝鮮半島南部，あるいは黄海に面した沿岸の藻場に生息する肉食魚である（篠原，1997）。沿岸磯魚資源として有用なことから，本種の種苗生産の研究は古くから行われてきた（片嶋ら，1964；丹下・竹田，1968；福原，1971）。天然海域においても，年齢や成長，産卵生態などの研究が行われている（栗田，1993；KURITA *et al.*, 1991, 1995；KURITA and OKIYAMA, 1996）。さらに，ふ化した仔魚が浮遊生活をしながら稚魚に発達し，その後着底するという初期生活史を送ることから，浮遊期や着底時の体色の変化（黒田，1952；小川，1963；栗田，1993）やホルモンの発達（MATSUMOTO and TANAKA, 1996）についても調べられている。しかし，体色をふくめた仔稚魚の外部形態についての情報は蓄積されているにもかかわらず，内部形

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態の知見は乏しい。

本研究では，まず，クジメ仔稚魚の遊泳と摂餌に関連する骨格系を中心とした形質の発達を観察した。さらに，観察結果に基づいた発育段階を設定することによって，ふ化から浮遊期，さらに着底に移行する仔稚魚期の形態的・機能的発育と生態的発達との関連を調べた。

2.　材料および方法

本研究で用いたクジメの標本は，1994年1月31日に神奈川県三浦半島の油壷地先で雄が保護していた卵を潜水により採集し，翌日京都府舞鶴市にある京都大学農学部附属水産実験所に運搬し，同所にてふ化・飼育したものである。2月1日にふ化水槽に収容された卵は，2月15日にふ化した。ふ化した仔魚500個体を，あらかじめ水温を16℃に設定しておいた100 ℓ水槽に収容し，飼育した。飼育は，完全遮光の室内で，照明を11L：13Dにして行った。海水は実験所前から取水したものをそのまま使用し，1日3回転の割合で水量を調節した。餌はナンノクロロプシスで培養したワムシをふ化（D-0）からふ化後19日（D-19）まで，油脂と酵母で栄養強化したアルテミアをD-5から実験終了（D-50）まで，配合飼料をD-20から実験終了まで与えた。水温は15.9～16.4 ℃であった。

ふ化当日（D-0）からふ化後40日（D-40）までは5日ごとに3～7個体の仔稚魚を，さらにD-46に5個体，D-50に1個体を採集し，5％ホルマリンで保存した。これらの仔稚魚（計55個体）をPotthoff（1984）の方法に従って透明二重染色処理し，観察に用いた。なお，本研究では，透明染色処理をする前のホルマリン保存状態での体長に基づいて記載を行った。さらにLeis and Trnski（1989）に従い，体長は，脊索末端部の上屈前あるいは上屈中の仔魚では脊索長を，上屈後の仔稚魚では標準体長を示すものとする。その結果，今回用いた仔稚魚は体長7.86～27.9 mmになる。これらの透明標本について，遊泳と摂餌に関する器官の化骨・形成過程を調べ，さらに計数や計測を行った。本研究の記載は，ある現象や事象が最初に観察された最小個体とそのふ化後日数に基づいて行った。なお，仔稚魚の行動の観察については，飼育水槽で適宜行った。

本研究で使用した標本はすべて東京水産大学水産資料館にMTUF-P(L) 7278で登録され，保管されている。

3.　結　果

3.1　成　長

ふ化当日（D-0）の仔魚の体長（平均±標準偏差）は8.08±0.18 mm（7個体）であった（Fig. 1A）。その後，体長は急激に増大し，D-10には10.0±0.56 mm（6個体），D-20には11.7±0.84 mm(4個体)，D-30には18.3±2.35 mm(7個体)，D-40には22.4±2.43 mm（5個体）となり，D-50には1個体であるが27.9 mmに達した（Fig. 1A）。

3.2　遊泳に関する形質

脊索末端部の角度　D-0ですでに7個体のうちの2個体（体長8.04と8.14 mm）で脊索の末端部が上屈し，角度は各々10.6と18.8度であった（Fig. 1B）。なお，まっすぐな脊索をもった最も大きな個体は8.35 mm（D-0）であった。脊索末端部の上屈はゆっくりとすすみ，上屈が完成したと判断できたのはD-20の13.0 mmの個体で，角度は41.3度であった。なお，大きさではD-25の12.4 mmが最小個体であった。その後の脊索末端部の角度は30～40度で推移した（Fig. 1B）。

尾鰭の支持骨と主鰭条　尾骨の構成骨はすでにD-0の体長8.04 mmで出現し，準下尾骨が認められた。下尾骨1はD-0の8.14 mmで出現した。D-5の9.07 mmでは，下尾骨1と2が癒合し，さらに下尾骨3と第3尾鰭椎前椎体の神経弓門・棘および第2，3尾鰭椎前椎体の血管弓門・棘が出現した。第2尾鰭椎前椎体の神経弓門はD-5の9.69 mmで出現した。D-10の9.33 mmでは，下尾骨3と4および準下尾骨と下尾骨1＋2の遠位部が癒合し，さらに第2尾鰭椎前椎体の神経棘と上尾骨（中央の1本）が出現した。同じくD-10の9.62 mmでは後方の上尾骨が，また10.4 mmでは前方の上尾骨が出現し，さらに後者では下尾骨1＋2が化骨し始めた。D-15の11.9 mmで尾部棒状骨と下尾骨5が出現し，また準下尾骨と下尾骨3＋4が化骨し始めた。D-20の11.4 mmでは，準下尾骨と下尾骨1＋2の根元が癒合した。D-20の13.0 mmで第2，3尾鰭椎前椎体の血管弓門・棘および第2，3尾鰭椎前椎体の神経弓門・棘が化骨し始めた。D-25の13.8 mmでは，下尾骨5が3＋4と癒合するとともに化骨し始め，さらに尾神経骨1と第2，3尾鰭椎前椎体が出現した。D-30の17.5 mmで上尾骨が3本とも化骨し始めた。

最初に出現した尾鰭主鰭条はD-5の9.07 mmの個体で見られた7本であった（Fig. 1C)。定数である9＋8＝17本にはD-15（11.0 mm）で達成された。その後は不分枝の副鰭条が徐々に増え，D-40でほぼ安定した（Fig. 1C）。

背鰭支持骨と背鰭鰭条　最初に背鰭支持骨が出現したのはD-15の体長11.0 mmの個体で，4本の近位担鰭骨が中央よりやや後方に認められた。遠位担鰭骨はD-15の11.5 mmの個体で最初に3個が出現した。すべての近位担鰭骨と遠位担鰭骨はD-25の13.8 mmの個体で最初に確認された。化骨の開始はD-30（17.5 mm）で，すでにすべての担鰭骨が化骨し始めていた。

背鰭鰭条はD-15（11.9 mm）で最初に出現し，13本の鰭条が見られた（Fig. 1D）。定数に達したのはD-25の15.6 mmが最初であった（Fig. 1D）。

臀鰭支持骨と臀鰭鰭条　最初に臀鰭支持骨が出現したのはD-15の体長11.0 mmの個体で，12本の近位担鰭骨

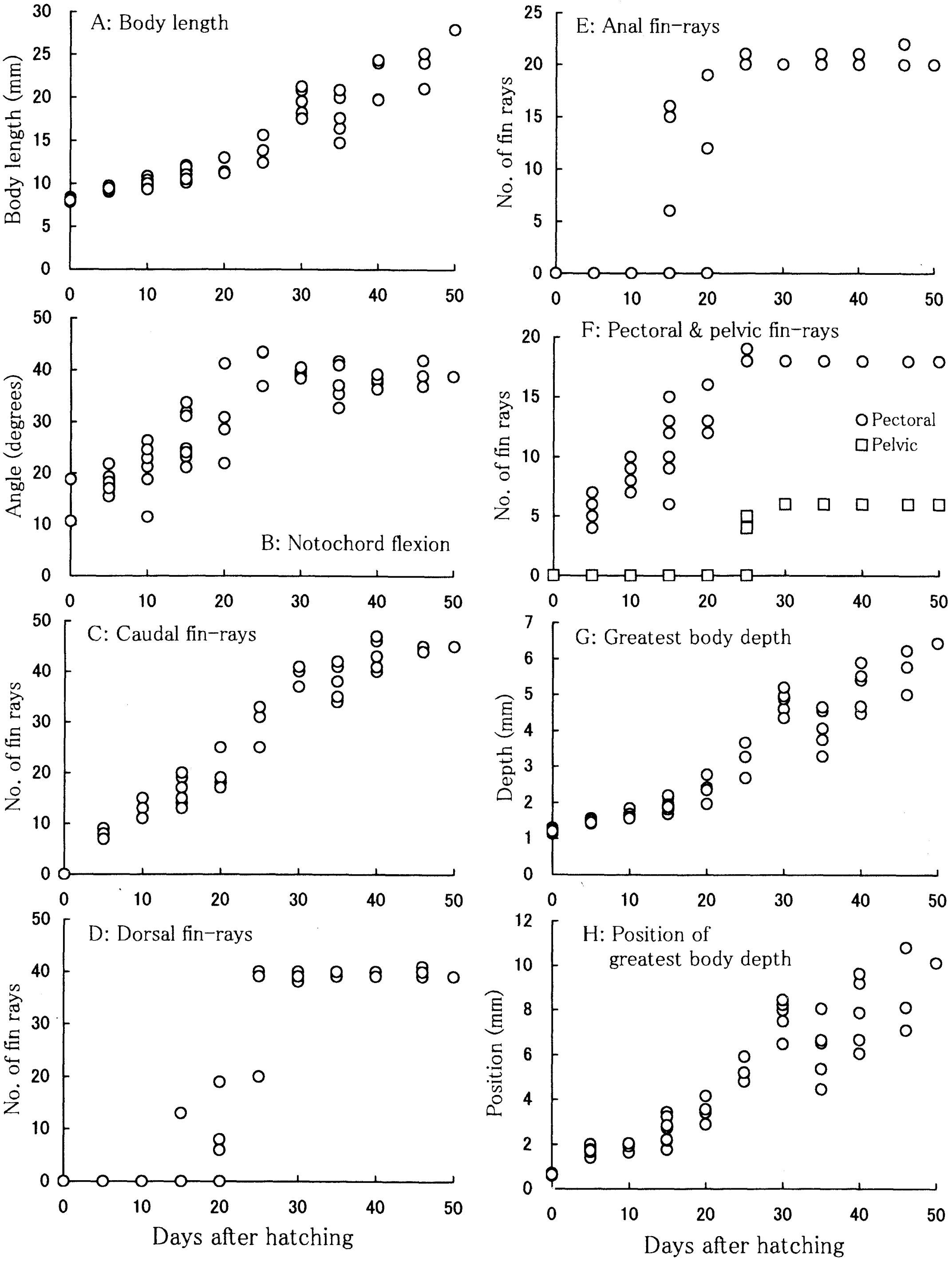

Fig. 1. Growth (A) and changes in swimming-related characters (B-H) with days after hatching in *Hexagrammos agrammus*.

が見られた。遠位担鰭骨はD-15の11.5 mmの個体で最初に7個が確認された。すべての近位担鰭骨と遠位担鰭骨はD-25の12.4 mmの個体で最初に出現した。化骨の開始はD-30（17.5 mm）で，すでにすべての担鰭骨が化骨し始めていた。

臀鰭鰭条はD-15の11.5 mmで最初に6本が出現した（Fig. 1E）。最初に定数に達したのは，D-25の13.8 mmの個体であった（Fig. 1E）。

胸鰭の支持骨と鰭条　D-0のすべての個体（最小個体は体長7.86 mm）で，すでに膜骨の擬鎖骨と肩甲–烏口軟骨，射出軟骨板が出現していた。なお，射出軟骨板は中央近位部に裂け目があり，遠位部で連結しているものの，上下2葉からなっていた。上擬鎖骨と後側頭骨はD-15（10.1 mm）で出現し，さらに同個体では射出軟骨板の中央の裂け目の上下にも裂け目が見られた。後方の後擬鎖骨はD-20（11.2 mm）で出現し，前方の後擬鎖骨はD-25（13.8 mm）で最初に出現した。後者の個体では，肩甲骨が化骨し始めていた。D-25の15.6 mmの個体では烏口骨が化骨し始めた。D-30（17.5 mm）では，4つに分かれた射出骨のすべてで化骨が認められた。

胸鰭鰭条はD-0の個体では出現しなかった。胸鰭鰭条をもつ最小の個体はD-5の9.07 mmで，5本の鰭条が認められた（Fig. 1F）。胸鰭鰭条が最初に定数に達したのはD-25（12.4 mm）であった。（Fig. 1F）。

腹鰭の支持骨と鰭条　軟骨性の腰帯はD-10の体長9.33 mmの個体で最初に出現した。成長とともに前方に長く伸び，最初の化骨はD-20（13.0 mm）で確認された。

D-25の体長13.8 mmの個体で最初に腹鰭鰭条（4本）が認められた（Fig. 1F）。定数に達したのはD-30の17.5 mmの個体が最初であった（Fig. 1F）。

脊椎骨　D-0の最小個体である体長7.86 mmの個体ですでに1番目から43番目までの神経弓門と18番目から43番目までの神経棘，および13番目以降の31個の血管弓門と18番目以降の24個の血管棘が出現していた。D-5の9.07 mmの個体では，もっとも前の2個の神経弓門・棘が化骨を開始し，またすべての血管弓門・棘が出現した。すべての神経弓門・棘が出現したのはD-5の9.69 mmの個体であった。血管弓門・棘の化骨が見られたのはD-10の9.33 mmが最初で，また，この個体では初めて椎骨が前方から5個出現した。D-20の13.0 mmの個体ではすべての神経弓門・棘と血管弓門・棘の化骨が始まり，すべての椎骨も出現した。しかし，椎骨は最も前方の5個だけが完全な形で，6番目以降は側方から見ると中央がくびれた形で，さらに最後尾の4個は神経弓門や血管弓門の根元から出現し始めている程度であった。完全な形の椎骨がすべて出現したのはD-25の13.8 mmの個体が最初であった。

最大体高とその位置　D-0の個体の最大体高は1.14～1.23 mm（Fig. 1G）で，その体長比は14.5～15.8%，また最大体高の位置は吻端から0.59～0.69 mm（Fig. 1H）で体長比は7.3～8.5%であった。最大体高もその位置も，その後D-15まではゆるやかに増大したが，D-15から30にかけてはやや急激に増大した（Fig. 1G, H）。なお，D-15の最大体高とその体長比は1.82～2.19 mm，16.5～18.4%，その位置は2.16～3.41 mm，17.3～29.4%であった。またD-30では各々4.34～5.19 mm，24.5～25.2%，6.47～8.43 mm，36.9～43.8%であった。

3.3　摂餌に関する形質

口幅　D-0ですでにすべての個体（7個体，最小個体は体長7.86 mm）で開口し，その口幅は0.625～0.685 mmであった（Fig. 2A）。その後徐々に大きくなり，D-30で変曲点が認められ，D-30以降はやや増大傾向がゆるやかとなった。D-46とD-50では少し口幅が大きくなった傾向が見られたが，観察個体数が少ないため明確ではなかった。なお，D-30での口幅の平均±標準偏差は1.56±0.132 mm（5個体）であった（Fig. 2A）。

顎骨　D-0の開口とともに膜骨性の主上顎骨はすべての個体ですでに出現していたが，前上顎骨は7個体中4個体で出現しその最小個体は体長7.99 mmであった。すでに主上顎骨の前方には前上顎骨と関節するために突起が，また前上顎骨の前方には主上顎骨と関節するための突起（上向突起）が発達していた。さらに，主上顎骨の後方は幅広くなっていた。

下顎では，すべてのD-0の個体はメッケル軟骨をもち，その前方と後方には膜骨性の歯骨と角骨が出現していた。後関節骨はD-5（9.07 mm）で出現した。

口裂に占める前上顎骨長の割合い　前上顎骨をもつD-0の4個体（最小個体は体長7.99 mm）における口裂に占める前上顎骨の長さの割合は15.6～37.0%であった（Fig. 2B）。その後割合はやや急に増加し，D-10には49.0±5.54%となり，その後は安定した（Fig. 2B）。

顎歯　先に出現したのは上顎歯で，D-15の7個体のうち5個体（最小個体は体長10.1 mm）で1～3本が出現した（Fig. 2C）。その後ゆるやかに増加した上顎歯はD-25では2～4本が見られたが，D-30でやや急激に増加し4～12本となった。その後もやや高い数でゆるやかに増加し，D-40で10～15本，D-46で13～16本，D-50では11本であった（Fig. 2C）。

下顎歯はD-25の13.8 mmで出現し，本数は2本だった（Fig. 2D）。D-30でやや急激に増加して3～10本が出現し，その後はゆるやかに増加した。D-40で11～14本，D-46で11～13本，D-50で14本であった（Fig. 2D）。

懸垂骨　D-0（最小個体は体長7.86 mm）ですでに棒状の舌顎—接続軟骨と方—後翼状軟骨が出現し，接続骨の部位ではすでに化骨が始まっていた。D-5（9.07 mm）では，口蓋軟骨が単独で出現し，方骨と舌顎骨が化骨し始めていた。D-10（9.33 mm）になると，口蓋軟骨と方—後翼状軟骨が接続し，1枚の三角形の軟骨板を形成した。後翼状骨の化骨はD-15（11.5 mm）で認められたが，最

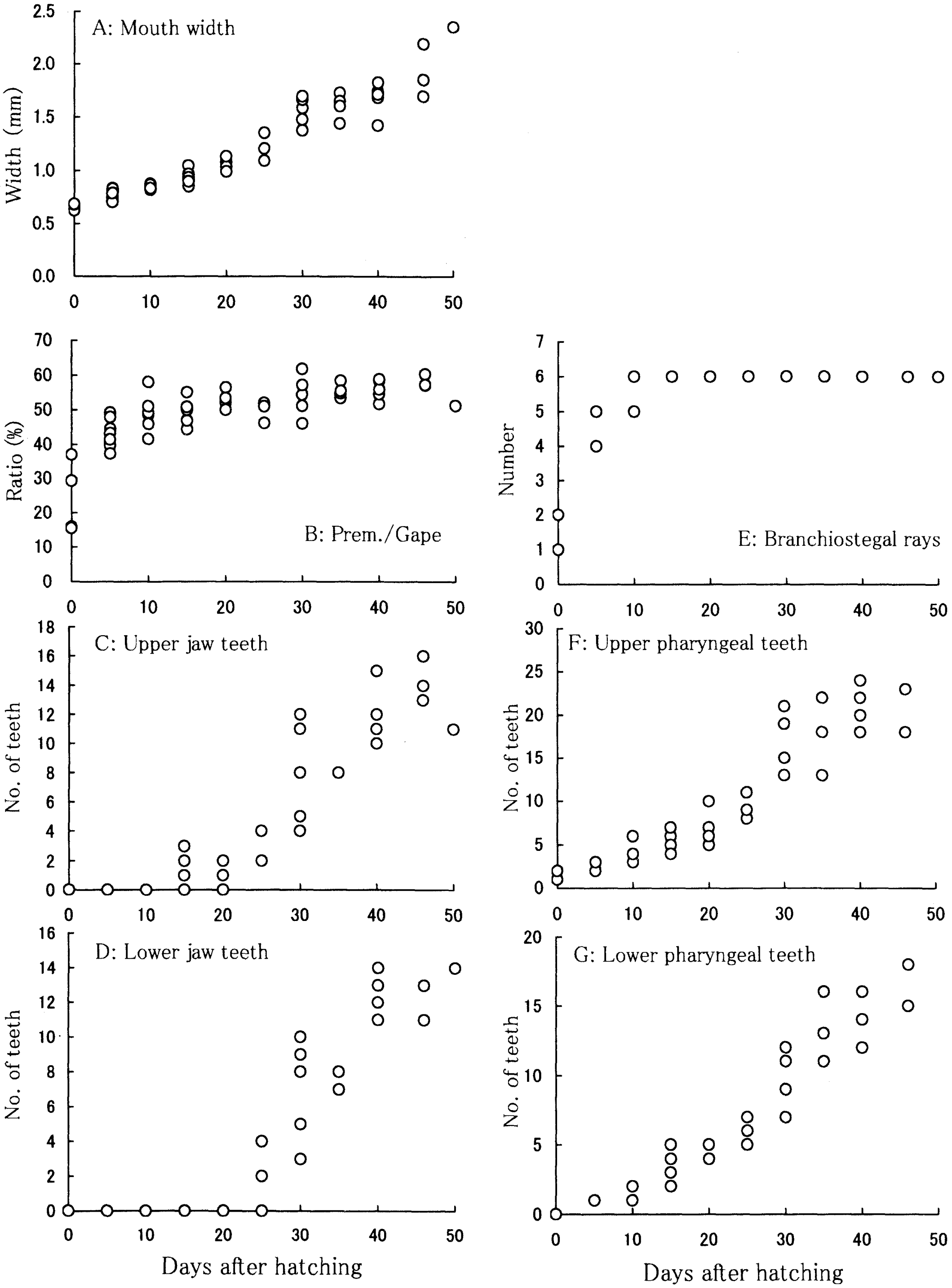

Fig. 2. Changes in feeding-related characters with days after hatching in *Hexagrammos agrammus.*

小個体はD-20の11.2 mmであった。膜骨性の外翼状骨と内翼状骨はD-20（11.2 mm）で最初に出現した。口蓋骨の化骨はD-25（13.8 mm）で認められた。

舌弓と鰓条骨　舌弓の構成要素である下舌軟骨，角舌—上舌軟骨，間舌軟骨のすべては，すでにD-0（最小個体は体長7.86 mm）で出現した。さらに，角舌骨部では化骨も始まっていた。D-5の9.07 mmでは上舌骨と下舌骨の化骨も始まった。間舌骨の化骨はD-10（9.33 mm）で認められた。

鰓条骨はD-0のすべての個体（最小は7.86 mm）ですでに1～2本が出現していた（Fig. 1E）。本数は急激に増加し，D-10（10.0 mm）で定数の6本に達した（Fig. 1E）。

咽頭歯　D-0（最小個体は体長7.86 mm）ですでに1～2本の上咽頭歯が出現した（Fig. 1F）。上咽頭歯の数は徐々に増加し，D-25には8～11本になった。その後，D-30では急激な増加が見られ（13～21本），その後はややゆるやかな増加が見られた（Fig. 1F）。

一方，下咽頭歯はD-5（9.07 mm）で初めて出現し，本数はすべての個体で1本であった（Fig. 1G）。その後ゆるやかに増加し，D-25には5～7本が出現したが，D-30で急激に増加し7～12本に達した（Fig. 1G）。D-30以降はゆるやかに増加した。

鰓蓋骨　最初に出現した鰓蓋骨は主鰓蓋骨で，すでにD-0（最小個体は体長7.86 mm）で出現していた。D-5（9.07 mm）にはすべての鰓蓋骨の出現が確認された。

3.4 行動の観察

ふ化した仔魚は，体全体をくねらせるようにして遊泳していた。最初に底生生活をしている個体を観察したのはD-36であったが，体色は緑色であった（なお，D-36には体長の測定を行っていないが，D-35では体長の範囲は14.7～20.9 mmであった）。D-46（最大個体は体長25.1 mm）になると，ほぼ3分の1の個体が底近くで生活していた。実験の最終日であるD-50では，体がやや茶色で底生生活をしていた個体が11個体に対して，緑がかった体色で浮遊していた個体が16個体であった。

なお，ここでいう底生生活とは，水槽の底面に腹部が触れていたり，底近くを遊泳していることを指す。これは，水面の表層近くを浮遊・遊泳している個体とは明らかに異なり，また，完全に着底した生活でもない。

4. 論　議

4.1 形態発育に基づく発育段階の区分

本研究で得られたクジメ仔稚魚の遊泳と摂餌に関する形質の出現や化骨の開始，数的完成，変曲点などをFig. 3とFig. 4にまとめた。本研究では，河野・曽田（1998）が採用した方法によって発育段階を区分した。すなわち，形質の発現や数的完成などの出現頻度が高く，なおかつ，いくつかの表徴形質によって変化の特徴の説明ができる体長区分を発育段階とする方法である。した

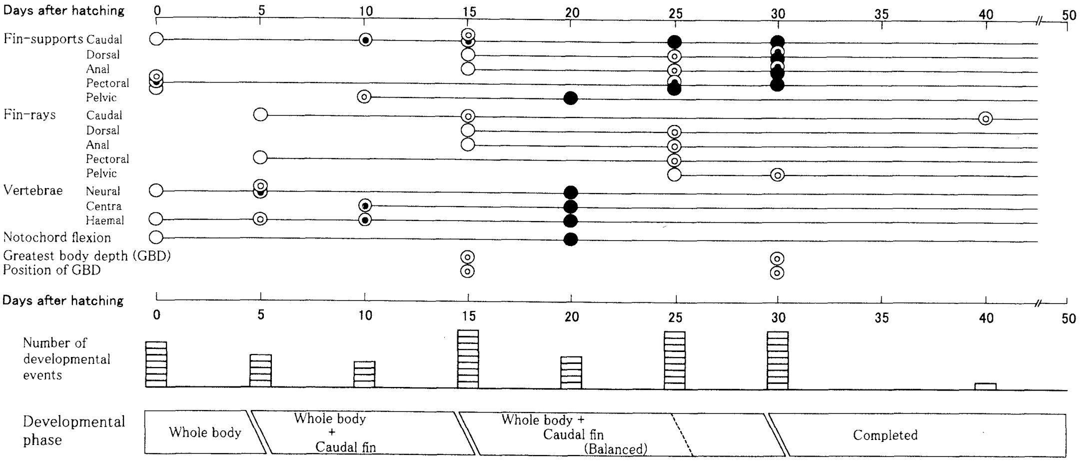

Fig. 3. Schematic representation of the development of swimming-related characters with days after hatching in *Hexagrammos agrammus*. ○: cartilaginous elements or fin rays start appearing, or notochord flexion start occurring; ◉: bony elements start appearing, or cartilaginous elements start ossifying; ◎: all cartilaginous elements start appearing, fin rays become complete in number, or flexion points of morphometric characters are observed; ●: all cartilaginous elements start ossifying, all bony elements start appearing, or notochord flexion becomes complete.

がって，各々の図には，発育上の出来事の出現頻度を日令ごとにヒストグラムで表した。また，以下の発育段階の説明では，日令を基準に行うが，体長も付記しておく。

遊泳機能　クジメの遊泳機能の発達は，以下のような4段階からなると判断された（Fig. 3)。

体全体遊泳期（ふ化[体長約8 mm]〜D-5 [約9 mm]）：すでにふ化時には，神経棘や血管棘が出現していた。これは，やや長いシラス型の体をくねらせて遊泳するために，体軸を補強していると考えられる。また，実際の遊泳観察でも，ふ化直後から体全体をくねらせて遊泳していた。

体全体遊泳期＋尾鰭推進期（D-5 [約9 mm]〜D-15 [約11 mm]）：神経棘や血管棘が数的に完成し，尾鰭と胸鰭の鰭条が出現し始める。さらに脊索末端部の上屈もすすむ。脊索末端部の屈曲と尾鰭鰭条の発達は，尾鰭による推進力の増加を示している（例えばKohno *et al.*, 1983)。また，神経棘と血管棘の発達は，尾鰭の推進力を体軸に沿って後方に伝えることで，より効率の良い推進力を得ているもとの考えられる（例えばGosline, 1971)。これらのことから，この期間には，体全体による遊泳力に，尾鰭による推進力が加わる時期であると判断される。

バランス遊泳期（D-15 [約11 mm]〜D-25／D-30 [約13〜17 mm]）：この時期にはいろいろな形態的変化が生じた。まず，最大体高とその位置に変曲点が見られたが，これは前進する能力の向上を示していると考えられる（Aleev, 1963；Kohno *et al.*, 1983, 1984)。背鰭と臀鰭の鰭条も出現し始め，D-20までには神経棘や血管棘のすべてが化骨しすべての椎骨も出現する。これらの形質の発現や発達は，Gosline（1971）が指摘しているように，尾鰭推進力による体の横ブレを制御し，尾鰭による推進力をより強いものとする。さらに尾鰭鰭条も数的に完成し，脊索末端部の屈曲も完了する。以上のことから，尾鰭による推進とシラス型体形をうまく利用した体全体を使った遊泳がバランスよく適合し，遊泳能力がかなり向上する時期であると考えられる。

D-25から30にかけてはほぼ完全な遊泳を行うと考えられる。しかし，腹鰭の鰭条が未発達で，さらに最大体高やその位置もまだD-30に変曲点が認められることから，この期間は完成期への移行期で，バランス遊泳期の一部であると判断した。

完成期（D-30 [約17 mm] 以降）：遊泳に関する形質の出現や化骨も完了し，また最大体高やその位置にも変曲点がみられた。したがって，この時期に，稚魚としての遊泳能力が獲得されたものと判断した。

摂餌機能　一方，摂餌機能の発達は，以下の3段階に大きく区分された（Fig. 4)。

吸い込み期（ふ化 [体長約8 mm]〜D-10 [約10 mm]）：ふ化時にすでに開口し，上顎と下顎の構成骨もほとんどが出現していた。さらに口腔を形成する懸垂骨と舌弓の構成要素もほとんどが出現し，いくつかの要素ではすでに化骨が始まっていた。初期の仔魚は口腔に陰圧を生じさせて餌を吸い込む（Gosline, 1971; Otten, 1982; Kohno *et al.*, 1996a, 1996b, 1997）が，このような口腔を形成する諸骨の発達は，餌の吸い込み能力がすでにかなりあることを示している。また，すでに発達している鰓条骨や鰓蓋骨も，口腔内陰圧を高める力を補佐している。上咽頭歯はふ化時に，また下咽頭歯もD-5から発達するが，Gosline（1971）によると，咽頭歯は捕らえた餌を確保し食道に送り込む働きがある。これらのことから，ふ化直後から，吸い込み摂餌という様式ではあるが，すでに高い能力を備えているものと判断できる。

機能的吸い込み期（D-10 [約10 mm]〜D-30 [約17 mm]）：口裂に占める前上顎骨の割合が一定になるが，これは口の開閉がかなり機能的になると考えられる（例えばKohno *et al.*, 1983, 1984)。口腔を形成する舌弓の化骨がほぼ完了し，懸垂骨の構成骨も化骨がすすむが，これは口腔内の陰圧をより高くする能力が向上したことを示す（河野・曽田，1998)。以上のことから，この期間には，かなり機能的な口の開閉と高い陰圧によって，かなり機能的な吸い込み摂餌を行うものと考えられる。上顎歯と下顎歯はD-15とD-25に出現し始めるが，この期間中は増加し続けることから，噛み付き様式には至らないと判断された。しかし，D-25（体長約13 mm)〜D-30の期間は，噛み付き様式の準備期と考えられる。

完成期（D-30 [約17 mm] 以降）：上・下顎歯も上・下咽頭歯も，数的にほぼ安定する。また口幅にも変曲点が認められる。したがって，自由な口の開閉と強力な口腔の陰圧による吸い込み摂餌に加えて噛み付き能力をも備え，稚魚の摂餌様式をほぼ獲得したと判断された。

なお，Kendall *et al.*（1984）の上屈仔魚（flexion larva）はD-0（約8 mm）からD-20（約13 mm）であった。さらに，各鰭の鰭条の定数からみた稚魚への変化はD-30（最小個体は体長17.5 mm）で，機能からみた稚魚への変化とほぼ一致した。

4.2　形態的・機能的発育と生態的発達の関連

クジメがふくまれるアイナメ類では，ふ化した後の数か月にわたる表層生活で，沿岸域から沖合いに分散し，その後沿岸の藻場や岩場，砂泥底域などに着底するという初期生活史を送る（岩槻・中田，1991；田中，1991)。ここでは，浮遊生活期のうち，遊泳・摂餌機能が完成する前と後に分けて，形態的な発育と生態的な発達とがどのように関連しているのかを論議する。

浮遊生活の前期　本種では，ふ化直後から遊泳機能も摂餌機能もある程度の能力を備えていると考えられた。これは，ほかの海産魚における形態的発育と比較しても，明らかに特異的である（Kohno *et al.*, 1983, 1984, 1997; 成澤ら，1997；Kohno, 1998)。例えば一般的な

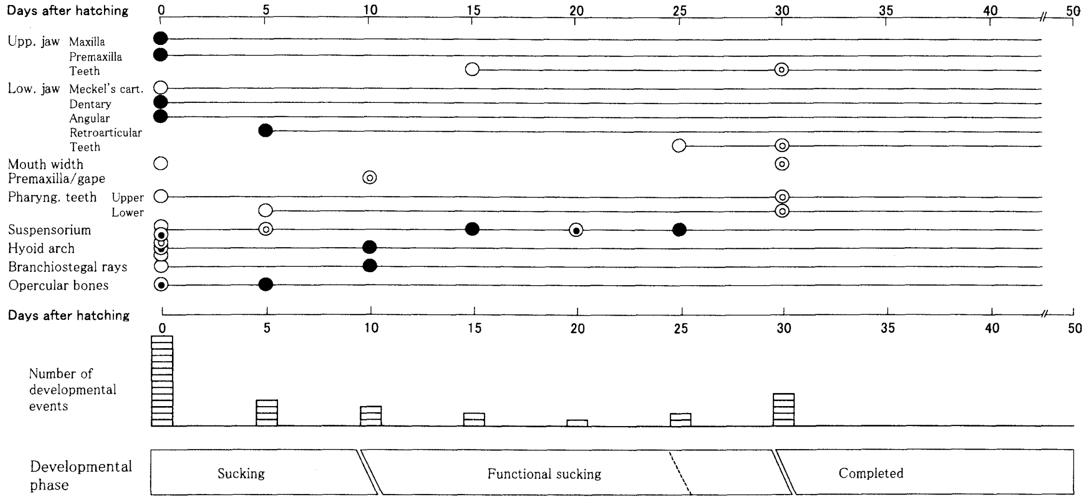

Fig. 4. Schematic representation of the development of feeding-related characters with days after hatching in *Hexagrammos agrammus*. ○: cartilaginous elements, teeth or branchiostegal rays start appearing, or mouth starts opening; ◉: cartilaginous elements start ossifying, or bony elements start appearing; ◎: all cartilaginous elements start appearing, or flexion points of teeth number or morphometric characters are observed; ●: all cartilaginous elements start ossifying, all bony elements start appearing, or branchiostegal rays become complete in number.

海産魚のふ化直後の仔魚では，遊泳に関連する形質は肩帯の擬鎖骨と肩甲–烏口軟骨，分化していない射出軟骨板くらいで，ほかの形質はふ化後1週間とか10日後に出現するが，本種では，肩帯以外にも尾鰭の支持骨や脊椎骨の血管・神経棘が出現し，さらに脊索末端部もすでに屈曲を開始していた。また摂餌についても，一般的な海産魚ではふ化当日は未開口で，数日して懸垂骨や舌弓などの口腔を構成する要素が出現するが，本種ではふ化した際にすでに開口し，さらに口腔や口裂を構成する要素がほとんど出現していた。なお，同じシラス型の体形をもつサバヒー（*Chanos chanos*）のふ化仔魚では，遊泳や摂餌に関する形質はほとんど発現しないことが知られている（Taki *et al*., 1987）。

岩槻・中田（1991, 1995）は，東京湾や紀伊水道の湾口部にアイナメ類の仔魚が，輸送されてくる，としている。さらに，田中（1991）は，沖合いから浅海域へと移動する接岸回遊を受動的な輸送を主とする前期と能動的な輸送を主とする後期とに分け，両期は変態によって区分されるとしている。しかし，形態的，機能的な観点から判断すると，少なくともクジメの場合には，ふ化から沖合いへの生活の場の拡大とそれに続く沖合いから浅海域への接岸回遊からなる浮遊生活期が，単なる受動的な分散ではなく，ある程度の能動的な移動・回遊によっているものと考えられる。

浮遊生活の後期から着底期　ふ化後30日，体長約17 mmで，形態的には遊泳や摂餌の機能がほぼ完成したと判断された。これは，丹下・竹田（1968）が観察した飼育個体の結果，すなわち全長20 mmを超えるふ化後27〜28日目に3個体中の1個体が底生生活をし始めたこととほぼ一致する。しかし彼らはまた，3個体中の2個体目は43日目頃に底生生活をし始めたことを報告している。本研究での観察でも，最初の底生生活個体が確認できたのはふ化後36日（35日目の最大個体の体長は20.1 mm）であった。一方，Matsumoto and Tanaka（1996）の飼育観察によると，最大の浮遊個体の体長は28 mm，最小の着底個体は37mm，着底あるいは底生生活はしていても体色が緑色から茶色へと変化している途中の中間型が25〜40 mmである。

以上の結果から，少なくとも飼育下では，体長20mmまでには遊泳・摂餌機能が発達して底生生活に移行できる準備ができ，さらに実際の着底は体長35 mmくらいであるが，体長20あるいは25〜40 mmの広い体長範囲で潜在的に着底は可能であると考えられる。

一方，天然海域では，黒田（1952）や小川（1963）の採集した浮遊していた個体の全長は45 mmあるいは43 mmで，小川（1963）のまとめた資料では，浮遊個体の全長は40〜45 mmである。これは，体長に換算すると34〜38 mmに相当する。さらに，本研究で用いた試料の採集場所である神奈川県三浦半島の油壷での野外採集によると，浮遊期は45日前後で，浮遊していた個体の最

大体長は32 mm，着底していた個体の最小体長は33 mmである（栗田，1993)。この様に，天然での着底体長は，飼育で観察された着底可能な体長の範囲の中でもより大きい方にかたより，しかもかなり限られた体長範囲となっている。また天然では，飼育で認められたような中間型は発見されておらず，浮遊型から底生生活型への体色および体形の変化は急に起こるものと考えられる。

生活史戦略の一つとして，各発育段階における死亡率をいかに減少させるか，ということがあげられる。本種のように浮遊生活から着底生活へと劇的な変化をする魚種にとって，いつ着底するかというのは環境条件に左右される（Cowen and Sponaugle, 1997）が，着底するかそのまま浮遊生活をするかということは発育段階の変化にともなう死亡率をいかに低く押さえるかという問題と関連する（Houde, 1997)。上述した天然と飼育下における着底様式の違いは，両者の環境要因の違い（例えば食圧や餌量，ストレスなど）に起因しているのかもしれない。

しかしいずれにしても，浮遊生活から着底あるいは底生生活に移行するためには，生理・生態的な変化や形態的な発達が必要である。本研究で明らかとなったように，少なくともクジメの場合には，底生生活に必要な形態的発達は，潜在的に着底可能となる体長 25 mmよりもかなり早い時期に見られた。これは，底生生活あるいは着底という生活史の中でのひとつの大きな転機に際して，機能的な裏付けを形態的に保証しているものと考えられる。

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Warm water structure that approaches to Kii Peninsula, separated from the straight zonal Kuroshio Path

Yoshihiko SEKINE* and Takayuki OKUBO**

Abstract : The warm Kuroshio water approach to Kii Peninsula which separates from coastal (northern) side of the straight zonal path and shifts along the eastern coast of the peninsula is frequently observed by the satellite thermal infrared imagery. Fortunately, we could observed the Kuroshio water approach to Kii Peninsula by Training Vessel "Seisui-maru" of Mie University in November 1997. The CTD and ADCP observations were carried out and the northward shift of the warm water along eastern coast of Kii Peninsula was observed. The main results of the observation is reported in this paper. It is detected that the warm water has a shallow thickness less than 50 m. The warm water shift to northeastward along the eastern coast of Kii peninsula with a velocity of 30 cm sec^{-1}, which agrees with those of Kimura and Sugimoto (1993, 2000) observed by direct current measurements. The observed northeastward velocity also agrees with that evaluated from satellite infrared imagery. It is suggested the velocity of 30 cm sec^{-1} along the eastern coast of the Kii Peninsula is mainly due to the westward velocity given in the separation process from the mean flow of the Kuroshio.

Key words : *Warm water separation, warm Kuroshio water tongue, Kii Peninsula*

1. Introduction

There have been various observations on the approach of the warm water separated from the Kuroshio to Kii Peninsula (TAKEUCHI, 1989; KIMURA and SUGIMOTO, 1987, 1990, 1993, 2000; SEKINE *et al*., 1991; KASAI *et al*., 1993). It is pointed out by SEKINE *et al*., 1991 that the warm Kuroshio water approaches to the eastern coast of the Kii Peninsula are classified into four types; the shallow warm streamer around the large cold water mass of the Kuroshio, the water tongue and the large detached warm eddy, both of which comes from the main axis of the Kuroshio, and the main axis of the Kuroshio. They also show that the warm water approaching to the eastern coast of Kii Peninsula is furthermore classified into two types by its thickness. One type is thinner than 100 m, which corresponds to the warm streamers and the warm water tongues. Another type is thicker than 200 m, which corresponds to the main Kuroshio axis and the large warm eddies detached from the main axis of the Kuroshio.

It is also commonly shown by KIMURA and SUGIMOTO (1990) and SEKINE *et al*., (1991) that the way of the approach of the warm water depends on the bimodal path of the Kuroshio. In periods of the large meander path, separated warm water is mainly formed in western side of the Izu Ridge south of Izu Peninsula and it shifts westward. In this case, the warm eddy approaches to Kii Peninsula from east and it shift southward along the coast of Kii Peninsula. Conversely, in periods of non-large meander path, as the main Kuroshio path runs zonally south of Kii Peninsula, the warm water comes from south and shifts northward.

Recently, KIMURA and SUGIMOTO (1993) showed that the spectrum of the current velocity by direct current measurements off Kii Peninsula has a dominant periods of 17–19 days with a wavelength of 400 km and a phase

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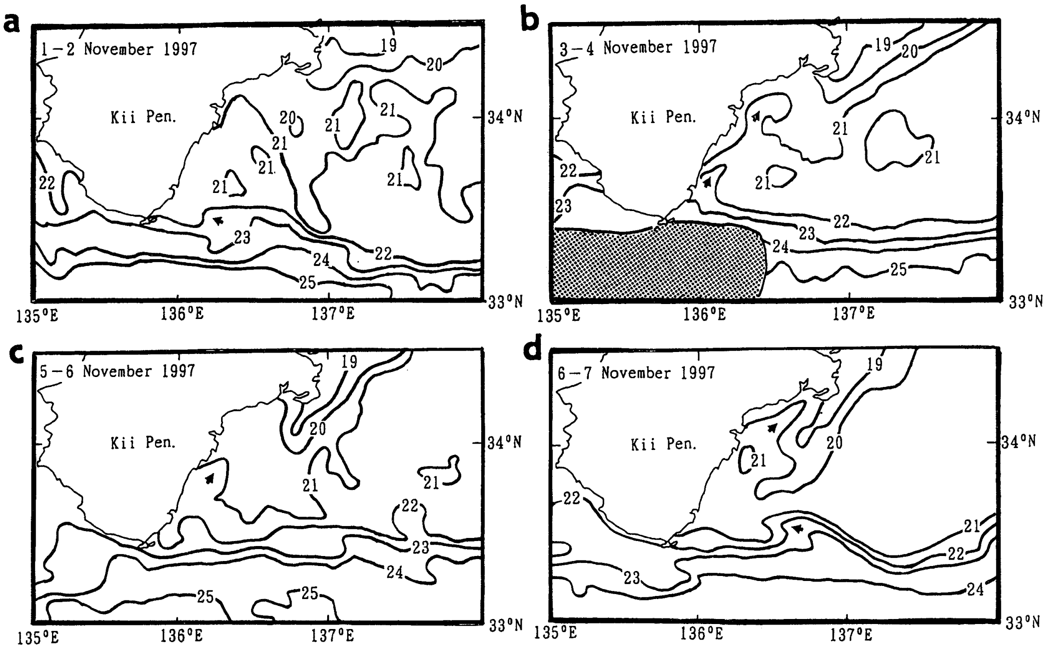

Fig. 1. SST (℃) shown by NOAA AVHRR composite on November (a) 1∼2, (b) 3∼4, (c) 5∼6 (6.13 AM) and (d) 6 (14.02 PM) ∼7, 1997. Small arrows indicate direction of the shift of the warm water, estimated by the comarison of the sequential imagery map of SST. Stipple area in (b) shows the cloud area.

velocity of 26 cm sec^{-1}. Furthermore, KIMURA and SUGIMOTO (2000) showed that there exists a phase velocity of 3 m sec^{-1}, which is estimated as a topographic Rossby wave. Since there exist many processes in the movement of the warm eddy detached from the Kuroshio, their classification and dynamics have not been well understood.

To know the dynamic process of the warm eddy detached from the main axis of the Kuroshio, detailed internal structure of the warm Kuroshio water should be observed more clearly. In this context, we can luckily observe a warm water approach to the Kii Peninsula by use of Training Vessel "Seisui-maru" of Mie University on 5–6 November, 1997. Composite of the satellite imageries of thermal infrared by NOAA 12–14 before and during the observation are shown in Fig. 1. Although repetition of the approach of the warm water is suggested on 1–4 November, a new warm water approach which is indicated by isotherm of 21℃ occurs on 5–6 November and it shifts northeastward along the eastern coast of the Kii Peninsula. We have observed this warm water off Kii Peninsula by use of CTD and ADCP and its oceanic structure has been clarified. Therefore, we presents the main results of the observation in this paper.

Details of the observation of the present study are described in the next section. The results of the observation are given in section 3, with a discussion in section 4.

2. Observation

CTD (MarkⅢ System of Niel Brown Instrument Systems, Inc.) observations along the observational lines shown in Fig. 2. were made by use of the Training Vessel "Seisui-maru" of Mie University during 5–6 November 1997. Three offshore observational lines are set off Kiinagashima, Owase Bay and Kata Bay, to observe the cross section of the warm water mass. The CTD observational points are placed every one nautical mile at the nearshore region and more two nautical miles at the offshore region. In order

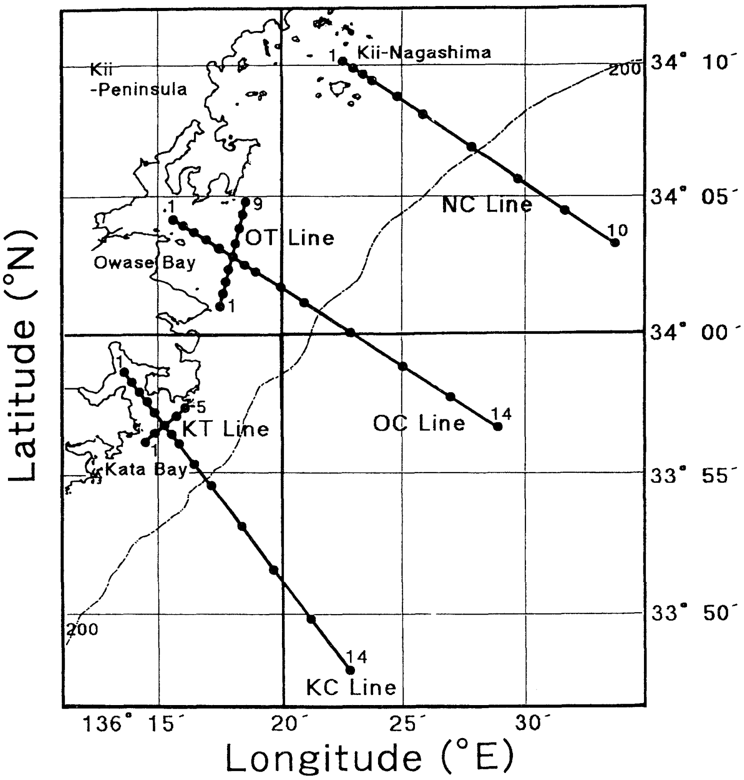

Fig. 2. Observational points and lines of CTD of the present study on November 5-6, 1997.

to see the influence on the oceanic condition of Owase Bay and Kata Bay, alongshore observational lines are set, which are referred to as OT line and KT line, respectively. ADCP observations at depths of 10m, 50m and 100m were also carried out along these observational lines.

CTD observation began at Station 1 of NC line (Fig. 2) at 5 PM on 5 November and that of the station 10 ended at three hours later. The observation of OC line began at 20.5 PM of the same day from the station 14 to the station 1, and ended at 12 PM. The observation of KC line began at 2 AM on 6 November from the station 14 to the station 1 and ended at 7.5 AM. In next, CTD observations along the observational lines off the Kata Bay (KT line) were carried out from 8 AM at Station 1 and it took 30 minutes. The observation of OT line began at 9 AM from the station 1 and ended at 10 AM at the station 9. Checks of the observed CTD data in comparison with standard salinity water were carried out at three observational points with about 10 layers and the worst-case accuracy of the observed CTD data was found to be 0.02 psu.

3. Results

Observed temperature, salinity and density (σt) fields along three offshore observational lines are shown in Fig. 3. As is indicated from Fig. 1, the warm Kuroshio water warmer than 21℃ is detected at the KC line (Fig. 3c). The warm water is also seen at OC line and NC line with a maximum temperature of 20.25℃. A saline water more than 34.45 psu is found at the KC line (Fig. 3c), however, such a saline water does not exist in other two lines of OC and NC (Fig. 3ab). Although the tongueshaped intrusion of the warm water is commonly suggested in three observational lines, the salinity is different between KC line and lines OC and NC. The CTD observations along NC line and OC line were carried out on 5 November, while the observation of KC line was made on 6 November (for details, see section, 2). It is suggested

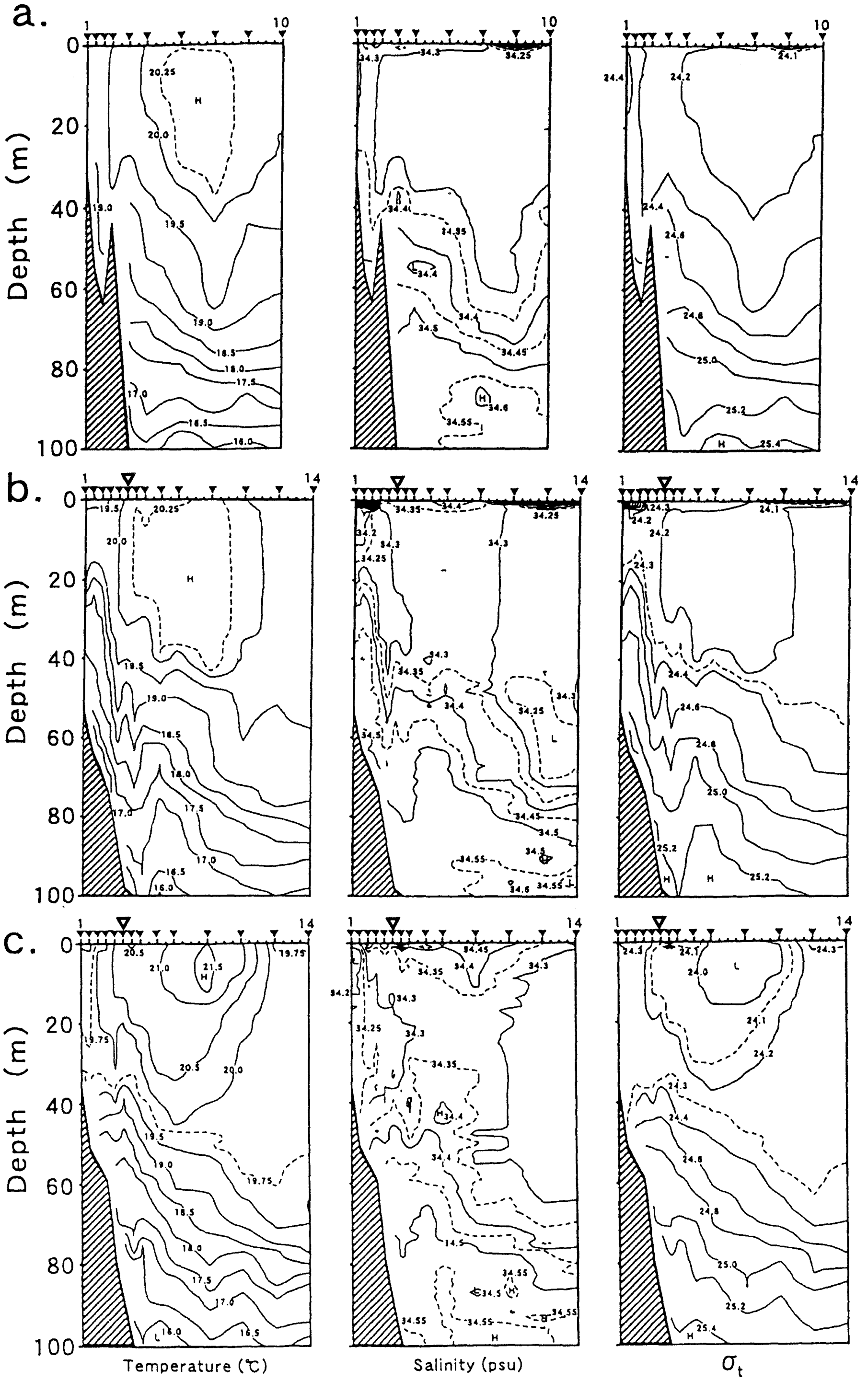

Fig. 3. Observed temperature (℃) (left), salinity (psu) (center) and density(σ t) (right) fields along NC line (a), OC line (b) and KC line (c). Large open triangles upper the small triangles showing each observational point correspond to the cross points with the observational line of OT line (b) and KT line (C).

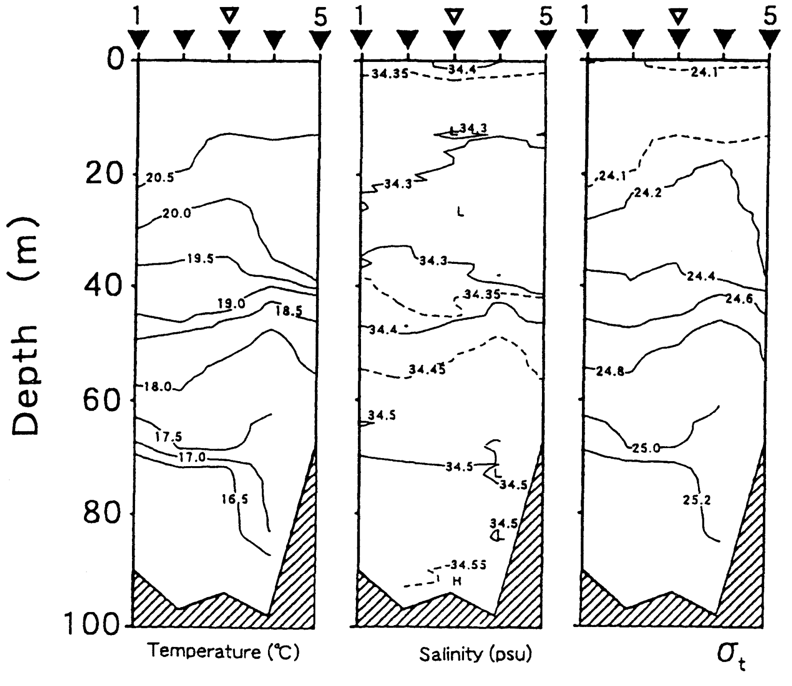

Fig. 4. Same as in Fig. 3 but for the KT line shown in Fig. 2. Cross point with the KC line is shown by open triangle.

that the observations along lines NC and OC were carried out after the approach of the warm water with the isotherm of 21℃ shown in Fig. 1b. However, the observation of line KC was made after new warm water approach shown in Fig. 1c, in which the front of the new warm water have not arrive at the observational lines OC and NC.

It should be noted that the warm water core has a thickness of 50 m (Fig. 3), which indicates that the warm water separated from the main Kuroshio path (Fig. 1) has a thickness smaller than that of the detached warm eddy with a thickness more than 200 m. It is also seen from the salinity fields of Fig. 3 that less saline water exists in a surface layer shallower than 2m along the observational lines OC and NC, while such a less saline water does not exist in line KC. On the basis of the T–S diagram of the Kuroshio region (e.g., Ishii *et al.*, 1983), there exists a less saline water in the surface layer due to the precipitation. The less saline water shown in Fig. 3ab may be caused by the precipitation, which suggests that the low salinity of the northeastward intrusion water at OC line and NC line in comparison with that of the KC line is also caused by the difference in vertical mixing with the less saline surface water.

Observed temperature, salinity and density fields along two alongshore observational lines KT and OT are shown in Figs. 4 and 5, respectively. As for KT line (Fig. 4), a warm water with the temperature of 20.5℃ and the salinity of 34.3 psu, which is detected along the KC line (Fig. 3c), exists horizontally along KT line and similar horizontal temperature and salinity distributions are perceived between KT line and KC line. Namely, lower layer water seen in Fig. 4 with a temperature of 16.5℃ and a salinity of 34.55 psu exists in the deepest layer of Fig. 3c. Although the observational line of OT line is longer than KT line, similar tendency is seen in Fig. 5, if we focus the common observational point; CTD observations at Station 5 of OT line and Station 6 of OC line are carried out independently, of which observational time difference is about 9 hours. It is suggested that a

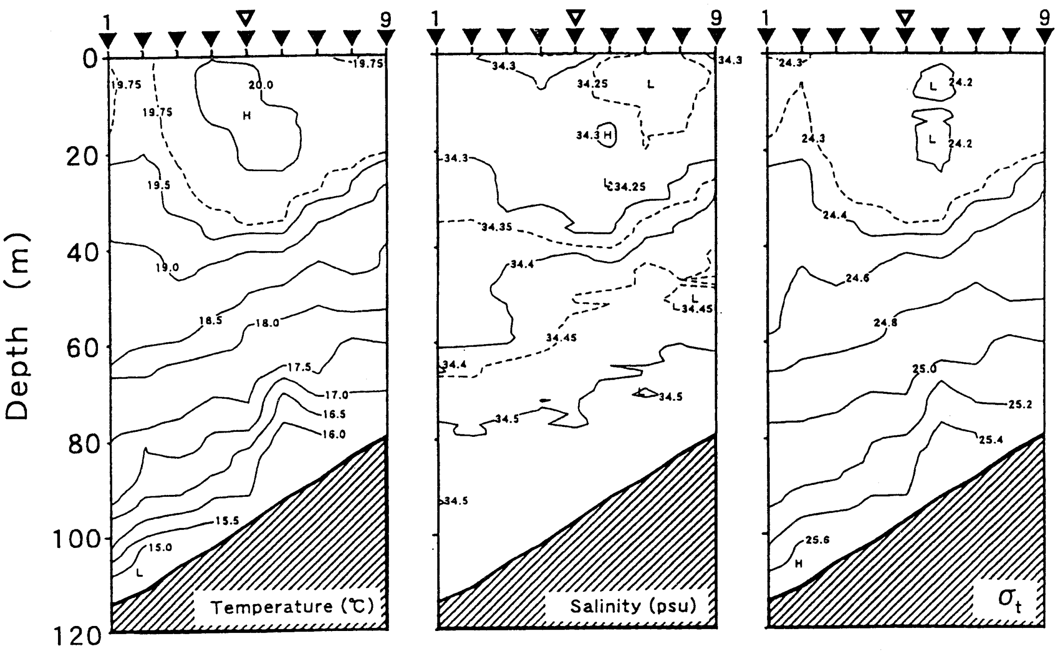

Fig. 5. Same as in Fig. 4 but for the OT line shown in Fig. 2

warm water structure is homogeneous along in the downward direction. Since the core water of the warm Kuroshio water does not reach to the bay mouth of Kata Bay (Fig. 4) and Owase Bay (Fig. 5), its influence on the oceanic condition of each bay is less in this case.

Observed velocity distribution by ADCP is shown in Fig. 6. Northeastward flow is dominated in a southern region at depths of 10m and 50m, while the northeastward flow is unclear in a northern region. This difference also implies that the new warm water shown in Fig. 3c approaches at the southern observational line KC, but it has not arrived at the two northern observational lines, OC and NC. It should be noticed that the northeastward flow in the southern region is clear at depths 10m and 50m, but it is unclear at a depth of 100m. This difference is explained by the fact that the thickness of the warm water tongue is about 50m (Fig. 3). The mean velocity of the northeastward flow along the eastern coast of the Kii Peninsula is 30 cm sec^{-1}, which agrees with the velocity of warm SST shift estimated from the SST imagery shown in Fig. 1.

4. Discussion

It is pointed out that the northeastward intrusion of the Kuroshio water has a velocity of 30cm sec^{-1}. This velocity agrees with that evaluated from satellite infrared imagery by use of the northeastward shift of the isotherms showing the warm water. This velocity also agrees with that shown by KIMURA and SUGIMOTO (1993, 2000) with a wavelength of 400 km and a period of 17–19 days. It is shown that the northeastward velocity shown by the present study is not due to the planetary or topographic Rossby wave, nor coastal Kelvin wave, because direction of the northeastward shift of the warm Kuroshio water shown by Figs. 1 and 6 is different from the directions of these waves.

The westward velocity of 30cm sec^{-1} after the separation from the eastward main Kuroshio path observed on 1 – 2 November shown in Fig. 1, which has the same velocity of the westward shift of the warm water newly separated on 6–7 shown in Fig. 1, is not considered as a external planetary Rossby wave; we assume that the wavelength of the planetary Rossby wave is 300km at most from Fig. 1, its phase velocity is about 8.1cm sec^{-1}. Here, the

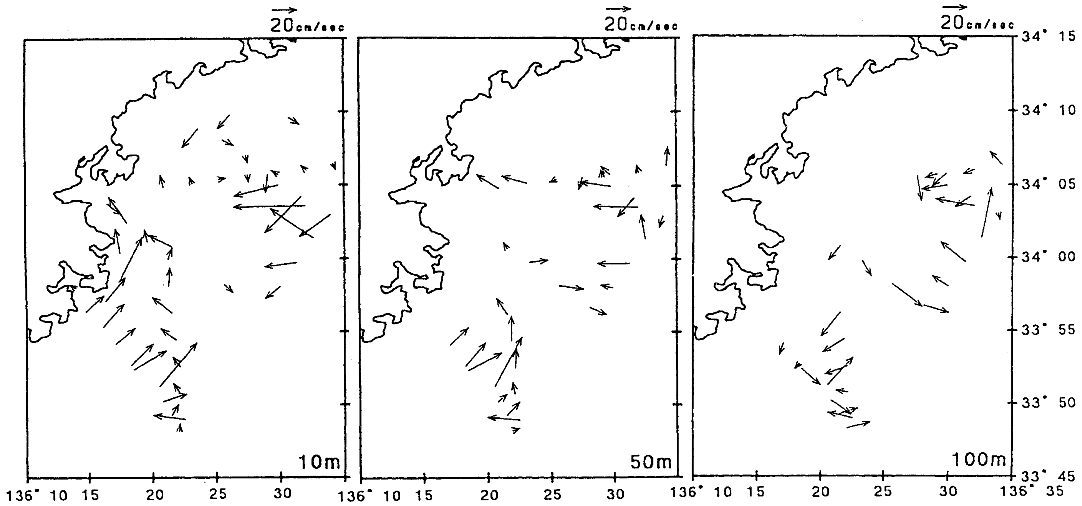

Fig. 6. Observed ADCP velocity at depths of 10 m (left), 50 m (center) and 100 m (right).

wavelength is estimated by assuming that the northward curve of isotherms of 21℃ and 22℃ in the zonal flow shown in Fig. 1d with a generation of new warm tongue east of Kii Peninsula is considered as a half wavelength of the planetary Rossby wave. As a phase velocity of the baroclinic planetary Rossby wave is much slower than the external wave, these two velocities are too small in comparison with the observed velocity of 30cm sec^{-1}. It is thus suggested that the northeastward velocity along the eastern coast of Kii Peninsula and westward velocity after the separation from the mean Kuroshio path of 30cm sec^{-1} are mainly associated with that given during the separation from the main Kuroshio path. However, more quantitative discussion is needed on this problem and it will be examined in the next stage of this study.

Acknowledgments

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Short note

Pigment composition of *Pedinomonas noctilucae* (Pedinophyceae), an endosymbiont of green *Noctiluca* (Dinophyceae)

Ken FURUYA* and Thaithaworn LIRDWITAYAPRASIT**

Abstract : Pigment composition of *Pedinomonas noctilucae*, a green flagellated endosymbiont of the green *Noctiluca* was examined using a unialgal culture by a reverse-phase HPLC method. The eight pigments identified were neoxanthin, antheraxanthin, violaxanthin, zeaxanthin, lutein, chlorophyll *b*, chlorophyll *a* and β, β-carotene in the order of elution. Five major pigments except antheraxanthin, were quantified to determine their pigment ratios to chlorophyll *a* for use in the evaluation of group-specific algal abundance from pigment composition.

Key words: Pedinomonas notilucae, *green* Noctiluca, *plant pigment, HPLC*

Noctiluca scintillans (Macartney) Ehrenberg, a widely distributed non-photosynthetic dinoflagellate forms dense blooms in temperate, subtropical and tropical coastal waters. The blooms of *N. scintillans* produce a strong pinkish red discoloration of the water in temperate regions. However, in southeast Asian tropical waters, *N. scintillans* causes green discoloration, as it contains the green flagellated endosymbionts, *Pedinomonas noctilucae* (Subrahmanyan) Sweeney (OSTROUMOFF, 1924; SWEENEY, 1971). The endosymbiont containing *Noctiluca* is commonly called the green *Noctiluca*, and their growth is sustained by the symbiont (SWEENEY, 1971: OKAICHI *et al.*, 1991). The presence of *P. noctilucae* is considered to be of vital impportance for bloom formation of the host organism. Although various biological characteristics of *P. noctilucae* have been revealed (SWEENEY, 1971, 1976; OKAICHI *et al.*, 1991), pigment composition of this species has not examined yet. In this communication, we describe the pigment composition of *P. noctilucae* as a baseline study for biomarker pigment analysis of the phytoplankton community in the Gulf of Thailand (MACKEY *et al.*, 1996). We thank Prof. Tomotoshi OKAICHI for valualle suggestions, Dr. Neelam RAMAIAH and Ms. Haruna SAITOH for their cooperation in the laboratory work.

A unialgal culture of *P. noctilucae* associated with the green *Noctiluca* was isolated from the inner Gulf of Thailand and maintained in the modified ESM medium (OKAICHI *et al.*, 1991). During the course of maintenance, cell morphology changed due to some unknown reason, from the flagellated form to a coccoid one lacking the flagella. The HPLC analysis reported here was made on the coccoid forms. The cultures were incubated at 28℃ under cool white fluorescence light at 10 and 150 μ mol $m^{-2}s^{-1}$ intensities. Cells during the exponential and stationary phases were harvested on GF/F filters by gentle suction with a pressure difference of 150 mmHg and frozen at −85℃. The

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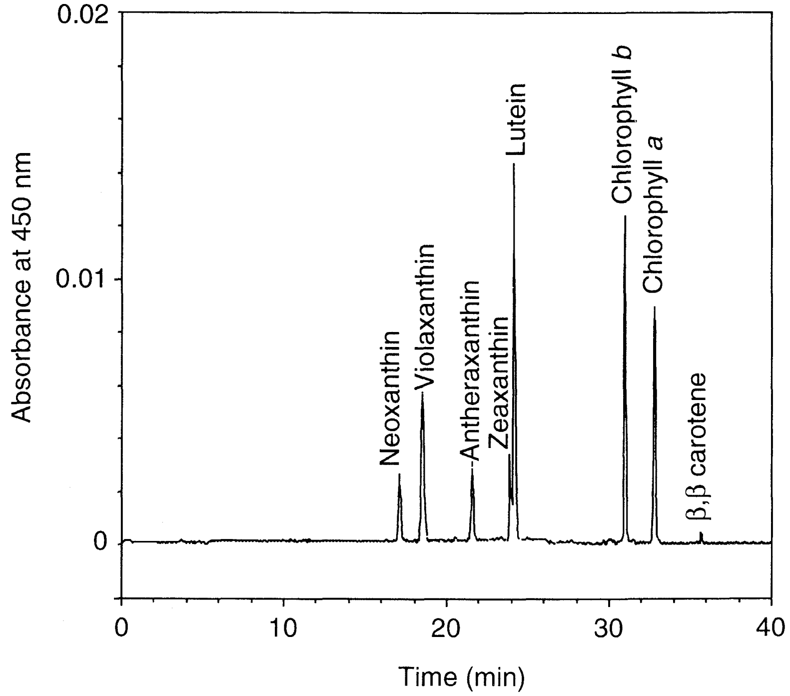

Fig. 1. Pigment composition of *Pedinomonas noctilucae* detected at 450nm.

filters were homogenized in 95% methanol with sonication and the extract passed through 0.2 μm PTFE syringe filters was subjected to the HPLC analysis (ZAPATA *et al.*, 2000) using a reverse phase C8 column. Details of the HPLC equipment we used are given in FURUYA *et al.* (1998).

Pigments were identified and quantified based on the retention time and peak area of the online absorption spectrum measured by a photodiode array spectrophotometer (SPD-M10AV, Shimadzu; 1.2 nm otpical resolution). Pure standards used for the identification and quantification viz., chlorophyll *a* (Chl. *a*), chlorophyll *b* (Chl. *b*) and β, β-carotene were obtained form Sigma Chemicals, while those for fucoxanthin, 19'-butanoyloxyfucoxanthin, 19'-hexanoyloxyfucoxanthin, peridinin, diadinoxanthin, alloxanthin, neoxanthin, violaxanthin, prasinoxanthin, echinenone, lutein, zeaxanthin, chlorophyll c_1 and chlorophyll c_2 were from the International Agency for ^{14}C Determination. Purity of these standards was examined both by the HPLC system and Shimadzu MPS-2400 spectrophotometer.

Six pigments identified as major-peaks were the neoxanthin, violaxanthin, zeaxanthin, lutein, Chl. *b* and Chl. *a* (Fig. 1). β, β-caroten e was eluted as the most non-polar pigment and appeared small peak that was possibly not well resolved from β, ε-carotene, if existed. A peak that was observed between the violaxanthin and zeaxanthin, was provisionally identified as antheraxanthin according to ZAPATA *et al.* (2000). This was re-examined by an additional analysis following the protocol of MANTOURA and LLEWELLYN (1983), and was confirmed to be antheraxanthin according to its characteristic phtodiode array spectrum (JEFFREY *et al.*, 1997). Three trace peaks were found at 3.8, 20.3 and 30.0 min. However, their identity was unclear, being extremely low in concentration that did not allow a clear inference from the diode array spectrum. Prasinoxanthin expected to appear between neoxanthin and violaxanthin (ZAPATA *et al.*, 2000) was not detected at all. *Pedinomonas minor* is known to lack prasinoxanthin (RICKETTS, 1970). Although available information is limited, the absence of prasinoxanthin seems

Table 1. Pigment composition of *Pedinomonas noctilucae* and the relative amount of respective pigments to Chl. *a* (w/w). Cells were harvested during the exponential phase from the cultures grown at 10 μmol m^{-2}s^{-1}(A) and 150 μmol m^{-2}s^{-1} (B) : "C" represents the cells harvested during the stationary phase from the culture grown at 150 μmol m^{-2}s^{-1}.

	Relative amount to chlorophyll *a* (w/w)					
Growth	Neoxanthin	Violaxanthin	Zeaxanthin	Lutein	Chlorophyll *b*	Chlorophyll *a*
A	0.078	0.128	0.088	0.271	0.115	1
B	0.080	0.118	0.059	0.224	0.092	1
C	0.132	0.194	0.244	0.477	0.088	1

to be a common feature of species belonging to the Pedinophyceae (MOESTRUP,1991).

Chl. *a* was the most abundant light-harvesting pigment and the ratio of Chl. *a* to Chl. *b* (w/w) remained rather constant around 10 (Table 1). In contrast, the relative amount of carotenoids to Chl. *a* increased during the stationary phase compared to that observed during the exponential phase. This was a common trend in the concentrations of the carotenoids detected. Although antheraxanthin was not quantified, a similar trend was observed in its peak area. β,β-carotene was not evaluated owing to its trace amount and a possible overlapping of β,ε-carotene. Light intensity did not exerted a significant influence on the pigment composition, as the ratios of the respective pigments to Chl. *a* did not vary much between the low and high light conditions. Nonetheless, light intensities used in the present study were rather low due to instrumental constraints. Since the light intensity near the surface in the tropical waters is much higher than those we used in our laboratory experiment, further investigation is required to confirm the variations, if any, in the pigment ratios that govern the predictability of group-specific algal abundance from pigment analysis (MACKEY *et al.*, 1996).

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資　料

La mer 第38巻第2号掲載欧文論文の和文要旨

Paolo MAGNI*・阿部奈緒*・門谷　茂*：表層堆積物中の底生微細藻類生物量の定量：分光光度法とHPLC法で測定したクロロフィル*a*量の比較

瀬戸内海の河口干潟域において，底生微細藻類中のクロロフィル*a*含有量を正確に見積もることを試み，いくつかの方法を検討した。すなわち，90%アセトンで抽出し，分光光度計を用いる方法，DMFで抽出し同様に分光光度計で測定する方法，及びDMFで抽出した後にHPLCを用いて測定する方法の3つである。

表層堆積物中のクロロフィル*a*含有量は，それぞれ7.0±0.9，7.0±1.1および7.2±1.0 $\mu \mathrm{g\,g}^{-1}$となり，互いに良く一致していた。しかしながら，堆積物柱を鉛直的に見て行くと，表層で一致していたものが，深度を増すとともに不一致が大きくなり，分光光度計で測定する方法では，HPCLを用いて測定する方法に比べて3～5倍の値を示し，クロロフィル*a*の分解生成物もクロロフィル*a*として，カウントされていることを示唆した。これらのことから，干潟堆積物柱の表層部以外のクロロフィル*a*含有量評価には，HPLCを用いて測定する方法が推奨される。(*香川大学農学部生命機能科学科　〒761-0795　香川県木田郡三木町池戸2393)

Suhendar I SACHOEMAR*・柳　哲雄：NOAA熱赤外画像によるジャワ島周辺の海面水温の季節変化**

ジャワ島周辺の海面水温の季節変動特性を明らかにするために，1995-1997年の3年間のNOAA熱赤外画像データを解析した。ジャワ島北部のジャワ海では，半年周期変動が卓越するのに対して，ジャワ島南部インド洋では周年変動が卓越する。ジャワ海の平均水温はインド洋のそれより1-2℃高い。ジャワ海の海面水温変動は主に海面熱収支に支配されているのに対して，インド洋のそれは季節風による沿岸湧昇に支配されている。(*九州大学大学院総合理工学府，**九州大学応用力学研究所　〒816-8580　福岡県春日市春日公園6－1)

関根義彦*・大久保孝之*：紀伊半島に接近する東に直進する黒潮から切離した暖水の構造

東西に走る黒潮直進（非蛇行）流路の北川から暖水が切離し，西進して紀伊半島東岸に接近し，その後東部海岸に沿って北上する現象が人工衛星の赤外画像から示唆される。1997年11月に，たまたまそのような暖水の北上を三重大学の勢水丸を用いてCTDおよびADCPによって観測することが出来た。本論ではこの観測結果を報告する。CTD観測により紀伊半島東岸に接近した黒潮系の暖水は，海面から50m程度の浅い舌状の構造を持ち，約30 cm sec^{-1}程度の速度で岸に沿って東北方向に北上することが示された。この速度は，KIMURA and SUGIMOTO（1993，2000）が示した水温変動から予測した流速とほぼ一致し，また人工衛星の赤外画像から推測される暖水の北上速度とほぼ一致する。暖水は黒潮から切離した時の西向きの流速で紀伊半島東岸を北上することが示唆された。(*三重大学生物資源学部海洋環境学講座　〒514-8507　三重県津市上浜町1515)

古谷　研*・Thaithaworn LIRDWITAYAPRASIT：グリーンノクチルカに細胞内共生する緑色鞭毛藻 *Pedinomonas noctilucae* の色素組成**

グリーンノクチルカに細胞内共生する緑色鞭毛藻*Pedinomonas noctilucae*の色素組成を，その単藻培養から逆相HPCLにより調べた。8種類の色素が検出され，溶出の順にネオキサンチン，アンテラキサンチン，ビオラキサンチン，ゼアキサンチン，ルテイン，クロロフィル*b*，クロロフィル*a*，ββ-カロチンであった。アンテラキサンチンを除く主要な5種類について，色素組成から植物プランクトン群集組成を定量するために必要な係数として，クロロフィル*a*に対する各色素の非を得た。(*東京大学大学院農学生命科学研究科水圏生物科学専攻　〒113-8657　東京都文京区弥生1-1-1，**Department of Marine Seience, Chulalongkorn University, Bangkok, Thailand 10330)

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学 会 記 事

1. 2000年7月27日（木）東京水産大学において平成12年度第2回幹事会が開かれた。

主な議事は下記の通り。

1）学術研究発表会のあり方について協議し，開催時期，講演要旨の取り扱い，会場の設営等について検討した。

2）学会誌のバックナンバーの残存状況について報告され，販売・処分の可能性について検討した。

3）長期会費滞納会員の取り扱いについて協議した。

4）第18期学術会議の海洋科学研連および水産学研連への委員派遣について，候補者の検討を行った。

5）日仏関連学会主催合同シンポジウムのパネラーの推薦について協議し，当面関，青木，長島，吉田各委員を候補者とし，詳細が明らかになり次第再度協議して最終的に決定することとした。

6）その他

(ア) 2000年度日仏学者交換事業で来日したLizon先生の滞在中の活動状況について報告された。

(イ) 学会誌の発行状況と今後の編集予定について報告された。

(ウ) 次回幹事会を10月26日（木）に東京水産大学で開催することとした。

2. 2000年10月26日（木）東京水産大学において平成12年度第3回幹事会が開かれた。

主な議事は下記の通り。

1）第18期学術会議海洋科学研究連絡委員会委員として前田明夫会員を，水産学研究連絡委員会委員として石丸　隆会員をそれぞれ推薦した。

2）10月24日に日仏関連諸学会連絡協議会が開かれ，須藤会長が出席した。懸案の合同シンポジウムは，12月9日（土）に「時間の本性を探る」をテーマに開催されることとなった。閉会後ワインパーティが開かれる予定。

3）会費長期滞納者に対して会費の督促を行い，納入されない場合は除名を含む何らかの処分を行うこととした。

4）2000年4月から9月までの学会会計の中間収支が報告され承認された。

5）学会誌のバックナンバーの処分法について協議し，第38巻3号に予定されている，総目次集発刊後，バックナンバーの残存状況を提示し，会費完納会員の希望者には安価で提供することとした。

6）学会誌の発刊予定について報告され，第38巻3号を日仏海洋学会40周年記念号として，第19巻（1981）～第37巻（1999）の総目次を掲載すること，第38巻第4号をJECSS-PAMS Proceedingsとすることが了承された。

3. 2000年11月21日（火）東京水産大学で平成13年度学会賞受賞候補者推薦委員会（第1回）が開催され，互選により青木三郎会員を委員長に選出し，候補者選出の方法，今後の日程について協議した。

4. 新入会員（正会員）

氏　名	所属・住所等	紹介者
富塚　明	長崎大学環境学部 〒852-8521　長崎市文教町1-14	松島　晟
Kashane Chalermwat	Department of Aquatic Science, Burapha University Bangsaen, Chonburi 20131, Thailand	山口征矢

5. 所属・住所等変更
（正会員・受付順）

高木和徳　〒104-0051　中央区佃2-1-2-3311
長谷川英一　水産庁さけ・ます資源管理センター
〒062-0922　札幌市豊平区中の島2条2丁目沢3-15-1

6. 退会（正会員）

堀　雅俊，佐々保雄，宮坂紘一，松島　晟

7. 受贈図書（受付順）

養殖研ニュース　45
Ship & Ocean Newsletter 1, 2
Bulletin of the National Science Museum 26 (2, 3)
なつしま　176, 177
Bulletin Tohoku National Fisheries Research Institute 162
NTT R & D 49 (10, 11)
農業工学研究所年報　12
Nii News　1
勇魚　23
海洋与湖沼　31（2, 3, 4）
J Ournal of the Korean Society of Oceanography 35(3)

お知らせ

日仏会館シンポジウム

時間の本性を探る

Le Temps

20世紀は，ミリ，ミクロ，ナノ秒というような超短時間に起こる諸現象の研究とその利用によって急速な進歩を実現しました。一方，宇宙科学，地球科学は最近の30年間に，誕生以来46億年の宇宙地球史の全貌を解明し始めました。改めて時間の本性を考えるよい時期に達しているように感じます。日仏科学・技術関連諸学会は最近明らかになりつつあるこれらの知見について認識を深め，時間というものの本性を考えてみることにしました。次のようなプログラムでシンポジウムを開きますので，なにとぞお誘い合わせのうえおいで下さいますようお待ちいたします。

日時　2000年12月9日（土）

会場　日仏会館ホール・入場無料

10：00　開会の辞　飯山敏道（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）「宇宙の時間・人間の時間」
小尾信弥氏（東京大学名誉教授，元放送大学学長）
司会　小林善彦（日仏会館常務理事）
12：00　昼休み
13：30　講演（2）「地球史解読の新たな流れと時間」
小西健二氏（金沢大学名誉教授）
司会　飯山敏道（日仏理工学会）
15：00　休息
15：30　講演（3）「演題未定」
今道友信氏（東京大学名誉教授）
司会　佐藤純一（日仏工業技術会）
17：00　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

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，日仏理工学会，日仏生物学会，日仏薬学会

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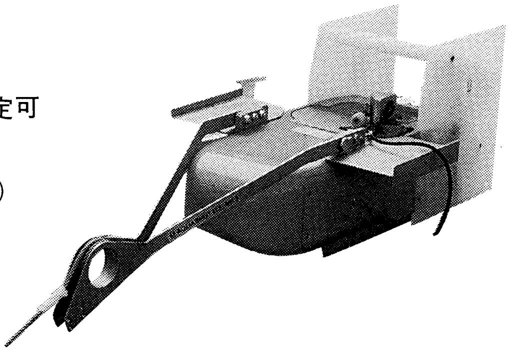

日仏海洋学会入会申込書

（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

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日仏海洋学会役員・評議員（2000-2001年度）

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