La mer 50 : 55-67, 2012
Société franco-japonaise d'océanographie, Tokyo

The role of greasyback shrimp (*Metapenaeus ensis*) in improved extensive shrimp farming systems in the Mekong Delta, Vietnam

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Abstract: In 2010, a variety of factors affecting the size and yield of *Metapenaeus ensis* were measured on shrimp farms in the My Xuyen (MX) and Dong Hai (DH) Districts, Mekong Delta, Vietnam. Studies were conducted in shrimp-rice paddy rotation systems (in MX) and in integrated shrimp-mangrove systems (in DH). A survey was conducted in 120 households, and samples were obtained from a total of 8 farms in the 2 districts. Results showed that *M. ensis* seed was collected from wild populations through tidal recruitment at sluice gates. The recruitment occurred multiple times per year. Yields of *M. ensis* in MX and DH were 31.0±5.9 kg • ha^{-1} • $year^{-1}$ and 39.2±4.7 kg • ha^{-1} • $year^{-1}$, respectively. The yields were positively correlated with the frequency of water exchange and with the depths of ditches and flat-forms ($p<0.01$). The contributions of *M. ensis* to the total shrimp yield in MX and DH were 6.0% and 12.2%, respectively, with respect to yield, and 8.5% and 7.3%, respectively, with respect to value.

Keywords: *Greasyback shrimp, Metapenaeus ensis, shrimp-rice paddy rotation systems, integrated shrimp-mangrove systems*

1. Introduction

Shrimp farming plays an important role in the societal and economic development of coastal communities in Vietnam (JOHNSTON *et al.*, 2000a; SINH, 2009). The area devoted to shrimp cultivation expanded from 90,000 ha in 1991 to 430,000 ha in 2003 (LOC, 2003), and the yield increased from 55,316 tons in 1995 to 413,132 tons in 2009 (ANONYMOUS, 2010a). Shrimp export values in 2007 were over US$ 1.2 billion (TU *et al.*, 2008).

In Vietnam, reported shrimp yields are mainly for the black tiger shrimp (*Penaeus monodon*), because this is the only species for which fishery managers have collected data and conducted annual assessments. The species has been studied by authors from both Vietnam and abroad from many viewpoints, such as fishery techniques, market factors, and societal and economic development. However, *P. monodon* is not the sole commercial shrimp species in Vietnam. Many other high-value species (e.g., *Metapenaeus ensis*, *Metapenaeus lysianassa*, and *Penaeus merguiensis*) are also harvested on shrimp farms. The seed sources for these (non-*P. monodon*) species are wild populations, referred to as "natural shrimp," collected by tidal recruitment (JOHNSTON *et al.*, 2000b). In contrast, artificial seed has been used in *P. monodon* since 1990 (NHUONG and HA, 2005).

The Mekong Delta (MD) in the southern region of Vietnam, with an area of about 39,000 km^2, contains 70% of the nation's shrimp farming. A variety of farming systems are used in this region.

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In traditional extensive shrimp farming systems, the wild seed is trapped and held until harvest. Stocking densities are low, food supplements are not provided, and there is no fertilization (BRENAN *et al.*, 2006). In improved extensive shrimp farming systems, the traditional system is modified by supplementation with artificial stocks of *P. monodon* (stocking density, 1−7 individuals • m^{-2}), either with or without feeding (PHUONG *et al.*, 2006; ANONYMOUS, 2007). Finally, in semi-intensive and intensive systems, which have steadily expanded since 2000 (VIET, 2006), *P. monodon* is cultured using intensive food and habitat enrichment schemes to produce rich harvests.

Metapenaeus ensis, which is caught and cultured as part of the traditional shrimp farming activities of local residents in Southeast Asia (LING, 1973), tolerates a wide range of salinity (5−30) and is in high local market demand because of its high meat quality (LIAO and CHAO, 1983; KING, 2001). In the Gulf of Carpentaria, Australia, the maximum total length is 154 mm for males and 189 mm for females (GARCIA, 1985). The longevity of *M. ensis* is approximately 14 months, as found in Hong Kong, China (LEUNG, 1991). Various aspects of this species have been investigated in different countries, such as its reproductive biology in Australia (COURTNEY *et al.*, 1989), its population dynamics in a shrimp pond in Hong Kong (LEUNG, 1997), and the modeling of population dynamics in Osaka Bay, Japan (TAGUCHI *et al.*, 2002).

In this study, we focused on the status of *M. ensis* in improved extensive shrimp farming systems in Vietnam. These systems constitute about 75% of the total shrimp farming area in MD. The results of this study contribute to the development of a critically needed database on resources vital to the socioeconomic well-being of populations in Southeast Asia, especially in the MD area.

2. Materials and Methods

2.1. Study sites

This study was conducted in 2010 in the My Xuyen (MX) district of Soc Trang Province and in the Dong Hai (DH) district of Bac Lieu Province in the MD (Fig.1). These locations are representative of the social, economic, and environmental characteristics of the MD region. MD, with its tropical climate, is biseasonal with a rainy season from June to November and a dry season from December to May (HUNG, 2009). An estimated 19% (786,329ha) of the total area is affected by changing water salinity, with predominately fresh water in the rainy season and brackish water in the dry season (VUONG and LIN, 2001). The most important locations for improved extensive shrimp farming systems are (1) in rice paddies by using shrimp-rice crop rotation and (2) in integrated shrimp-mangrove habitats.

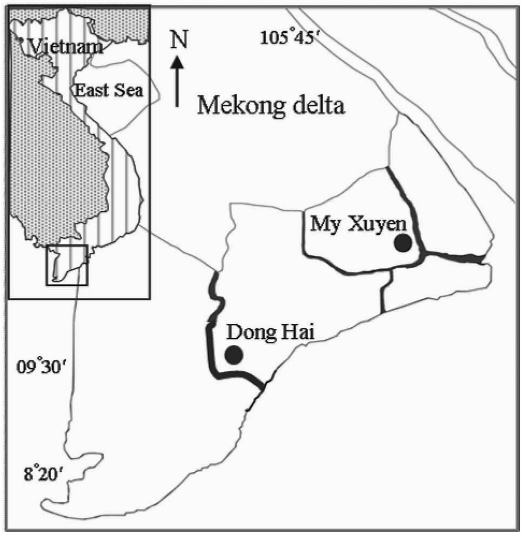

Fig. 1. Location map of Vietnam, the Mekong Delta, and sampling sites in the My Xuyen (MX) and Dong Hai (DH) Districts.

The shrimp-rice paddy rotation system, which was introduced 30−40years ago (VUONG and LIN, 2001; PRESTON *et al.*, 2003), consists of rice cultivation in the wet season (on flat-form areas in predominately fresh-water conditions) and shrimp culturing in the dry season (in predominately saline-water conditions) (BRENNAN *et al.*, 2002). Rice is cultivated from June/July to September/October, when salinity is 0−3, while shrimp are cultured from January/March to May/June, when salinity is greater than 3.

The total land area of the MX district is

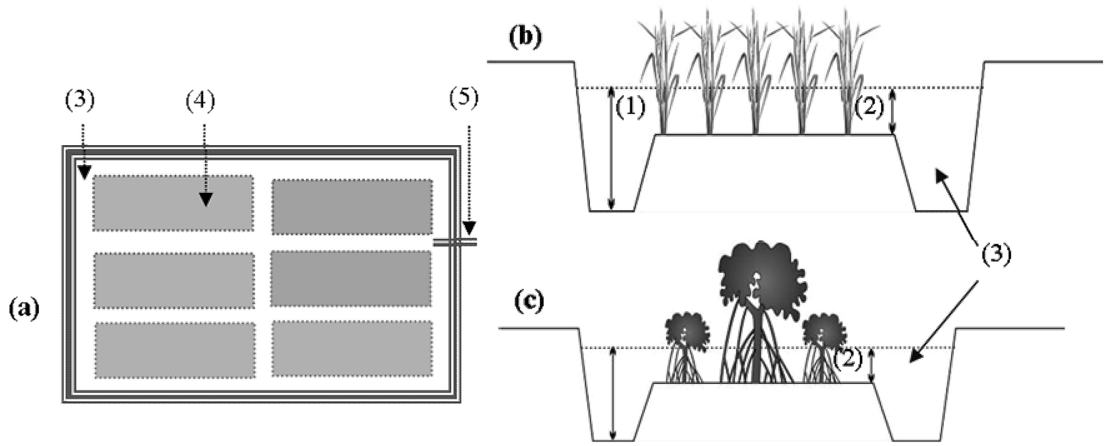

Fig. 2. Construction of farms in the My Xuyen and Dong Hai Districts, designed for improved extensive shrimp culture farming. (a) Relative proportions of ditch and flat-form areas; (b) and (c) Transects of a shrimp-rice paddy rotation system and an integrated shrimp-mangrove system located in MX and DH, respectively, showing (1) ditch depth; (2) depth of flat-form; (3) ditch; (4) flat-form; and (5) sluice gate.

54,450ha (ANONYMOUS, 2010b). The area of shrimp-rice paddy rotation increased from 500ha in 1982 to 6,635ha in 1988 (PRESTON *et al.,* 2003) and to 20,200ha in 2010 (ANONYMOUS, 2011a). Combined shrimp-rice farming provides enhanced income and economic benefits to farmers, as compared with that provided by the cultivation of either shrimp or rice alone (VUONG and LIN, 2001). Mangrove forests occupy 52,786ha in the DH district (ANONYMOUS, 2010c), in regions where salinity ranges from 28 to 34 (ANONYMOUS, 2010d). Shrimp-mangrove farms are designed so that mangrove trees occupy flat-form areas and shrimp are cultured throughout the year. The operational principles of this system are described by BINH *et al.* (1997) and JOHNSTON *et al.* (2000a). The design of these farms is shown in Fig. 2.

2.2. Data collection

Information was collected in a survey of 60 households from each district, it contains farming area, depth of flat-form and ditch, frequency of water change, yields and prices of *M. ensis* and *P. monodon* and other shrimps, investment and income. The participants were farmers who were applying the improved extensive system in these districts.

Table 1. Areas and abbreviations of farms in the two districts where samples were collected.

My Xuyen		Dong Hai	
Farm	Area (ha)	Farm	Area (ha)
AMX	1	ADH	4.3
BMX	1.5	BDH	2.5
CMX	1	CDH	3
DMX	0.6	DDH	3.4
Mean ± SD	1.03 ± 0.4	Mean ± SD	3.3 ± 0.8

Shrimp sampling was conducted at a total of 8 farms in the MX and DH districts (4 farms in each district). Table 1 shows the area of each farm. The distance between farms in both districts was about 0.2 km. Shrimp culturing/harvesting in MX occurs only during the dry season; therefore, sampling was conducted only between January and June. *Metapenaeus ensis* in MX farms was collected at night by using trap nets, as shown in Fig. 3 (a), with a mesh size of 1.5－1.7 cm. The trap nets were submerged in the ditch, as shown in Fig. 2 (b－3). Sampling was performed on 2 nights, for approximately 8h each night (9：00PM to 5：00 AM), by using 6 trap nets at each farm during each sampling time.

In contrast, shrimp culturing in DH occurs

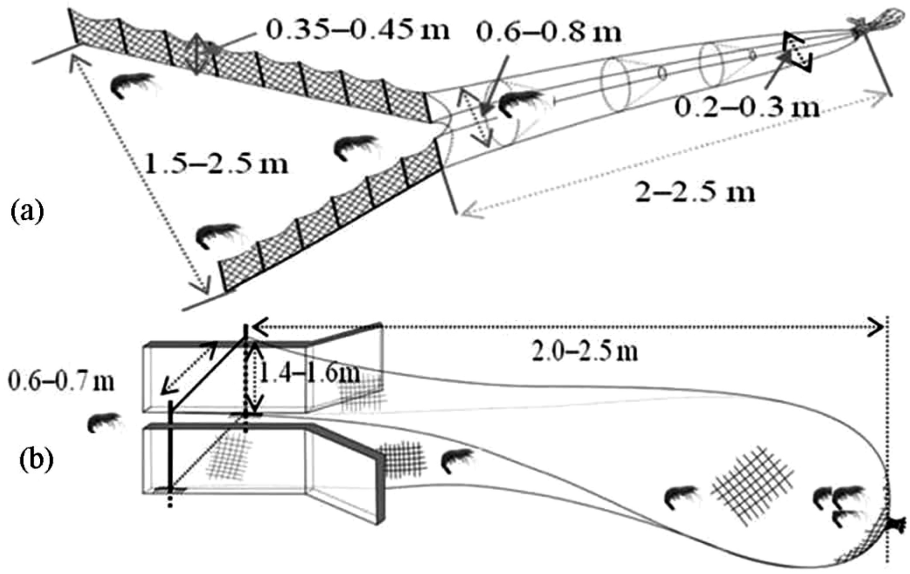

Fig. 3. Trap net design used to catch shrimp in ditches (a) and sluice gates (b).

throughout the year, and sampling was conducted in February, April, June, August, October, and December in 2010. The sampling was conducted during the spring tide of each month, drainage was controlled using a sluice gate, as shown in Fig. 3 (b), through which shrimp were recruited and harvested. *Metapenaeus ensis* was sampled on 2 nights, for 3－4h per night, by using a single sluice gate at each farm.

Shrimp samples collected inside the farms included shrimp obtained via new recruitment and old shrimp from previous recruitments. The samples of *M. ensis* were kept in ice prior to the measurement of carapace length (CL). CL was measured to the nearest millimeter by using calipers and defined as the shortest distance between the posterior margin of the orbit and the mid-dorsal posterior edge of the carapace. In addition, salinity was measured as an important physical characteristic of the water (MACIA, 2004).

2.3. Data analysis

The non-parametric Wilcox test was used to test the significance of differences between the observed variables in the 2 districts. Akaike's Information Criterion (AIC) (AKAIKE, 1973) was used to select the variables that affected the yield, and these variables were used in the multivariate regression models (DALGAARD, 2002; FARAWAY, 2005).

In this case, the dependent variable, y, is defined as the yield of *M. ensis*, and the maximum number of independent variables, which were defined later, is 6. The number of models, which are constructed using a single independent variable (x_1, x_2, $\cdots$, or x_6), can be calculated by the combination $C(6, 1)=6$, i.e., $y=f_1(x_1)$, $y=f_2(x_2)$, $\cdots$, $y=f_6(x_6)$. The number of models, which are constructed using 2 independent variables (x_1, x_2), (x_1, x_3), $\cdots$, or (x_5, x_6), can be calculated by the combination $C(6, 2)=15$, i.e., $y=f_7(x_1, x_2)$, $y=f_8(x_1, x_3)$, $\cdots$, $y=f_{21}(x_5, x_6)$. The total number of models can be calculated by the summation of the combinations $\sum_{i=1}^{6} C(6, i)=64$. We calculated the AIC values for each of the 64 models and selected the optimal model as the one with the lowest AIC (FARAWAY, 2005).
When the linear regression equation is expressed as follows :

$$\hat{y} = \hat{\alpha} + \hat{\beta}_1 x_1 + \hat{\beta}_2 x_2 + \cdots + \hat{\beta}_k x_k$$

with $k+1$ parameters $(\hat{\alpha}, \hat{\beta}_1, \hat{\beta}_2, \cdots, \hat{\beta}_k)$, and the

Table 2. Parameters of the improved extensive shrimp farming systems in the MX (mainly shrimp –rice paddy rotation systems) and the DH (mainly integrated shrimp–mangrove forest systems) (mean±standard deviation).

Item	My Xuyen (n=60)	Dong Hai (n=60)
Period of shrimp culture (month•year^{-1})	6	12
Farming area (ha•household^{-1})	0.9±0.3^{a}	1.7±0.6^{b}
Depth of flat–form (m)	0.5±0.3^{a}	0.4±0.1^{b}
Depth of ditch (m)	0.9±0.1^{a}	0.8±0.1^{b}
Frequency of water exchange (times•year^{-1})	6.6±1.2^{a}	19.5±1.8^{b}
Yield of M. ensis (kg •ha^{-1}•year^{-1})	31.0±5.9^{a}	39.2±4.7^{b}
Coefficient of variation of M. ensis yield (CV)(%)	18.9	11.9
Price of M. ensis (US$•kg^{-1})	3.4±0.5^{a}	3.5±0.1^{a}
Yield of P. monodon (kg•ha^{-1}•year^{-1})	539.5±265.7^{a}	322.2±91.7^{b}
CV of P. monodon yield (%)	49.3	28.4
Price of P. monodon (US$•kg^{-1})	5.3±0.4^{a}	6.7±0.7^{b}
Yield of aquatic other species (kg•ha^{-1}•year^{-1})	30.5 ±.5.7^{a}	29.2±7.6^{a}
CV of aquatic other species (%)	18.8	26.0
Price of aquatic other species (US$•kg^{-1})	1.7±0.2^{a}	1.5±0.1^{b}
Total investment from shrimp (US$•ha^{-1}•year^{-1})	861.5±179.7^{a}	308.5±71.6^{b}
Net income from shrimp (US$•ha^{-1}•year^{-1})	2,380 ±1,666^{a}	2,108±741.8^{b}
CV of income from shrimp (%)	70	35.1
Total cost from rice paddy US$•ha^{-1}•crop^{-1})	934±130	0
Net income from rice paddy (US$•ha^{-1}•crop^{-1})	645.7±117.6	0
Coefficient of variation of rice paddy (%)	18	Invalid
Total of net income (US$•ha^{-1}•year^{-1})	2,444.8±1,650^{a}	2,108±741.8^{b}
Total of net income (US$•household^{-1}•year^{-1})	2,716.5±1,485^{a}	3,584±1,681^{b}
CV of net income household^{-1}year^{-1} (%)	54.6	36.3

Mean values of parameters in the same row with the different superscripts show significant different ($p<0.01$)

residual sum of squares is expressed as $RSS=\sum_{i=1}^{n}(\hat{y}_i-y_i)^2$, then AIC is calculated by :

$$AIC = \log\left(\frac{RSS}{n}\right)+\frac{2k}{n}$$

where n is the number of samples.

The density function was used to determine the variations in CL for each sampling time. The CL had a normal distribution; analysis of variation and Tukey's honestly significant difference test were used to test for the significance of CL variations between different months.

To relate these data to characteristics of the shrimp culture system, 8 variables (defined later) were selected from the surveys for analysis. These variables were considered to have effects on the system in terms of the aquaculture (Macia, 2004), and they were hypothesized to have effects on the yield and CL of *M. ensis*. Factor analysis (FA) was used to reduce the original number of variables and identify new variables that explained the most important variances in the data.

3. Results

3.1. Contribution of *M. ensis* to households

The contribution of *M. ensis* to the total shrimp yield in the MX and DH districts in 2009 was 6.0% and 12.2%, respectively, in terms of physical yield, and 8.5% and 7.3%, respectively, in terms of crop value. The yields of

Table 3. Results of factor analysis, based on eight parameters obtained from the survey of 120 households in My Xuyen and Dong Hai. The eight parameters were extracted from Table 2.

	My Xuyen		Dong Hai	
	Factor 1	Factor 2	Factor 1	Factor 2
P. monodon yield (kg•ha^{-1}•year^{-1})	0.9		0.99	
Depth of flat–form (m)			0.77	
Depth of ditch (m)	0.50		0.64	
Net income (US$•ha^{-1}•year^{-1})	0.97		0.95	
M. ensis yield (kg•ha^{-1}•year^{-1})		0.87		0.94
Frequency of water exchange (times•year^{-1})		0.70		0.79
Yield of other species (kg•ha^{-1}•year^{-1})				
Total cost of shrimp production (US$•ha^{-1}•year^{-1})				
Coefficient of determination	0.26	0.16	0.37	0.21
Total coefficient of determination		0.42		0.58

M. ensis were found to be more stable than those of *P. monodon*. The coefficients of variation for *M. ensis* yields were 18.9% and 11.9% in the MX and DH districts, respectively, while those for *P. monodon* yields in the 2 districts were 49.3% and 28.4%, respectively (Table 2).

According to farmers in MX, the main purpose of food supplements is to feed *P. monodon,* because this species is stocked at a density of 5–6 individuals • m^{-2}. In contrast, in DH the land area per household is larger than the land area of MX households ($p<0.01$) (Table 2), and *P. monodon* is stocked at lower densities (1–3 individuals • m^{-2}) 3–5 times per year. This pattern of stocking is referred to as thinning (by harvesting) and subsequent stock compensation, enabling shrimp farms to maintain a low density of individuals without food supplements.

The total investment for shrimp culturing in MX was higher than that in DH ($p<0.01$). However, the situation reversed with respect to the net income from shrimp culturing in the 2 districts, which was significantly different ($p<0.01$) (Table 2). However, farmers in MX also obtain an income from rice paddy harvests in the rainy season (Table 2) ; therefore, their income per hectare is actually higher than that of the DH residents. While DH is located in the ecological mangrove region, the region can not grow rice paddy. Besides, shrimp culture activities of farmers in the region are used depending much on natural environment, low investment and low yield, farming area of each household in DH is larger area than in MX, thus, their income per household are higher than in MX (Table 2).

FA was used to identify 2 orthogonal linear combinations of the 8 original parameters measured in MX (Table 3). These 2 factors are shown in Fig.4 (a). Factor 1 has 3 components, representing a positive correlation between the depth of the ditch and the yield of *P. monodon* and net income. Factor2 has 2 components, representing a positive correlation with the number of water exchanges and the yield of *M. ensis.* These factors explained 42% of the original variance; factors 1 and 2 explained 26% and 16%, respectively, of the variance in the data.

Similarly, the first 2 factors of the FA in DH explain 58% of the variance in the 8 original parameters measured in DH (Table 3). These factors (Fig. 4 (b)) showed that factor 1 has 4 components, representing a positive correlation among the yield of *P. monodon*, the depth of the flat-form, the depth of the ditch, and the net household income. Factor2 has 2 components, representing the yield of *M. ensis* and the number of water exchanges. Factors 1 and 2 explained 37% and 21%, respectively, of the variance in the DH data.

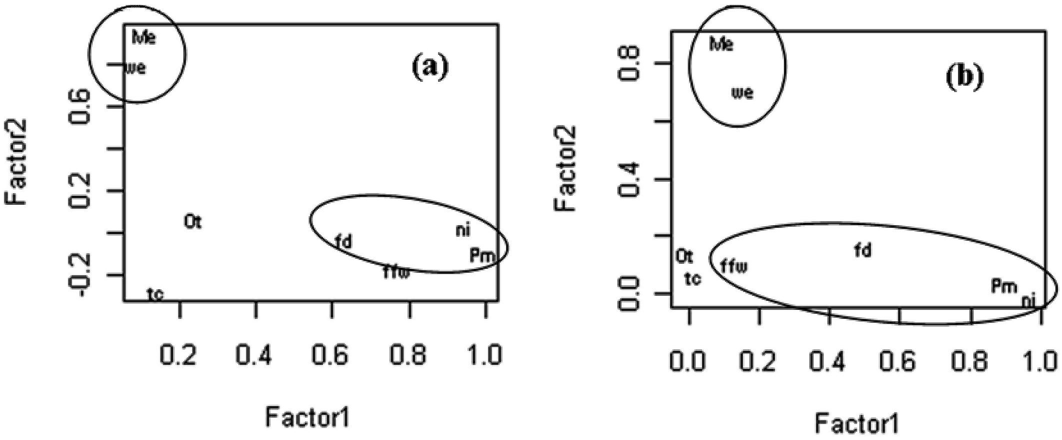

Fig. 4. Plot of the first 2 factor analysis loading vectors for My Xuyen (a) and Dong Hai (b). Me : *M. ensis* yield; we : number of water exchanges; Ot : yield of other species; fd : depth of ditch; ffw : depth of flat-form; tc : total cost; ni : net income; and Pm : *P. monodon* yield.

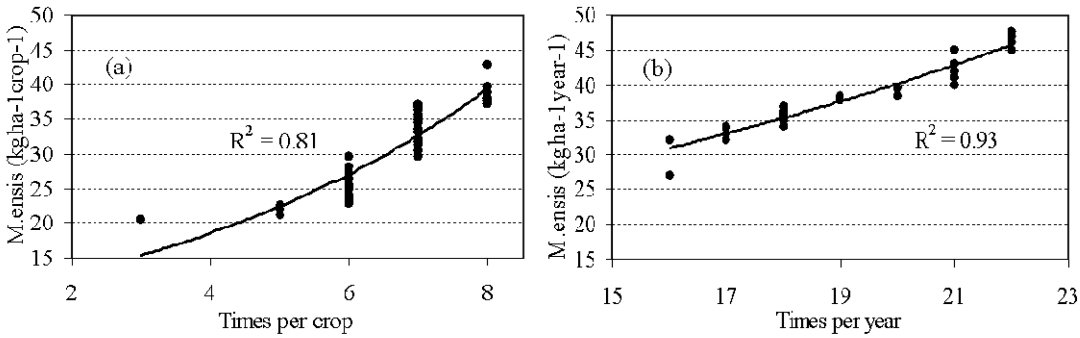

Fig. 5. Correlation between frequecies of water exchange and *M. ensis* yields in My Xuyen (a) and Dong Hai (b).

3.2. Variables affecting the yield of *M. ensis*

Farmers in MX often add more water to their farms to compensate for leakage or evaporation, and they limit the drainage of water away from farms because brackish water is scarce and the quality is variable. We found that the number of water exchanges in DH was higher than that in MX ($p<0.01$; Table 2) and that yields of *M. ensis* were positively correlated with the number of water exchanges (Fig. 5).

Ditches and flat-forms were deeper in MX than in DH ($p<0.01$). Results of the multivariate regression analysis were as follows. When 6 independent variables (x_{1sr}, x_{2sr}, x_{3sr}, x_{4sr}, x_{5sr}, and x_{6sr}) were used, the model explained 46% of the variance in the yield of *M. ensis*, where x_{1sr}, x_{2sr}, x_{3sr}, x_{4sr}, x_{5sr}, and x_{6sr} denote the rate of water exchange, depth of ditch, depth of flat-form, yield of other species, yield of *P. monodon*, and price of *P. monodon*, respectively. The number of water exchanges (x_{1sr}) was significant in all the cases; this variable is a significant predictor of *M. ensis* yields ($p<0.01$). The optimal model that minimized the AIC value (AIC=184, $R^2=0.45$) was as follows :

$$y_{sr}=3.6+3.18\,x_{1sr}+0.96\,x_{2sr}+11.35\,x_{3sr} \qquad (1)$$

Table 4. Predictions for optimal yields of *M. ensis* in the My Xuyen (MX) and Dong Hai (DH) districts with multivariate regression models. Subscriptions of *sr* and *sm* denote the shrimp rice in MX and shrimp mangrove in DH, respectively. *y* denotes the *M. ensis* yield. x_1, x_2, x_3, x_4, x_5, *and* x_6 denote the frequency of water exchange, depth of ditch, depth of flat-form, yield of other species, yield of P. monodon, and quantity of *P. monodon* stocked, respectively.

MX (N=60)			DH (N=60)		
Model	AIC	R^2	Model	AIC	R^2
$y_{sr}=f\ (x_{1sr}, x_{2sr}, x_{3sr}, x_{4sr}, x_{5sr}, x_{6sr})$	188	0.46	$y_{sm}=f\ (x_{1sm}, x_{2sm}, x_{3sm}, x_{4sm}, x_{5sm}, x_{6sm})$	144	0.59
$y_{sr}=f\ (x_{1sr}, x_{2sr}, x_{3sr}, x_{4sr}, x_{5sr})$	186	0.46	$y_{sm}=f\ (x_{1sm}, x_{2sm}, x_{3sm}, x_{4sm}, x_{5sm})$	143	0.58
$y_{sr}=f\ (x_{1sr}, x_{2sr}, x_{3sr}, x_{4sr})$	185	0.46	$y_{sm}=f\ (x_{1sm}, x_{2sm}, x_{3sm}, x_{4sm})$	141	0.58
$y_{sr}=f\ (x_{1sr}, x_{2sr}, x_{3sr})$	184	0.45	$y_{sm}=f\ (x_{1sm}, x_{2sm}, x_{3sm})$	140	0.57
			$y_{sm}=f\ (x_{1sm}, x_{2sm})$	139	0.56
			$y_{sm}=f\ (x_{1sm})$	138	0.56

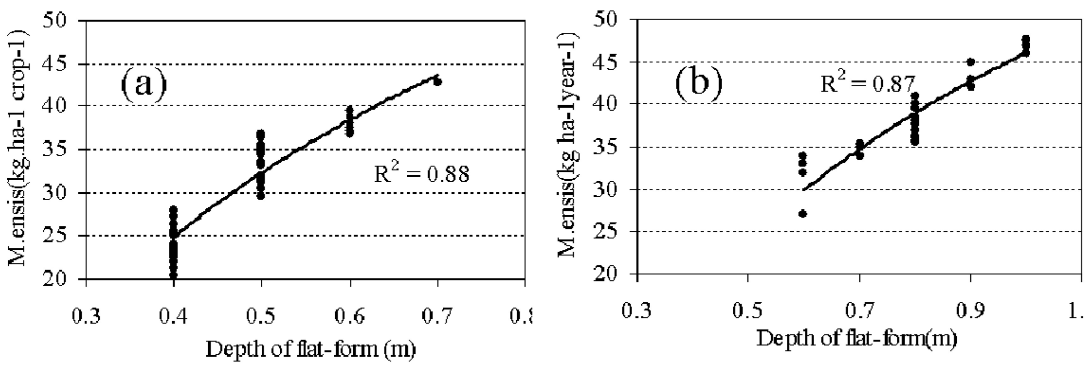

Fig. 6. Correlation between yields of *M. ensis* and depth of flat-form in My Xuyen (a) and Dong Hai (b).

This optimal model can explain 45% of the variance in *M. ensis* yields (Table 4).

Similarly, in DH, the model constructed using 6 independent variables (x_{1sm}, x_{2sm}, x_{3sm}, x_{4sm}, x_{5sm}, and x_{6sm}) explained 59% of the variance in *M. ensis* yields. The optimal model (AIC=138, R^2=0.56) was constructed using only one variable, *x1sm*, and explained 56% of the variance in *M. ensis* yields. The model is represented as follows :

$$y_{sm}=1.167+1.950\ x_{1sm} \quad (2)$$

The results of both univariate (Fig. 5) and multivariate regression analyses (Table 4) confirmed that water exchange is the principal factor that enhanced yields of *M. ensis*. In addition, these results also showed that farms with deeper flat-forms had higher yields of *M. ensis* than those with shallow flat-forms (Fig. 6). Furthermore, yields of *M. ensis* were higher in farms with deeper ditches ($p<0.01$) in both shrimp-rice paddy rotation and integrated shrimp-mangrove systems.

3.3. Variations in CL

Size density diagrams of *M. ensis* in MX are shown in Fig. 7, with CL for the early crop in January with a peak concentration of 18.0−23.0 mm. Other months, however, show broader (less concentrated) density peaks for CL. CL appeared to vary between 18.0 and 30.0 mm, and there were significant differences in CL between the different months ($p<0.01$),

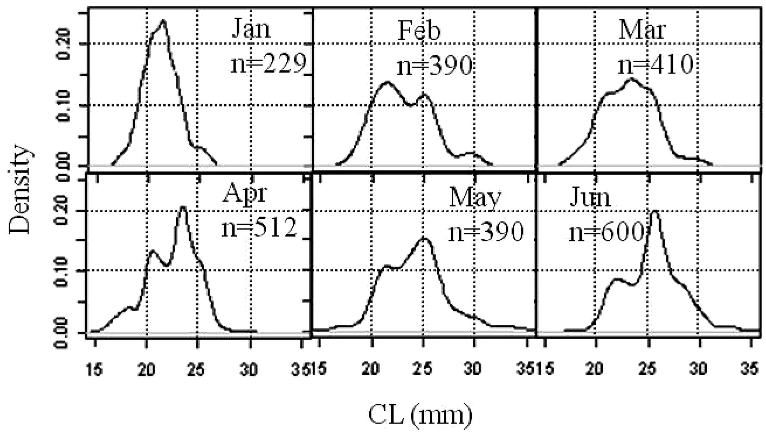

Fig. 7. Size density of carapace length (CL) for *M. ensis* in the My Xuyen District at each of the 6 sampling times; *n* : total number of shrimp in 4 farms per month.

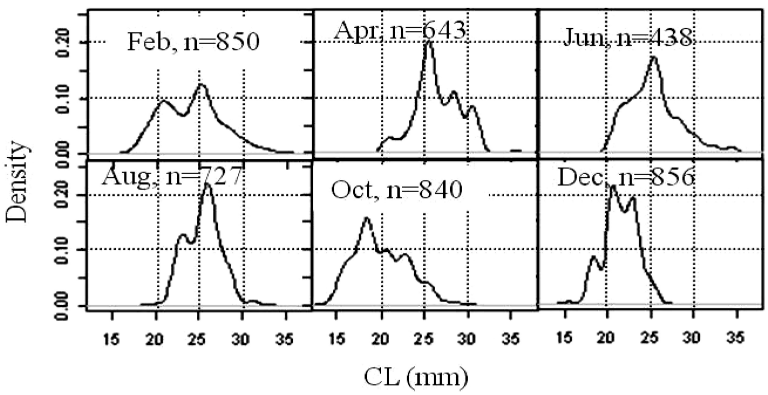

Fig. 8. Size density of carapace length (CL) for *M. ensis* in the Dong Hai District at each of the 6 sampling times; *n* : total number of shrimp in 4 farms.

except for February–March ($p>0.05$). Similarly, the size density structure of CL for the 6 sampling periods in DH (Fig. 8) showed significant differences in CL between the different months ($p<0.01$), except for June–August ($p>0.05$).

Differences in salinity, depth of ditch, and depth of flat form for farms in MX and DH are shown in Tables 5 and 6. The flat-form depth of the farms and depth of the ditches in both MX and DH did not differ with respect to location or the months sampled. However, the salinity values were quite different between the locations. The salinity values in DH were much higher than those in MX. Furthermore, in MX, the salinities in April–June were higher than those in January–February.

4. Discussion

Coastal shrimp farming started in Vietnam in the 1970s, with development of extensive farming systems. *Metapenaeus ensis* farming has declined in recent years, possibly because of mangrove forest clearing, over-harvesting, and urbanization (Johnston *et al.*, 2000a). The natural shrimp harvest in MX was 181 kg $\cdot ha^{-1}$

Table 5. Depth of ditches (m), depth of flat-forms (m) and salinity measured during the six sampling periods in MX (mean±standard deviation).

	January (N=16)	February (N=16)	March (N=16)	April (N=16)	May (N=16)	June (N=16)
Flat-form depth (m)	0.4±0.1	0.4±0.1	0.45±0.1	0.5±0.1	0.5±0.1	0.5±0.1
Ditch depth (m)	0.8±0.2	0.7±0.2	0.8±0.2	0.8±0.2	0.9±0.1	0.8±0.2
Salinity	15.5±2.0	15.5±1.5	15±2.2	19.7±2	20.0±3	19.5±2.3

Table 6. Depth of ditches (m), depth of flat-forms (m) and salinity measured during the six sampling periods in DH (mean±standard deviation).

	February (N=16)	April (N=16)	June (N=16)	August (N=16)	October (N=16)	December (N=16)
Flat-form depth (m)	0.4±0.2	0.4±0.2	0.4±0.1	0.45±0.2	0.4±0.2	0.4±0.2
Ditch depth (m)	0.8±0.2	0.7±0.5	0.8±0.1	0.8±0.1	0.9±0.2	0.8±0.2
Salinity	25.0±2.5	30.0±2	31.0±1.2	30.0±1.2	29.0±3.1	29.0±2.2

in 1997 (Be *et al.*, 2003). Currently, the harvest is about 31.0±5.9 kg•ha^{-1}•$year^{-1}$. The harvest of *M. ensis* in mangrove habitats was 100−600 kg•ha^{-1} in 1993−1994 (Binh and Lin, 1995), whereas now it is about 39.2±4.7 kg•ha^{-1}•$year^{-1}$. Thus, the income generated by *M. ensis* harvests is declining. This species, however, is still very important to local residents because natural stocks are free. The farming of *M. ensis* has been a substantial help to poor shrimp farmers in the MD, where the GDP per capita was US$ 1,113 in 2009 (Anonymous, 2011b).

Shrimp culturing is the primary income source for residents in both MX and DH districts, with combined *M. ensis* and *P. monodon* polycultures common in all farms. However, variations in *P. monodon* yields probably reflect household investment levels. For this reason, the *P. monodon* yields were selected as one of the main components of factor 1 and could explain the variability in the *M. ensis* yields.

Multivariate analyses confirmed that *M. ensis* and *P. monodon* populations on shrimp farms are not in competition. The correlation between *M. ensis* and *P. monodon* yields in the MX and DH districts was significantly low, i.e., 0.02 and 0.11, respectively. This is because *P. monodon* was stocked at a low density in these systems, and the wild-stock density of *M. ensis* was also low.

Water exchange is the best mechanism for recruitment of post-larval *M. ensis* in farms. We found that *M. ensis* yields depend strongly on the number of water exchanges. However, the waters of the MD coastal region are highly turbid (Anonymous, 2010e). Sediment can quickly fill ditches and accumulate on flat-forms, especially if water exchanges occur multiple times in a year. Farmers must then incur the costs of annually excavating the sediment (Preston *et al.*, 2003). Yields of *M. ensis* are also dependent on factors such as wild-seed abundance, the water levels of flooded farms, farm design, and water quality (Binh *et al.*, 1997).

Our results show that recruitment of *M. ensis* is strongly dependent on the frequency and volume of water exchanges on farms. The size density structures of *M. ensis* populations varied throughout the year, with one to several peaks in the CL per month; CL varied between 18 mm and 30 mm. CL varied from month to month in both MX and DH, implying that yields of this species are sustained throughout the year.

The yield of *M. ensis* in MX was lower than that in DH because *M. ensis* in MX is affected to a greater extent by natural conditions. Shrimp culture farming operates only during the dry season (6 months) in MX. However, local residents can get other income from cultivating paddy rice in the same area. It is an effective way to use agricultural land, and it can be considered to be applicable to coastal areas. The integrated shrimp-mangrove system also has low yields. However, the average area per household is 1.7 ha. The existence of integrated shrimp-mangrove farms not only provides a livelihood for local residents but also helps to sustain mangrove forests. Both of these systems require low investments and are a consistent income source for local residents.

Although *M. ensis* yields are lower than those of *P. monodon*, the species contributes significantly to the alleviation of poverty in coastal communities (Joffre and Schmitt, 2010). *Metapenaeus ensis* not only supplements the incomes of farmers but also has positive impacts on regional biodiversity and contributes to the natural balance of ecological systems (Islam *et al.*, 2004)

5. Conclusions

Populations of *M. ensis* are combined with those of *P. monodon* in improved extensive farming systems throughout MD. *Metapenaues ensis* populations rely on the recruitment of wild seed, with multiple recruitments during the year representing the opportunity for sustained yields. *Metapenaeus ensis* cultures yield significant economic support to low-income populations, requiring only small investments to realize modest returns. The shrimp are harvested for the market; however, yields of *M. ensis* are lower than those of *P. monodon*. For this reason, farmers cannot depend on *M. ensis* alone for their livelihood.

Acknowledgments

The primary author would like to thank the Vietnamese Government for support in the form of a scholarship through the Ministry of Education and Training/Vietnam International Education Development (Project 322). We also thank two anonymous reviewers for their many useful suggestions that led to improvements in the manuscript.

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Received: September 6, 2011
Accepted: March 21, 2012

La mer 50 : 69-76, 2012
Société franco-japonaise d'océanographie, Tokyo

Application of chemical mass balance to determination of phytoplankton composition from pigment profiles in seawater

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Abstract: We applied a chemical mass balance (CMB) receptor model to determine the composition of phytoplankton from pigment profiles in seawater collected from Sendai Bay, Japan. In descending order, the relative abundances of the six predominant phytoplankton classes expressed as a proportion of total chlorophyll *a* were Bacillariophyceae > Prasinophyceae ≧ Cryptophyceae ≧ Haptophyceae ≧ Pelagophyceae ≧ Dinophyceae. The results obtained by using CMB model were similar to those obtained by the CHEMTAX software: the Bacillariophyceae accounted for about 65% (CMB) or 64% (CHEMTAX) of the total phytoplankton, and the proportions of the other classes ranged from 5% to 11%. Many DNA sequences obtained from the clone library of the *psbA* gene encoding the D1 protein were highly similar to those of the Bacillariophyceae. The DNA sequencing results were similar to those obtained by CMB. We anticipate that CMB, which is used to investigate sources of pollutants, can be applied as a simple method of evaluating phytoplankton community composition using a pigment ratio approach.

Keywords: *phytoplankton pigment, chemical mass balance analysis, DNA sequencing.*

1. Introduction

Phytoplankton are primary producers in the ocean and use many kinds of pigments for photosynthesis. Pigment profiles vary among phytoplankton classes. Analysis of pigment profiles in seawater has been used to investigate seasonal changes in phytoplankton dominance (METAXATOS and IGNATIADES 2002, RODRIGUEZ *et al.* 2003, HASHIHAMA *et al.* 2008), enabling higher throughput than can be achieved by cell counting under a microscope. Phytoplankton pigments are analyzed by using high-performance liquid chromatography (HPLC) ; the proportional concentration of each phytoplankton class is calculated statistically by, for example, factor analysis using a steepest descent algorithm (CHEMTAX; MACKEY *et al.* 1996) or multiple regression analysis using ordinary least squares (BUSTILLOS-GUZMAN *et al.* 1995, SUZUKI *et al.* 1997, 2002). CHEMTAX software (MACKEY *et al.* 1996, 1997) is frequently used for the calculations (SUZUKI *et al.* 2002, RODRIGUEZ *et al.* 2003, HASHIHAMA *et al.* 2008) and CHEMTAX v. 1 is an excellent free software package, but it functions only within a commercial programming language.

Chemical mass balance (CMB) software is used to solve mass balance equations by an effective variance least-squares method. It was developed by Dr. TOM COULTER of the U.S. Environmental Protection Agency and was

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configured by HAYAKARI and HANAISHI (2001) to operate with add-in Microsoft Excel software (Microsoft, U.S.A.). Because Microsoft Excel is the world's most popular spreadsheet software, CMB has the advantage of ease of use because it does not need a special programming language. Moreover, CMB is different from previous multiple regression analyses of phytoplankton pigments, as it is based on a mass balance equation with a weighted least-squares regression analysis (HOPKE 2002). The CMB receptor model is used in environmental studies to investigate sources of pollutants, such as airborne particulate matter in the atmosphere (HOPKE 2002) and dioxins (KASHIWAGI *et al.* 2006, OKUMURA *et al.* 2008).

If the datasets of mass concentrations of particulate matter components are replaced by pigment profiles, CMB, like CHEMTAX, can be used to estimate phytoplankton composition by a pigment ratio approach. As CMB software (ver. 8J0612) can be used when only few data are available, we expected it to be suitable for monitoring phytoplankton communities in coastal areas in cases where there are only a few sampling points. Here, we used the CMB receptor model to estimate phytoplankton community composition from pigment profiles in seawater. We then compared the results of CMB analysis with those of CHEMTAX and DNA sequencing, both of which have recently been used to investigate plankton diversity (SAVIN *et al.* 2004, ZEIDNER and BEJA 2004, ZHU *et al.* 2005, JING *et al.* 2010).

2. Materials and methods

2.1. Sampling and HPLC analysis of pigments

In May 2007, a seawater sample was collected from the ocean surface off Oginohama in Sendai Bay, Japan (lat 38°23′N, long 141°24′E). This area contains fertile grounds used for Pacific oyster (*Crassostrea gigas*) aquaculture. The 200-ml sample was filtered through a glass fiber filter (25-mm Whatman GF/F filter, Whatman PLC, Springfield Mill, U.K.). The pigments were extracted from the filter for 24 h in 1 ml methanol, and the extract was centrifuged at 10000×*g* for 10 min. After dilution of the supernatant to 80% with distilled water in an HPLC auto-sampler (Shimadzu, Kyoto, Japan), the pigments were analyzed by the method of ZAPATA *et al.* (2000), with a slight modification whereby a guard column was attached between the injection valve and the analytical column.

Each pigment was identified from the retention times of pigment standards, and the concentration was calculated from the peak area on the chromatograph from the HPLC diode array detector. We used eight pigment standards: 19′-butanoyloxyfucoxanthin (But-fuco), 19′-hexanoyloxyfucoxanthin (Hex-fuco), chlorophyll *a* (Chl-*a*), chlorophyll *b* (Chl-*b*), fucoxanthin (Fuco), neoxanthin (Neo), and peridinin (Perid) were purchased from Wako Chemicals (Osaka, Japan) and DHI Laboratory (Hørsholm, Denmark), and alloxanthin (Allo) was refined by HPLC from pigment extracts of unialgal cultures of *Rhodomonas salina* CS-174 (Cryptophyceae), purchased from CSIRO Marine Research (Hobart, Tasmania, Australia). The concentrations of standard pigments dissolved in acetone or ethanol were calculated from the extinction coefficients ($E_{1\,cm}$; L g^{-1} cm^{-1}), as measured by spectrophotometer (GE Healthcare Ultrospec 3000) over a 1-cm cuvette path length. The $E_{1\,cm}$ and measurement wavelength, and the solvent used for each pigment, were obtained from published data (JGOFS 1994, JEFFREY *et al.* 1997). The concentrations of pigment standards were calculated as follows (JGOFS 1994):

$$C_s = (A_{max} - A_{750\,nm})/E \times 1000 [mg/g] \qquad (1)$$

where C_s is the pigment concentration (mg L^{-1}), A_{max} is the absorbance maximum, $A_{750\,nm}$ is the absorbance at 750nm to correct for light scattering, and E is the extinction coefficient (L g^{-1} cm^{-1}).

2.2. Analysis by CMB and CHEMTAX

The pigment concentrations determined by HPLC were input into a CMB spreadsheet in Microsoft Excel. Data for the typical pigment ratios of each class of phytoplankton were also input (Table 1). We selected six phytoplankton — *Phaeodactylum tricornutum* (Bacillariophyceae), *Pelagococcus subviridis* (Pelagophyceae), *Pycnococcus provasolii* (Prasino-

Table 1. Typical pigment / chlorophyll a ratios of each class of phytoplankton used in this study

	Perid	But–fuco	Fuco	Neo	Hex–fuco	Allo	Chl *b*	Chl *a*
Prasinophyceae				0.151			0.945	1.000
Bacillariophyceae			0.755					1.000
Dinophyceae	1.063							1.000
Haptophyceae					1.706			1.000
Pelagophyceae		0.368	0.974					1.000
Cryptophyceae						0.229		1.000

phyceae), *Amphidinium carterae* (Dinophyceae), *Emiliania huxleyi* (Haptophyceae), and *Chroomonas salina* (Cryptophyceae) and calculated their pigment ratios from the published data (Jeffrey and Wright 1997) used for the initial ratio matrix in the CHEMTAX user's manual (Mackey *et al.* 1997). After inputting all data, we analyzed the phytoplankton profiles in the environmental sample by CMB according to the CMB user's manual (Hayakari and Hanaishi 2006).

The mass environmental concentration of pigment i (C_i) is shown in Equation (2) : (in the original equation, C_i is the mass concentration of component i of particulate matter) ;

$$C_i = \sum_{j=1}^{p} a_{ij} S_j \quad i=1,.....,n \qquad (2)$$

where a_{ij} is the fractional concentration of pigment i of class j (in the original equation, a_{ij} is the density of particulate matter containing component i in emissions from source j to the receptor) ; S_j is the total mass concentration contributed by class j (originally the total mass concentration contributed by source j) ; p is the number of classes and n is the number of pigments, with $n \geqq p$ (originally, p was the number of sources and n was the number of components). C_i and a_{ij} are known, and S_j is found from the effective variance least-squares solution of an over-determined system of equations.

The calculations are accompanied by an error in the fractional concentration of the pigment from each class (or, in the Air Pollution Control Technology Manual [Environment Agency, Government of Japan 1997], the emission source profile data) and by an error in the established data on the environmental concentration of the pigment (or, in the abovementioned manual, the concentration of the component on environmental particles). Both of these errors must be considered. The effective variance least-squares method is solved in Equation (2) by multiplying the concentration of each pigment (or, in the manual, the concentration of each chemical) by a percentage weight that is proportional to the fractional concentration of the pigment from each class (or, in the manual, the precision of the emission source profile data) and the measured environmental concentration of each pigment (or, in the manual, the environmental concentration of each chemical component). Repeat computations are conducted to seek S_j, which minimizes the function x^2 in Equation (3) :

$$x^2 = \sum_{j=1}^{n} \frac{(C_i - \sum_{j=1}^{p} a_{ij} S_j)^2}{V_i} \qquad (3)$$

In Equation (4) V_i is the effective variance :

$$V_i = \sigma {c_i}^2 + \sum_{j=1}^{p} {\sigma_{aij}}^2 S_j^2 \qquad (4)$$

where σ_{Ci} is the error that accompanies component i, and σa_{ij} is the error that accompanies the measurement of a_{ij}.

To evaluate whether the calculated values were appropriate, the χ^2, R^2, and percent mass values were also calculated by CMB. In the CMB manual, the χ^2 value is the weighted sum-of-squares of the differences between the calculated and measured fitting species concentrations; a value less than 1 indicates a very good fit to the data, and values between 1 and 2 are acceptable. The R^2 value is the fraction of the variance in the measured concentrations that is explained by the variance in the calculated species concentrations. R^2 ranges from 0 to 1.0; the closer the value is to 1.0, the better the source contribution estimates explain the measured concentrations. Percent mass is the ratio of the model-calculated source contribution to the measured mass concentrations, expressed as a percentage. This ratio should equal 100%, although values ranging from 80% to 120% are acceptable (COULTER 2004, HAYAKARI and HANAISHI 2006).

After the data for the typical pigment ratios of each phytoplankton class were input (Table 1), we also used CHEMTAX to analyze the phytoplankton community profile in the same environmental sample according to the CHEMTAX user's manual (MACKEY *et al.* 1997).

2.3. DNA sequencing and BLAST similarity search

For DNA sequencing, a 500-ml seawater sample was filtered through a Durapore membrane filter (diameter, 47 mm; pore size, 0.45 μm; Millipore, Merck KGaA, Darmstadt, Germany). The filter containing the sample was suspended in 1 ml of lysis buffer (20 mM Tris • HCl [pH8.0], 5 mM EDTA, 0.3% (wt : vol) SDS, 200 μg/ml proteinase K). The suspension was vortexed for 30s and then incubated at 55℃ for 1 h and at 95℃ for 5 min. The filter was then removed from the lysis buffer and the liquid phase containing nucleic acids was separated by centrifugation at 10,000 $\times g$ for 10 min. The supernatant diluted with distilled water was used as a template for polymerase chain reaction (PCR) analysis.

The *psbA* gene, which encodes polypeptide D1 of the photosystem II reaction center complex, was amplified by PCR with the degenerate primers PsbAF (5′-TTC GGT CAA GAA GAA GAG ACT TA−3′) and PsbAMR (5′-YTC RTG CAT HAC YTC VAW RCC−3′), which have specificity for many algae. Primers were selected by using Primer3 software (ROZEN and SKALETSKY 2000). PCR was performed under the following conditions: 94℃ for 10 min; 40 cycles of 94℃ for 30s, 55℃ for 1 min, and 72℃ for 1 min; and a final step at 72℃ for 7 min.

After PCR amplification, the PCR products were purified with a High Pure PCR Cleanup Micro Kit (ROCHE DIAGNOSTICS, Germany). The purified products were cloned by DYNAEXPRESS TA PCR Cloning Kit (BIODYNAMICS LABORATORY INC., Tokyo, Japan). After colony-direct PCR (30 cycles of 98℃ for 10 s, then annealing and extension at 68℃ for 1 min) with the universal primers M13P7 (5′-CGC CAG GGT TTT CCC AGT CAC GAC−3′) and M13P8 (5′-AGC GGA TAA CAA TTT CAC ACA GGA AAC−3′), colonies containing inserts were identified by agarose gel electrophoresis. After purification of the PCR products of the insert colonies using ExoSAP-IT (GE HEALTHCARE, England), DNA sequencing was performed with a DYEnamic ET Terminator Cycle Sequencing Kit (GE HEALTHCARE) by using the primer M13P8 on an automated ABI 3100 DNA sequencer (APPLIED BIOSYSTEMS USA). Sequences were then aligned by using phred/phrap/consed software (EWING *et al.* 1998, GORDON *et al.* 1998, SAITO 2009) and phytoplankton species were identified from sequences aligned by using BLAST.

3. Results and discussion

3.1. Measured pigment concentrations and concentrations calculated by the CMB model

We compared measured and calculated pigment concentrations (Fig. 1). Measured pigment concentrations were in the order Chl-*a* >

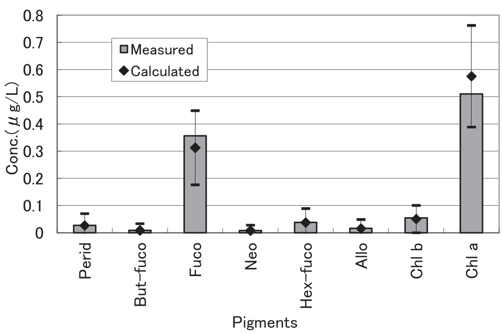

Fig. 1. Comparison of measured and calculated pigment concentrations in a seawater sample from Sendai Bay, Japan. Error bars were calculated by assuming a 5% error in the measured concentrations.

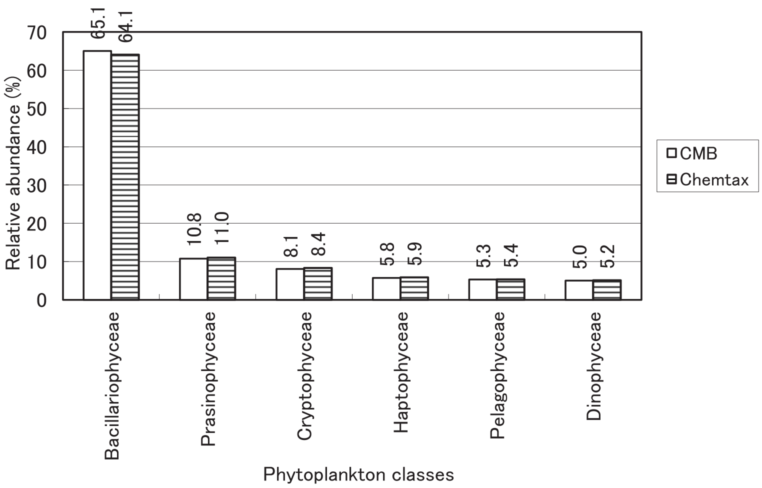

Fig. 2. Relative contributions of six phytoplankton classes to total chlorophyll a in a sample of seawater from Sendai Bay, Japan, as calculated by CMB and CHEMTAX.

Fuco > Chl-*b*. Hex-fuco, Perid, Allo, But-fuco, and Neo were at the same low level as Chl-*b*. The calculated concentration of each pigment was consistent with the measured concentration. The χ^2, R^2, and percent mass values calculated by CMB were 0.62, 0.99, and 101.6%, respectively. We consider that these three values indicate the validity of the class contribution estimates.

Chl-*a*, which is in all phytoplankton, usually has the highest concentration of all pigments detected in environmental samples (WRIGHT *et al.* 1991, ZAPATA *et al.* 2000), as it did in this study. Fucoxanthin, which is found in the Bacillariophyceae and Pelagophyceae (JEFFREY and WRIGHT 1997), was also detected at high concentrations. Our pigment profiles are therefore similar to those reported elsewhere (WRIGHT *et al.* 1991, ZAPATA *et al.* 2000).

3.2. Comparison between CMB and CHEMTAX

We compared the relative contributions of six phytoplankton classes to total chlorophyll *a* calculated by CMB and CHEMTAX (Fig. 2). Both approaches indicated that the relative abundance of the Bacillariophyceae was highest, followed in descending order by Prasinophyceae ≧ Cryptophyceae ≧ Haptophyceae ≧ Pelagophyceae ≧ Dinophyceae. The results of the CMB and CHEMTAX analyses were similar. The Bacillariophyceae accounted for about 65% (CMB) or 64% (CHEMTAX) of all phytoplankton (Fig. 2). The proportions of Prasinophyceae, Cryptophyceae, Haptophyceae, Pelagophyceae, and Dinophyceae were about 11%, 8%, 6%, 5%, and 5% (both CMB and CHEMTAX), respectively. In Sendai Bay, the Bacillariophyceae outnumber the Dinophyceae in all seasons (IIJIMA *et al.* 2004) ; therefore, we believe that the phytoplankton community composition determined in this study is characteristic of that in Sendai Bay.

The pigment concentrations in phytoplankton are known to vary with environmental conditions such as light and nutrient conditions, and among species or strains within the same class (MACKEY *et al.* 1998, SCHLUTER *et al.* 2000, LIONARD *et al.* 2008). As the change of the pigment : chlorophyll a ratios of phytoplankton accompanying environmental conditions are reflected in the CMB analyses, we anticipate that CMB is a useful tool for investigating phytoplankton composition in the environment.

3.3. DNA sequencing and BLAST similarity search

The BLAST search showed that many of the *psbA* gene DNA sequences were highly similar to those of the Bacillariophyceae (Table 2).

Table 2. Results of a BLAST search of DNA partial sequences from water samples from Sendai Bay

Phylogenetic group	Sequences producing significant alignment (GenBank accession no.)	Identity (%)	Number of aligned reads	Ratio of each phylogenetic group (%)
Bacillariophytceae	*Odontella sinensis* (Z67753)	268/285 (94%)	12	63.6
	Thalassiosira pseudonana (EF067921)	256/260 (98%)	2	
Haptophyceae	*Isochrysis* sp. (AY119753)	271/282 (96%)	1	13.6
	Emiliania huxleyi (AY741371)	243/255 (95%)	1	
	Phaeocystis antarctica (AY119756)	232/241 (96%)	1	
Prasinophyceae	*Ostreococcus* sp. (EU851961)	272/278 (97%)	1	9.1
	Micromonas pusilla (FJ858269)	278/285 (97%)	1	
Rhizaria	*Paulinella chromatophora* (DQ789030)	184/215 (85%)	3	13.6

Bacillariophyceae sequences accounted for about 64% of all phytoplankton. This proportion is close to the values obtained by CMB (65%) and CHEMTAX (64%). Within the Bacillariophyceae, *Odontella sinensis* was significantly aligned by BLAST. *Odontella* spp. are frequently observed in the coastal zones of the Tohoku region of Honshu, Japan (Takano 1990) ; our results are consistent with these observations. The results of the BLAST search for similar DNA sequences suggest that the Haptophyte species were *Isochrysis* sp., *Emiliania huxleyi* and *Phaeocystis antarctica*, and the Prasinophytes were *Ostreococcus* sp., *Micromonas pusilla* and Rhizaria was *Paulinella chromatophora*. Although we did not detect any Cryptophyceae, Pelagophyceae or Dinophyceae DNA sequences, the pigments characteristic of these phylogenetic groups indicate that they accounted for 5.0% to 8.4% of the total phytoplankton, as determined by CMB and CHEMTAX. If more DNA sequences are available, it should be possible to detect the DNA sequences of these classes. Although the bias of PCR frequently adds uncertainty to the quantification of organisms (Diez 2001), our DNA sequencing results were roughly similar to those of CMB and CHEMTAX. As more results of CMB analysis accumulate, CMB will become an easy-to-use tool for investigating natural phytoplankton community composition.

Acknowledgments

We thank Dr. S. Hayakari and Dr. R. Hanaishi (Aomori Prefectural Institute of Public Health and the Environment) for their helpful comments on the CMB analysis. We also thank Dr. H. Yamauchi (Miyagi Prefectural Fisheries Research Development Center). This article was contributed by the Fisheries Research Agency of Japan (TNFRI-B135).

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Received: October 20, 2008
Accepted: March 23, 2012

La mer 50 : 77-84, 2012
Société franco-japonaise d'océanographie, Tokyo

串本・浦神間水位差に現れる季節的変化

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Seasonal variation of the sea level difference between Kushimoto and Uragami tide–gauge stations

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Abstract : Sea level difference between Kushimoto and Uragami tide–gauge stations has been used as an indicator of flow pattern in the sea south of Japan: the difference is small when the Kuroshio has meandering path and is large when it has straight path. The difference exhibits seasonal variation, and it becomes large in the summer season in the years when the Kuroshio takes straight path throughout year as in 2003 and in 2009. We analyzed the sea level data of Kushimoto and Uragami tide–gauge stations for 17years from 1994 through 2010. It is shown that the Kuroshio takes straight path when the separation distance of the northern edge of the Kuroshio is smaller than 15km from the tip of Cape Shionomisaki. The sea level difference data were selected only for the time that the separation distance is smaller than 15km, and the average sea level for 17years are calculated. Significant seasonal variation can be seen in the averaged sea level difference curve. However, the seasonal variation is not so clear in comparison with cases in 2003 and 2009. The sea level changes at Kushimoto and Uragami tide–gauge stations were investigated for the years of 2003 and 2009. Both of the sea levels tend to rise in summer time, but the magnitude of the rise at Kushimoto is considerably larger than that at Uragami. MAEKAWA *et al.* (2011) showed that the water off the Kushimoto tide–gauge station is originated to the surface water of the current zone of the Kuroshio, when the Kuroshio takes straight pass.. Thus, the main cause of seasonal variation of the sea level difference would be sought for seasonal warming of the surface water of the Kuroshio area. The water would be brought from upstream (southern) area of the Kuroshio, and would be heated much more than surface water in Kumano–nada in summer season.

Keywords : *Sea level difference between Kushimoto and Uragami, seasonal variation, intrusion of the Kuroshio Water off the southwest coast of Kii Peninsula, water off Kumano –nada*

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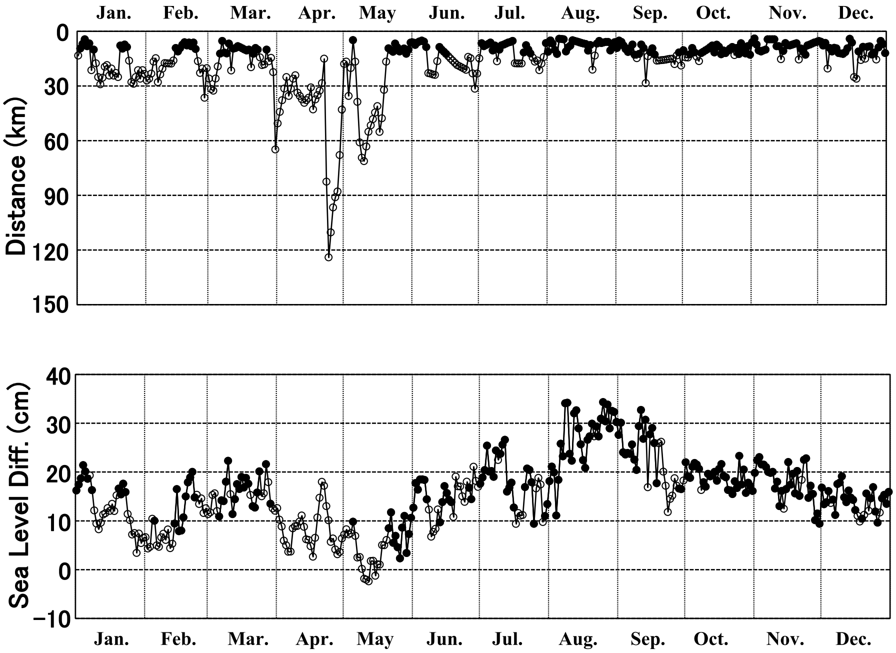

Fig. 1 The distance (upper figure in km) between the northern edge of the Kuroshio and the tip of Cape Shionomisaki, and the sea level difference (lower figure in cm) between Kushimoto and Uragami tide gauge stations in 2003. The sea level differences are shown with solid circles when the separation distance is shorter than 15km, and with open circles when the separation distance is longer than 15km.

1. はじめに

われわれは，紀伊半島南西海岸に見られる振り分け潮をはじめとして，紀伊半島の先端付近の微細海況の解析を行ってきた（Takeuchi *et al.*, 1998. Nagata *et al.*, 1999, Uchida *et al.*, 2000, 中村ら，2008，田中ら，2008，前川ら，2011，2012)。その中で，前川ら（2011）は，串本・浦神検潮所間の水位差に季節変化があり，水位差が夏期に大きくなる可能性があることを指摘している。このような傾向は 2003 年や 2009 年など年間を通して黒潮が直進路を維持している年に明確に現れる。しかし，顕著な季節変化が見られない年も少なくない。和歌山県農林水産総合技術センター（以後和歌山水試と略記）では，潮岬灯台近くに目視観測点を設けて，毎日午前 9 時前後に，沖合数百 m の海面を観測し，潮波の立ち方の目視観測を行っており，漁海況情報の一つとして活用している。目視観測者は夏期に潮波が大きくなり，黒潮の接岸流が強くなる傾向があると指摘している（このことは，別に検討する予定である)。

前川ら（2011）は，黒潮流路の指標となる串本・浦神の水位差は，潮岬半島沖の東西わずか数 km の部分で生じていることを指摘すると共に，水位差を生じさせているのは，300m 以浅の海洋構造であることを示した（このことは藤田（2001）が指摘しているが，その詳細な水平分布を提示したのは初めてである)。このような表層の構造は，黒潮強流帯域においても，明確な季節変動を示しており，振り分け潮に伴って紀伊半島南西岸にもたらされる黒潮系水の特性も季節変化を示すであろう。振り分け潮の発生そのものは，福田ら（2002）が数値試シミュレーションで再現に成功しているが，このような表層構造や微細海況構造に関しては，観測による資料の収集が，現在でも必要とされる。本論文では，1994 年から 2010 年までの 17 年間の資料を解析するとともに，顕著な季節変化を示す 2003 年および 2009 年の資料を解析し，この季節変化の特性を検討する。

2. 串本・浦神間水位差の季節変化

2–1 年々の季節変化

前川ら（2011）は串本・浦神間水位差の季節変化について，その Fig. 2 に 2009 年の変化を示している。しかし，黒潮流路の変遷もあり，前述したような典型的な変化が毎年見られるとは限らない。ここでは，2009 年と同様に明確な季節変化が見られた 2003 年について，串本・浦神間水位差の変化を Fig. 1 の下段に示す。図の上段に衛

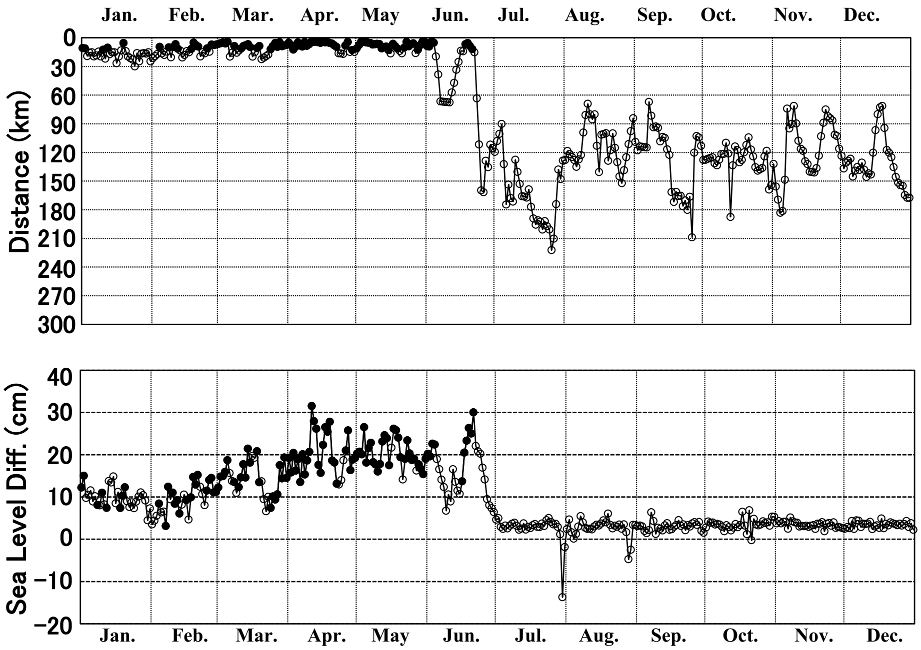

Fig. 2　Same as in Fig.1 except for in 2004.

星資料から求めた黒潮北縁の潮岬先端からの距離（以下では簡単のため黒潮離岸距離と呼ぶ）の変化を示してある。これは，和歌山水試が NOAA/HRPT 受信解析装置（TeraScan）を用いて直接受信している。衛星の画像の分解能は，1.1km 程度とされているが，実際の画像からはより細かく黒潮北縁の離岸距離を読みとることが可能であり，ここでは 0.1km 単位で決めた値を用いている。ただし，陸と海のコントラストが大きいこともあり，黒潮北縁が潮岬先端から約 3.7km 以内に近づくと北縁位置の決定は難しくなり，この場合は黒潮離岸距離を 3.7km とした。また，海洋保安庁海洋情報部が発行している海洋速報では黒潮流軸の位置が記載されており，これは黒潮北縁より 24km 沖側とされている。しかし，流軸位置が 24km より岸寄りに示されている場合があり，この定義に従えば，北縁の位置は陸上にあることになる。海洋速報の情報を参考にしているが，衛星資料を基にした北縁位置を本論文で論じている。水位差については串本・浦神のそれぞれの観測値を東京湾中等潮位（TP）上に換算した後，その差をとり，水位差 0 が，両水位が同レベルに対応するように表記している。

前川ら（2011）が示した 2009 年と同様に，2003 年は年間を通して黒潮は安定した直進路をとっており，水位差が夏期に高くなるという季節変化が，明瞭に現れている。参考のため Fig. 2 に 2004 年の水位差の変化を同様に黒潮離岸距離と共に示すが，この年は，黒潮の流路が 7 月に潮岬から離れて，それ以後は典型的な蛇行路をとるようになった年である。7 月以降の水位差は 5cm 以下の安定した値をとるようになるとともに，季節変化は全く見られなくなった。Fig. 1 および Fig. 2 では，黒潮離岸距離が潮岬先端から 15km 以内の場合を黒丸で，15km 以上の場合を白丸で示してあるが，これらの図から 15km 以内の場合のみをとると，黒潮が蛇行路をとっている場合のデータをほぼ除くことができることがわかる。なお，ここでも黒潮の直進路，蛇行路という表現を便宜上用いているが，少なくとも潮岬近傍の海況に影響するのは，日本南岸沖の全体的な流路特性ではなく，黒潮北縁が潮岬からどれだけ離れているかの離岸距離である。離岸距離は，潮岬の東西の沿岸水が一体的なものであるか，両者が分離されているかを決定する要因である。

Fig. 2 に見られるように黒潮が蛇行路をとり，黒潮北縁の位置が潮岬先端から遠く離れると，串本・浦神間の水位差は非常に小さくなる。以下に 1994 年から 2010 年までの 17 年間の資料の解析を行うが，このように短い期間の解析においては，その期間内で蛇行路をとっていた頻度の高い月の水位差の平均値は小さくなり，直進路をとっていた頻度の高い月の水位差の平均値は大きくなる。われわれの解析期間において，蛇行路をとってい

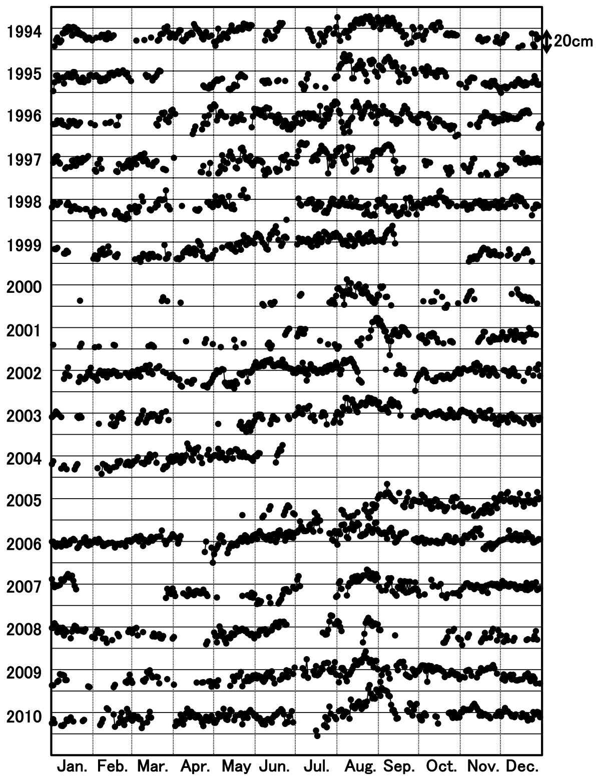

Fig. 3 The sea level difference between Kushimoto and Uragami when the separation distance of the northern edge of the Kuroshio is less than 15km from the tip of Shionomisaki from 1994 to 2010.

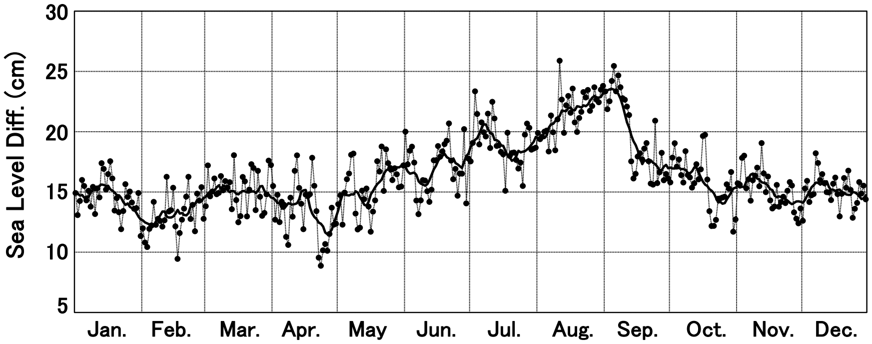

Fig. 4 Same as in Fig. 3 except for the daily average for the 17 years. The thick curve indicates 11 days running mean.

た頻度は，2～4 月の期間が，他の月に比べてかなり大きく，2～4 月の水位差は見掛け上小さくなってしまう。そこで，以下の解析では，黒潮離岸距離が 15km 以内の場合のみを選んで行うことにする。

黒潮離岸距離が 15km 以内の場合のみを選び出して，1994 年から 2010 年までの 17 年間のそれぞれの年の水位差の変化を示したのが Fig. 3 である。ただし，ここでは，見やすくするため閏年については 12 月 31 日のデータを除いてある。この図を見ると，季節変化がほとんど見られない年もあるが，全体的に見て 8～9 月頃を中心として水位差が大きくなっている傾向が認められる。黒潮離岸距離 15km 以下の場合のみの各日付についての平均値を示したのが Fig. 4 である。直進路のデータのみを用いているから，水位差は年間を

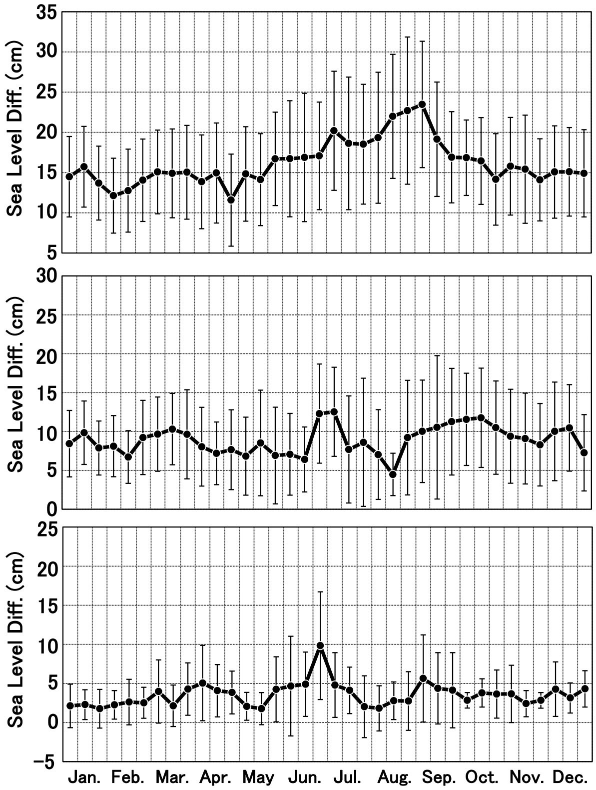

Fig. 5 Variation of the sea level difference averaged for each ten days: (upper figure) for the case that the separation distance of the northern edge of the Kuroshio is less than 15km from the tip of Shionomisaki, (middle figure) for the case the separation distance is from 15km through 30km, (lower figure) for the case the separation distance is larger than 30.1km. The vertical lines attached to data points indicate error bars.

通して正の値を示している（正の値は串本側の水位が浦神側の水位よりも高いことを表す）。解析期間が短いため1日毎の平均値の曲線には細かい振動が現れる。11日間の移動平均をとった曲線もFig. 4に示してあるが，この移動平均によって，細かい振動はほぼ除かれている。いずれにせよ，8～9月頃を中心として水位差が大きくなる季節変化は平均値の曲線に明確に現れている。11日間の移動平均をとることによって，スムーズな曲線が得られたことから，以下の検討では，1日毎の平均ではなく，その11日間の移動平均値，または旬平均値を基に議論することにする。

2-2 旬平均水位差の季節変動と黒潮離岸距離

旬平均を求めるに当たり，大の月では，1～10日を上旬，11～20日を中旬，21～31日を下旬と定義し，2月を除く小の月では，これに対して下旬を21～30日と定義した。2月については1～10日を上旬とするのは変わりないが，11～19日を中旬とし，20日から28日，あるいは29日までを下旬と定義した。この定義に従って，串本・浦神間の水位差の旬平均を計算して示したのがFig. 5である。1994年から2010年までの17年間のデータから，黒潮離岸距離を15.0km以内（上図），15.1～30.0km（中図），30.1km以上（下図）の3つの場合について示した。ただし，解析期間についてのデータ数は，3つの場合について，互いにかなり違っており，15.0km以内の生起日数が57.3%， 15.1～30.0kmのそれが23.4%，30.1km以上のそれが19.3%である。

Fig. 5には各計算値に対して標準偏差σを縦棒で示してあるが，Fig. 3に見られるように年々変動が大きいため，標準偏差の値はかなり大きくなっている。これらの平均値の曲線を見ると，15.0km以内の場合にのみ，9月頃をピークとして，夏期に水位差が大きくなる季節変化を認めることができる。この結果は，夏期に水位差が大きくなる現象は，黒潮が直進路をとり，潮岬の東西

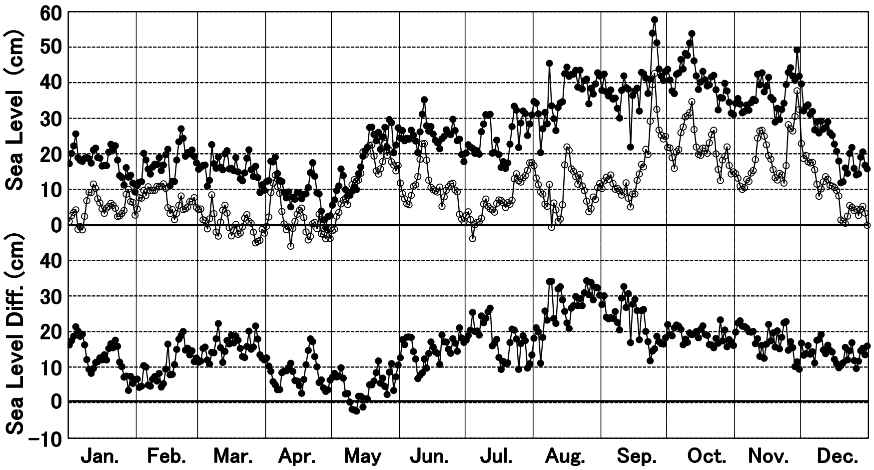

Fig. 6 Variations of the sea level at Kushimoto (solid circle) and at Uragami (open circle) are shown in upper figure in 2003. Sea level difference between two stations is shown in lower figure.

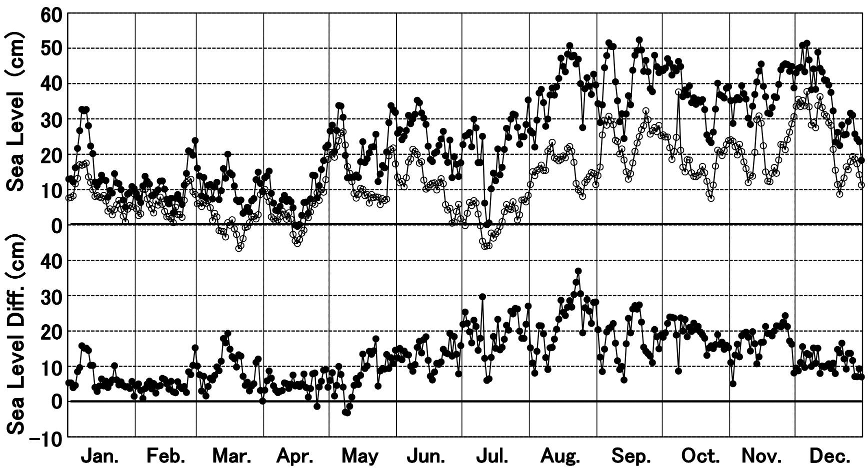

Fig. 7 Same as in Fig 6 except for in 2009.

の沿岸水が分離された場合にのみ，水位差に季節変動が現れることを示唆している。より明確な結論を得るには，解析期間をより長くとり，データ数を増す必要があるが，過去に解析期間を延ばすことは，衛星データを含め，データの取得や，利用できるデータの精度等に問題がある。この論文では，明確な季節変化が見られた 2003 年と 2009 年の場合を検討することによって，季節変化の生じる原因を考えることにする。

3. 2003 年及び 2009 年に見られた串本，浦神のそれぞれの水位の季節変化

2003 年と 2009 年の串本および浦神の水位の変化を Fig. 6 及び Fig. 7 にそれぞれ示す。これらの値は，東京湾中等潮位（TP）からの変位として表し，1 時間間隔の水位データにタイドキラーフィルター（花輪・三寺，1985）を施した後，毎正午の値を抜き出して示したものである。また，これらの図の下段には両検潮所間の水位差を再掲してある。

2003 年，2009 年共に，串本・浦神の両地点で，夏期の水位が上昇する傾向を示す。これは大気からの加熱による表層水温の上昇に伴う現象として解釈されよう。しかし，夏期の水位上昇は，串本の上昇量が浦神のそれよりもはるかに大きく，それによって両地点間の水位差が形作られていることがわかる。

従って，水位差の季節変化を起こす主要因は，

串本側に求めざるを得ない。黒潮離岸距離が15km以内であるときは，通常黒潮は直進路をとっており，振り分け潮の発生に伴い黒潮流域の表層水が紀伊半島南西岸に侵入してくる時である。主温度躍層より下の黒潮水が顕著な季節変化を示さないが，主温度躍層以浅の黒潮表層水の水温は季節変化を起こし，大気からの加熱により夏期上昇する。紀伊半島南西岸に侵入してくる黒潮表層水の水温が夏期には上昇し軽くなり，串本側の水位の夏期の上昇を起こすことは当然のことと考えられる。もちろん，正確な上昇量を求めるには塩分の変化も論ずる必要がある。

Fig. 6およびFig. 7に見られるように，浦神の水位も若干夏期に上昇する。南方から運ばれてくる黒潮表層水の夏期の水温上昇は，浦神沖の沿岸水よりも大きいことは十分考えられる。しかし，潮岬西方で振り分け潮に伴って沿岸域に侵入してくる水が，黒潮のどの部分の水であるかが明らかにされていない以上，定量的な検討は出来ない。われわれは，水の動きを明確にするため，水塊分析や種々のトレーサー解析を進めているが十分に成功するに至っていない。前川ら（2012）は，溶存酸素の鉛直プロファイルの微細構造に注目した解析を試みて，潮岬東方の黒潮流の中に熊野灘沖の沿岸水が黒潮流域に取り込まれ，運び去られることを示唆している。もしそれが正しければ，浦神沖の沿岸水が常に更新されていて，そのため季節変化が抑制される可能性がある。このような沿岸水の更新は，黒潮が長期にわたって直進路を維持している場合，効果的であろう。今まで，われわれは，振り分け潮の関連で潮岬西方の海況について詳細な検討を進めてきた。しかし，串本・浦神間の水位差の季節変化のような問題を論じるためには，熊野灘沖の海況特性についても詳細な検討を行う必要があろう。

4. おわりに

串本・浦神間の水位差が夏期に増大するという季節変化が現れることは，黒潮直進時に紀伊半島南西岸に振り分け潮が現われさらに，その南西海岸に侵入する黒潮水は，黒潮域の表層の水であるとする前川ら（2011）の推論を支持するものである。しかし，ここで論じてきたように，この水位差の季節変化を起こす主要因は，紀伊半島南西岸に侵入する黒潮表層水の季節変化であるが，熊野灘側の沿岸水の季節変化が，この水位差の減少に寄与していることも忘れてはならない。振り分け潮の発生についても，今後解明すべき問題が山積している。福田ら（2002）は，数値実験で振り分け潮の発生を再現することに成功しているが，これは，南西沿岸域にもたらされる水が表層水に限られ，振り分け潮の発生が水深100m程度の位置で起こっているような，微細な構造を説明するものではない。前川ら（2011）が論じているように，振り分け潮の発生に結びつくような水平水温・塩分場の等値線の岸向きの膨らみが観測されているものの，ADCPによって観測された流速場にはその部分で岸に向かう流れは見出せない。振り分け潮の発生のメカニズムは，まだ十分に解明されていない。これを明らかにするには，黒潮流域のどこの水が，どのような経路に沿って沿岸域にもたらせられるのかを正確に知ることが必要である。

謝辞

本研究を進めるにあたり，種々のご助言，ご支援を頂きました勢水丸の内田誠船長に心からの感謝の意を表します。

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受付：平成 24 年 1 月 6 日
受理：平成 24 年 3 月 27 日

La mer 50 : 85-89, 2012
Société franco-japonaise d'océanographie, Tokyo

マタナゴ当歳魚におけるアマモ場からアラメ場への成長に伴う移動

吉永　潔

Ontogenetic habitat shift in yearling surfperch *Ditrema temmincki pacificum* from a seagrass bed to a seaweed bed at Tateyama, central Japan.

Kiyoshi YOSHINAGA

Abstract : To confirm ontogenetic migration in yearling surfperch *Ditrema temmincki pacificum* from a seagrass bed to a seaweed bed, fish censuses were carried out in both beds using SCUBA from February to November in 2002 to 2004 at Tateyama, Chiba Prefecture, central Japan. Newborn fish were most numerous in the seagrass bed in May, yearling density tending to be greater in the seaweed bed than in the former in August. A mark–release experiment conducted in the seagrass bed in May and June, 2005, in which yearlings were marked by clipping the operculum before release to the capture site, indicated that individuals were still present at the site a month later. However, marked fish appeared in the seaweed bed in July to September, being absent from the seagrass bed in August and September, demonstrating that *D. temmincki pacificum* yearlings moved from the seagrass bed to the seaweed bed with growth.

Keywords : *Ditrema temmincki pacificum*, habitat shift, seagrass bed, seaweed bed

1. はじめに

マタナゴ*Ditrema temmincki pacificum*は関東地方から瀬戸内海にかけての太平洋沿岸に分布するウミタナゴ科魚類の一種である（KATAFUCHI and NAKABO, 2007）。Abe（1969）によれば，本種（原著ではウミタナゴ*Ditrema temmincki*となっているが，KATAFUCHI and NAKABO（2007）に従いマタナゴとした）は生活史の初期段階にはアマモ場に分布するが，成長に伴い岩礁域へ生息場を変えることが推察されている。このような成長に伴う生息場間の移動は多くの水産有用種で知られており（例えば，GILLANDERS *et al.*, 2003；佐野ら，2008），複数の生息場をセットで維持することが生産の維持にとって重要であると考えられている（小路，2009）。ウミタナゴ科魚類は水産有用種であり（櫻井ら，2008），生息場の変化の知見は重要である。しかし，実際にマタナゴがアマモ場からいつ，どのような成長段階で移動するのかについては，直接的にまだ確認されていない。

そこで本研究では，マタナゴ当歳魚の生息場間の移動を明らかにするために，まず，アマモ場とその沖合いにある岩礁域（アラメ場）において当歳魚の個体数密度の季節変化を潜水観察で調べた。生息場間の移動があるならば，当歳魚は最初アマモ場で多く，その後季節の進行に伴い岩礁域で増加すると考えられる。さらに，アマモ場に出現した当歳魚に対し，標識・放流調査を実施することにより，生息場間の移動が実際に行われているかどうかを確認した。

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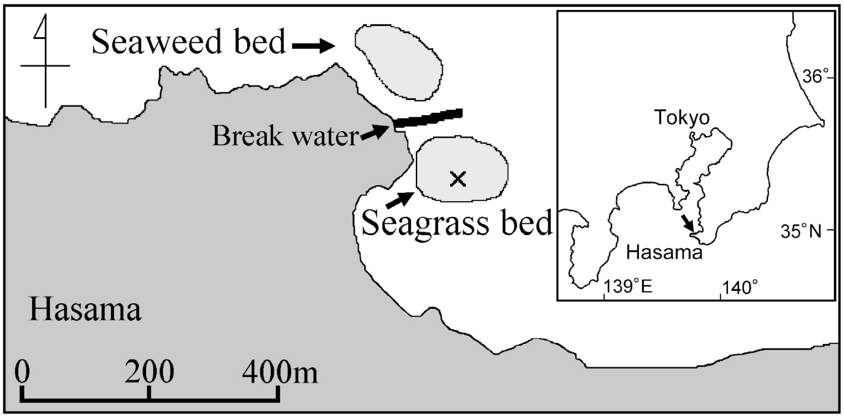

Fig. 1. Map of the study site at Hasama, Tateyama, showing the seagrass and seaweed beds in which underwater observations were conducted. ×, collection and release site for yearlings in the mark–release experiment.

2. 調査場所と方法

本研究は千葉県の南端に位置する館山市波左間（34°58′N，139°46′E 測地系 WGS84）で実施した（Fig. 1）。同調査地では，防波堤をはさみ西側の沖合いは岩礁域でアラメ *Eisenia bicyclis* が，東側は砂地でアマモ *Zostera marina* が密生している。このアマモ場およびアラメ場においてマタナゴ当歳魚がどの月に多く出現するかを明らかにするために，2002 年から 2004 年の 2，5，8 および 11 月にスキューバ潜水による目視観察を行った。各月において，それぞれの藻場の水深 5m 以浅に，1×50m のトランセクトを 5 本，10m 以上離してランダムに設置し，トランセクト内に出現したマタナゴ当歳魚の個体数を計数・記録した。トランセクト 1 本あたりの観察時間は 10 分とし，9:00 から 15:00 までの満潮時に観察を行った。なお，松清（1963）は山口県瀬戸内海のマタナゴについて，全長は満 1 年で約 150㎜ になると報告している。そこで本研究では，全長 150㎜ 未満の個体を当歳魚とした。

マタナゴ当歳魚の個体数について，年ごとに月と生息場間での違いを二元配置分散分析によって検討した。月間と生息場間で有意な差が存在した場合には，Scheffé test を用いて，各月間あるいは各生息場間での有意差の有無を検定した。二元配置分散分析において，月と生息場に交互作用が存在した場合，各月に対する生息場間の差と各生息場における月間の差をそれぞれ Scheffé test によって調べた（Underwood, 1997）。なお，本研究の主目的は，マタナゴ当歳魚の個体数が月ごと，あるいは生息場ごとでどのように異なり，また，それらの異なりが 2002 年から 2004 年にわたって，同じように認められるかどうかを明らかにすることである。このため，個体数における年間の違いについては解析を行わなかった。分散分析による検定を行う際には，等分散性および変量の正規性を得るために，個体数を対数変換[log（x+1）]した。

マタナゴ当歳魚における生息場の移動を実証するために，標識・放流調査を行った。2005 年 5 月 28 日から 6 月 19 日にかけて，合計 157 個体（全長 70〜90㎜）の当歳魚をアマモ場でタモ網等により採集し，両側の鰓蓋後縁部を数 ㎜ 切除した後，採集地点と同じアマモ場へ放流した。この標識方法はオイカワ *Zacco platypus* ですでに用いられており，実績がある（福岡県水産海洋技術センター，2000）。放流後，6 月 25 日から 9 月 23 日まで，アマモ場とアラメ場においてスキューバ潜水による目視観察を行った。目視観察では約 24m/分の速度で 10 分間遊泳し，進行方向の左右 1m ずつの範囲内（トランセクトの面積は 2×240m）に出現したマタナゴの個体数と鰓蓋の切れ込みの有無を記録した。この観察は調査期間中，1〜3 週間の間隔で計 9 回行い，1 回の観察ではアマモ場とアラメ場でそれぞれ 3 本のトランセクトを設置した。

なお，本研究の実施後，日本産ウミタナゴ属魚類は Katafuchi and Nakabo（2007）によって 2 種 2 亜種に分類された。本研究で観察したほとんどの個体は体側が銀色で背側が暗青色もしくは暗赤色であり，この特徴は関東地方から瀬戸内海の太平洋沿岸に分布するマタナゴに一致した。また，調査地から採集した 5 個体の標本を同定したところ，すべてマタナゴであった。したがって，本研

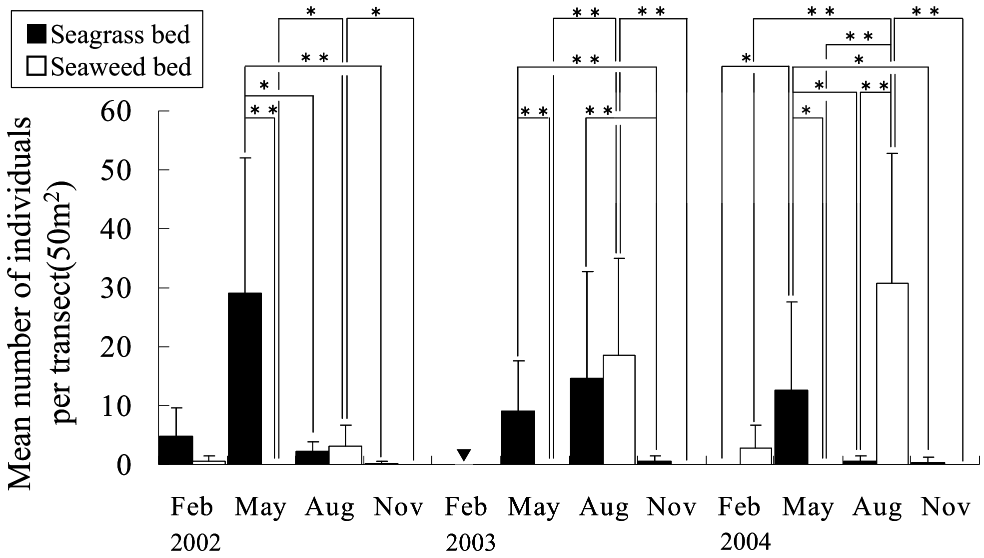

Fig. 2. Mean number of *Ditrema temminckii pacificum* yearlings observed per transect （$50m^2$, $n=5$） in the seagrass and seaweed beds in each month from 2002 to 2004. Vertical bars indicate standard deviation. Asterisked horizontal bars indicate significant differences in yearling densities （$^*p < 0.05$, $^{**}p < 0.01$）. ▼, not observed.

究で観察した個体はマタナゴとした。

3. 結果および考察

3.1 個体数の季節変化

アマモ場とアラメ場におけるマタナゴ当歳魚の個体数の季節変化を Fig. 2 に示した。1 トランセクトあたりの平均個体数について，年ごとに月および生息場間で比較したところ，いずれの年においても交互作用が認められた（2002 年は$F_{3,32}=10.6$，$p < 0.0001$；2003 年は$F_{2,24}=9.79$，$p=0.0008$；2004 年は$F_{3,32}=19.2$，$p < 0.0001$）。そこで各月に対する生息場間の差と各生息場における月間の差をそれぞれ比較した結果，どの年においてもアマモ場では 5 月に多くみられ，11 月に少なかった（2002 年と 2003 年は$p < 0.01$，2004 年は$p < 0.05$）。一方，アラメ場では 8 月に多く，5 月と 11 月に少なかった（2002 年は$p < 0.05$，2003 年と 2004 年は$p < 0.01$）。生息場間では，いずれの年でも 5 月においてアラメ場よりもアマモ場で多かった（2002 年と 2003 年は$p < 0.01$，2004 年は$p < 0.05$）。また，8 月において 2002 年と 2003 年は生息場間でほとんど違いがみられなかったものの，2004 年ではアラメ場で有意に多かった（$p=0.0001$）。

Hayase and Tanaka（1980a）によれば，マタナゴは 5 月にアマモ場で産仔する。また，産出直後の稚魚の全長は約 50〜60㎜であると報告されている（松清，1963；Abe, 1969）。本調査地では，5 月に多くの当歳魚がアマモ場で観察されており，それらの全長は約 50㎜であった。したがって，マタナゴは本調査地でもこの頃にアマモ場で産仔していると考えられた。一方，8 月になるとアマモ場の当歳魚の個体数は減少し，アラメ場で多くなる傾向がみられた。これは当歳魚がアマモ場からアラメ場に移動したことを示唆する。

3.2 標識放流

アマモ場では，放流直後の 6 月 25 日と 7 月 3 日に標識個体が観察されたが，その後，まったく確認されなかった（Table 1)。一方，アラメ場ではその逆の現象がみられ，標識個体は 6 月 25 日には観察されなかったが，その後，7 月 3 日，8 月 1 日，9 月 3，11 および 23 日に出現が確認された（Table 1)。標識放流時の全長は 70〜90㎜であったが，9 月にアラメ場で確認された標識個体は約 100㎜であった。以上の結果は，本調査地のマタナゴ当歳魚が成長に伴い，アマモ場からアラメ場へ移動したことを示している。

このような成長に伴う生息場の変化については，マダイ *Pagrus major* でも報告されている。この種の稚魚では，成長とともに増加する摂餌要求量に対して相対的に餌生物が不足し，新たな生息場を求めて浅海砂浜域から沖側へ移動すると考えられている（藤川, 1986)。また，メバル類は春季

Table 1. Mean number (± standard deviation, n=3) of marked yearlings per transect (480m^2) in the seagrass and seaweed beds in 2005

Date	Seagrass bed	Seaweed bed
25 June	0.67±0.58	0
3 July	0.33±0.58	0.33±0.58
17 July	0	0
1 August	0	0.67±0.58
20 August	0	0
28 August	0	0
3 September	0	0.33±0.58
11 September	0	0.33±0.58
23 September	0	0.33±0.58

にアマモ場で多いワレカラ類を捕食して成長し，夏季にアマモ場で餌生物が少なくなるとガラモ場へ移動する（布施, 1962a, b）。産出直後のマタナゴはアマモ場でヨコエビ類やワレカラ類などを専食することが知られている（Hayase and Tanaka, 1980b）。それら餌生物の現存量はアマモの消長と同様の周年変化を示し，春に最も多く，その後は減少して冬季に最も少なくなる（高間, 1980）。また，既往の報告から（吉川, 1978a, b），夏季におけるヨコエビ類とワレカラ類の 1m^{2}あたりの個体数をアマモ場とアラメ場で比較してみると，両者の個体数密度はアラメ場のほうで多かった。これらのことから，本調査地のマタナゴ当歳魚は産出されたアマモ場においてヨコエビ類などを餌として成育し，その後，餌要求量の増大と，夏季のアマモ場餌現存量の減少に伴い，餌を求めてアラメ場へ移動したのではないかと考えられた。

謝辞

調査の実施および本論文のとりまとめにあたりご指導頂いた東京大学大学院農学生命科学研究科 佐野光彦博士，黒倉寿博士，南條楠土博士，島根大学汽水域研究センター　堀之内正博博士，財団法人自然環境研究センター　井上隆博士，英文校閲を頂いた Graham S. Hardy 博士に深謝します。また調査を実施するにあたり，ご理解とご協力をいただいた波左間漁業協同組合代表理事組合長 佐野錬一氏，佐野秀雄氏，横須賀市自然・人文博物館館長　林公義氏，および波左間海中公園スタッフの方々に心よりお礼申し上げます。

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受付：平成 24 年 1 月 26 日
受理：平成 24 年 4 月 7 日

La mer 50 : 91, 2012
Société franco-japonaise d'océanographie, Tokyo

資　料

第 50 巻第 3−4 号掲載欧文論文の和文要旨

Tran Van VIET[1, 2]，桜本和美[2]：ベトナム・メコンデルタ地区における改良型集約的ヨシエビ養殖の役割

ベトナムメコンデルタのミースイエン（MX）地区とドンハイ（DH）地区におけるヨシエビ Metapenaeus ensis の養殖生産量に与える要因について分析した．MX 地区はエビ養殖と稲作を交互に行うローテーションシステムを実施し，DH 地区はマングローブ水域での集約的養殖を実施している．2010 年 1 月から 12 月までの間，上記 2 地区の 8 養殖業者から 120 の漁業者を抽出し，養殖期間や養殖地の面積など 22 項目について調査した．因子分析法により養殖生産量に与える主要因を特定し，その結果をもとに重回帰分析を行った．その結果，（1）平均生産量は MX 地区で 31.0 kg/ha/year，DH 地区で 39.2 kg/ha/year，（2）生産量は養殖池の水の交換頻度と養殖池の深さと高い相関を示し，(3）上記 2 地区におけるエビの全生産量に占める M. ensis の生産量は，MX 地区で 6.0%，生産額で 8.5%，DH 地区では生産量で 12.2%，生産額で 7.3%であった．また，漁業者一人当りの生産額では DH の方が MX よりも有意に高かった．

（1 College of Aquaculture and Fisheries, Can Tho University, Vietnam Tel.：84−07103−831587 ; Fax：84−0713−830247, E-mail：tvviet@ctu.edu.vn,　2 東京海洋大学大学院 海洋科学技術研究科　海洋科学系研究院　海洋環境学部門 〒108−8477 東京都港区港南 4−5−7）

奥村裕[1]，神山孝史[1]，鈴木敏之[2]：植物色素を基にした植物プランクトン組成解析へのケミカル・マス・バランス法の適用

仙台湾で採取した海水試料から植物プランクトンの色素組成を分析後，ケミカル・マス・バランス法（CMB）により，分類群組成の推定を試みた。CMB 法による解析の結果，植物プランクトン全体に占める各分類群の割合は，珪藻>プラシノ藻≧クリプト藻≧ハプト藻≧ペラゴ藻≧渦鞭毛藻の順に少なくなっていた。解析結果を CHEMTAX 法と比較すると，珪藻の割合は CMB 法で 65%，CHEMTAX 法で 64%となり，それ以外の分類群は CMB 法，CHEMTAX 法ともに 5%〜11%となり，CMB 法による解析結果は CHEMTAX 法とおおよそ一致した。また，PsbA（光化学系 II 反応中心の D1 サブユニットをコードする）遺伝子のクローン・ライブラリから得た遺伝子配列も，珪藻と相同性が高い配列が多く，CMB 法による解析結果は遺伝子配列の結果ともおおよそ一致していた。CMB 法は化学物質の排出起源の推定以外にも，色素組成を基に植物プランクトンの群集組成を簡易的に評価する方法として，利用できる可能性が示された。

(1（独)水産総合研究センター　東北区水産研究所　〒985−0001　宮城県塩釜市新浜町 3−27−5,　2)（独)水産総合研究センター　中央水産研究所 〒236−8648　横浜市金沢区福浦 2−12−4)

La mer 50 : 92-95, 2012
Société franco-japonaise d'océanographie, Tokyo

学　会　記　事

1. 6 月 10 日（日），日仏会館（東京都恵比寿）において 2012 年度総会を開催した。

日　時：2012 年 6 月 10 日（日）15 時 35 分〜16 時 10 分

場　所：日仏会館　501 会議室

出席者：61 名（出席；13，委任状による出席；48，定足数；130×1/6＝22 名）

議　長：小松会長

第 1 号議案　2011 年度事業報告

1）荒川庶務幹事より会員異動状況が報告された。

2011 年度増減　正会員　＋5－7＝－2，学生会員 ＋3 名

2012 年 3 月末現在　名誉会員　5，正会員115，特別会員　10，学生会員　5，賛助会員　7

2）活動状況

荒川庶務幹事より，評議員会（2011.6.18　日仏会館），幹事会（2011.5.30　東京海洋大学），総会（2011.6.18　日仏会館），研究発表会（2011.6.18　日仏会館）を各 1 回開催，論文賞 2 件の授与，評議員選挙，会長選挙，学会賞委員半数改選を行ったことについて報告された。

小松会長より，義援金募金活動状況および日仏共同研究助成申請・採択について報告された。

3）編集関係

吉田編集委員長より，学会誌「La mer」49 巻 1/2 号，3/4 号（創立 50 周年記念号）の発刊について報告された。

各報告ののち，第 1 号議案は承認された。

第 2 号議案　2011 度収支決算報告および監査報告

神田会計幹事より，資料 1 にもとづき 2011 年度収支決算が報告された。長島監事より，2011 年度の会計が適切であるとの監査結果が報告された。

各報告ののち，第 2 号議案は承認された。

第 3 号議案　2012 年度事業案

荒川庶務幹事より，1）総会（1 回），学術研究発表会（1 回），評議員会（1 回），幹事会（3 回）の開催，2）学会賞，論文賞の候補者の推薦と授与，3）学会賞委員選挙（半数改選），について説明された。

吉田編集委員長より，4）La mer 50 巻 1–4 号の発刊について説明された。

小松会長より，5）東北カキシンポジウム，日仏会館学術講演会の企画・開催について，説明された。

各項目の説明ののち，第 3 号議案は承認された。

第 4 号議案　神田会計幹事より，資料 2 にもとづき 2012 年予算案が説明された。

審議ののち，第 4 号議案は承認された。

第 5 号議案　荒川庶務幹事より，資料 3 にもとづき 2012 年度–2013 年度役員，評議員，学会賞推薦委員について紹介ののち，第 5 号議案は承認された。

報告事項

①小松会長より，津波で被災した三陸養殖漁業復興のための義援金募金活動の状況が報告された。

②荒川庶務幹事より，アメリカ先進陸水海洋学会 2012 年大会を本学会が後援していることについて報告された。

③内田広報幹事（代理荒川総務幹事）より，学会内メーリングリストの作成について報告された。

以上

平成 23 年度収支決算

収入の部

費　目	予算額	決算額	増　減	備　考
前年度繰越金	736,584	736,584	0	
正会員会費	1,048,000	936,000	112,000	131 名（8,000 円×131 名）
特別会員	96,000	60,000	36,000	16 名（6,000 円×16 名）
学生会員会費	24,000	12,000	12,000	6 名（4,000 円×6 名）
賛助会員会費	130,000	140,000	▲10,000	7 社（10,000 円×13 口）
学会誌売上金	164,800	120,000	44,800	
広告料	60,000	20,000	40,000	
別刷り代等	461,150	500,000	▲38,850	別刷り，超過頁，カラー印刷費
掲載料	150,000	800,000	▲650,000	3 編×50,000 円
雑収入	73,298	100,000	▲26,702	学術著作権使用料他
寄付金	550,000	0	550,000	笹川財団
収入合計	3,493,832	3,424,584	69,248	

支出の部

費　　目	予算額	決算額	増　減	備　　考
学会誌印刷費	1,645,800	1,800,000	▲154,200	49巻1．2号　49巻3．4号
送料・通信費	104,720	150,000	▲45,280	
事務費	612,635	700,000	▲87,365	人件費，事務用品，封筒他
交通費	11,100	20,000	▲8,900	
会議費	29,924	5,000	24,924	
学会賞経費	18,194	50,000	▲31,806	賞状他
50周年記念事業	0	0	0	
雑費	18,230	25,000	▲6,770	振込み手数料他
次年度繰越	1,053,229	674,584	378,645	
支出合計	3,493,832	3,424,584	69,248	

平成24年度予算（案）

収入の部

費　　目	24年度予算	23年度予算	増減	備考
前年度繰越金	1,069,241	736,584	332,657	
正会員会費	936,000	936,000	0	117名（8,000円×117名）
特別会員	60,000	60,000	0	10名（6,000円×10名）
学生会員会費	16,000	12,000	4,000	4名（4,000円×4名）
賛助会員会費	130,000	140,000	▲10,000	7社（10,000円×13口）
学会誌売上金	150,000	120,000	30,000	
広告料	20,000	20,000	0	
別刷り代等	500,000	500,000	0	別刷り，超過頁，カラー印刷費
掲載料	700,000	800,000	▲100,000	14編×50,000円
雑収入	100,000	100,000	0	
寄付金	0	0	0	
収入合計	3,681,241	3,424,584	256,657	

支出の部

費目	24年度予算	23年度予算	増減	備考
学会誌印刷費	1,800,000	1,800,000	0	4冊×450,000円
送料・通信費	100,000	150,000	▲50,000	
事務費	700,000	700,000	0	人件費，事務用品，封筒他
交通費	20,000	20,000	0	
会議費	15,000	5,000	10,000	
学会賞経費	50,000	50,000	0	賞状他
雑費	25,000	25,000	0	振込み手数料他
次年度繰越（予備費）	971,241	674,584	296,657	
支出合計	3,681,241	3,424,584	256,657	

日仏海洋学会　役員・評議員（2012－2013 年度）
会　長：小松輝久
副会長：森永　勤　吉田次郎

顧　問：今脇資郎
編集委員長：吉田次郎
幹　事：（庶務）荒川久幸，長井健容
（会計）神田穣太，市川　香
（編集）田中祐志，磯田　豊
（研究）北出裕二郎，千手智晴
（渉外）小池康之，中野俊樹
（広報）内田　裕，柳本大吾
監　事：野村英明，宮崎奈穂
評議員：荒川久幸，石坂丞二，石丸　隆，磯田　豊，市川　香，今脇資郎，内田　裕，神田穣太，北出裕二郎，小池勲夫，小池　隆，河野　博，小松輝久，斉藤誠一，千手智晴，田中祐志，中田英昭，長島秀樹，森永　勤，門谷　茂，柳　哲雄，山口征矢，山崎秀勝，吉田次郎
（選挙選出 24 名）
小池康之，中野俊樹，長井健容，柳本大吾
（会長推薦 4 名）　以上 28 名
賞委員：
2012年度：吉田次郎，瀬川　進，千手智晴，有元貴文，北出裕二郎，小松輝久，荒川久幸，河野　博，石坂丞二　以上 9 名

2. 6 月 10 日（日），日仏会館（東京都恵比寿）において 2012 年度研究発表会を開催した。
日　時：2012 年 6 月 10 日（日）10 時 00 分～15 時 40 分
場　所：日仏会館　501 会議室
プログラムは以下の通り。

10：00－11：20　座長　吉田次郎（海洋大）

1. Hypolimnetic turbulence enhancement and superposition of large-scale internal waves in a strongly stratified Lake Biwa (Japan)
Guillaume Auger[1], Hidekatsu Yamazaki[1], Hikaru Honma[1], Takeyoshi Nagai1, Michio Kumagai[2]
(1：TUMSAT, 2：Ritsumeikan University)
2. ビンセネス湾沖で係留観測によって捉えた南極底層水の特性
○北出裕二郎[1]，嶋田啓資[2]，田村岳史[3]，深町　康[2]，青木　茂[2]，大島慶一郎[2]，牛尾収輝[3]
（1：海洋大環境，2：北大低温研，3：極地研）
3. Effect of Turbulent Mixing on Modification of Water Masses in the Central Equatorial Pacific
○ Lingqiao Cheng, Yujiro Kitade (TUMSAT)
4. 日本南岸の黒潮流路変動
前田恵理子[1]，出口大貴[1, 2]，根本雅生[1]，○吉田次郎[1]
（1：東京海洋大学，2：神奈川海洋科学高校）

13：40－15：20　座長　飯淵　敏夫（海生研）

5. Phosphorus stress of microphytoplankton community in the western subtropical North Pacific.
○ Mathias GIRAULT, Hisayuki ARAKAWA, Fuminori HASHIHAMA (TUMSAT)
6. 海底堆積粒子の粒径の相違による褐藻類アラメ配偶体の生残・成長への影響
○渡辺隼人，松本陽，荒川久幸（海洋大環境）
7. アイゴは海藻と動物のどちらを選択するか？
○柴田玲奈[1]，片山知史[2]，荒川久幸[3]，齊藤　肇[1]
（1：水工研，2：東北大・農，3：海洋大環境）
8. 東シナ海における冬季流れ藻の分布と輸送に関する研究
○水野紫津葉[1]，小松輝久[1]，鰺坂哲朗[2]，福田正浩[1]，國分優孝[1]，Alabsin natheer[1]，阪本真吾[1]，青木優和[3]
（1：東大・大海研，2：京大院・農，3：東北大・農）
9. 仙台湾におけるアカガイの加入量変動
○佐々修司[1]・佐々木浩一・南卓志・片山知史[2]
（1：東大・大海研，2：東北大・農）

15：30－16：10　総会
16：20－16：30　2012 年度日仏海洋学論文賞の授賞式

1. 小野敦史会員（東京海洋大学）
Distribution and population structure of salps off Adelie Land in the Southern Ocean during austral summer, 2003 and 2005, 48 (2), 55–70, 2010
2. 柴田玲奈会員（水産総合研究センター）
アイゴ成魚に対する動物性餌料の重要性, 48 (3-4), 103–111, 2010

3. 入会

氏名	所属
田上英明	海洋政策研究財団 〒105-0001 東京都港区虎ノ門 3-4-10　虎ノ門 35 森ビル
加茂　崇	鹿児島大学大学院連合農学研究科 〒890-0056　鹿児島県鹿児島市下荒田4-50-20
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佐々修司	東京大学海洋研究所行動生態計測 〒277-0882　千葉県柏市柏の葉 5-15

4. 寄贈図書および資料
農工研ニュース（農村工学研究所）；No. 75-79,
神奈川県立博物館研究報告；41,
FRAN NEWS；28-30,

水産総合研究センター研究報告；35–36,
広島観光コンベンション；Vol. 84–86,
Ship & Ocean Newsletter（海洋政策研究財団）；No. 265–285,
農村工学研究所報告；51,
なつしま（JAMSTEC）；306–315,
水産技術；第 4 巻 1–2,
J–STAGE NEWS（独立行政法人科学技術振興機構）；No. 29–3,
「海―自然と文化」（東海大学海洋学部）；Vol. 9 No. 2,
Techno–ocean News（テクノオーシャンネットワーク）；No. 42–45,
高知大学海洋生物研究報告（高知大学総合研究センタ）；No. 26,
海洋白書；2012 年度,
日本海ブロック資源研究会報告；21–22 年度,
養殖研究レター；Vol. 2,
Ocean Breeze；5–8,
日仏獣医学会誌；Vol. 22, 1–2,
ATOMOSPHERE AND OCEAN RESEARCH INSTITUTE THE UNIVERSITY OF TOKYO; 2011,
増養殖研究レター；1,
日仏生物学会誌；Vol. 51,
ABSCJF；No. 42,
気候システムニュース；No. 2,
中国海洋大学学報；Vol. 41 187–199, 42 200–203,
Progress in fishery sciences; Vol. 32 4–6, 33 1–2,
Oceanologia et Limnologia sinica; Vol. 41 1–6,
Meereswissenchaftliche Berichte Marine Science Repoorts; Vol. 84–85,
Annual Report；2011 年度版,
Chinese journal of Oceanology and limnology; Vol. 29 1–5

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（正会員・学生会員）

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自　宅	住　所　〒 電　話　　　　E-mail:	
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）

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日　仏　海　洋　学　会

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