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Estimation of the sediment flux from the cultured Japanese oyster in Ofunato Estuary and its annual variation
- Calculation by incorporating the monthly mean environmental data for ten years -

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Abstract : As the first step of obtaining an optimal culture-density of oysters in a farm, the magnitude of sediment flux from Japanese oyster *Crassostrea gigas* was examined in Ofunato Estuary. By applying monthly averages of observed environmental data such as water temperature, salinity and chlorophyll-*a* concentration from 1985 to 1994 to a population dynamics model, the fluxes of sediments discharged by oysters were calculated, and the calculated values of sediment fluxes were compared with observed ones. The results of our simulation qualitatively reflect the patterns of seasonal variation of the fluxes. Also, in quantity, our results are not contradictory to observed values when the dispersion by the flow in the bay is taken into account. In conclusion, the population dynamics model we adopted is applicable to estimate the fluxes of sediments discharged by oysters in Ofunato Estuary. Moreover, by using the environmental data obtained from respective years instead of the averaged values, it is suggested that environmental characteristics of each year are reflected in the sediment fluxes.

Keywords : *Crassostrea gigas, Ofunato Estuary, population dynamics model, sediment flux.*

1. Introduction

The Japanese oyster *Crassostrea gigas* is a typical bivalve cultured commercially. In Japan, the cultivation of this species is done mostly by the suspended culture using rafts. In 2003 the oyster harvest in Japan yielded 224,861 t in live weight (JAPANESE MINISTRY of AGRICULTURE, FORESTRY and FISHERIES, 2005), corresponding to 46% of the total cultivated shellfish production in the nation. Since oysters take in a large amount of seawater in respiration and ingestion, they purify seawater by filtering suspended materials. For example, filtration rate of an oyster is estimated about 2.5 L h^{-1} in 80 mm shell length (KOBAYASHI *et al.*, 1997). However, oyster excretions also increase organic material in the bottom sediment. Therefore, the bottom environmental conditions in oyster farming areas were pointed out as the important factor of sustaining the high productivity of oyster (KUSUKI, 1977a, b). Especially, in France where oysters are cultivated in the bottom culture system, the bottom condition is one of the most important factors for oyster culture. Effects of the oyster cultivation on the ecosystem of an intertidal mudflat were investigated and estimated by the model (LEGUERRIER *et al.*, 2004). KUSUKI (1977a) estimated that the amount of faecal materials was about 19.3 t per a raft during the period from June to next April using experimental data. He directly measured faecal materials of oysters only four times in the farming areas of Hiroshima Bay, western Japan. However, the direct measurements of oyster's faecal materials in the farming areas of northern Japan were not carried out although the environmental conditions of seawater were investigated and

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compared between western and northern Japan (Kamiyama *et al.*, 2005). How many organic materials do oysters remove from seawater and how many suspended materials do they add to seawater as excrements in northern oyster farming area? What is the optimal value of culture-density of oysters in a farm? In the present paper, as the first step to solve these problems, we calculate the fluxes of sediments excreted by oysters in Ofunato Estuary, by applying observed environmental properties to a population dynamics model.

By comparing the calculated values of sediment flux with observed ones, we examine whether the model is applicable to *C. gigas* in Ofunato Estuary and how much oyster excretion is observed as sediment in the farm. The population dynamics model we adopt was developed by one of the authors (MK) and his co-workers and successfully applied to *C. gigas* in mariculture fields in Hinase waters of the Okayama Prefecture, Japan (Kobayashi *et al.*, 1997). The significant feature of this model is in that it includes the effects of time-evolutional size variance of oysters.

In addition, by using the environmental data obtained from respective years instead of the averaged ones, we examine annual fluctuations in the sediment flux due to the differences in the environmental condition.

2. Methods

2.1 Description of the study site

Ofunato Estuary is located on the northeastern Pacific coast of Japan (Fig.1). It is a typical semi-closed bay where Sakari River flows in with an average flow rate of 2.80 m^{3}s^{-1}. The size of this Estuary is 6km in length and 1.5km in width with a maximum depth of 38m. It has 7.89km^2 in area and 1.24×10^8 km^3 in volume. In Ofunato Estuary, the Japanese oyster is commercially cultured and its annual landing is about 300 t in wet weight in the 1980s (Miyazawa and Hayakawa, 1994).

2.2 Simulation model

To examine the growth of *C. gigas*, we use a population dynamics model composed by Kobayashi *et al.* (1997) which is based on a series of papers (Powell *et al.*, 1992; Hofmann *et al.*, 1992; Hofmann *et al.*, 1994; Powell *et al.*, 1994; Powell *et al.*, 1995). This model was applied to *C. gigas* in Hinase waters, Okayama Japan. Fundamental equations, coefficients and biological factors used in the model are shown in Table 1. In the present paper, this model is used without modification except the forms of reproductive efficiency, R_{eff} (Eq.17).

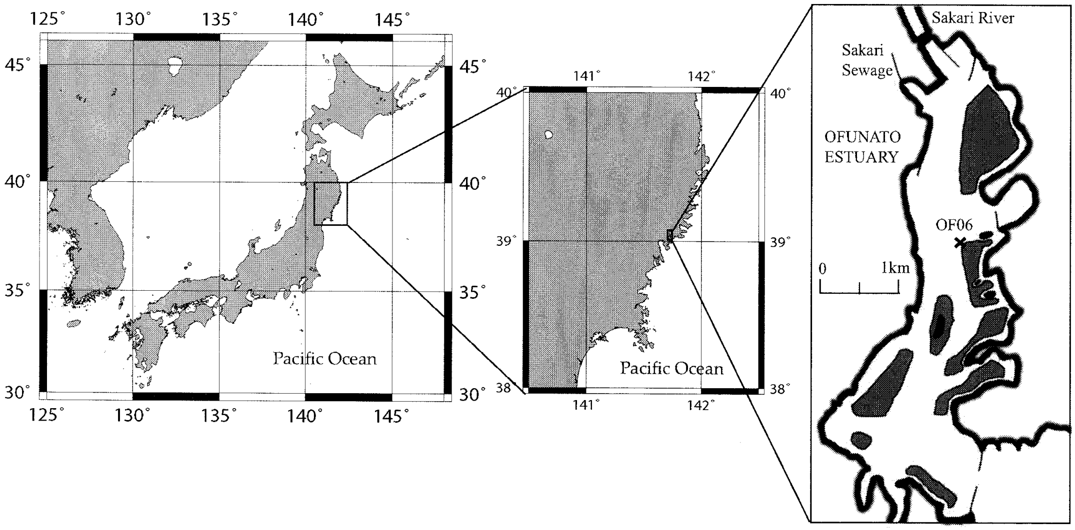

Fig. 1. A map of study site, Ofunato Estuary. The surfaces occupied by oyster rafts are indicated by gray. Black-painted regions in the Estuary indicate small islands. Environmental data are observed at Station OF06.

Table 1 Fundamental equations, coefficients and biological factors used in our population dynamics model

Fundamental equations

Time-evolution equation

(1) $dO_j/dt = P_{gj} + P_{rj}$ + (gain of O_j from O_{j-1}) − (loss of O_j to O_{j+1}) + (gain of O_j from O_{j+1}) − (loss of O_j to O_{j-1})

The constitution of net production

(2)* $NP_j = P_{gj} + P_{rj} = A_j - R_j$

Reproductive efficiency $R_{\mathrm{eff}\,j}$

(3) $P_{rj} = R_{\mathrm{eff}\,j} NP_j$

Formulations of production rates (by (2) and (3))

(4)* $P_{gj} = (1 - R_{\mathrm{eff}\,j})\ (A_j - R_j)$

(5)* $P_{rj} = R_{\mathrm{eff}\,j}\ (A_j - R_j)$

j (=1,2,-10) : suffix indicating each size class

O_j : oyster standing stock in each size class

t : time

P_{gj} : somatic production rate

P_{rj} : reproductive tissue production rate

NP_j : net production

A_j : assimilation rate

R_j : respiration rate

Concrete forms of the rates

Respiration rate (per mass)

(6)* $R_j / W_{dj} = r_s\ (69.7 + 12.6T)\ W_{dj}^{-0.25}$

Modification factor by salinity

(7) $r_s = 1$ at $20 \leqq S$

$r_s = 1 + (r_t - 1)\ (20 - S)/5$ at $15 < S < 20$

$r_s = r_t$ at $S \leqq 15$

Temperature-dependent factor

(8)** $r_t = 0.0915\ T + 1.324$ at $20℃ \leqq T$

$r_t = 0.007\ T + 2.099$ at $T < 20$ ℃

Assimilation rate

(9) $A_j = a_{\mathrm{eff}} I_j$

Ingestion rate

(10) $I_j = FR_j \times$ Food

Assimilation efficiency

(11) $a_{\mathrm{eff}} = 0.75$

Filtration rate

(12)*** $FR_j = f_s f_T FR_{wj}\ T^{0.5}/4.47$

Size-dependent factor

(13) $FR_{wj} = 2.51\,W_{dj}^{0.279}$ at $2.0\ \mathrm{g} < W_{dj}$

$FR_{wj} = 0.117\,W_{dj}^3 - 1.05\,W_{dj}^2 + 3.09\,W_{dj} + 0.133$ at $W_{dj} \leqq 2.0$ g

Modification factor by salinity

(14) $f_s = 1$ at $20 \leqq S$

$f_s = (S-10)/10$ at $10 < S < 20$

$f_s = 0$ at $S \leqq 10$

Modification factor by the concentration of suspended material

(15) $f_\tau = 1 - 0.01 (\log_{10} \tau + 3.38)/0.0418$

Ambient food concentration

(16) Food $= 0.088$ Chl-*a* $+ 0.520$

Reproductive efficiency (for size classes $j=4$ to 10)

(17) $R_{\mathrm{eff}} = 0.8$ at $21℃ \leqq T$

$R_{\mathrm{eff}} = 0.073T - 0.73$ at $10℃ < T < 21℃$

$R_{\mathrm{eff}} = 0$ at $T \leqq 10℃$

(between May and August)

$R_{\mathrm{eff}} = 0.8$ at $21℃ \leqq T$

$R_{\mathrm{eff}} = 0.27T - 4.86$ at $18℃ < T < 21℃$

$R_{\mathrm{eff}} = 0$ at $T \leqq 18℃$

(between September and April)

(18) $R_{\mathrm{eff}} = 0$ (for size classes $j = 1$ to 3)

a_{eff} : assimilation efficiency

R_j : respiration rate (μL O_2 consumed h^{-1})

W_{dj} : dry meat weight (g)

T : water temperature (℃)

S : salinity

FR_j (FR_{wj}) : filtration rates (L filtered per individual h^{-1})

τ : total particulate content (g L^{-1})

Food : ambient food concentration (mg dry wt L^{-1})

Chl-*a* : chlorophyll-*a* concentration (μg L^{-1})

Caloric conversions

Oysters : 5210 cal g dry wt^{-1} (= 21809 J g dry wt^{-1})

Food : 5168 cal g dry wt^{-1} (= 21634 J g dry wt^{-1})

Energy consumption of oysters by respiration : 4.83 cal mL^{-1} O_2 (= 452928 J mol^{-1} O_2)

Spawning

Trigger condition : when the gonadal fraction reaches 50% of total meat weight

Result : all of the reproductive tissue is lost

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* In the previous papers such as KOBAYASHI *et al.* (1997) and POWELL *et al.* (1992), both respiration rate used in (2), (4) and (5), R_j and respiration rate per mass used in (6), R_j / W_{dj} were written as R_j.

** The values of r_t at 20℃ derived from two equations in (8) are not corresponding to each of them. However, we used these equations, which are based on the experimental data of SHUMWAY and KOEHN (1982), in the same manner as POWELL *et al.* (1992) did.

*** The effect of temperature on relative filtration rate of *C. gigas* was examined experimentally by WALNE (1972) and found to be of the form:

FR (at 20℃) $= 2$ FR (at 5℃),

where FR is the filtration rate (L filtered per individual h^{-1}). Thus, the influence of temperature on filtration rate can be obtained as Eq. 12.

Table 2 Biomass and length dimensions of the oyster size classes used in this model.

Model size class	Biomass (g dry wt)	Length (mm)
1	0.507×10^{-8}–0.202×10^{-1}	0.3–25
2	0.202×10^{-1}–0.642×10^{-1}	25–35
3	0.642×10^{-1}–0.219	35–50
4	0.219–0.409	50–60
5	0.409–0.695	60–70
6	0.695–1.10	70–80
7	1.10–1.65	80–90
8	1.65–2.37	90–100
9	2.37–3.83	100–115
10	3.83–5.84	115–130

We summarize the model used in this study as below.

Oysters are divided into 10 size classes ($j=1,2,-10$) according to the shell length. To examine the biomass of oysters, we need to convert the size class into biomass. The biomass and length dimensions of the oyster size classes are shown in Table 2. Owing to this classification of mass, the effect of time-evolutional size variance of oysters in the process of growth is included through time-evolution, which is explained as follows: After a time-step, total energy (biomass) of oysters belonging to a class is changed by biological processes. This increase/decrease of energy transfers a part of the oysters to the next upper/lower class because the energies (biomasses) are fixed in each class. As a result, non-single mass distribution is obtained through time-evolution from single initial mass, which is very unique character of this model.

The time-evolution equation of oyster standing stock Eq.1 represents that net production changes biomass of individual oysters in quantity and that individuals which evolve from the former size classification after a time step are classed into a new size class thereafter. Moreover, the net production is determined by the environmental parameters such as temperature, salinity and chlorophyll-a concentration through two rates A_j (Eq.4) and R_j (Eq.5), whose concrete forms are represented by Eqs.6–18. Table 1 also mentions the conditions of spawning. Equation 18 represents that oysters with size classes $j = 1$ to 3 are too young to spawn. One of the important points in our calculation is that the assimilation rate is obtained from the ingestion rate using an assimilation efficiency of 0.75 (Eqs.9–11), an average value obtained from GERDES (1983) (0.724–0.760). In reality, all calculations are done in terms of energy, which is not explicitly shown in the equations described above. Caloric conversions are also mentioned in Table 1.

As above-mentioned, we do not use the reproductive efficiency, R_{eff} of KOBAYASHI *et al.* (1997). The function of R_{eff} used in Hinase waters by KOBAYASHI *et al.* (1997) represents that reproductive tissue is not produced for $T < 23$℃. If we apply the function used in Hinase waters to Ofunato Estuary, oysters cannot spawn since water temperature of Ofunato Estuary is lower than that of Hinase waters. Therefore, at first, we had used the following function:

$$\text{(17a)}\quad \begin{aligned} R_{\mathrm{eff}} &= 0.8 && \text{at } 21℃ \leqq T; \\ R_{\mathrm{eff}} &= 0.073T-0.73 && \text{at } 10℃<T<21℃; \\ R_{\mathrm{eff}} &= 0 && \text{at } T\leqq 10℃; \end{aligned}$$

(in all seasons).

This function is different from that in Hinase waters, only in numerical values. However, our simulation using Eq.17a showed an unnatural result that spawning lasts from June to December, which was dependent on depth. In fact, the decline of water temperature in autumn induces that energy share to reproductive tissues sharply decreases, which is really observed for the Japanese oysters (KUSAKA *et al.*, 1991). Thus, we use Eq.17, which represents that for $T \leqq 18$℃, $R_{\mathrm{eff}} = 0$

between September and April. By the use of Eq.17, the end of spawning came earlier, namely in October. Therefore, the natural conditions are reflected.

2.3 Calculation of sediment fluxes

In Ofunato Estuary, starting from May, individual oysters are cultivated over 2 years. In the present work, the growth of oysters from May 15 is simulated. Namely, all oysters are put into size class 2 on May 15. Then, the development of oysters for a 2-year period is simulated by the methods described in the previous subsection. We take 1 day as a time-step in our numerical simulation. In the farm, oysters are bound to ropes. In our simulation, oysters are bound at six depths of 0, 5, 10, 15, 20 and 25m, and the surface density of oysters at each depth is set to 100 ind.m^{-2} for the convenience of calculation. In other words, oysters at depths between 0 and 2.5m are represented by those at 0m, and oysters between 2.5 and 7.5m are represented by those at 5m and so on. Environmental properties at each depth which are necessary for our simulation, water temperature, salinity and chlorophyll-*a* concentration, were observed in Ofunato Estuary between 1985 and 1994 (HAYAKAWA *et al.*, 2001; HAYAKAWA *et al.*, 2002).

We run two types of simulations. At first, we calculate the growth of oysters by using the monthly averaged values of the environmental properties to examine whether the population dynamics model we adopted is applicable to oysters in Ofunato Estuary. Next, by simulations using the monthly values obtained from respective years, we investigate the effects of the environmental characteristics on the growth of oysters. Especially, we use two 2-year data, namely, the data between May 1986 and April 1988 and those between May 1990 and April 1992. In the period between May 1987 and April 1988, lower chlorophyll-*a* concentration was observed, while it was higher between May 1991 and April 1992. Thus, we can obtain the fluxes of sediments excreted by oysters in the two typical periods. Note that calculation from one year before is necessary to see the effects of the environmental characteristics of a year because individual oysters are cultivated over 2 years and both first-year oysters and second-year ones are simultaneously cultivated.

The fluxes of the oyster excretion are calculated as follows. The materials ingested but not assimilated are excreted. Assuming an assimilation efficiency of 0.75, 0.25 is the excretion rate of oyster. In Ofunato Estuary, the depth of the cultivation is shallower than 12m. At three depths of 5, 10 and 15m, the fluxes of sediments are calculated as the sum of excretions of oysters at upper levels. Namely, 50 ind.m^{-2} at 0m and 50 ind.m^{-2} at 5m contribute to the flux of sediments at 5m. And, 50 ind.m^{-2} at 0m, 100 ind.m^{-2} at 5m and 50 ind.m^{-2} at 10m contribute to the flux of sediments at 10m. Moreover, 50 ind.m^{-2} at 0m, 100 ind.m^{-2} at 5m and 100 ind.m^{-2} at 10m contribute to the fluxes of sediments at 15m and deeper levels.

3. Environmental data

In our simulation, we use the environmental properties at the middle of Ofunato Estuary, named as Station OF06. This station is located near a raft (the culture facilities of oysters). Our simulation needs observations of water temperature, salinity and chlorophyll-*a* concentration at each depth. Moreover, observed values of sediment fluxes are also necessary to compare them with the results of our simulation. These environmental data were obtained from 1985 to 1994 and were reported in HAYAKAWA *et al.* (2001) and HAYAKAWA *et al.* (2002). We summarize the characteristics of their average data as below.

Chlorophyll-*a* concentrations are high in early spring (February-March; 4μg L^{-1} at 5m and 10m). For the surface layer (0m), higher chlorophyll-*a* concentrations are observed between May and October (3–9μg L^{-1}), showing a maximum (9μg L^{-1}) in September.

The sea surface temperature is highest (23℃) in August. At deeper depths, it reaches a maximum later (17℃; in October at 25m).

Salinity of sea surface fluctuates between 20 and 33, which do not affect the growth of oysters, because of the higher optimal salinity of *C. gigas* (MANN *et al.*, 1991).

Between May 1987 and April 1988, lower

chlorophyll-*a* concentration was observed. Especially, the maximum value at surface layer was $2\mu g\ L^{-1}$ and that at 5m was $3\mu g\ L^{-1}$. Meanwhile, in the period between May 1991 and April 1992, higher chlorophyll-*a* concentration was observed. At 0m, it exceeded $10\mu g\ L^{-1}$ between July and September 1991, especially $20\mu g\ L^{-1}$ in September 1991. Extremely low salinities had occasionally been observed (6.6 at July 1986 and 12.3 at October 1991).

4. Results of simulations and comparison with observational data

4.1 Simulation using 10 years' averaged data

At first, we describe the results of the simulation using monthly averaged environmental data from 1985 to 1994.

Individual oysters are cultivated over 2 years. We show the simulated growth of oysters at the depth of 0m as an example (Fig. 2), showing that oyster size increases with time. As in Fig. 3, sediment fluxes at three depths of 5, 10 and 15m over 2 years show monotonic increases until September of the first year and thereafter remain nearly stable until January of the second year. The fluxes then nearly monotonically increase again until September and thereafter nearly monotonically decrease until landing, May of the third year. However, the fluxes have small peaks at each March. The peaks of September are probably ascribed to the growth of oysters in summer season. That is because the highest chlorophyll-*a* concentration at surface layer appears from June to September. The secondary peaks of March are also probably ascribed to higher chlorophyll-*a* concentration. Our simulation shows that, at deeper levels, oysters grow later and the spawning is weaker because of lower temperature.

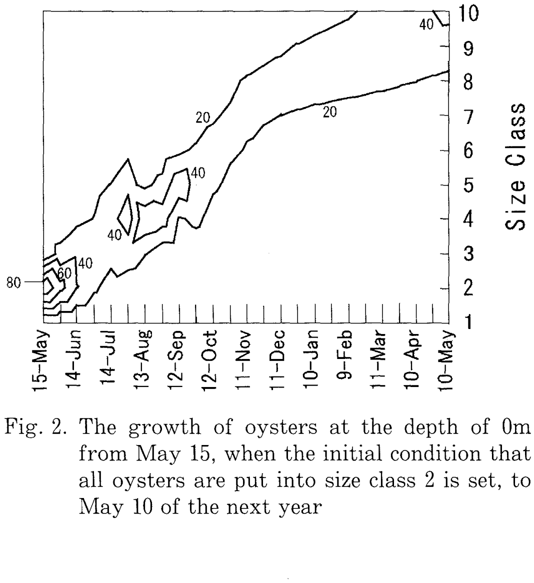

Fig. 2. The growth of oysters at the depth of 0m from May 15, when the initial condition that all oysters are put into size class 2 is set, to May 10 of the next year

The oysters are cultivated over 2 years from May, but, in each farm, oysters are planted every spring. Namely, oysters of first-year and oysters of second-year are of the same number in each raft. Then, the oysters of age-1 and age-2 equally contribute to the sediment fluxes. The seasonal variation of the sediment fluxes is obtained by averaging the contributions by oysters of age-1 and age-2. As shown in Fig.4, the sediment fluxes have a maximum in September and a secondary peak in March. Figure 5 shows contour lines of the calculated sediment fluxes, which must be compared with the average values of observational results. The observation shows that the sediment (total carbon) fluxes reach a maximum in September ($22\ g\ m^{-2}day^{-1}$ at deeper levels than 15m) and March ($16\ g\ m^{-2}day^{-1}$) and a minimum in January ($12\ g\ m^{-2}day^{-1}$) (HAYAKAWA *et al.*, 2001; HAYAKAWA *et al.*, 2002). Both the calculated values and the observed ones have similar properties of having a maximum at September and a secondary peak in March and a minimum in January.

Next, quantitatively sediment fluxes are considered. To this end, the surface density of oysters in our calculation, 250 $ind.m^{-2}$ (50 $ind.m^{-2}$ at 0m, 100 $ind.m^{-2}$ at 5m and 100 $ind.m^{-2}$ at 10m), must be converted to real density in Ofunato Estuary. The production of oysters in Ofunato Estuary is about 100 kg $year^{-1}$ per 1km rope (wet weight) (MIYAZAWA and HAYAKAWA, 1994). An oyster is estimated about 1-2.5g dry meat weight. This is converted to 5.3-12.0g wet meat weight (KOBAYASHI *et al.*, 1997). So, the density of oyster in Ofunato Estuary is about 0.8×10^4-1.9×10^4 $ind.km^{-1}\ year^{-1}$. A raft of oyster cultivation has 112 ropes of 12m long. Thus, the surface density of oysters immediately below the raft is estimated as 600-1300 $ind.m^{-2}$. Then,

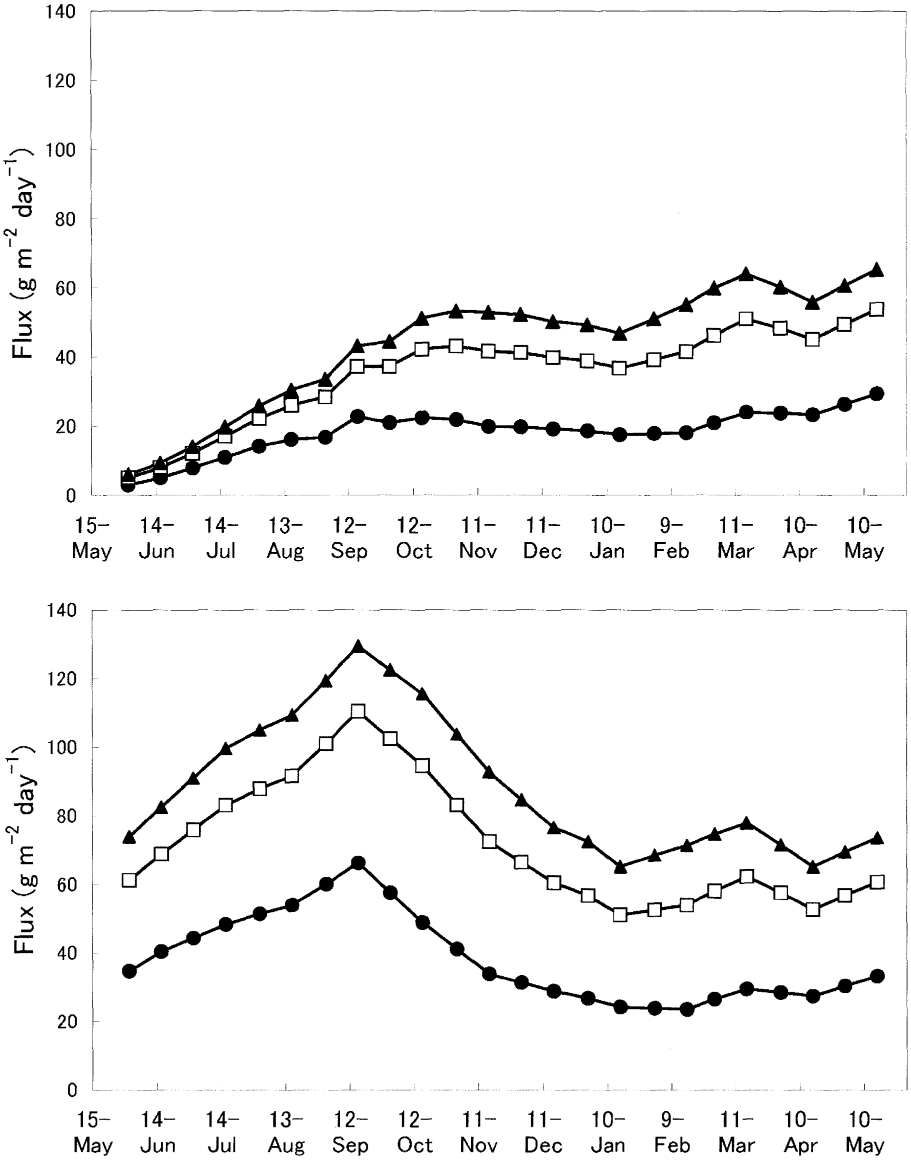

Fig. 3. The time-evolution of sediment fluxes over 2 years at three depths of 5, 10 and 15m. The values at each depth are indicated by symbols; ●: 5m, □: 10m and ▲: 15m. (a) for first one-year period (upper); (b) for second one-year period(lower).

Table 3 The sediment fluxes under an oyster-cultivation raft (in unit of g m^{-2}day^{-1})

Season	Simulated values	Observed values
September (maximum)	170–430	22
March (secondary peak)	140–350	16
January (local minimum)	110–270	12

The respective supposed surface densities of oysters are different. (See Text.)

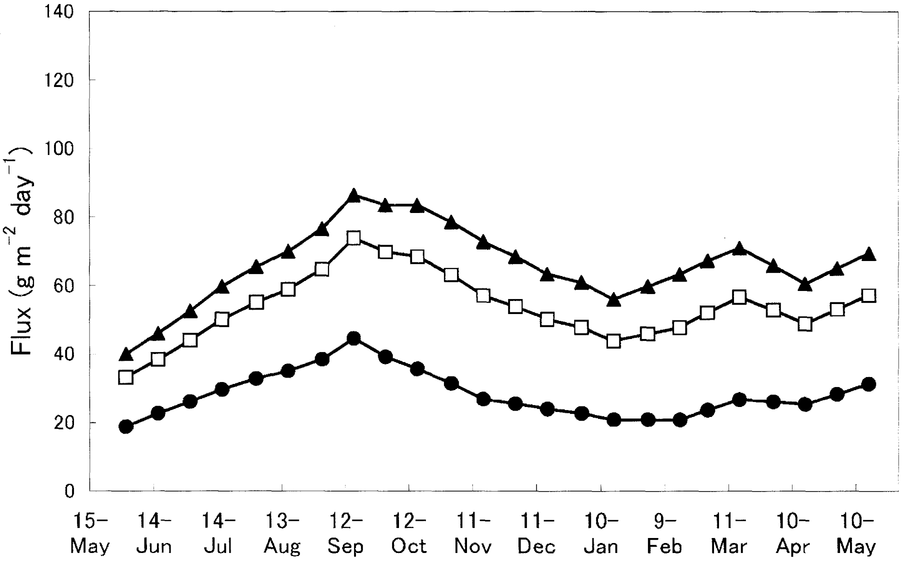

Fig. 4. The seasonal variation of the sediment fluxes obtained by using average data. Symbols are same as in Fig.3.

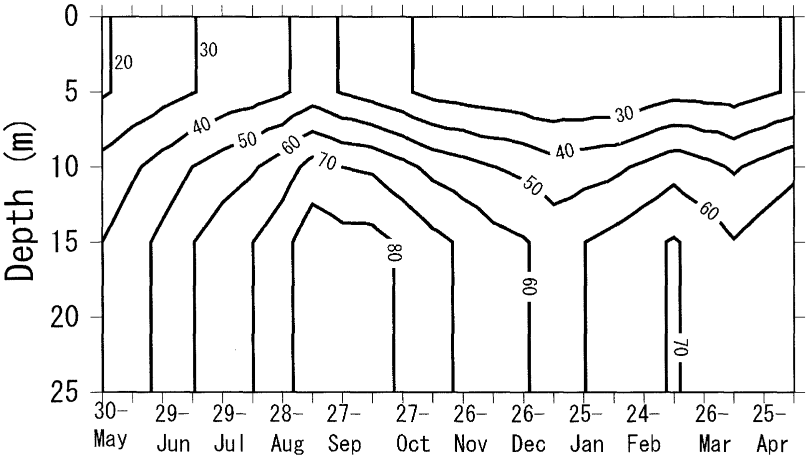

Fig. 5. The seasonal variation of the vertical distribution of sediment flux (calculated values). Numerals attached to curves represent the values of fluxes (g m^{-2} day^{-1}).

the calculated sediment fluxes multiplied by 2–5 must be compared with observed ones. In Table 3, both values of the sediment fluxes are shown. The calculated values are 10–20 times larger than observed ones. However, this does not defeat our model but only indicates that the assumption that sediments discharged by oysters remain just under a cultivation raft is oversimplified. In practice, the tidal flow disperses sediments and reduces the fluxes. The area occupied by rafts is $8\times10^4\mathrm{m}^2$, and its fraction to the total area of Ofunato Estuary (8×10^6 m^2) is 0.01. If the sediments spread over the bay, the fluxes are rarefied to the level of 1/100. The results of our simulation suggest the rate of rarefaction withl/10–1/20. They are comparable to observational data.

4.2 The case using two 2-year data

In this subsection, we describe the results of

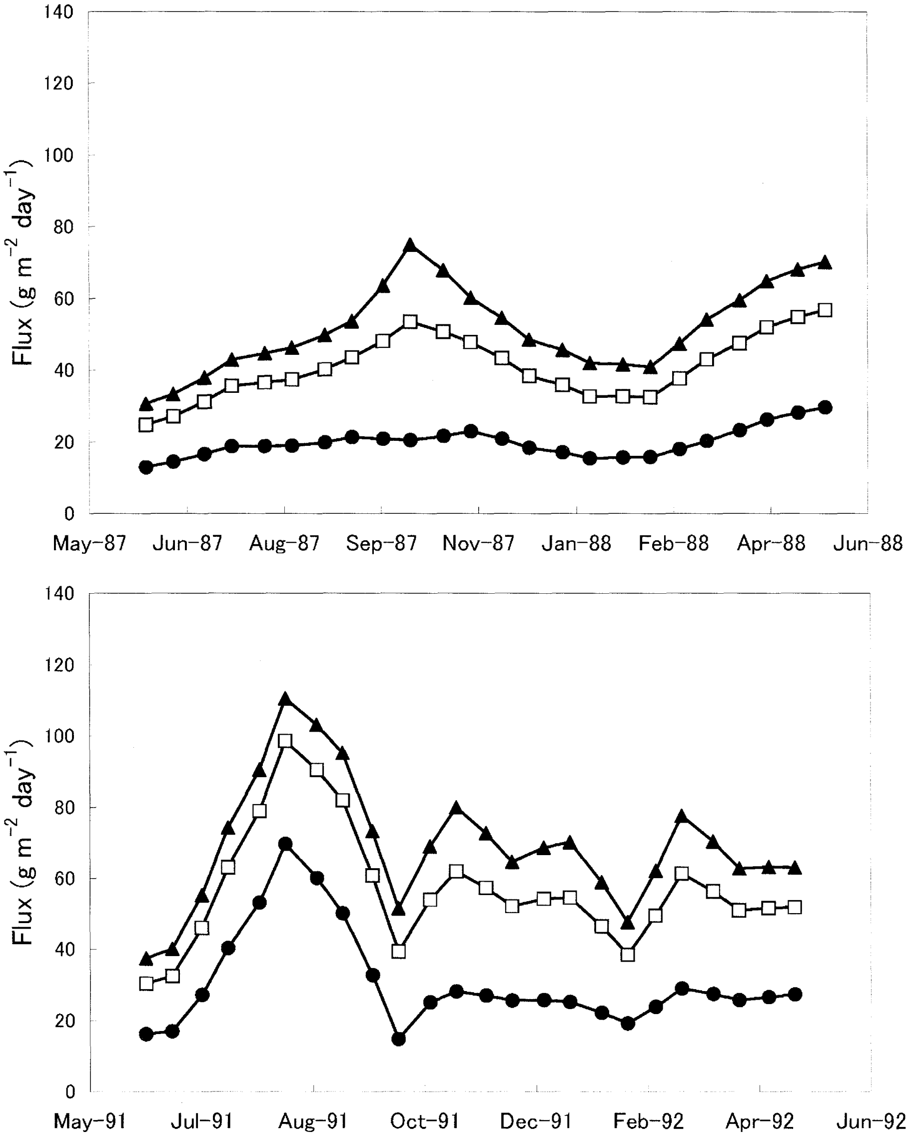

Fig. 6. Temporal changes in the sediment fluxes by using the monthly values obtained from respective years. Symbols are same as in Fig. 3. (a), the period between May 1987 and April 1988 (upper); (b), between May 1991 and April 1992 (lower).

our simulations for the case of two periods, when extremal chlorophyll-*a* concentrations were observed. In the period between May 1987 and April 1988, lower chlorophyll-*a* concentration was observed, while between May 1991 and April 1992 higher one was observed. The temporal changes of the sediment fluxes between May 1987 and April 1988 shown in Fig. 6 (a) were obtained by calculation using environmental data between May 1986 and April 1988. Likewise, those between May 1991 and April 1992 shown in Fig. 6 (b) were obtained by the data between May 1990 and April 1992. Figures 6 and 4 show that for 250 ind.m^{-2}, the maximal values of the sediment fluxes in each calculation are 110 g m^{-2}day^{-1} for 1991–1992, 86 g m^{-2} day^{-1} for the averaged data and 75 g m^{-2}day^{-1} for 1987–1988, which suggests that the sediment fluxes have a positive correlation with chlorophyll-*a* concentration. Both for the averaged data and in the period between 1987 and 1988, maximal values are reached in October, while in the period between 1991 and 1992, the maximum is in August and the value in October was a minimum, which is ascribed to the extremely low salinity at surface layer in October. Without this low salinity, the growth of oysters would not be hindered and the fluxes after October 1991 would be larger. But, in reality, the values of fluxes are not larger than those for the averaged data. This can be because such high chlorophyll-*a* concentration causes a rapid growth and strong spawning, making the oysters lighter in their weight (KUSAKA *et al.*, 1991). Finally, the fluxes in the period between 1987 and 1988 are larger than those for the averaged data but the difference is not large. This may suggest importance of other foods than phytoplankton.

5. Concluding remarks

We have used a population dynamics model by KOBAYASHI *et al.* (1997) and environmental data in Ofunato Estuary obtained between 1985 and 1994 (HAYAKAWA *et al.*, 2001; HAYAKAWA *et al.*, 2002), and simulated sediment fluxes by oysters. Our simulation of using the monthly averaged values obtained from this observation has been able to qualitatively reflect the patterns of seasonal variation of the fluxes. Quantitatively, our results are not contradictory to observational data when we take into account the dispersion over the bay. Thus, we conclude that the population dynamics model we have adopted is applicable to oysters in Ofunato Estuary and that the sediments observed in the farm originate from oysters. As to the environmental data, by using the values obtained from respective years instead of the averaged values, we have understood how the environmental characteristics of each year are reflected in the sediment fluxes. Namely, the fluxes have a positive correlation with chlorophyll-*a* concentration. But, it is also suggested that food of oysters is not only phytoplankton (SONIAT *et al.*, 1984; SONIAT and ROY, 1985), which has been considered in our model, in the second term of the right-hand side of 0.520 in Eq.16. It has been noted that the fluxes decrease rapidly probably because the *C. gigas* growth is hindered when the salinity is low (12.3). The composition of foods of oysters is a next subject in our study.

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学会記事

1. 2005年11月5日（土）（財）日仏会館後援による日仏海洋シンポジウムを日仏会館ホールにて開催

招待講演者

- Hubert j CECCALDI博士（フランス高等研究院名誉教授　同名誉所長　フランス科学アカデミー）
  基調講演：「海洋・水産分野における日仏交流の意義と今後の展望」
- Bernard SALVAT博士（フランス高等研究院名誉教授同名誉所長）
  講演：「海洋生態系における日仏共同研究の成果、サンゴ礁保全研究の立場から」
- Jean Pierre FERAL博士（C.N.R.S.研究部門総括　フランス高等学院研究部長）
  講演：「南大洋における沿岸無脊椎動物の発生、群集構造および進化の様式」
- 徳山英一博士（東京大学海洋研究所教授）
  講演：「海洋底科学からの展望」
- 小松輝久博士（東京大学海洋研究所助教授）
  講演：「日仏研究交流、沿岸生態系の保全と修復を目指して」
- 石黒（長谷川）直子博士（岡山大学自然科学研究科　日本学術振興会特別研究員）
  講演：「フランス留学への道」

2. 新入会員

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5. 退会（逝去者含）

中川平介　鳥羽良明　内藤靖彦　佐藤孫七　嶋野敏夫　望月賢二　乙部弘隆

寄贈図書

La mer (Bulletin de la Société franco-japonaise d'océanographie)
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Reproductive biology of two sillaginid fishes, *Sillago sihama* and *S. aeolus*, in tropical coastal waters of Thailand

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Abstract: Reproduction in two co-occurring sillaginid fishes, *Sillago sihama* and *Sillago aeolus,* was investigated on the basis of 1,140 and 836 specimens, respectively, collected from Sikao Bay, Trang Province, Thailand, between May 2003 and April 2004. Histological examinations of gonads showed that the smallest mature females and males in *S. sihama* were 117 and 106 mm in standard length (SL), respectively, and 113 and 109 mm SL, respectively, in *S. aeolus*. The body size at which 50% of individuals attained maturity was estimated to be 130 mm SL for both sexes in both species. The lowest spawnable gonadosomatic indices for female and male *S. sihama* were 0.53 and 0.04, respectively, and 0.47 and 0.03, respectively, in *S. aeolus*. Spawning occurred continuously throughout the year in both species, with peaks in activity between August and November (*S. sihama*) and July and December (*S. aeolus*). Oocytes at various developmental stages, together with post-ovulatory follicles, were found in the mature ovaries of both species during their spawning periods, suggesting that they are multiple spawners.

Keywords: *reproduction, Sillago sihama, Sillago aeolus, Thailand*

1. Introduction

Sillaginidae has traditionally been an important fish family as a food resource in many Indo-West Pacific countries. Three genera (*Sillago, Sillaginodes*, and *Sillaginopsis*) are currently recognized, including thirty-one species. *Sillago sihama* and *Sillago aeolus*, widely distributed throughout tropical and subtropical waters in the west-central Pacific and Indian oceans (MCKAY, 1999), inhabit sandy and/or muddy substrates in inshore areas (SATAPOOMIN, 2005), feeding mainly on benthic invertebrates, including polychaetes, shrimps, and crabs (TONGNUNUI *et al.*, 2005).

In Thailand, these two species are the most abundant and commercially important sillaginids, although three other congeneric species are distributed around the coast (SIRIMONTAPORN and CHOONHAPRAN, 1995). In Sikao Bay, Trang Province, *S. sihama* and *S. aeolus* are both common, coexisting in shallow sandy areas where they are gill-netted year-round by local fishermen.

In spite of their abundance and popularity as food, there is a paucity of information on the reproduction of *S. sihama* and *S. aeolus*, the only previous study of the latter species having been conducted in the subtropical waters of Okinawa Island, southern Japan (RAHMAN and TACHIHARA, 2005). Reproductive information on a commercially exploited species is crucial for an understanding of its population dynamics, such being fundamental for developing an effective management model.

The objective of the present study was to provide reproductive information on *S. sihama* and *S. aeolus* in Thailand, including the gonad

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development, spawning season, and size at maturity.

2. Materials and Methods

The study was carried out at Sikao Bay (7° 30' N, 99°13' E) in Trang Province on the southwest coast of Thailand. The bay, approximately 40 km long with a mouth width of 30 km opening broadly to the Andaman Sea, has a relatively flat sandy substrate with several small rocky reefs along the coast. The maximum water depth was about 20 m.

Sikao Bay is subjected to relatively short dry (January to April) and long rainy (May to December) seasons, the latter being accompanied by strong winds associated with the southwest monsoon, and the former by light winds from the northeast monsoon. Water in the sampling area had an essentially marine salinity. Water temperatures (taken at Rajamangala Beach) ranged from 27.0 to 30.9℃ (annual average 29.4℃), but no seasonal trends were apparent. Environmental deterioration resulting from human activities little occurred in and adjacent to the bay.

A total of 1,140 (66–224 mm in standard length, SL) and 836 (60–200 mm SL) specimens of *Sillago sihama* and *S. aeolus*, respectively, were sampled monthly from gill net fishery landings operated within Sikao Bay between May 2003 and April 2004. Gill nets (500 m wide, 1 m deep, and 25 mm × 25 mm square mesh) were set primarily on the sandy bottom in the central area of the bay (water depth about 15 m) between 05:00 and 07:00 hours, and retrieved between 09:00 and 10:00 hours. Both species were collected during the same gill net operation.

In the laboratory, SL and body weight (BW) were measured for each specimen (to the nearest 1 mm and 0.1 g, respectively) within four hours of collection. The gonads were removed, sexed macroscopically, weighed to the nearest 0.01 g, and preserved in 10% buffered formalin. The gonadosomatic index (GSI) was calculated for each fish as follows: GSI = gonad weight × 100 / BW.

For histological examinations, middle portions of the right gonad were dehydrated in ethanol and embedded in paraffin wax. The embedded gonads were serially sectioned at 6-μm thickness and stained with Mayer's hematoxylin and eosin. Developmental stages of oocytes were categorized according to WALLACE and SELMAN (1981) and MUNEHARA *et al.* (1987). The ovarian stage was defined by the developmental stage of the most advanced oocytes within an ovary. The stage of testicular development, on the other hand, was determined by the percentage of the area (> 50%) of a particular spermatogenic cell type relative to the total area of all spermatogenic cells in the entire section (RAHMAN and TACHIHARA, 2005). The terminology of spermatogenic cells mainly followed that used by GRIER (1981).

To clarify size at maturity, the stage of gonad development was recorded for each specimen. Length at first maturity was estimated by plotting GSI values with different gonadal maturity stages against SL. The size at which 50% of individuals had reached maturity was obtained by examining the proportion of fish with gonads at different maturity stages in each10-mm SL size class.

Specimens larger than the size at 50% maturity were used to examine seasonal changes in GSI and gonad maturation. The GSIs and proportions of the various gonad developmental stages of females and males were plotted monthly to determine the seasonality of spawning. In this analysis, the proportions of spent females were used to estimate spawning frequency.

3. Results

3.1 Gonad development

The histological observations revealed that gonad developmental patterns and maturity stages in each sex were essentially similar between *Sillago sihama* and *S. aeolus*. Accordingly, the maturity stages of both species are described as follows:

Ovaries were assigned into four maturity stages: 1) The immature stage was categorized by ovaries which contained oocytes at the early perinucleolus or late perinucleolus stage (Figs. 1A, 2A). 2) The maturing stage refers to juvenile fish about to begin maturing. Their ovaries possessed early perinucleolus, late perinucleolus, and sometimes yolk vesicle stage

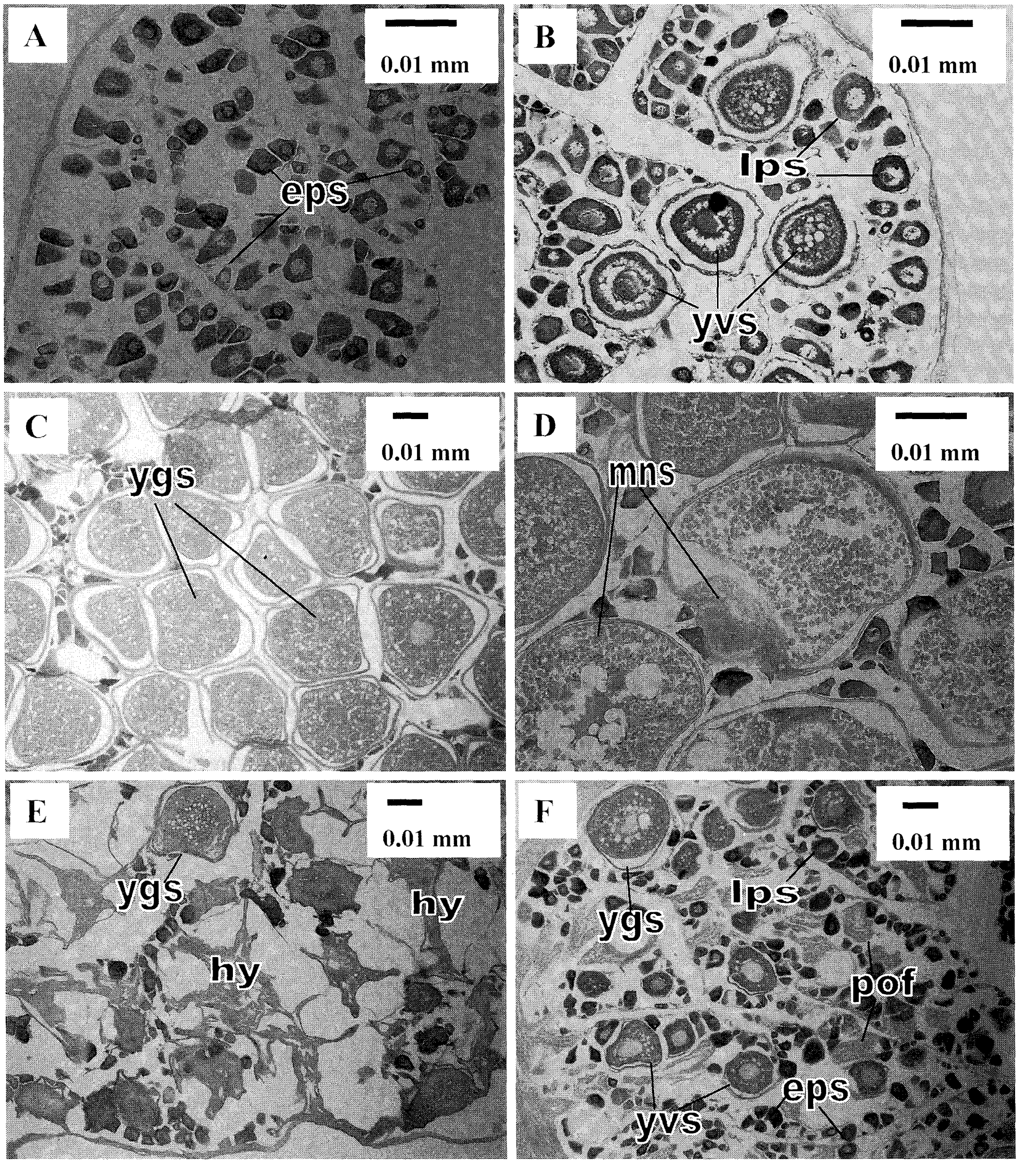

Fig. 1. Histological sections of ovaries in *Sillago sihama*. (A) Immature stage (114 mm SL). (B) Maturing stage (129 mm SL). (C) Mature active stage (156 mm SL). (D) Mature active stage (149 mm SL). (E) Mature active stage (143 mm SL). (F) Spent stage (154 mm SL). eps, early perinucleolus stage oocyte; lps, late perinucleolus stage oocyte; yvs, yolk vesicle stage oocyte; ygs, yolk globule stage oocyte; mns, migratory nucleus stage oocyte; hy, hydrated oocyte; pof, post-ovulatory follicle.

oocytes, but were dominated by late perinucleolus stage oocytes (Figs. 1B, 2B). 3) The mature active stage was defined by gonads with oocytes from the early perinucleolus to hydrated stages, but was dominated by yolk globule, migratory nucleus, and hydrated stage oocytes (Figs. 1C-E, 2C-E). 4) The spent stage was characterized by ovaries in which all stages of oocytes, including migratory nucleus and hydrated stage oocytes, occurred along

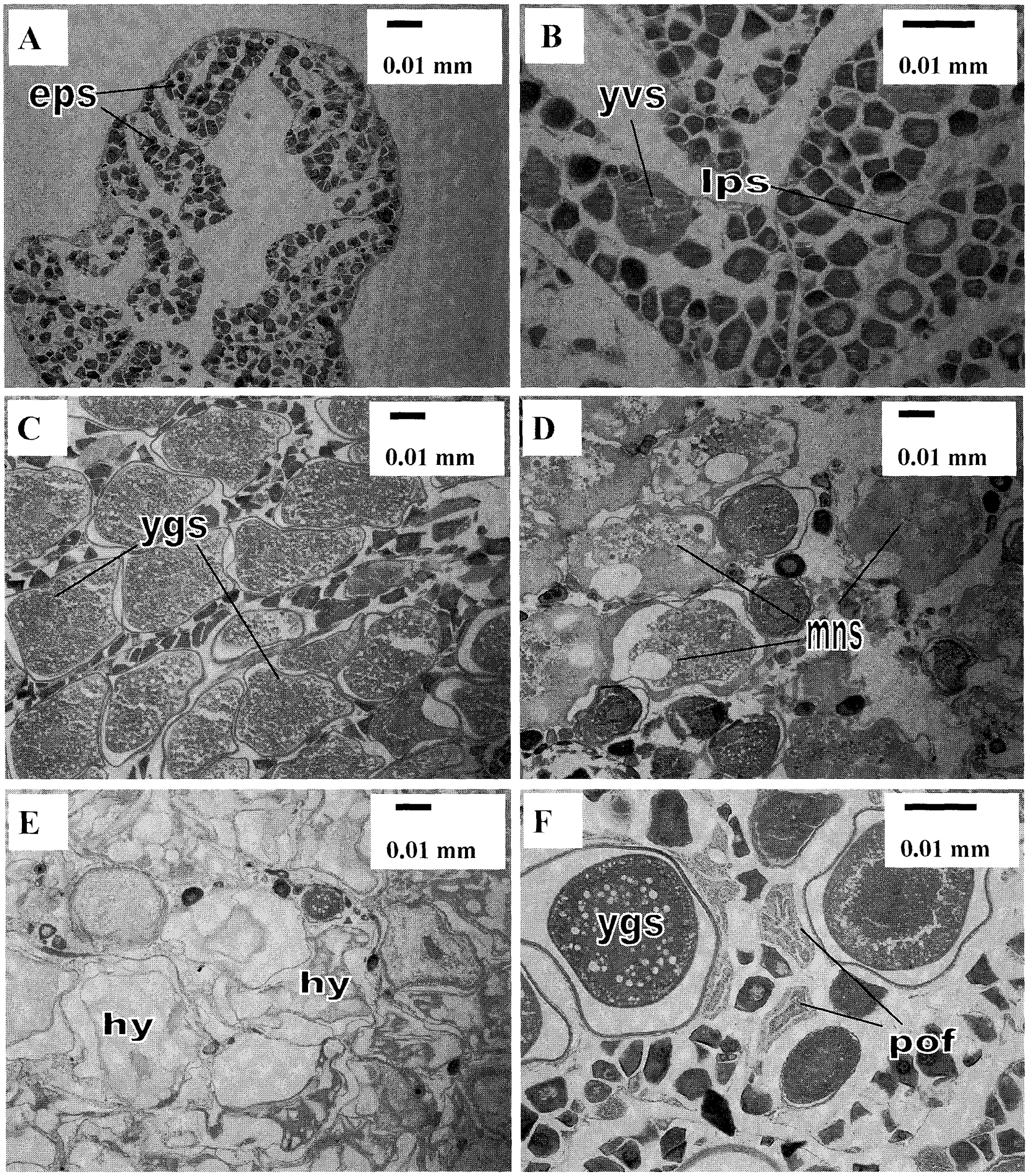

Fig. 2. Histological sections of ovaries in *Sillago aeolus*. (A) Immature stage (129 mm SL). (B) Maturing stage (130 mm SL). (C) Mature active stage (184 mm SL). (D) Mature active stage (140 mm SL). (E) Mature active stage (150 mm SL). (F) Spent stage (162 mm SL). Abbreviations as in Fig. 1.

with post-ovulatory follicles (Figs. 1F, 2F).

Testes were categorized into five maturity stages: 1) The immature stage was represented by testes with spermatogonia and primary spermatocytes (Figs. 3A, 4A). 2) The maturing stage was characterized by testes in which crypts containing secondary spermatocytes predominated, but a few spermatogonia and primary spermatocytes were also found (Figs. 3B, 4B). 3) The mature stage was defined by testes in which primary and secondary spermatocytes were present, but spermatids were dominant in crypts. In addition, some crypts of spermatozoa coalesced into newly-

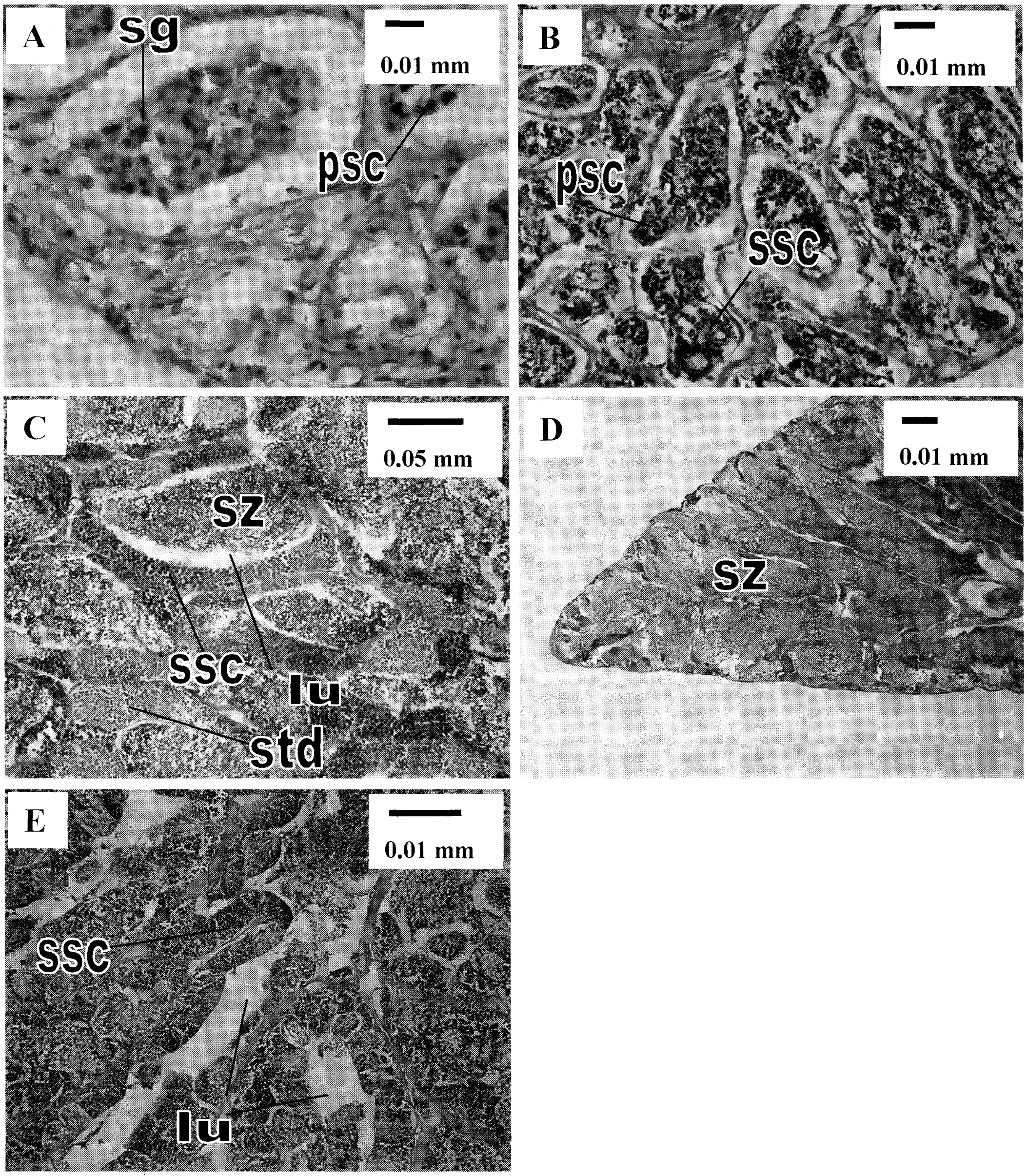

Fig. 3. Histological sections of testes in *Sillago sihama*. (A) Immature stage (119 mm SL). (B) Maturing stage (131 mm SL). (C) Mature stage (125 mm SL). (D) Ripe stage (151 mm SL). (E) Spent stage (152 mm SL). sg, spermatogonia; psc, primary spermatocyte; ssc, secondary spermatocyte; lu, lumen; sz, spermatozoa; std, spermatid.

formed sperm sinuses (Figs. 3C, 4C). 4) The ripe stage was characterized by testes dominated by spermatids and spermatozoa. Sperm sinuses were filled with spermatozoa (Figs. 3D, 4D). 5) The spent stage was categorized by testes possessing new crypts of spermatogonia and primary spermatocytes. Moreover, testes also had empty crypts with residual spermatozoa (Figs. 3E, 4E).

Each ovary and testis could be allocated to one of the above four and five maturity stages, respectively, in both species. In this study,

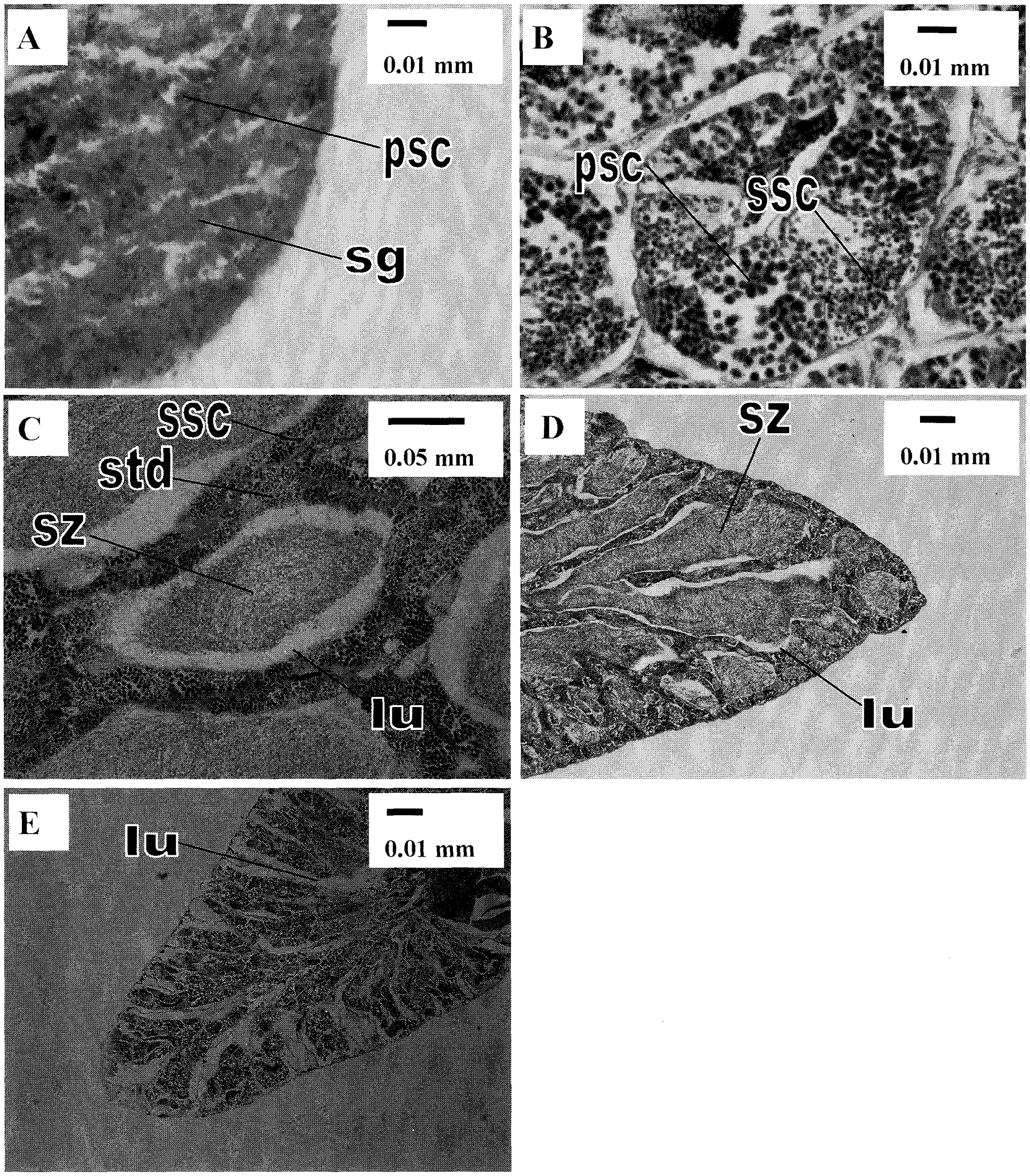

Fig. 4. Histological sections of testes in *Sillago aeolus*. (A) Immature stage (105 mm SL). (B) Maturing stage (119 mm SL). (C) Mature stage (145 mm SL). (D) Ripe stage (142 mm SL). (E) Spent stage (140 mm SL). Abbreviations as in Fig. 3.

sexually mature individuals were defined as females with ovaries at the mature active and spent stages, and males with testes at the mature, ripe, and spent stages.

3.2 Length at maturity

The relationship between SL and GSI at different maturity stages showed that the proportions of mature females and males of the two species increased with size (Figs. 5, 6). In *S. sihama*, the smallest mature female was 117 mm SL with a GSI value of 0.80 and the largest immature female, 175 mm SL with a GSI value of 0.62. The GSI values for mature females

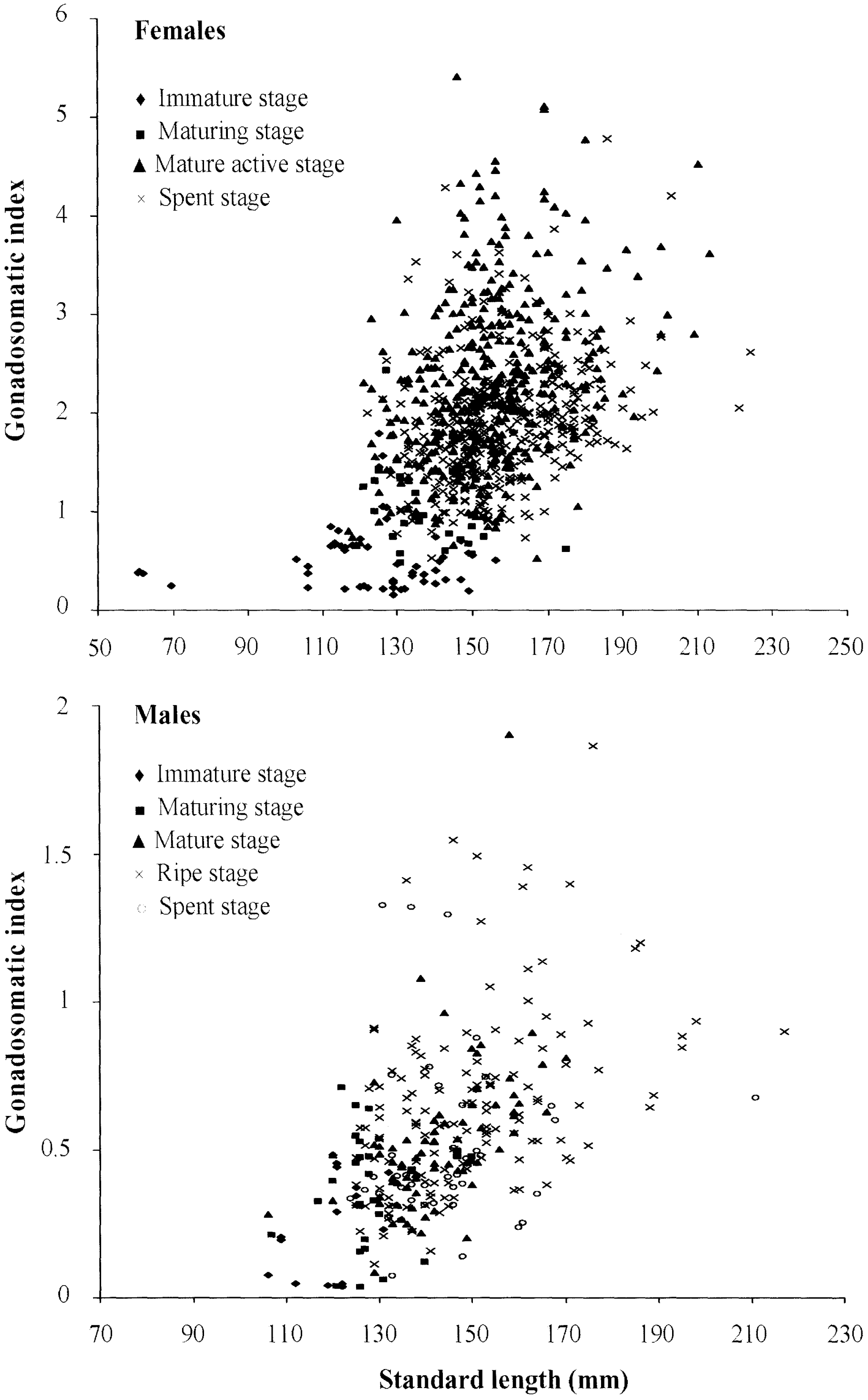

Fig. 5. Relationships among standard length, gonadosomatic index, and gonadal maturity stages for female and male *Sillago sihama* collected at Sikao Bay from May 2003 to April 2004.

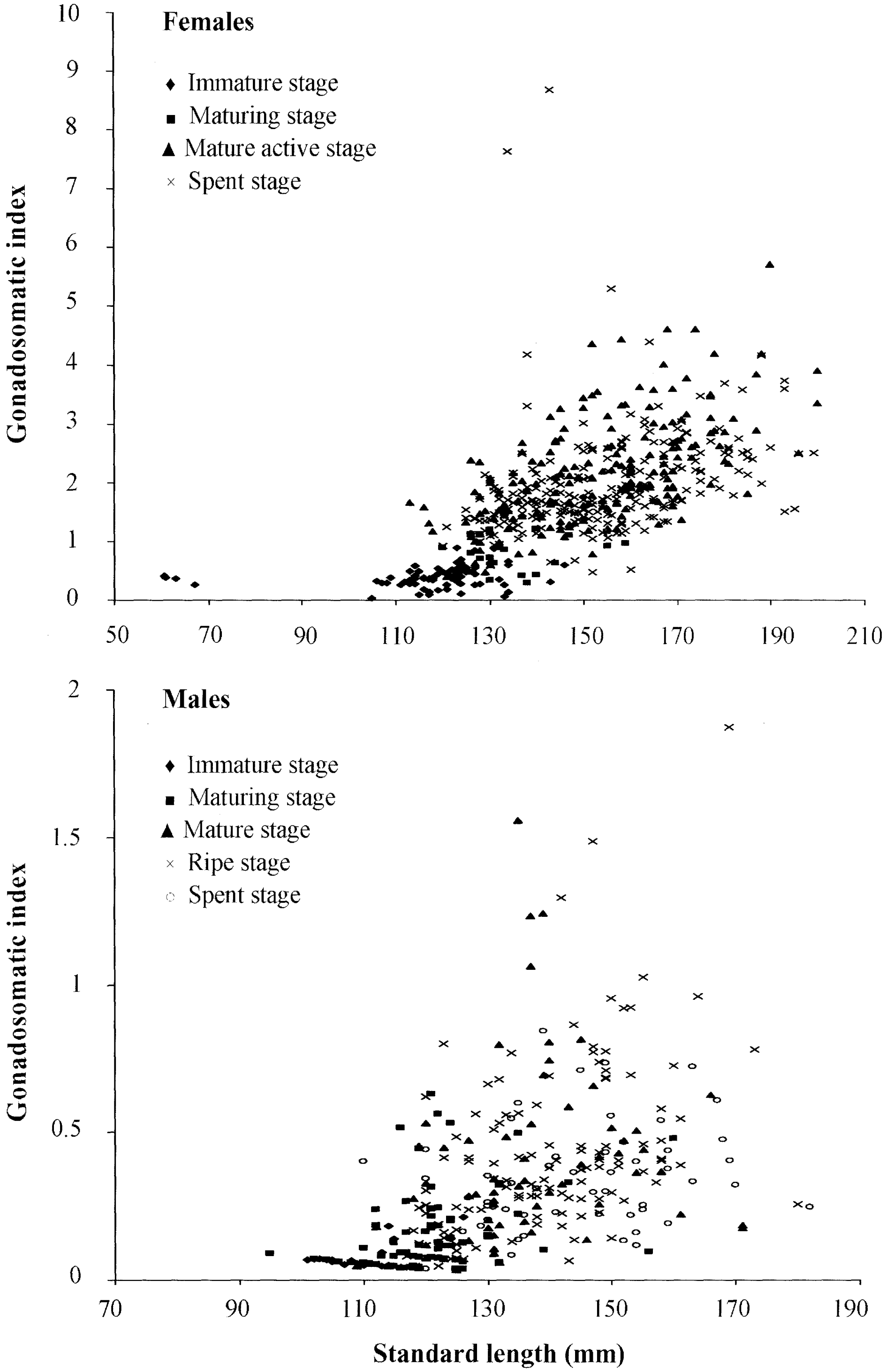

Fig. 6. Relationships among standard length, gonadosomatic index, and gonadal maturity stages for female and male *Sillago aeolus* collected at Sikao Bay from May 2003 to April 2004.

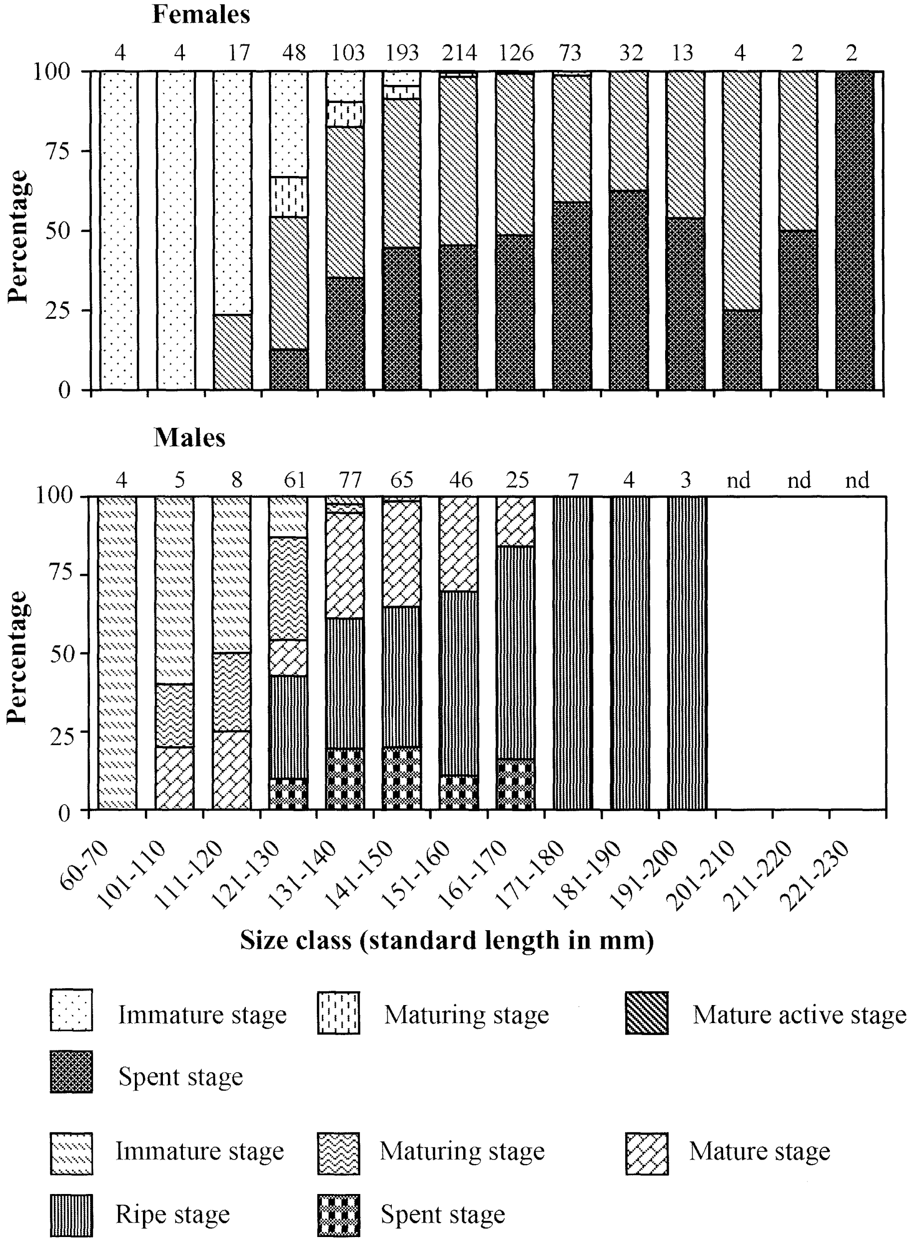

Fig. 7. Percentage frequencies of occurrence of various gonadal maturity stages in different size classes for female and male *Sillago sihama* collected at Sikao Bay from May 2003 to April 2004. Number of specimens sampled given above each column. nd, no data.

ranged from 0.53 to 5.41 (Fig. 5A). The smallest mature male was 106 mm SL with a GSI value of 0.28 and the largest immature male, 150 mm SL with a GSI value of 0.47. The GSI values for mature males ranged from 0.04 to 1.90 (Fig. 5B).

In *S. aeolus*, the smallest mature female was 113 mm SL with a GSI value of 1.66 and the largest immature female, 159 mm SL with a GSI value of 0.97. The GSI values for mature

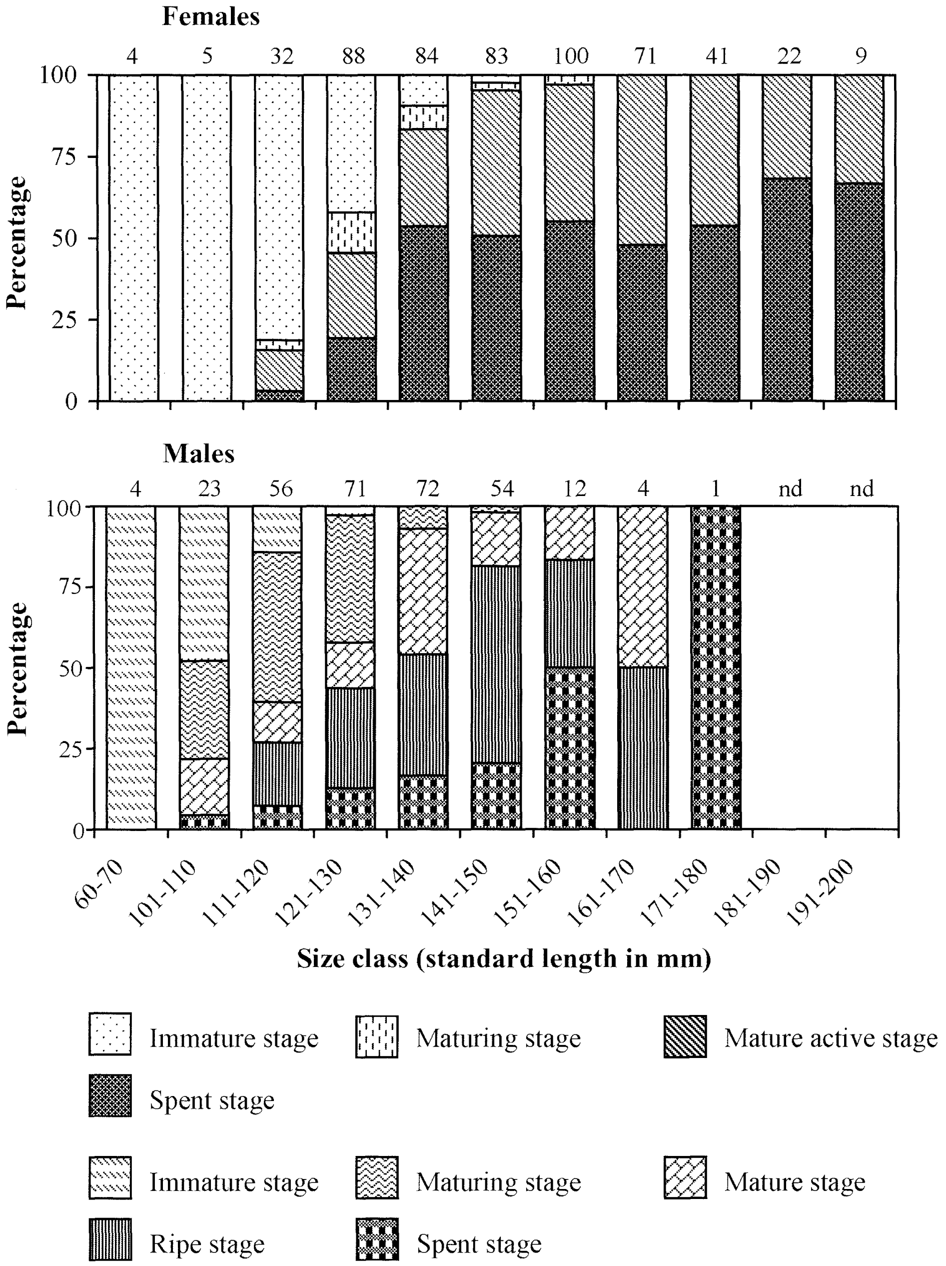

Fig. 8. Percentage frequencies of occurrence of various gonadal maturity stages in different size classes for female and male *Sillago aeolus* collected at Sikao Bay from May 2003 to April 2004. Number of specimens sampled given above each column. nd, no data.

females ranged from 0.47 to 8.69 (Fig. 6A). For males, the smallest mature specimen was 109 mm SL with a GSI value of 0.04 and the largest immature male, 160 mm SL with a GSI value of 0.47. The GSI values for mature males ranged from 0.03 to 1.87 (Fig. 6B).

The relationship between SL and the proportions of various gonadal maturity stages indicated that body size at 50% maturity occurred in the 121–130 mm SL size class for both sexes of both species (Figs. 7, 8). Therefore, the size at 50% maturity was determined as 130 mm SL for both species and sexes. Virtually all females and males larger than 150 mm SL possessed mature gonads in both species (Figs. 7, 8).

3.3 Spawning season

The monthly mean GSIs varied little from month to month for females and males of 130 mm SL or more in both species (Figs. 9, 10). The mean GSIs in *S. sihama* fluctuated between 0.80 in May to 2.77 in January for females, and between 0.39 in May and 0.70 in October for males (Fig. 9). Those for *S. aeolus* ranged from 1.41 in September to 3.47 in May for females, and from 0.21 in May to 0.96 in January for females (Fig. 10).

The monthly percentages of gonadal maturity stages indicated that in both species, females with ovaries at the mature active and spent stages, and males with testes at the ripe and/or spent stages occurred every month (Figs. 11, 12). However, these histological observations showed that there was a seasonal change in the proportion of spawning females in each species, although such a change was not found in males. The proportions of spent females were relatively high between August and November in *S. sihama* (Fig. 11A), and between July and December in *S. aeolus* (Fig. 12A).

4. Discussion

The lowest possible spawning GSI values of females of *Sillago sihama* and *S. aeolus* at Sikao Bay were determined as 0.53 and 0.47, respectively, because their ovaries contained yolk globule stage oocytes with post-ovulatory follicles. In males, the lowest spawnable GSI values were defined as 0.04 for *S. sihama* and 0.03 for

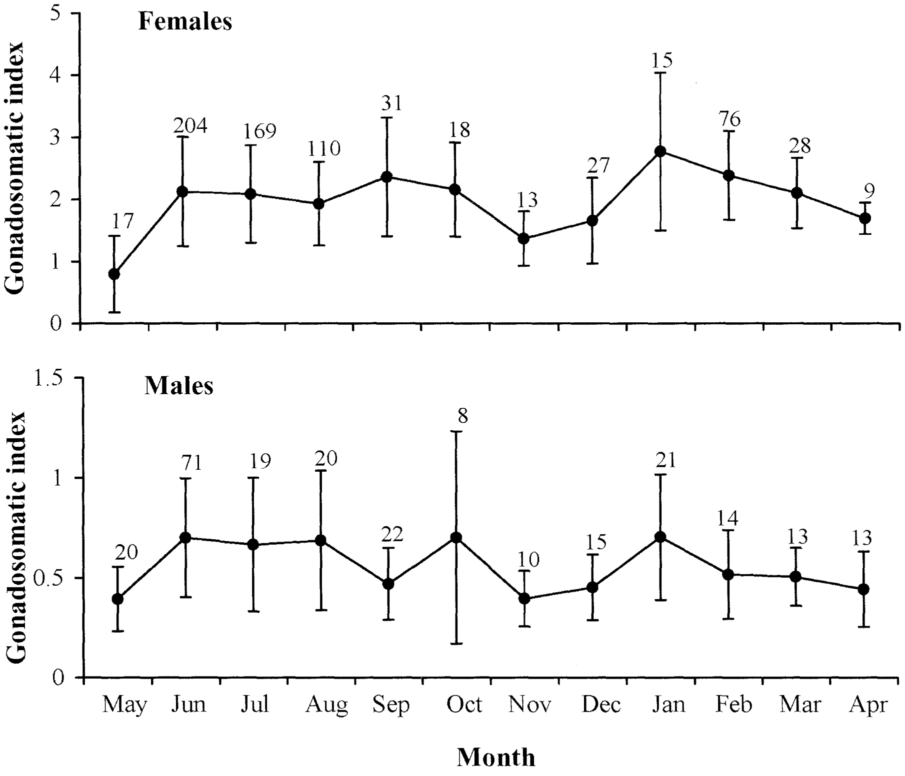

Fig. 9. Monthly mean gonadosomatic indices for adult females and males (≥ 130 mm in standard length) of *Sillago sihama* collected at Sikao Bay from May 2003 to April 2004. Bars indicate standard deviation. Number of specimens examined given above each bar.

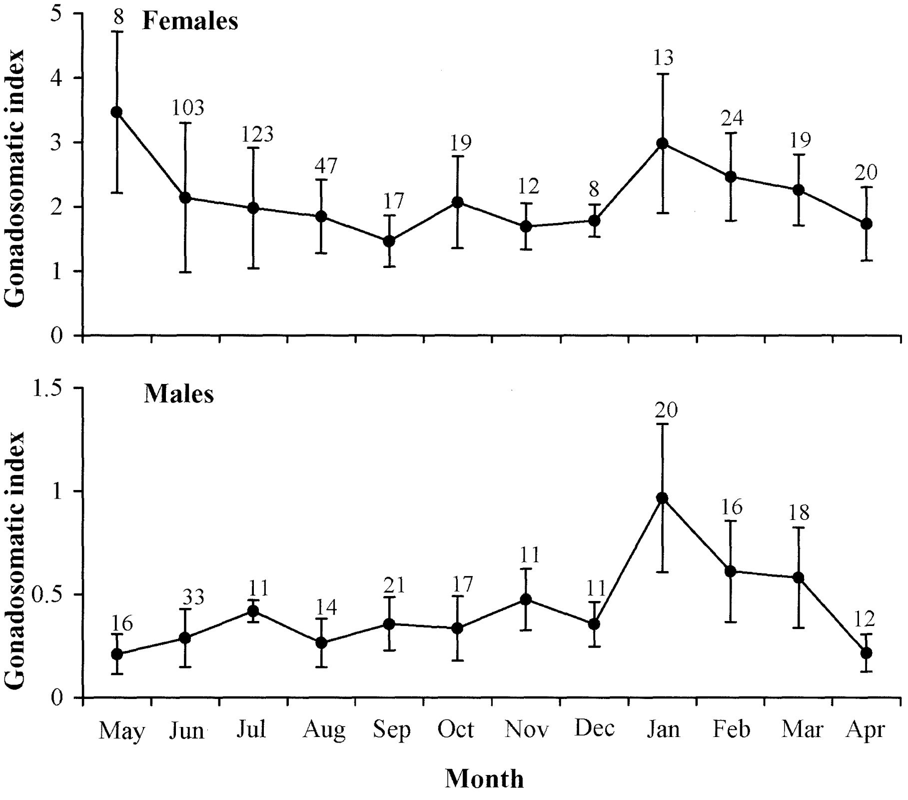

Fig. 10. Monthly mean gonadosomatic indices for adult females and males (≥ 130 mm in standard length) of *Sillago aeolus* collected at Sikao Bay from May 2003 to April 2004. Bars indicate standard deviation. Number of specimens examined given above each bar.

S. aeolus, because most crypts in their testes contained numerous spermatids and/or residual sperms. These findings indicated that possible spawning GSI values in each sex are very similar between the two species at Sikao Bay. However, such GSI values of *S. aeolus* at the study site were lower than those (1 for females and 0.05 for males) of conspecifics at Okinawa Island (RAHMAN and TACHIHARA, 2005). Furthermore, the minimum GSI values of mature individuals for each sex of the two species were lower than those described for other temperate *Sillago* species, such as *S. robusta* and *S. bassensis* (HYNDES and POTTER, 1996).

At Sikao Bay, the lengths (130 mm SL) at 50% maturity for *S. sihama* females and males were the same as in *S. aeolus*. According to their age and growth information (TONGNUNUI, 2006), most females and males of both species in the bay attain this length at the end of their first year of life. Such a small size at 50% maturity has been recognized in some congeneric species, including *S. burrus* (130 mm SL in both sexes) and *S. robusta* (123 and 120 mm SL in females and males, respectively), in temperate, shallow inshore waters (HYNDES and POTTER, 1996; HYNDES *et al.*, 1996). In addition, the smallest mature fish were reported to be 120 and 113 mm SL for female and male *S. aeolus*, respectively, from subtropical, nearshore waters of Okinawa Island (RAHMAN and TACHIHARA, 2005). Several studies have indicated that such rapid attainment of small-sized maturity in inshore species may be due partly to benefits derived from feeding in highly productive shallow waters (HYNDES *et al.*, 1996; HYNDES and POTTER, 1997; RAHMAN and TACHIHARA, 2005).

In the present study, mature individuals of *S. sihama* and *S. aeolus* were observed to have

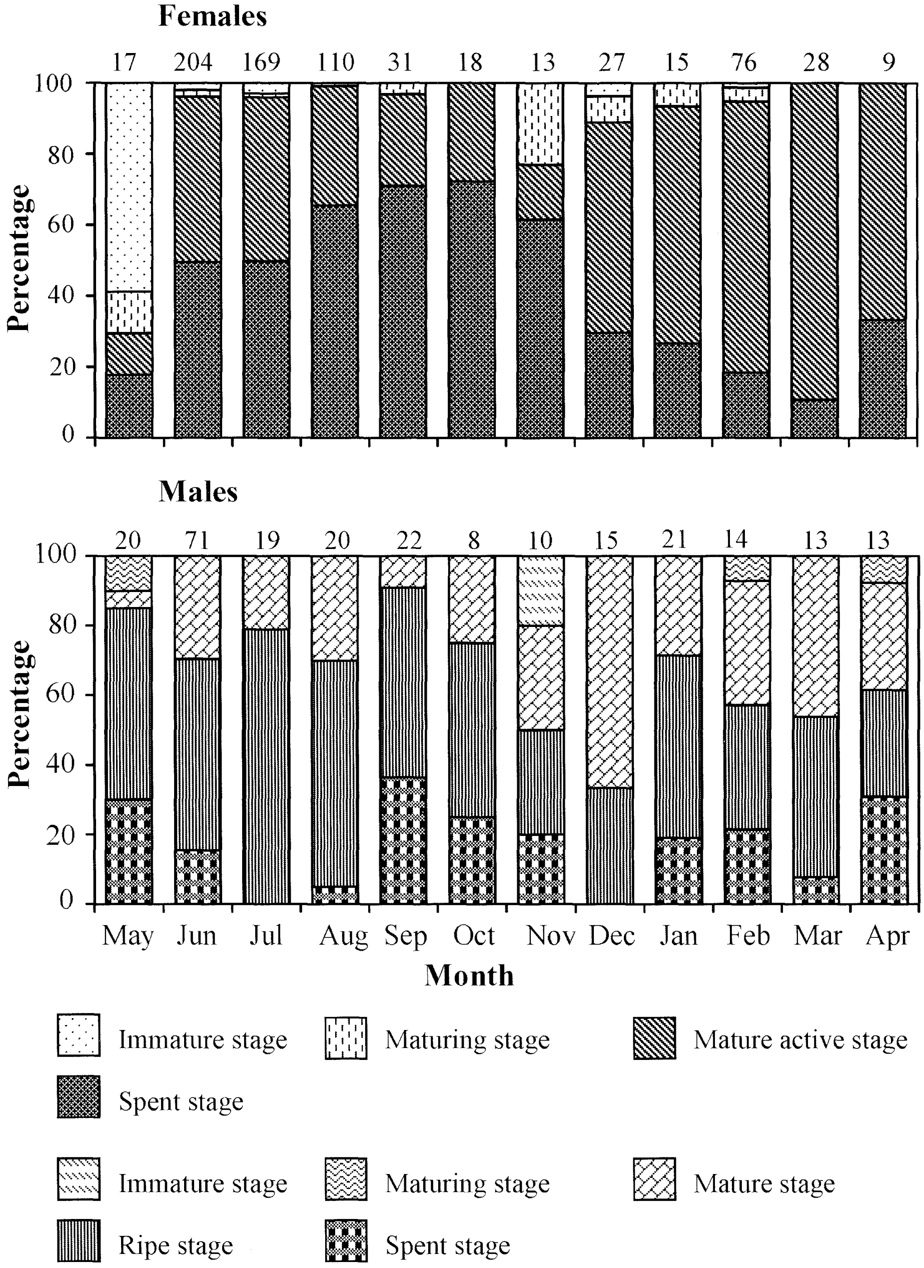

Fig. 11. Monthly percentage frequencies of occurrence of gonadal maturity stages for adult females and males (≥ 130 mm in standard length) of *Sillago sihama* collected at Sikao Bay from May 2003 to April 2004. Number of specimens examined given above each column.

spawnable GSI values throughout the year, histological examinations showing also that their ovaries and testes were functional for spawning each month. These results demonstrate that in the two species, spawning occurred continuously throughout the year, although histological observations revealed that spawning activity peaks occurred between August and November in *S. sihama*, and between July and December in *S. aeolus*.

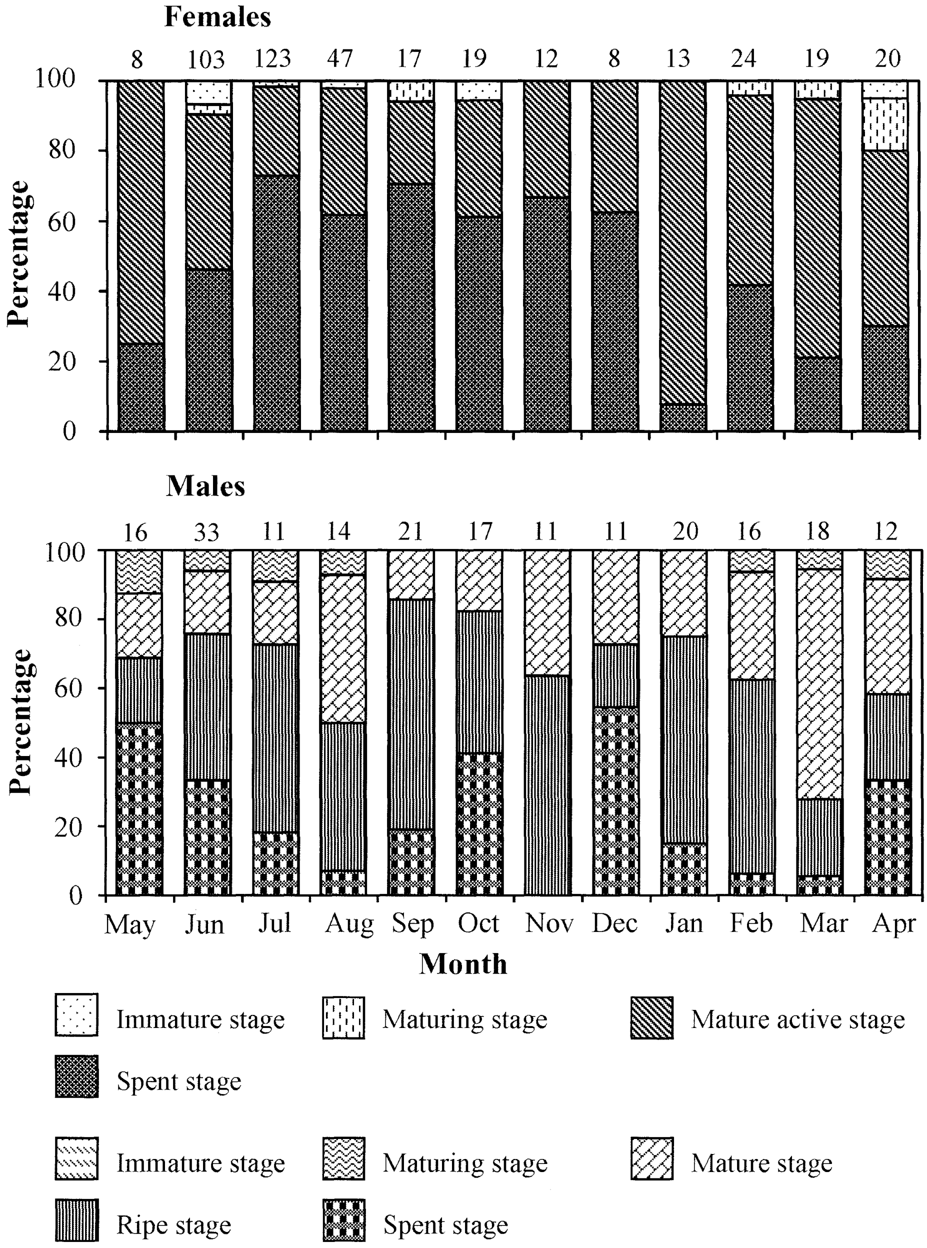

Fig. 12. Monthly percentage frequencies of occurrence of gonadal maturity stages for adult females and males ($\geq$ 130 mm in standard length) of *Sillago aeolus* collected at Sikao Bay from May 2003 to April 2004. Number of specimens examined given above each column.

However, such spawning patterns of the two species at Sikao Bay contrasted with a conspecific (*S. aeolus*) and other sillaginids studied in temperate and subtropical coastal waters of Australia (HYNDES and POTTER, 1996, 1997; HYNDES *et al.*, 1996) and Japan (SULISTIONO *et al.*, 1999; RAHMAN and TACHIHARA, 2005), the latter fishes spawning during a short period in spring or summer. COULSON *et al.* (2005) reported that the spawning period of *Sillago schomburgkii* in subtropical environments commenced earlier and continued for longer than in temperate waters, suggesting that water temperature plays a crucial role in stimulating spawning activity in sillaginids. The year-round spawning of *S. sihama* and *S. aeolus* at Sikao Bay may, therefore, be a reflection of the higher water temperatures at that locality.

Histological examinations revealed that oocytes at various developmental stages, in addition to post-ovulatory follicles, were found in the mature ovaries of *S. sihama* and *S. aeolus* during their spawning periods (Figs. 1F, 2F). These facts provide strong circumstantial evidence that the two species are multiple spawners, i.e. spawning on several occasions during the breeding period (CAILLIET *et al.*, 1986). Since similar phenomena have been documented in several other species of *Sillago*, as well as in *Sillaginodes* (HYNDES and POTTER, 1996, 1997; HYNDES *et al.*, 1996; FOWLER *et al.*, 1999; COULSON *et al.*, 2005; RAHMAN and TACHIHARA, 2005), multiple spawning may be a common life-history trait of sillaginids in tropical and temperate waters.

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Salinity tolerance of larvae in the Penicillate crab *Hemigrapsus takanoi* (DECAPODA: BRACHYURA: GRAPSIDAE)

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Abstract : The penicillate crab, *Hemigrapsus takanoi* was established recently in Japan. Larval tolerance of this species to salinity is unknown. In laboratory experiments, we examined the salinity tolerance of larvae from hatching to the first juvenile stage. Successful development through metamorphosis occurred only in salinity of 25, 30 and 35 and average water temperature of 23.83 ± 0.91℃. Larvae in 10, 15 and 20 ‰ could not pass the megalopal stage, while in salinity 5 only 4 larvae successfully metamorphosed to the second zoeal stage but deceased two days later. Results of the salinity tolerance suggest that the zoea and megalopa of *H. takanoi* develop in higher salinity conditions and recruit to the wider salinity range when they reached juvenile and adult stage.

Keywords : *Hemigrapsus takanoi*, salinity tolerance, survival, development days

1. Introduction

Genus of *Hemigrapsus* presently consists of 9 species, with five of them inhabiting Japanese waters: *Hemigrapsus sanguineus* de Haan 1835, *H. penicillatus* de Haan 1835, *H. longitarsis* Miers 1879 (DAI and YANG, 1991), *H. sinensis* Rathbun 1929 (SAKAI, 1976) and *H. takanoi* (ASAKURA and WATANABE, 2005). *Hemigrapsus* species occur from the high to low intertidal zones of bays and estuaries (OKAMOTO and KURIHARA, 1987). *Hemigrapsus penicillatus* and *H. takanoi* occur where salinity ranges from 5 to > 35 ‰ (pers.obs.). *Hemigrapsus takanoi* is found under a variety of substrates, such as oyster shells and stones and sometimes co-locates with its sibling species *H. penicillatus* (pers.obs).

Estuarine environments are characterized by abrupt and pronounced salinity fluctuations (ATTRILL, 2002). Therefore, organisms surviving in this demanding condition have evolved adaptations to cope with such extreme variability (JONES, 1981). The ability to withstand wide salinity fluctuations may be conditioned by other environmental factors such as temperature, oxygen level, nutrient availability, pollutant, light, presence of predators and substrate mobility (CAMERON and MANGUM, 1983; ELLISON, 1994). According to TAYLOR and SENEVIRATNA (2005) animals may survive salinity variations by: 1) avoidance behavior; 2) tolerance of internal change; or 3) physiological cooperation. Although some species are specifically adapted to live in estuarine conditions, others show evidence of not favouring this environment while still being able to cope within it.

Hemigrapsus penicillatus (the sibling species of *H. takanoi*) is recognized for its wide tolerance and adaptability to rapid environmental changing conditions (GOLLASCH, 1999;; NIJLAND, 2003), however information on larval tolerance of *H. takanoi* is not available. An understanding of the effects of salinity on the survival and development of early life stage of

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H. takanoi is essential for interpreting the influence of this environmental factor on the settlement and distribution pattern of this species. This study addressed this need by conducting laboratory experiments with the objective of examining the range of tolerance of larva of *H. takanoi* to salinity from zoeal to first crab stage.

2. Materials and Methods

Collection and maintenance of adult crabs

Adult females of *H. takanoi* were collected from Kasai Rinkai Park, Tokyo Bay, Japan in September 2004. They were then brought to the laboratory in Banda Marine Field Station of Tokyo University of Marine Science and Technology and kept in plastic tanks with a salinity of 10. Shelters were placed, mussels (*Xenostrobus secures*) and green algae (*Ulva* sp.) was provided as food for the adult females. These conditions were similar to the natural environment from which the crabs were collected.

Rearing condition and observation

Freshly hatched larvae were transferred from 1.5-litre Pyrex glass containers to the test conditions (5, 10, 15, 20, 25, 30 and 35 salinities; 75 individuals per treatment). The desired salinities were obtained by diluting natural seawater with filtered tap water. Salinity measurements were done using Atago hand refractometer (‰). The salinity tolerance used in this study was survival rate and the duration of development of individual postembryonic stage (ANGER, 1996). First larval metamorphosis to the next stage was counted as the first day of developments in the stage.

The containers were placed in a temperature-controlled shallow baths without control of illumination and aeration. Water temperature was recorded every day during the experiment. Food was supplied every morning after the transference of the zoeas to the new containers with a cylindrical pipette. Larvae from the first to the third zoeal stage were fed with fresh rotifers reared on *Chlorella* and progressively larger sizes of *Chlorella*-fed *Artemia* and rotifers from fourth to megalopal stage. The number of survivors and developmental durations were recorded everyday. Dead larvae were preserved in 5 % formalin for later re-identification of stages (ISLAM *et al.*, 2003). Different stages of zoea were easily distinguished by their body size and characteristics such as the increment of setae in telson, the growth of pleopod cover and the appearance of periopod.

Statistical analyses

Survival analyses (SWINSCOW and CAMPBELL, 1997) were applied to detect the effect of salinity on the survival of larva. The log rank test (VENABLES and RIPLEY, 1999) was employed using individual development days in all salinities.

3. Results

Survival days among seven salinity conditions were significantly different ($P=0$). The highest survival rate (5.3 %) was observed in water salinity at 25 ‰. During the experiment, the average of water temperature was 23.83 ± 0.91 ℃.

Changes in the number of surviving larvae with days after hatching are shown in Fig. 1. Larval survival gradually decreased during zoeal stage and abruptly when reached megalopal stage. The mortality of the larvae was increased rapidly at 5 ‰ of salinity. Only four larvae successfully metamorphosed to the second zoeal stage but they only survived for two days. All larvae in salinity 5 died after six days from hatching.

Above 50 % survival of larvae reared at 20 ‰, 30 % at 15 ‰ and 1.4 % at 10 ‰ reached megalopal stage. However, none of this larva had successfully metamorphosis to the juvenile stage. Six individuals in salinity of 25 ($n=3$), 30 ($n=2$) and 35 ($n=1$) ‰ had completed to the first juvenile stage.

The first megalopa metamorphosis to juvenile stage was observed on the 25th day after hatched at 25–35 salinities. The larval stages were completed only by larvae reared in 25–35 ‰ on the 29th day with the highest SR (4 %) found at 25 ‰.

Development period to each larval stage are summarized in Table 1. Larva completed each

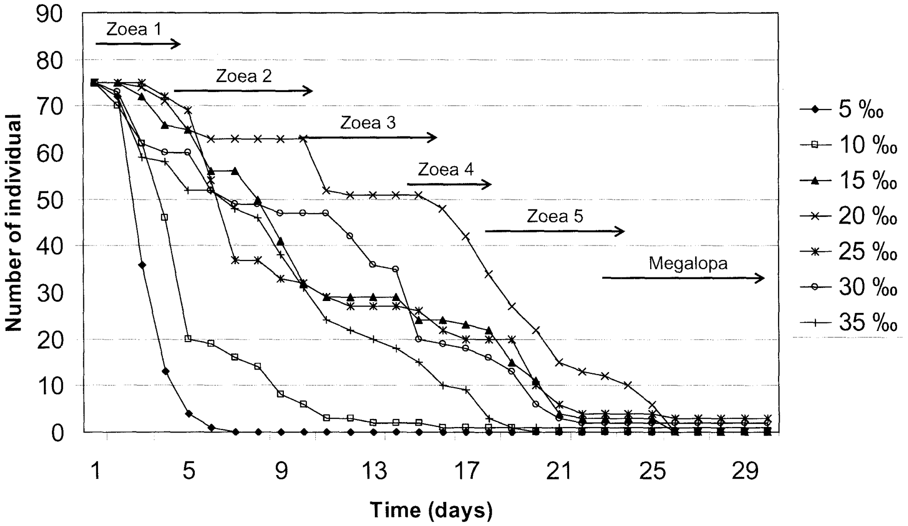

Fig. 1. The survival of larvae at varying salinities.

Table 1. Development period (days) from hatching to reach first juvenile stage of *Hemigrapsus takanoi* reared at seven salinities.

Salinity	Days to each stage											
(‰)[a]	Z1	N	Z2	N	Z3	N	Z4	N	Z5	N	M	N
10	3 (1.16)	29	4 (2.99)	32	3 (1.47)	11	4 (0.19)	1	4 (0.24)	1	-	0
15	3 (0.36)	9	4 (2.33)	25	3 (2.8)	21	3 (5.03)	29	6 (4.56)	18	-	0
20	3 (0.16)	4	6 (0.96)	8	6 (3)	15	4 (6.59)	26	4 (3.68)	12	-	0
25	4 (0.32)	6	6 (5.33)	40	4 (0.56)	3	4 (1.44)	6	2 (3.73)	14	4 (0.64)	2
30	4 (0.80)	15	6 (1.73)	13	3 (2.08)	12	3 (3.63)	17	4 (4)	15	4 (0.32)	1
35	3 (0.68)	17	3 (0.8)	10	3 (2.04)	17	3 (1.76)	11	4 (2.35)	11	7 (2.45)	8

a) Only four larvae survived to the second zoeal stage (Z2) at 5 ‰, but all died after 2 days.

b) Mean (coefficient of variation). N denotes the number of larvae, which successfully molted from previous stage.

zoeal stage (Z2–Z5) at around 3–6 days and 4–7 days for megalopal stage.

4. Discussion

As is true of temperature, young organisms in general have a narrow range of salinity tolerance than adults (MOORE, 1958; LUPPI *et al.*, 2003). Salinity also affects the growth rates, survival and development of marine invertebrates (CADMAN and WEINSTEIN, 1988; YOUNG and HAZLETT III, 1978). Changes in the salinity of seawater may affect the organisms in the water through the specific gravity in the control and variations in osmotic pressure (GILLES and PEQUEUX, 1983).

Even though adult of estuarine crabs were thought to have a wide range of salinity adaptation (NIJLAND, 2000; 2003), larval stages commonly have a narrow tolerance to salinity and temperature ranges (CHARMANTIER, 1998; SASTRY, 1983). In this study, seven different salinities were used to investigate salinity tolerance of *H. takanoi* larva showing that the penicillate larva (*H. takanoi*) could only survive to the juvenile stage at 25 to 35 ‰.

According to KINNE, (1964, 1971); ROSENBERG and COSTLOW (1979), acclimatization on salinity during earlier stages should enhance the tolerance in the later stages, however none of larva was survived at 10 ‰, which was the acclimatization salinity after hatching. These studies showed that the acclimatization of salinity after hatching would not completely enhance their survival. Physical environmental factors, such as, temperature, season, stage of life cycle (BROWN *et al.*, 1992) and essential dietary nutrients (Mc. CONAUGHA, 1985) may have significant effects on the duration of larval period, growth and development.

Furthermore, megalopa in this study had failed to metamorphosis to juvenile stage in salinities 10, 15 and 20 ‰. First zoea metamorphosis to megalopa stage was found in salinity of 10 ‰. However, this individual died during metamorphosis. Larva in 15 and 20 ‰ also metamorphosis at 19th and 23rd days but all died before completing metamorphosis. During experiment water temperature was fairly stable but fluctuated drastically within day 17th to 21st. During this period, megalopa started to metamorphose to the juvenile stage, which may relate to the massive death of megalopa. Further studies are required to investigate the relationship between water temperature and salinity to the survival of *H. takanoi* larva.

This study revealed that one larva survived to juvenile stage in seawater (35 ‰). This finding may support the assumption by GOLLASCH (1999) that the invasion of *Hemigrapsus takanoi* (formerly recognized as *H. penicillatus*) to Western Europe was a result of fouling of ships or ballast water. However, this assumption still requires further investigations. A comprehensive study is planned with *H. takanoi* and *H. pencillatus* it's sibling to elucidate the biological attributes, life history, and environmental tolerance of both species.

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Reproductive biology of blacktip grouper, *Epinephelus fasciatus*, in Sulu Sea, Philippines

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Abstract : The maturation size, spawning season, sex ratio and hermaphroditism were studied in blacktip grouper, *Epinephelus fasciatus*, caught from Sulu Sea and landed at the Puerto Princesa City Market, Palawan, Philippines. Histological observations on gonads extracted from 1,119 individuals (105–330 mm in total length, TL) showed 542 individuals (125–280 mm TL) to be females, with 347 (153–330 mm TL) males, 139 (148–310 mm TL) hermaphrodites and 91 indeterminable individuals. Spawning occurred year round, although the gonadosomatic indices of females declined at the ends of both the dry (May) and rainy (October) seasons. The minimum size at maturity was determined to be 138 and 175 mm TL for females and males, respectively. Hermaphrodites were judged to function as males, because 127 out of 139 hermaphroditic individuals possessed mature testes. The sex ratio was 0.640 or 0.897 (hermaphrodites included as functioning males).

Keywords : Epinephelus fasciatus, *Spawning season, Sex ratio, Hermaphrodite, Gonad development*

1. Introduction

Groupers belonging to the subfamily Epinephelinae are commercially important tropical/subtropical fishes in the Indo-Pacific Ocean, especially in southeast Asian countries. The reproductive biology of the group has been frequently investigated, including studies by SHAPIRO (1987: review of grouper reproduction), ABU-HAKIMA (1987: reproductive biology of *Epinephelus tauvina*), KUO *et al.* (1988: artificial sex reversal in *E. fario*), MISHINA and GONZARES (1994: reproductive biology of *Cromileptes altivelis*), TAN-FERMIN *et al.* [1994: artificial sex reversal in *E. suillus* (= *coioides*)], ADAMS *et al.* (2000: sex ratio of *Plectropomus leopardus*) and LEE *et al.* (2002: reproductive biology of *E. merra*). The blacktip grouper, *E. fasciatus*, is one of the most common and the most widespread *Epinephelus* species, ranging from the coast of East Africa to the southeastern Pacific Ocean (HEEMSTRA and RANDALL, 1993). The species' reproductive biology of the species, including the spawning season, spawning behavior, sex ratio and seasonal changes of gonadosomatic index has been well studied, especially in Japan (MURAI *et al.*, 1984; OKAMURA, 1991, 1992; HAZAMA, 1993; KAWABE *et al.*, 2000). However, the study area has been limited to temperate/subtropical waters on the distributional margin of the fish. Moreover, no histological studies of the gonads have been carried out. Although the tropical waters around the Philippines are central to the species' distribution, blacktip grouper being locally abundant and commercially important (INGLES and PAULY, 1984; KOHNO, 1987), little information is available on their

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reproductive biology in that area. Therefore, this study investigated the maturation size, spawning season, sex ratio and hermaphroditism of *E. fasciatus* from the Philippines, based mainly on histological observations of the gonads.

2. Materials and Methods

Specimens used in the present study totaled 1,119 individuals (105–330 mm in total length, TL), having been caught by fishermen, using hook and lines, in Puerto Princesa Bay, depth of ca. 30m, and landed at Puerto Princesa City Market, Palawan Island, Philippines, in the period from 1995 to 2000. Sampling was conducted irregularly from 1995 to 1998 and essentially monthly from 1999 to 2000. The TL and the body and gonad weights (*BW*, *GW*), measured nearest to 1 mm and 0.01 g, respectively, of each specimen were measured while fresh. Gonadosomatic index (GSI) was calculated as $GSI = [GW / (BW - GW)] \times 1{,}000$.

For sex determination and histological observation, extracted gonads were fixed in 10% buffered formaldehyde seawater solution formalin immediately after the samplings, and the middle portions were dehydrated by ethanol and embedded in meta-acrylic resin (Technovit 7100), sectioned at 6μm, and stained with basic fuchsin and methylene blue. Gonad phases were defined by the most developed germ cells. Nomenclature for description of the stages of oogenesis and spermatogenesis was taken from YAMAMOTO *et al.* (1965) and OOTA *et al.* (1965), respectively. The criteria outlined by SADOVY and SHAPIRO (1987) were used in the diagnosis of protogynous hermaphroditism.

3. Results

3.1. Fish size and gonad development

Out of 1,119 individuals examined, 91 (8.1%) were not sexually determined even based on histological observations. The residual 1,028 were classified into three sexual categories: females, males and transitions.

The mean TL of females was 190 mm (n = 542, 52.7% of sex-determined specimens), ranging from 125–280 mm (Fig. 1) and the mean BW 115 g ranging from 30.4–366 g. Their ovaries were classified into the following five phases (Fig. 2), based on the most developed egg-cells in each ovary: phase 1–until peri-nucleolus stage (Fig. 2A); phase 2–until yolk vesicle stage (Fig. 2B); phase 3–until yolk globule stage (Fig. 2C); phase 4–until ripe-cell stage (Fig. 2D); phase 5–until atretic oocyte stage (Fig. 2E).

The mean of males were 230 mm (n = 347, 33.8%, range 153–330 mm TL) (Fig. 1) and 202 g (62.0–580 g BW), respectively. Their testes were divided into the following five phases, based on the most developed germ-cells in each testis (Fig. 3) : phase 1–until spermatogonium stage; phase 2–until spermatocyte stage; phase 3–until spermatid stage; phase 4–until mature spermatozoa stage; phase 5–empty crypts with residual spermatozoa. In many males (344 out of 347 specimens), ovigerous lamella and an ovarian cavity were clearly apparent. Atretic oocytes were observed in the gonads of 109 males, and gonads of large males were covered with thick tunica.

Transitions numbered 139 (13.5%) with a mean TL and BW of 208 mm (range 148–310 mm) (Fig. 1) and 154 g (53.0–535 g), respectively. Transitional individuals possessed both the spermatozoa and oocytes as follows (Fig. 4) : in a 180 mm TL specimen, peri-nucleolus stage oocytes and crypts filled with mature spermatozoa were observed, and ovarian lumen and sperm sinuses were also present (Fig. 4A) ;

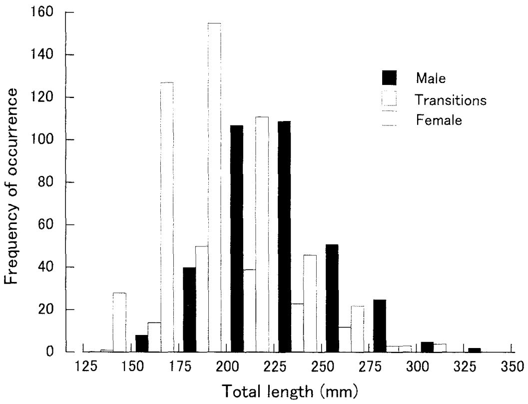

Fig. 1. Size-frequency distributions for female, transitional individuals, and male blacktip grouper *Epinephelus fasciatus* caught at Palawan Island, Philippines, between 1995 and 2000.

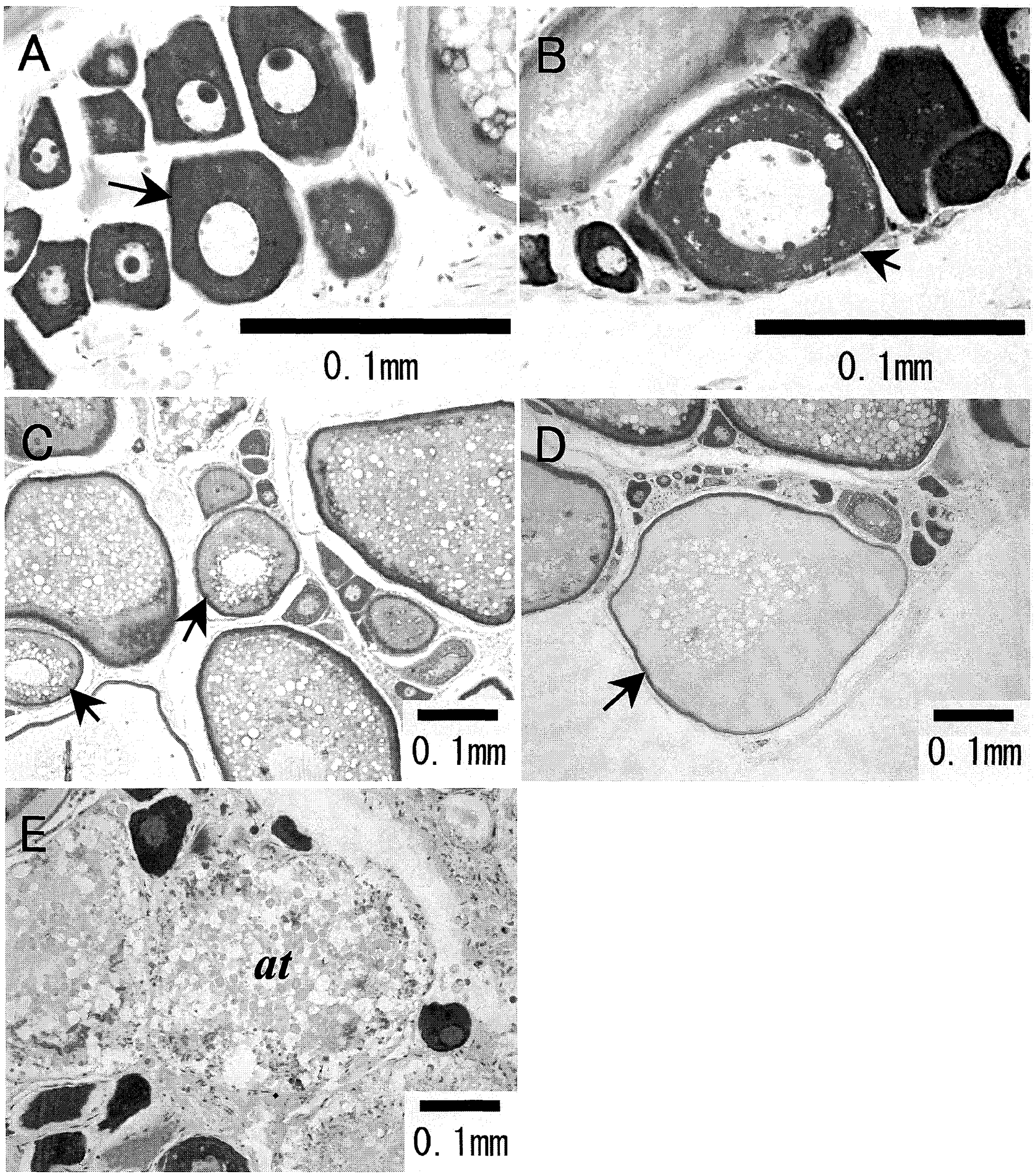

Fig. 2. Histological sections of female blacktip grouper, *Epinephelus fasciatus*, gonads at different developmental stages. A, peri-nucleolus stage oocyte (arrow) ; B, yolk vesicle stage oocyte (arrow) ; C, yolk globule stage oocytes (arrows) ; D, ripe cell stage oocyte (arrow); E, atretic oocyte (*at*).

and the yolk globule stage oocytes with crypts filled with spermatids were recognized in a 235 mm SL specimen (Fig. 4B). In most of the transitions (138 of 139), ovigerous lamella and an ovarian cavity were clearly apparent. Atretic oocytes were observed in the gonads of 39 transitions.

3.2. Sex ratio

Females comprised more than 80% of specimens of 100–150 mm TL, their ratio decreasing with growth to 15.7% of 250–300 mm TL specimens (Fig. 5). On the other hand, males were not identified among specimens <150 mm TL, but comprised 12.9% of 150–200 mm TL

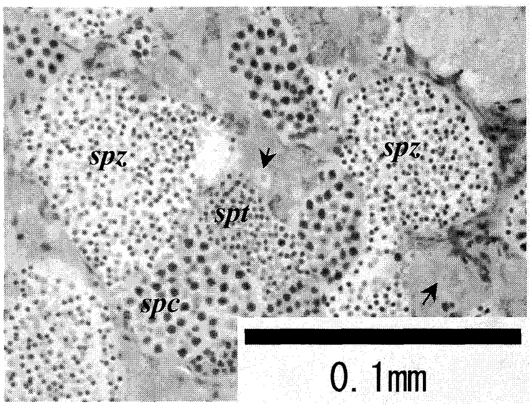

Fig. 3. Histological sections of male blacktip grouper, *Epinephelus fasciatus*, gonads. *spc*, spermatocytes; *spt*, spermatids; *spz*, spermatozoa. Arrows indicate spermatogonia.

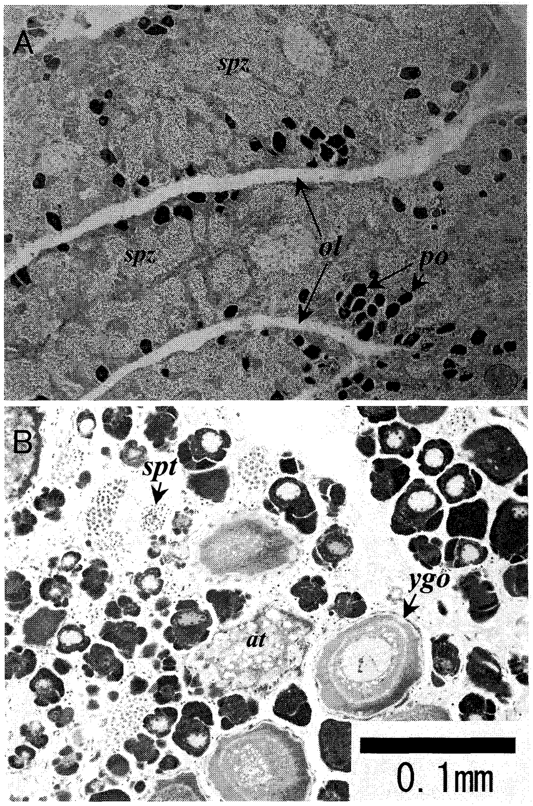

Fig. 4. Histological sections of transitional gonads of blacktip grouper, *Epinephelus fasciatus* (A, 180 mm TL ; B, 235 mm TL). *at*, atretic oocyte; *ol*, ovarian lumen; *po*, peri-nucleolus oocytes; *spt*, spermatids; *spz*, spermatozoa; *ygo*, yolk globule oocytes.

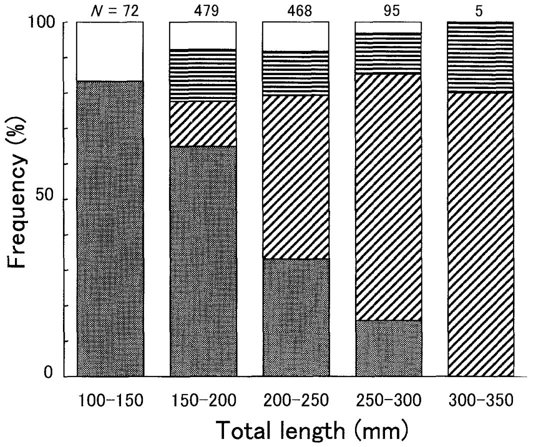

Fig. 5. Sex frequencies in blacktip grouper, *Epinephelus fasciatus*, caught at Palawan Island, Philippines, shown by 50-mm-TL-interval size classes. Open area, sex unidentified; shaded area, females; oblique-lines, males; horizontal-lines, hermaphrodites.

specimens, the ratio increasing with growth and reaching 80% of specimens of 300–350 mm TL. Transitions occupied about 10% of each size class greater than 150 mm TL.

3.3. GSI development with growth

The GSI values of females increased in specimens from ca. 140 mm TL, reaching the highest value (ca. 100) in specimens of ca. 200 mm TL and decreasing suddenly in specimens > 270 mm TL (Fig. 6). Ovarian developmental phase 1 appeared in specimens from 125–270mm TL, phase2 from 128–240 mm TL, phase 3 from 138–280 mm TL, phase 4 from 142–275 mm TL and phase 5 from 145–255 mm TL. Specimens determined as mature (developmental phases ≥3) showed GSI values from 2.0 to 100.0.

On the other hand, male GSI values were low, ranging from 0.1 to 16.0 (Fig. 7). Testicular developmental phase 1 appeared in specimens from 160–290 mm, phase 2 from 160–240 mm, phase 3 from 175–280 mm, phase 4 from 160–330 mm and phase 5 from 153–305 mm.

GSI values of transitions ranged from 0.1 to 14.7 (Fig. 8). Ovarian development in 127 specimens was recognized as phase 1, in 7 specimens as phase 2, in 5 specimens as phase 3 and 1 specimen as phase 5. Testicular development in

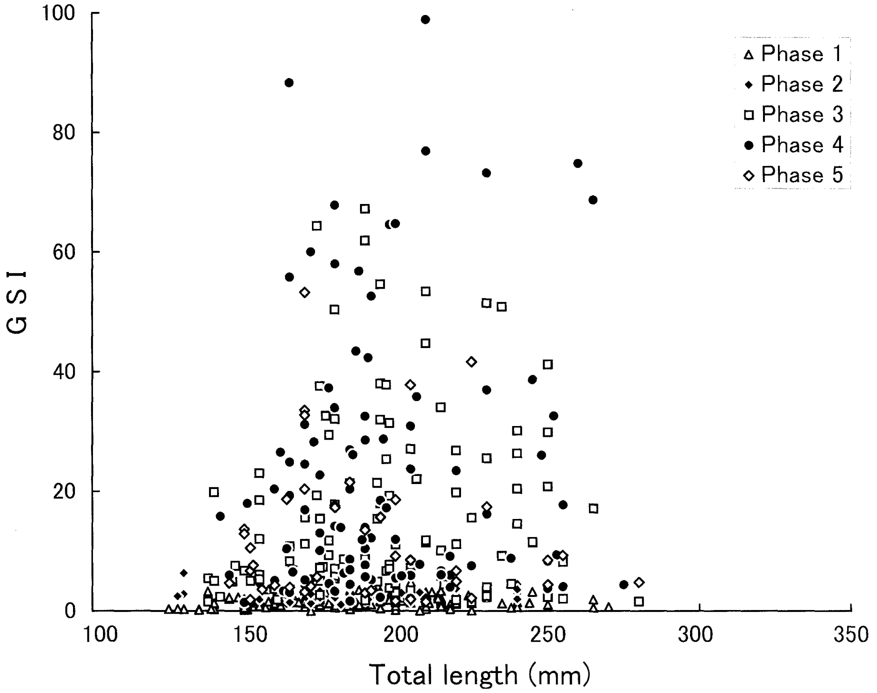

Fig. 6. Relationship between gonadosomatic index (GSI) and total length in female blacktip grouper, *Epinephelus fasciatus*, caught at Palawan Island, Philippines, with gonad developmental phases (see text).

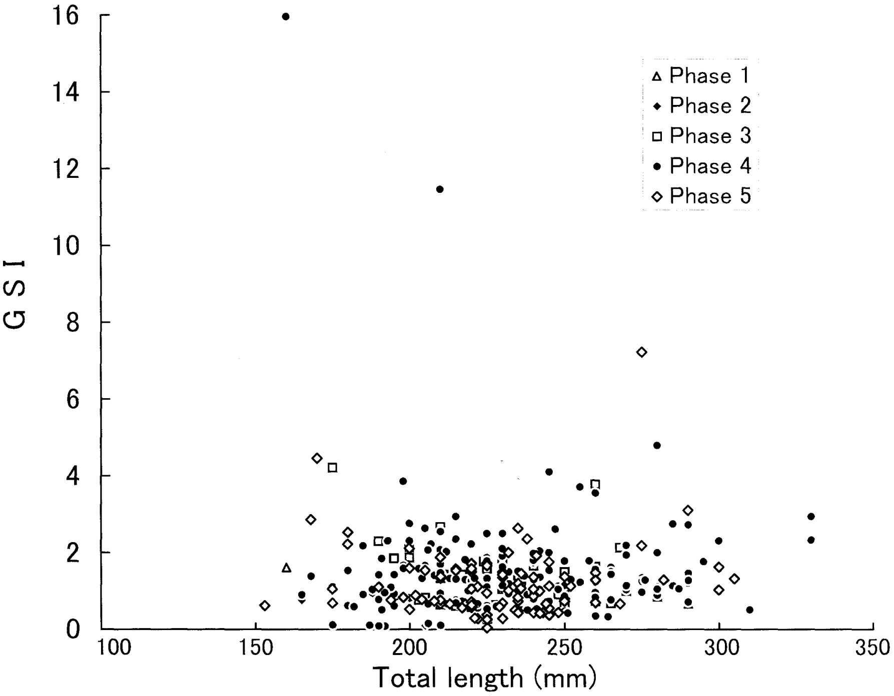

Fig. 7. Relationship between gonadosomatic index (GSI) and total length in male blacktip grouper, *Epinephelus fasciatus*, caught at Palawan Island, Philippines, with gonad developmental phases (see text).

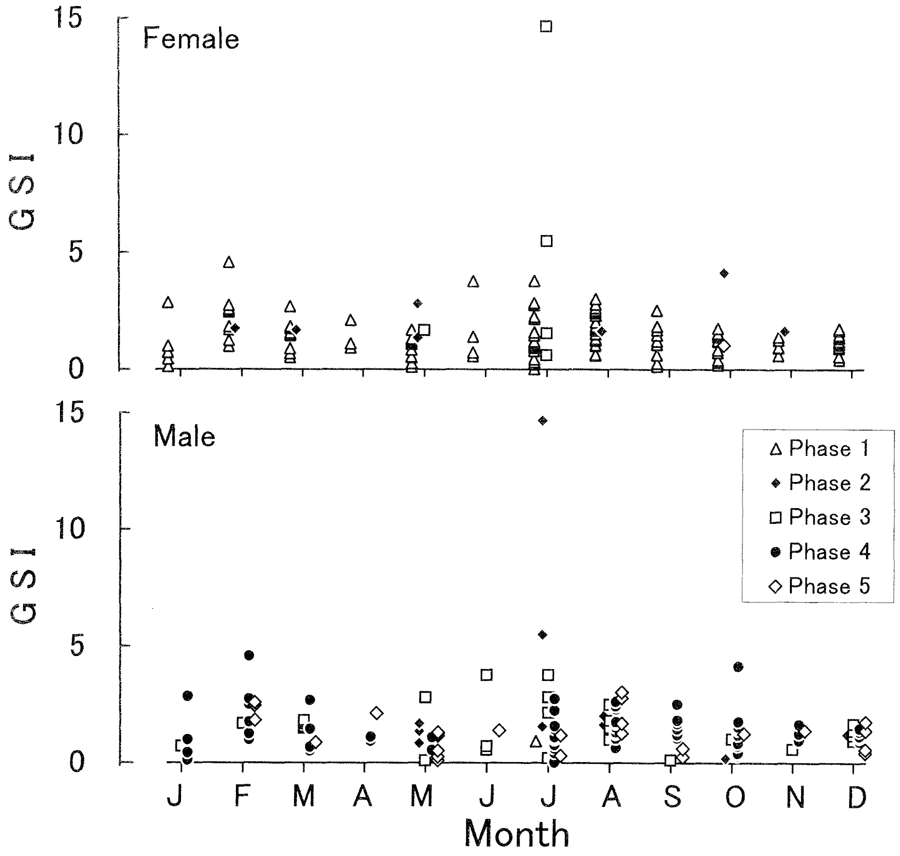

Fig. 8. Monthly changes of gonadosomatic index (GSI) in "female" (upper) and "male" (lower) hermaphroditic blacktip grouper, *Epinephelus fasciatus*, with gonad developmental phases (see text).

28 specimens was phase 3, being phases 4 and 5 in 72 and 27 specimens, respectively.

3.4. Seasonal changes of GSI and gonad developmental phase

The mean GSI values fluctuated from month to month, those in females varying from 2.3 in May to 19.9 in December and from 0.7 in March to 2.0 in August in males (Fig. 9). The mean GSI values were relatively low at the ends of both the dry (May) and rainy (October) seasons in both sexes.

Both female and male specimens with gonad developmental phases ≥3 were found all year round (Fig. 10). In females, individuals possessing the gonad developmental phases ≥3 occupied more than 70% in February, July and December, while in males those with the gonad developmental phases ≤2 appeared only in January, May, June, August and October.

4. Discussion

The present study confirmed that the blacktip grouper, *Epinephelus* fasciatus, is a protogynous hermaphrodite. This is provided by the fact that transitional atretic oocytes were present within the testes and that sperm sinuses were found in the gonadal wall, all of which being features strongly indicative of protogeny (SADOVY and SHAPIRO, 1987). Furthermore, the gonadal and population structures of the species were characteristic of a monandric species (SADOVY and SHAPIRO, 1987; NAKAI and SANO, 2002) ; many males had gonads retaining the ovigerous lamella and an ovarian cavity, and bi-modal size frequency distributions were observed, in which modal size of females being less than that of males.

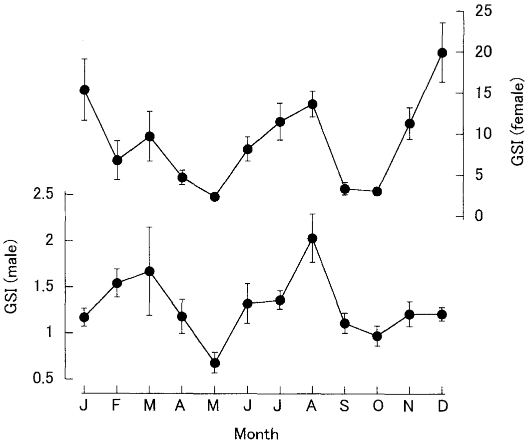

Fig. 9. Monthly changes of the mean gonadosomatic index (GSI) with standard error (bars) in female (upper) and male (lower) blacktip grouper, *Epinephelus fasciatus*, caught at Palawan Island, Philippines, between 1995 and 2000.

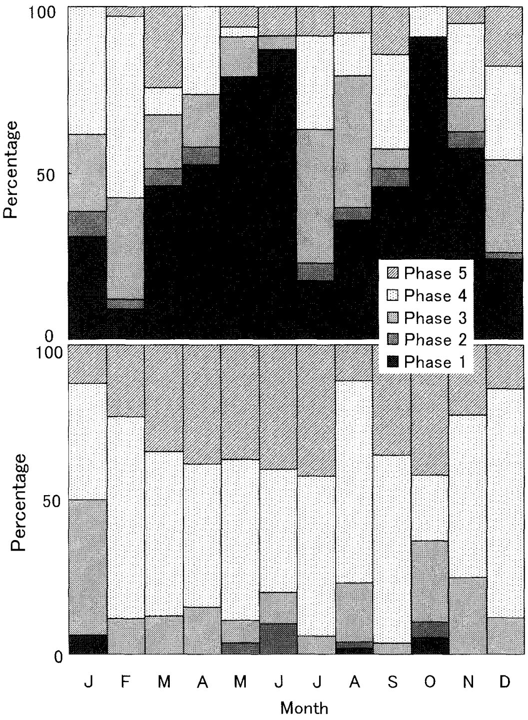

Fig. 10. Monthly changes of percentage frequency distribution of gonad developmental phases in female (upper) and male (lower) blacktip grouper, *Epinephelus fasciatus*, caught at Palawan Island, Philippines, between 1995 and 2000.

The spawning of blacktip grouper occurs year round in Palawan waters, Philippines, specimens of both sexes with gonad developmental phases ≥3 appearing throughout the year. High GSI were maintained in both sexes year round with much higher values in females than in males. Spawning activities would decrease, however, at the ends of both the dry and rainy seasons (May and October) when female GSI values were lower.

In captivity in Japan, the spawning season of this species was reported as June-November in Kochi Prefecture (OKAMURA, 1992), June and July in Wakayama Prefecture (HAZAMA, 1993) and throughout the year at the Ogasawara (Bonin) Islands (KAWABE *et al.*, 2000), the former two sites being temperate and the latter, subtropical. However, wild specimens caught by hook and line in Ogasawara indicated that the spawning season would be limited to April to June (MURAI *et al.*, 1984). According to SHAPIRO (1987), spawning occurs from September to February in New Caledonia, tropical southern hemisphere waters. These findings indicate that the spawning season of the species depends mainly on water temperature, higher temperatures having a prolonging effect; thus the spawning season is longer in lower latitude (tropical) waters. However, especially in captivity, the nutritional condition of the fish, as well as water temperature, would affect the spawning period, as pointed out by KAWABE *et al.* (2000).

Although sex was determined in specimens as small as 125 and 153 mm TL (females and males, respectively) in the present study, the smallest specimens with the mature gonads (developmental phases ≥3) were 138 and 175 mm TL for the respective sexes. Therefore, the former sizes are recognized as the biological minimum size for each sex in blacktip grouper. Hermaphrodites, the smallest recorded being 148 mm TL, are believed to function mainly as males, because only a few (6 out of 139 specimens) possessed ovaries at developmental phases ≥3, in contrast to those having testes of phase 3 or greater (127 out of 139 specimens).

Grouper sex ratios are known to be less than 1.0, males being fewer than females, because of protogynous hermaphroditism (TAN and TAN, 1974; Sadovy and Shapiro, 1987; Shapiro, 1987; Tanaka *et al.*, 1990). In the present study, out of 1,028 sex-determined specimens, female, male and hermaphrodite numbers were 542, 347 and 139, occupying 52.7%, 33.8% and 13.5%, respectively, resulting in a sex ratio of 0.640. Including the hermaphrodites as functioning male results in the sex ratio increasing to 0.897. The reported sex ratio of wild blacktip grouper at the Ogasawara Islands is 0.743 (Murai *et al.*, 1984), compared with 1.238 in captivity in Kochi (Okamura, 1991, 1992).

In other grouper species, reported sex ratios are: 0.075 for *Cromileptes altivelis* (Mishina and Gonzares, 1994), 0.075 for *Epinephelus* tauvina (Abu-Hakima, 1987), 0.18–0.35 for *E. guttatus* and 0.53–1.0 for *E. striatus* (Colin *et al.*, 1987), and 0.193 for *E. morio* (Brule *et al.*, 1999). According to Heemstra and Randall (1993), the maximum sizes of the aforementioned species range between 700 and 1,000 mm TL. Although the sex ratio of these larger grouper species (maximum TL >700 mm) is usually much lower than 1.0, it is generally higher (0.640–0.897) in blacktip grouper [maximum TL 400 mm, according to Heemstra and Randall (1993)]. Such differences in sex ratios between large and small grouper species may reflect different reproductive strategies. Further studies are necessary for confirmation of this.

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The Influence of the Andaman Sea and the South China Sea on Water Mass in the Malacca Strait

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Abstract : The Malacca Strait is an important waterway link between the Indian Ocean and the South China Sea. It is also an important fisheries area for the neighbouring states. Improved understanding of the water mass variations over the monsoon seasons can lead to better management of this water body. The purpose of this paper is to present the seasonal variations in the water mass properties in the Strait. Data from the World Ocean Database for the Strait was utilised to assess the seasonal variation in temperature, salinity and dissolved oxygen. The data indicated the introduction of cool, deep, saline water from the Andaman Sea during the Southwest Monsoon. During the Northeast Monsoon the situation reversed and there was ingress of lower salinity water mass from the south. This may be attributed to the larger river discharge experienced during the Northeast Monsoon and the introduction of lower salinity water from the South China Sea. The influence of the Andaman Sea and the South China Sea is supported by the variation in the T-S plots for the Malacca Strait. This indicates that although very saline water characteristics are fairly consistent over the year, identifiable as the Andaman Sea water, the lower salinity water characteristics separate into two distinct masses, one representing the South China Sea water and the other representing freshwater influence from river inflows. This is especially discernible in the Northeast Monsoon and in the subsequent Inter-monsoon period. Such results have implications for the movement and exchange of materials between the Andaman Sea and the South China Sea via the Malacca Strait.

Keywords : *Strait of Malacca, water mass, Andaman Sea, South China Sea, monsoon, salinity, temperature, dissolved oxygen*

1. Introduction

The Malacca Strait represents an important link between the Indian Ocean, the Andaman Sea, the South China Sea as well as the Java Sea. Thus it can be an important conduit for interaction and transfer of water properties between the various seas. The Malacca Strait is also important for the fisheries resource of its neighbouring states. As the Southeast Asian region is affected by Monsoon winds, wind-driven water movements can occur in the Strait. From previous observations, it is known that during the Northeast Monsoon, water from the South China Sea penetrates at least into the southern sector of the Malacca Strait (CHIA *et al.* 1988; PANG and TKALICH, 2003) and that there is incursion of the Andaman Sea from the north (LIONG, 1974; FAIRBRIDGE, 1996; TOMCZACK and GODFREY, 2003). The movement of these water masses may be found from investigation of the physical properties of seawater, such as salinity, water temperature and dissolved oxygen. The first two parameters are regarded to behave conservatively in mixing processes, while dissolved oxygen can be regarded as quasi-conservative. A vast amount of ocean data for the area is available from Ocean Data bases such as the World Ocean Data Center (WODC), National Oceanographic and Atmospheric Agency (NOAA), National Ocean Data Center (NODC) of the United States. An understanding of the physical-chemical variations over the monsoon seasons can lead to better management of this waterway resource. A

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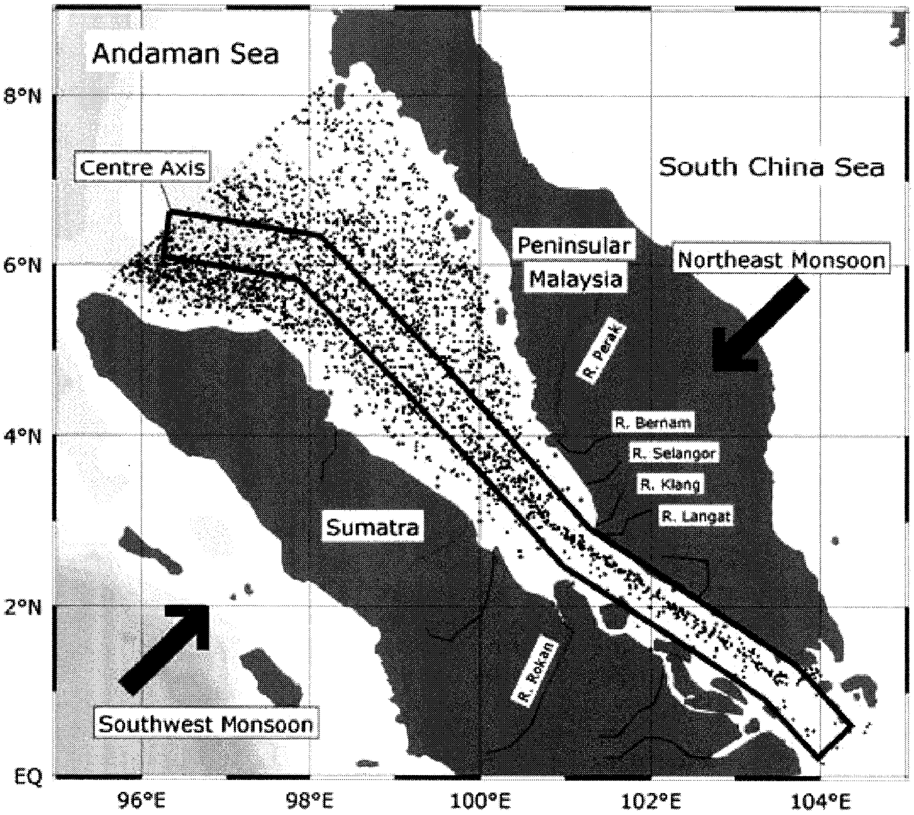


Fig. 1. Location of the Malacca Strait study area and location of stations from the World Ocean Data Base 2001. The centre axis of the Strait used for vertical section plots is also indicated.

previous analysis of the seasonal variations (IBRAHIM *et al.*, 2003) had indicated the importance of the Andaman Sea to the Malacca Strait circulation. The purpose of this paper is to present the seasonal variations in the water mass properties in the Strait. A mechanism for the variations is also proposed.

2. Methods

Water temperature, salinity and dissolved oxygen data for the Malacca Strait were obtained from the World Ocean Data Base (NOAA, 2001). Stations whose coordinates placed on land, as delineated by the ODV (Ocean Data View) high-resolution global coastline and topography file "odvmpOP_coast GlobHR_w32" based on ETOPO5 (0.2×0.2 degree grid), were omitted. Stations indicating sampling at deep depths (greater than 150 m depth) in the shallow southern sector of the Strait were also omitted. The final dataset, comprising 4,476 stations (Fig. 1), were supplied by 558 cruises carried out between 1889 and 2001. This resulted in a total of 95,063 samples of the Malacca Strait waters. The data availability by month and for different years is shown in Fig. 2.

ODV (mp) 1.4 software (SCHLITZER, 2003) was used to process the data and to create contour plot visualizations. The visualizations are presented in two forms: seasonal surface variations and axial section (Fig. 1) variations of water temperature, salinity and dissolved oxygen along the Malacca Strait. The data were separated into four seasonal groups (Table 1) to represent the different monsoonal periods. The monsoonal periods defined here are delayed by one month from the traditional climatic divisions for Malaysia, as the response of the sea is expected to lag behind that of the

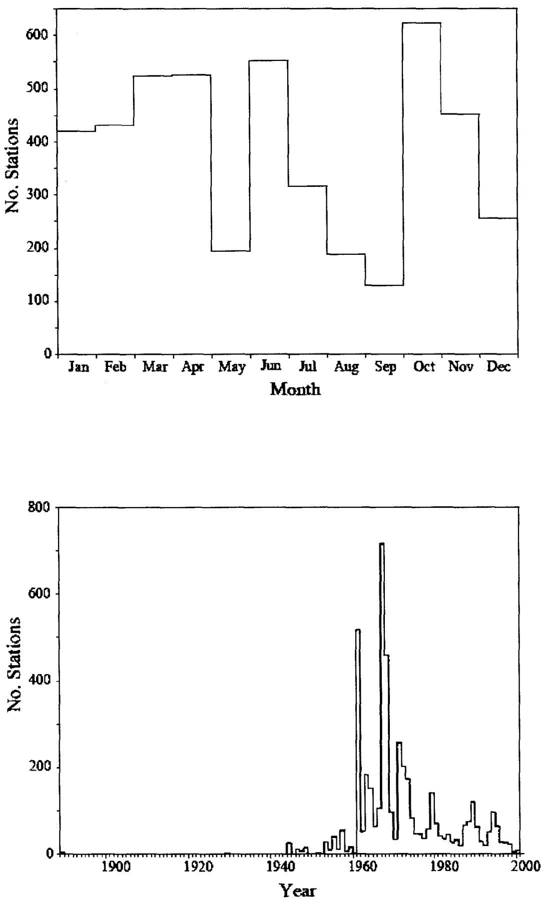


Fig. 2. Temporal distribution of station data in the Malacca Strait. (a) The number of stations data available by month. (b) The number of stations data available year by year.

atmosphere. In addition, coincidentally, division into the four monsoonal periods defined in Table 1 also resulted in some uniformity in the amount of data available for each season (Table 2). As the number of variables (water temperature, salinity and dissolved oxygen) increase, the number of stations and samples reduces.

3. Results and Discussion

Three formats are used to present the results of visualisation of the water temperature, salinity and dissolved oxygen data separated into the four seasons: a surface contour plot, a contour plot in the vertical section through a defined centre axis, and temperature-salinity plots. The data were also grouped into the four seasons. These data visualisations indicated the sequential change in water movement through the Strait during the different seasons.

The contour plots in Fig. 3 show the horizontal variation in surface water temperature, salinity and dissolved oxygen in the Strait. These figures indicate the importance of freshwater inflow in the central section of the Malacca Strait. The central portion of Peninsular Malaysia has several large river systems (Perak, Bernam, Selangor, and Klang-Langat Rivers) (Fig. 1) which drain a substantial part of the peninsula. The Rokan estuary in Sumatra (Fig. 1) also drains into the centre of the Strait. During the Northeast Monsoon (Fig. 3a), the large low salinity plume may be explained by the higher rainfall and subsequent river discharge. The isohalines in the central portion of the Strait veer northward with the coast on the right hand indicating the net flow direction from the South China Sea entering through the southern end. This situation is reversed in the Southeast Monsoon season (Fig. 3c) when there is a clear indication of the intrusion of high salinity Andaman Sea water from the north. The Southwest Monsoon period is drier than the Northeast one and the influence of river discharge is reduced. However, in the second Inter Monsoon during September to November (Fig. 3d) there is also an area with lowered surface salinity in the southern portion of the Strait. The reasons for this are unclear and need to be investigated further. The data here are primarily from samples taken during a single cruise in November 1957. A clearer picture may be obtained by considering the vertical variation in water temperature, salinity and dissolved oxygen. This may be obtained by considering contour plots in the vertical along a centre axis of the Strait, as indicated in Fig.1.

Figure 4 shows the vertical variation in water temperature, salinity, density (σ_t) and dissolved oxygen in the Strait along a 30 km wide centre axis. The interlacing of lower salinity water at the surface with higher salinity water at the bottom can be discerned by the sigma-shaped salinity contour lines in the figures for all four seasons. Fig. 4a indicates the pervasive

Table 1 Monsoon periods used for sea data separation.

Season	Period (months)
Northeast Monsoon	December, January, February (DJF)
Inter-Monsoon	March, April, May (MAM)
Southwest Monsoon	June, July, August (JJA)
Inter-Monsoon	September, October, November (SON)

Table 2 Data distribution among the four Monsoon periods.

	Northeast Monsoon (DJF)			Inter-Monsoon (MAM)			Southwest Monsoon (JJA)			Inter-Monsoon (SON)		
Variable	T	TS	TSO	T	TS	TSO	T	TS	TSO	T	TS	TSO
Cruises	157	21	10	157	16	9	153	12	3	157	12	5
Stations	1105	339	296	1131	213	141	1052	73	51	1188	71	55
Samples	18092	2035	1803	26821	1365	791	25206	538	330	24944	615	469

influence of the less saline South China Sea water through the whole Strait during the Northeast Monsoon. The dissolved oxygen values indicate the fairly uniform nature of the upper layer of the Strait despite the much fresher waters observed in the central portion of the Strait. With the start of the Inter Monsoon (Fig.4b), however, the Andaman Sea water starts to intrude into the Strait. Salinity increases, reaching maximum values during the Southwest Monsoon (Fig. 4c). During the following Inter Monsoon (Fig. 4d) salinity in the southern sector decreases and the salinity contours move northward in the Strait. This increase in freshwater may be partially attributed to the intrusion of lower salinity South China Sea water (HUSAIN et al., 1986; LIEW *et al.*, 1987). The area of interlacing between the two water masses starts from the north entrance of the Malacca Strait and extends down to the constriction of the funnel-shaped Malacca Strait. This latter area also coincides with the rise of the topographic sill in the Strait.

The intrusion of the South China Sea water into the Strait is generally regarded to be a result of onshore Northeast Monsoon winds resulting in increased throughflow into the Malacca Strait (YANAGI *et al.*, 1997). We may invoke a similar mechanism for the intrusion of the Andaman Sea water into the Strait. We may hypothesise that during the Southwest Monsoon, the Indian Ocean water is moved onshore into the Andaman Sea and into the Malacca Strait due to the sea level difference between the Indian Ocean and the South China Sea (YANAGI *et al.*, 1997). The normally cold, deep, saline water of the Andaman Sea is moved into the shallower Malacca Strait and is mixed upward into the water column. This is indicated by the deeper layer of oxygenated water during the Southwest Monsoon season (Fig. 4c) compared to the very stratified condition during the Northeast Monsoon season (Fig. 4a).

The influence of the South China Sea and the Andaman Sea on the water mass characteristics of the Malacca Strait is also supported by an analysis of the temperature-salinity plots for the whole Strait when they are separated into the four seasons. Three different origins of water masses may be distinguished based on location and salinity values: the salty Andaman Sea (AS) water from the northwest, low salinity surface water from river fresh water (FW), the South China Sea (SCS) water entering from the southeast. They are presented in Fig. 5. In particular, in Fig 5a, during the Northeast Monsoon, the three bodies of water in the Strait are distinctly separated. The trend of relative dominance of the water mass, dependent on the number of samples available in each water mass, may also be noted. This is particularly true for the FW water mass which almost disappears during the Southwest Monsoon (Fig. 5c) and the second Inter Monsoon (Fig.

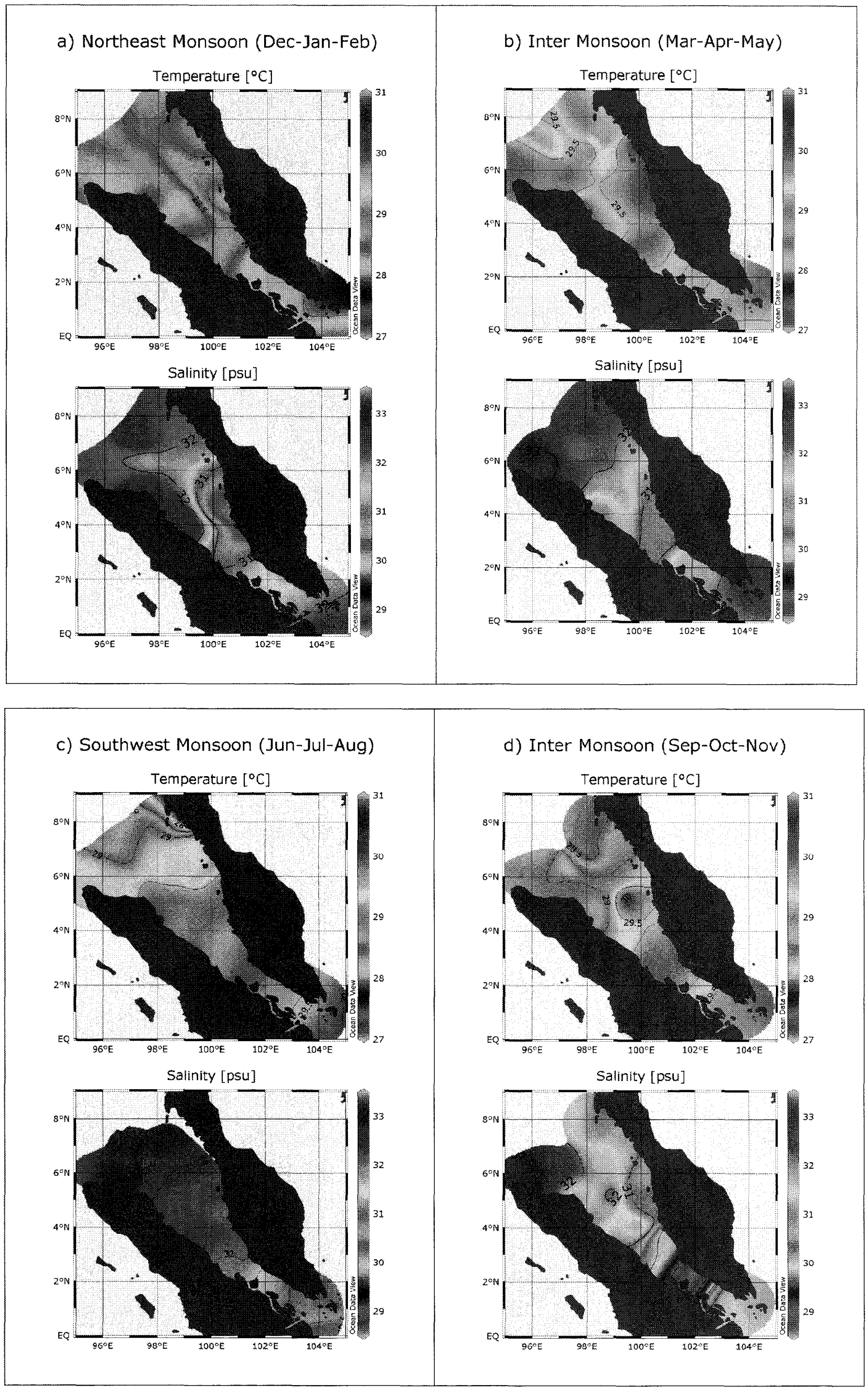
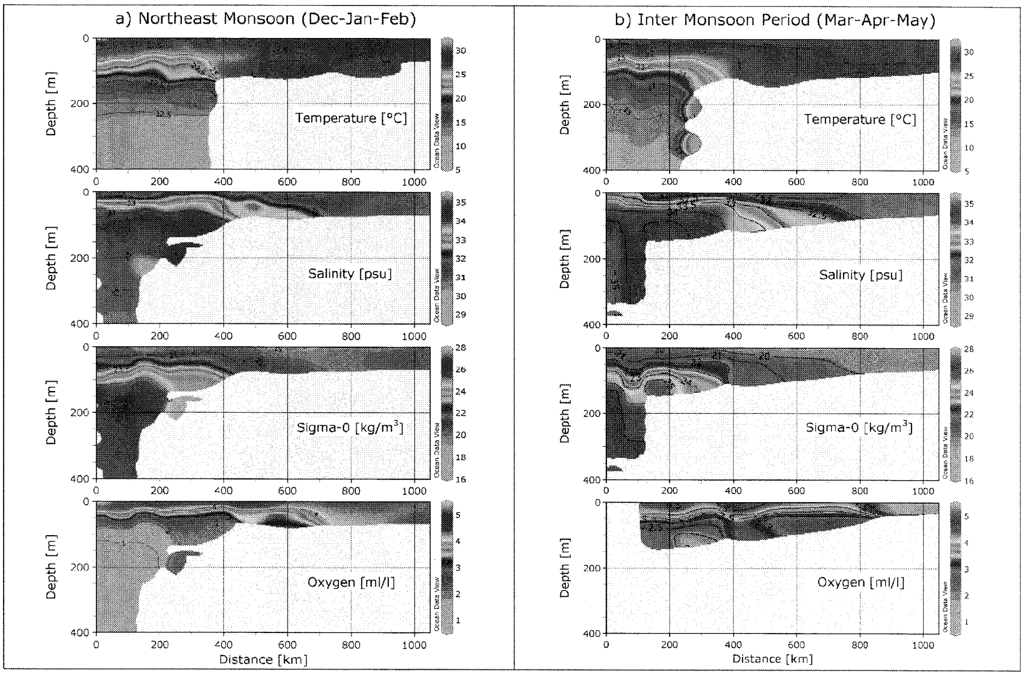
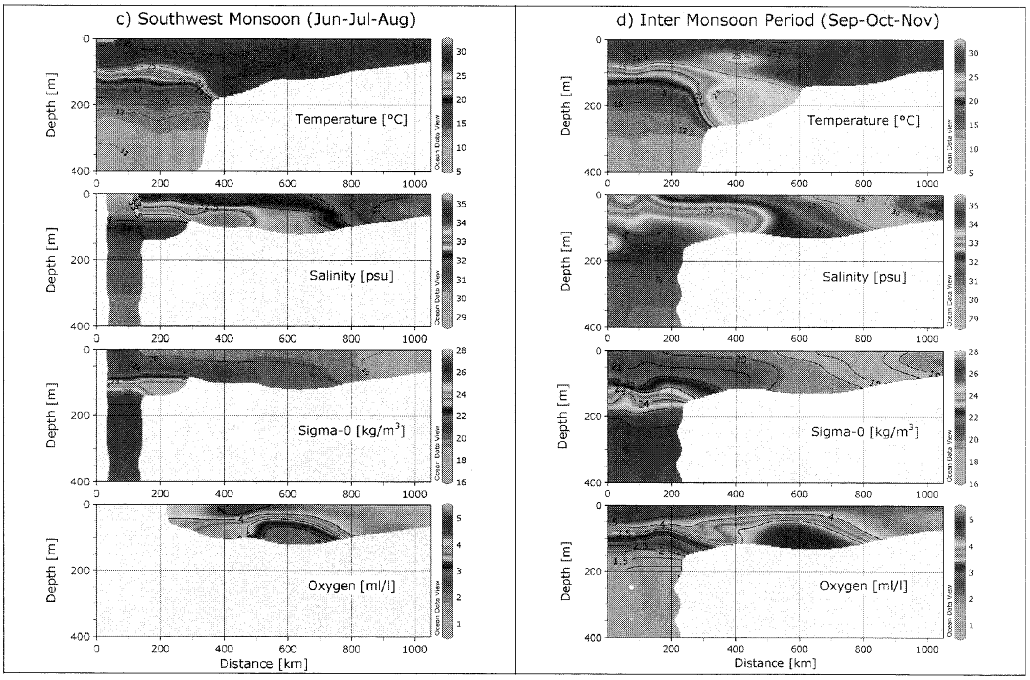


Fig. 3. Seasonal horizontal variations in surface water temperature and salinity in the Malacca Strait. (a) Northeast Monsoon season. (b) Inter Monsoon season. (c) Southwest Monsoon season. (d) Inter Monsoon season.



a) Northeast Monsoon (Dec-Jan-Feb)

b) Inter Monsoon Period (Mar-Apr-May)



c) Southwest Monsoon (Jun-Jul-Aug)

d) Inter Monsoon Period (Sep-Oct-Nov)

Fig. 4. Seasonal vertical variations in water temperature, salinity and dissolved oxygen in the Malacca Strait. (a) Northeast Monsoon season. (b) Inter Monsoon season. (c) Southwest Monsoon season. (d) Inter Monsoon season.

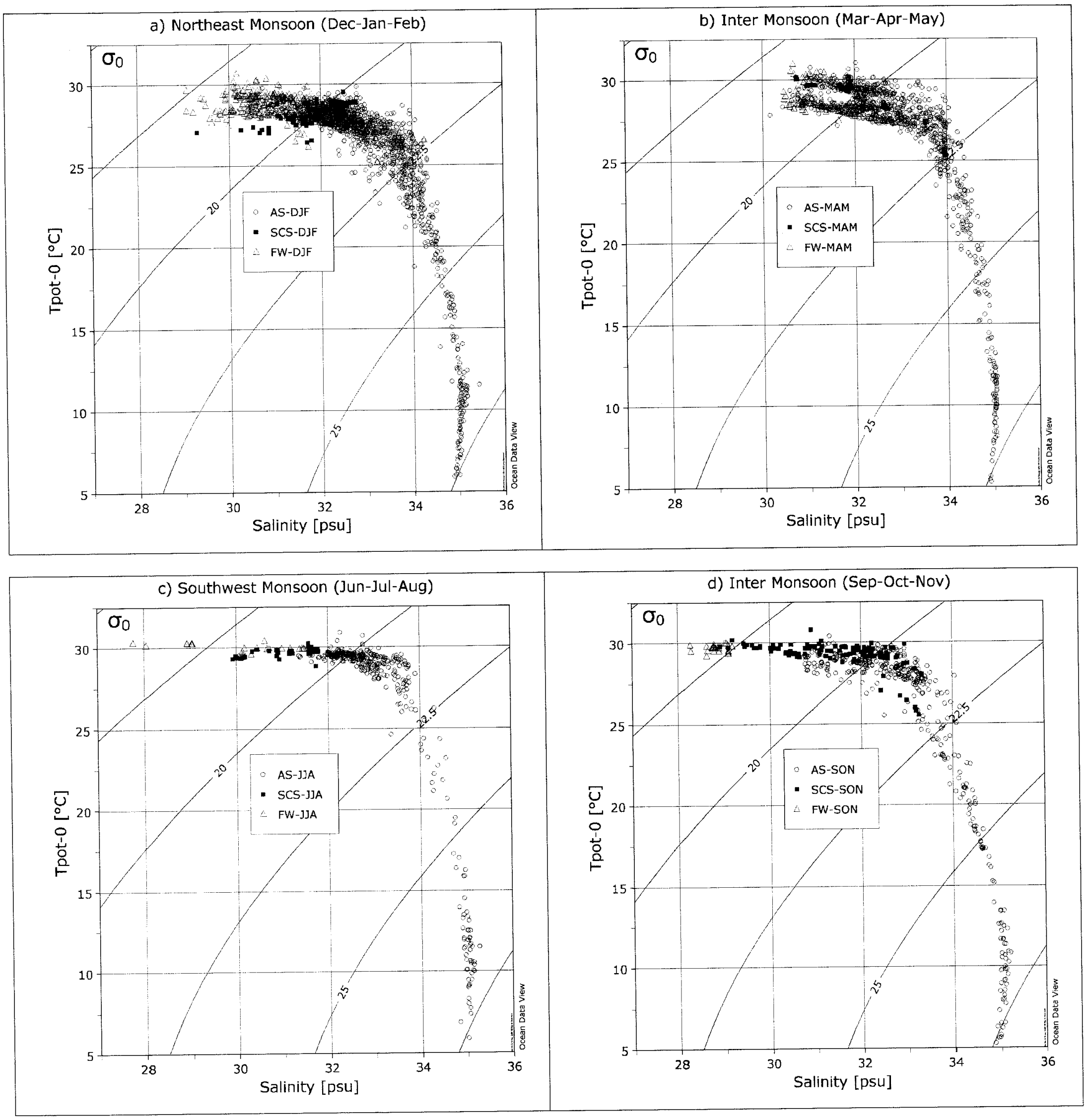


Fig. 5. Seasonal temperature-salinity plot for the Malacca Strait. (a) Northeast Monsoon season. (b) Inter Monsoon season. (c) Southwest Monsoon season. (d) Inter Monsoon season.

5d) of September-October-November. The South China Sea (SCS) water mass is also in retreat. During the Southwest Monsoon, then, the water mass in the Strait is primarily affected by the Andaman Sea (AS) characteristics, while during the Northeast Monsoon the South China Sea (SCS) and the fresh water (FW) input from rivers dominate in the surface waters.

The pattern of variation in water mass in the Strait may be compared to the movement of saline and fresh water in the estuary. At the start of high tide, the sea water will flow into an estuary and push the fresh water further upstream. At the end of high tide, the sea water retreats, flowed by the riverine fresh water flows. In an estuary, the driving force is the tidal elevation which changes the water presuure gradient force along the river channel. In the Malacca Strait the change in the pressure gradient force needs to be coupled to seasonal change. We postulate that the seasonal change is the Monsoon wind and resultant sea surface slope.

We may postulate a wind-driven oscillating pump (Fig. 6) as a mechanism to explain the variation in the movement of the Andaman Sea and the South China Sea in and out of the Malacca Strait. The movement may be generated by the altering pattern of Monsoon winds over the region. Similar mechanism has been proposed to explain the flow of the South China Sea Warm Current (CHAO *et al.*,1995) and the reversal of flows in the Singapore Strait (PANG and TKALICH, 2003). During the Northeast Monsoon the prolonged blowing of strong Northeasterly winds over the South China Sea results in elevated sea levels off the East Coast of Peninsular Malaysia due to wind stress over the South China Sea (YANAGI *et al.*, 1997). Such difference in sea level intensifies the throughflow into the south of the Strait and pushes the Andaman Sea water out of the Strait (Fig 6a) and can contribute to the flow of the North Equatorial Current (TOMCZAK *et al.*, 2003) across the Indian Ocean. Higher rainfall and the resultant higher surface runoff result in low salinity at the water surface in the Malacca Strait. During the Southwest Monsoon, the southwesterly winds blow along the Indian Ocean and across the Andaman Sea. This may result in elevated sea level around the northern end of the Malacca Strait and the Andaman Sea water flows into the Strait. In addition, sea levels along the east coast of Peninsular Malaysia are depressed compared to sea levels along the west coast (YANAGI *et al.*, 1997). These factors would result in the Andaman Sea water intruding further south into the Malacca Strait, causing the Strait water to become more saline. The extreme relative movement of the three water masses after each Monsoon is followed by a period of relaxation in each of the Inter Monsoons. This relative movement over the seasons is illustrated by Fig. 6. Information on the pattern of water mass variations in the Strait can assist in mapping movement of water masses and indicate the movement or transport of materials. This study indicates that in the Northeast Monsoon period the Malacca Strait is strongly influenced by waters from the South China Sea. Thus we may postulate that materials from the South China Sea flow into the Strait during the Northeast Monsoon. During the Southwest Monsoon, the Andaman Sea water enters at least midway into the Strait before retreating during the Northeast Monsoon. Mixing of the Andaman Sea water mass with the South China Sea water mass in the Strait may provide a means of transport of materials from the South China Sea into the Indian Ocean via the Andaman Sea. The fresh water input from rivers into the Malacca Strait may also be transported in this manner. The variation in water mass movement may have implications in terms of transport of pollutants and nutrients through the Strait. This in turn may affect the ecological health of the Strait and have impact on its aquatic resources. A better understanding of the movement of water masses through the Strait can assist in identifying potential resources of pollutants and prioritising which sources need to be managed or controlled first.

4. Conclusion and Summary

Comparison of seasonal variations of water temperature, salinity, and dissolved oxygen in the Malacca Strait indicates the importance of not only the South China Sea but also the Andaman Sea in influencing the movement and characteristics of the Strait water. River flow due to rainfall also appears to introduce significant amounts of freshwater input into the Strait. A wind generated mechanism for the intrusion of the Andaman Sea water in the Strait is proposed. This needs to be investigated further. The possibility of similar effects on other parameters, especially nutrients (LIONG, 1974), could have consequences for the behaviour in fisheries resources in the Strait.

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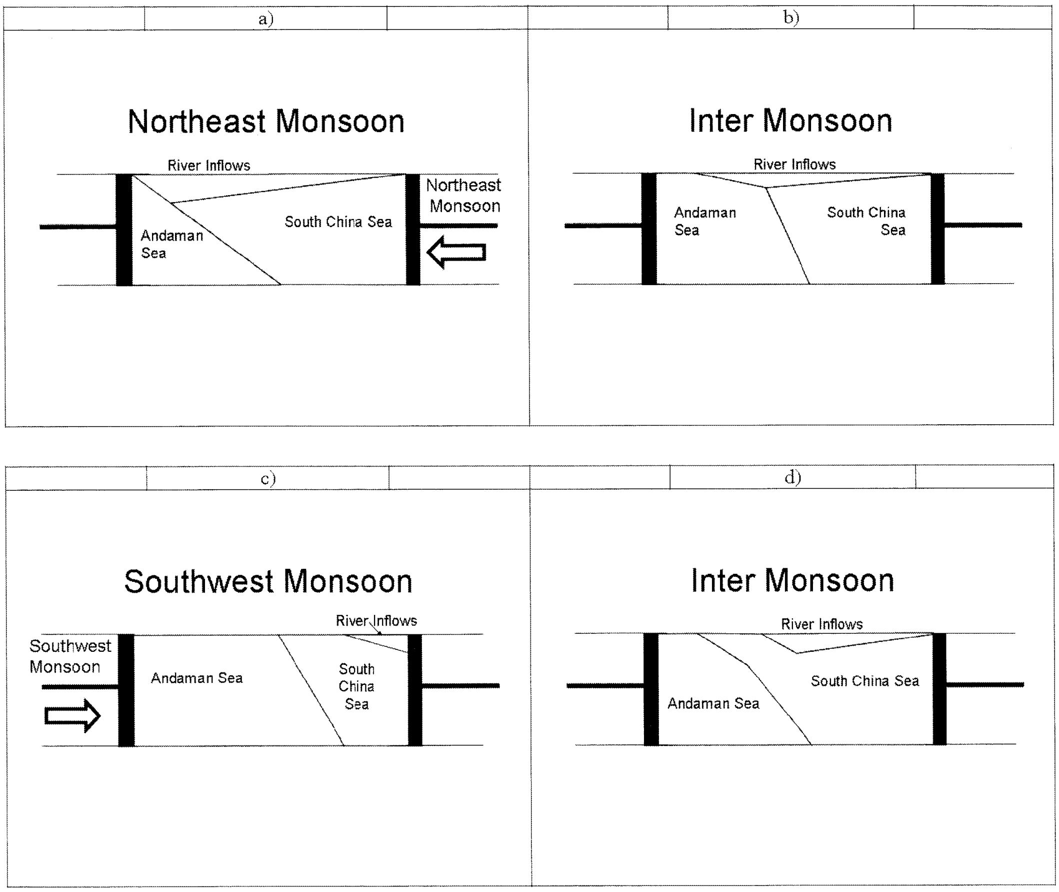

Fig. 6. Proposed mechanism for the seasonal variations observed in the Malacca Strait. (a) Northeast Monsoon season. (b) Inter Monsoon season from Northeast to Southwest. (c) Southwest Monsoon season. (d) Inter Monsoon season from Southwest to Northeast.

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資　料

第43巻第4号掲載欧文論文の和文要旨

伊沢瑞夫*・小林雅人：大船渡湾における養殖マガキからの沈降粒子フラックスの見積り ―10年間の月別平均環境データを用いた季節変動と経年変動―

養殖マガキの最適養殖密度を求めるための第一段階として、大船渡湾を対象にマガキの排泄物沈降フラックスを計算した。個体群動態モデルに1985年～1994年の10年間に毎月観測した水温、塩分、クロロフィルa濃度などの環境データの月別平均値を適用し、カキの排泄物の沈降フラックスを求めて観測値と比較した。計算結果は、定性的には排泄物沈降フラックスの季節変化を反映しており、また定量的にも、湾内の流れによる分散を考慮に入れると観測値と矛盾しない。これらのことから結論として、我々が採用した個体群動態モデルは、大船渡湾におけるカキ排泄物沈降フラックスの推定に適用可能と言える。さらに、平均値ではなく各年毎の環境データを用いると、各年の環境特性が沈降物フラックスに反映していることが示唆される。

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第44巻第1号掲載欧文論文の和文要旨

Prasert Tongnunui*,・佐野光彦*・黒倉　壽*：タイ国の熱帯沿岸域に生息するモトギスとホシギスの成熟様式**

タイ国トラン県シカオ湾において、2003年5月から2004年4月までに採集した1,140個体のモトギスと、836個体のホシギスの標本を用いて、両種の成熟様式を明らかにした。生殖腺の組織学的観察から、最小成熟体長はモトギスの雌で117㎜（標準体長）、雄で106㎜、ホシギスの雌で113㎜、雄で109㎜であった。また、50％の個体が成熟する体長は、両種の雌雄でともに130㎜であった。産卵は周年にわたり行われており、その盛期はモトギスで8月から11月、ホシギスで7月から12月であった。両種において、卵巣内に空濾胞とともに、成熟段階の異なる卵母細胞が同時にみられた個体が存在したことから、両種は年に複数回産卵することが示唆された。

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Winda Mercedes Mingkid*,・横田賢史*・渡邊精一*：タカノケフサイソガニ *Hemigrapsus takanoi* (DECAPODA: BRACHYURA: GRAPSIDAE）の初期発生における塩分耐性**

タカノケフサイソガニの初期発生段階での塩分耐性を明らかにするために、ふ化したゾエアを塩分5～35‰の1.5L水槽にそれぞれ75個体収容して稚ガニ期までの生残数を調査した。稚ガニ期まで生存したのは25, 30, 35‰水槽のそれぞれ3, 2, 1個体で、10, 15, 20‰の水槽ではメガロパ期に全ての個体が死亡した。5‰の水槽では4個体が1回脱皮に成功した後全て死亡した。本種は低塩分濃度での幼生の生残率は低くなるものの、稚ガニまでの成長段階で広い塩分耐性を有することが示唆された。

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三品裕昭[1]. ベンジャミン ゴンザレス[2]、ホナリオ バグリャワン[2]、茂木正人[1]、河野　博[1]：パラワン島（フィリピン）におけるアカハタの繁殖生態

フィリピンのスールー海で漁獲され、パラワン島のプエルトプリンセサ市の市場に水揚げされたアカハタについて繁殖生態を調べた。採集は1995年から2000年にかけてで、計1119個体（全長105～330mm）の全長、体重、生殖腺重量を計測し、月ごとの生殖腺指数（GSI）を求めると同時に、生殖腺を組織学的に観察し雌雄および成熟度の判定を行った。その結果、雌は542個体（全長125～280mm）、雄は347個体（全長153～330mm）、雌雄同体個体は139個体（全長148～310mm）で、生物学的最小形は雌で全長138mm、雄で全長175mmであった。雌、雄および雌雄同体個体の全長の分布状況と、雌雄同体個体の生殖腺に卵巣薄板の構造が存在したことから、本種は他のハタ類と同様に雌性先熟であることが示唆された。139個体の雌雄同体個体のうち127個体が成熟した雄性細胞を持ち、雄として機能していた。性比は0.640、雌雄同体個体を雄と見なすと0.897であった。GSIは乾季と雨季の終わりにあたる５月と10月に低かったが、雌雄の生殖腺の発達状態から産卵は周年行われると考えられた。

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ゼリナ・イブラヒム*、柳　哲雄：マラッカ海峡水塊に対するアンダマン海と南シナ海の影響**

過去の水温・塩分・溶存酸素観測データを用いて、マラッカ海峡における水塊の季節変動に対するアンダマン海と南シナ海の影響を調べた。南西季節風時には低温・高塩分のアンダマン海下層水が海峡内に浸入するが、北東季節風時には高温・低塩分の河川系水と南シナ海水が海峡内に浸入する。このようなマラッカ海峡における水塊の季節変動は、季節風によるアンダマン海と南シナ海の水位差によって駆動される海峡内通過流の季節変動によって引き起こされる。

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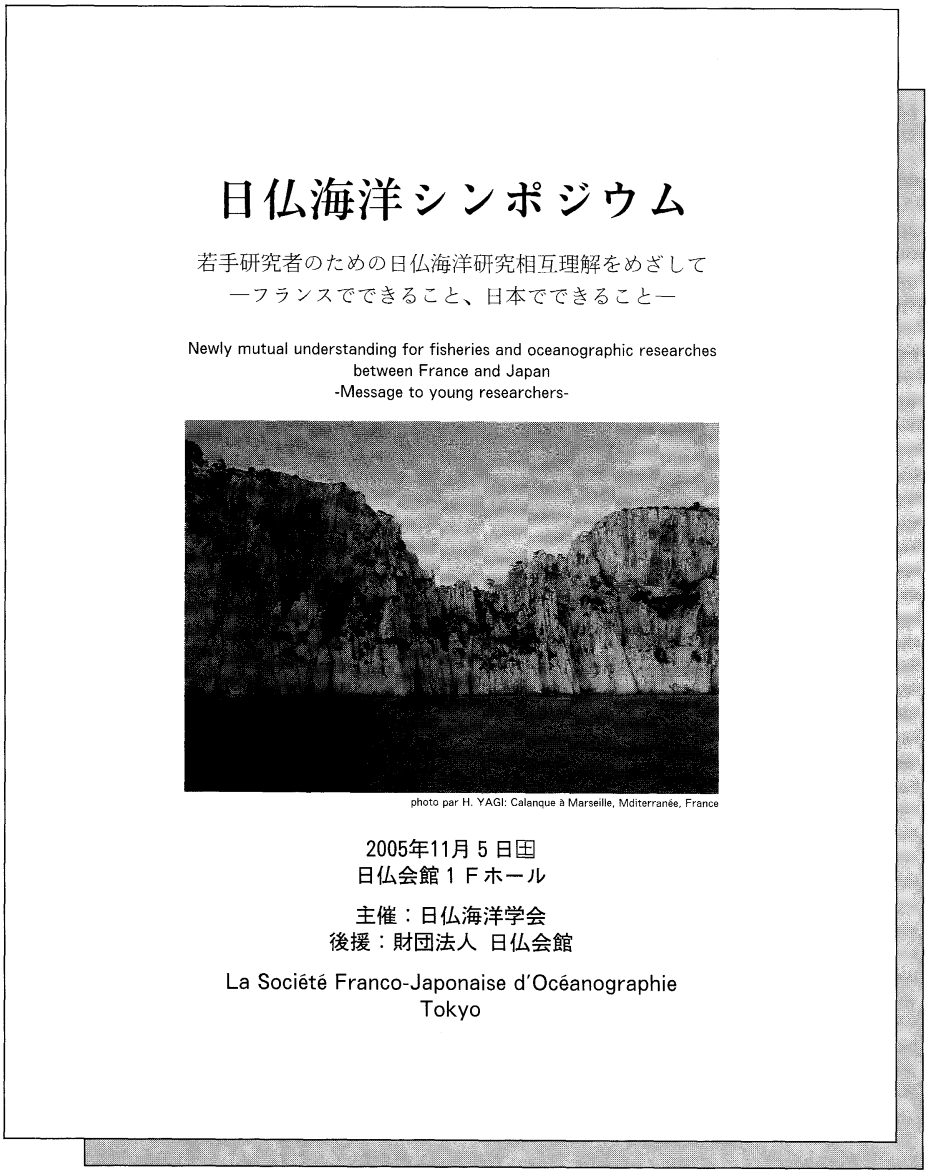
日仏共同研究事業計画
日仏海洋シンポジウム
「若手研究者のための日仏海洋研究相互理解をめざして
－フランスでできること，日本でできること－」

報告書



日仏海洋シンポジウム

若手研究者のための日仏海洋研究相互理解をめざして
―フランスでできること、日本でできること―

Newly mutual understanding for fisheries and oceanographic researches
between France and Japan
-Message to young researchers-

photo par H. YAGI: Calanque à Marseille, Mditerranée, France

2005年11月５日㊏
日仏会館１Ｆホール

主催：日仏海洋学会
後援：財団法人 日仏会館

La Société Franco-Japonaise d'Océanographie
Tokyo

日仏海洋学会
La Société Franco-Japonaise d'Océanographie
東京

下記のとおりシンポジウムを開催した。

1．主催：日仏海洋学会（東京）

2．目的と趣旨：

1960年代から続いてきた日仏海洋研究の協力関係が停滞している現在，新たに第四世代の研究交流を再構築し，日仏間の研究交流を再度促進するためミニシンポジウムを開催する。また，実際に日仏の間で活躍を希望する若手研究者の渡仏・来日のためのサポート体制を整備する。

3．開催日時と場所：

開催日時：2005年11月5日(土)9：30頃～16：30程度（具体的時刻は調整中）
開催場所：日仏会館ホール　（東京都渋谷区恵比寿3－9－25）
Tel (03)5424-1141　Fax(03)5424-1200

4．組織委員会：

(1)組織委員長：須藤英雄　東京海洋大学　名誉教授（日仏海洋学会会長）
(2)組織委員：①Hubert Jean CECCALDI エックス・マルセイユ大学名誉教授
　（仏日海洋学会（パリ））
②高井陸雄　東京海洋大学長
③徳山英夫　東京大学海洋研究所　教授
④田畑日出男　国土環境株式会社　代表取締役会長
⑤信田臣一　信田缶詰株式会社　代表取締役社長
⑥八木宏樹　日仏海洋学会　副会長　小樽商科大学教授
⑦森永　勤　日仏海洋学会　庶務幹事　東京海洋大学教授
⑧和泉　充　日仏海洋学会　東京海洋大学教授
⑨熊谷　純　（社）楽水会 常務理事（事務局長）
(3)組織委員会住所：東京都渋谷区恵比寿3－9－25　日仏会館内
(4)組織委員会連絡先：
東京都港区港南4－5－7　東京海洋大学海洋科学部海洋環境学科
環境測定学研究室　森永　勤　気付　Tel (03)5463-0462　Fax (03)5463-0467
E-mail：morinaga@s.kaiyodai.ac.jp

5．実行委員会：

(1)実行委員長：森永　勤　東京海洋大学　海洋科学部教授
(2)実行委員
①会計担当：＊小池　隆　荒川久幸　戸田勝善
②庶務担当：
【企画】＊森永　勤　八木宏樹　小池康之　井上敏彦　茂木正人
【研究】＊八木宏樹　吉田次郎　長島秀樹　松山優治　山口征矢　石丸　隆
　桜本和美　河野　博　土屋光太郎
【広報】＊吉田次郎　小池義夫　山崎秀勝　神田穣太　堀本奈穂
【記録】＊井上敏彦　（藤井英美）　北出裕二郎
【通訳】＊小池康之　八木宏樹

※実行委員会における役割分担の詳細

①会計担当：
日仏会館からの補助金の受け入れと管理（銀行口座の開設を含む）
必要経費の支出
アルバイトの雇用と賃金支出
収支報告書の作成

アペリティフ・パーティの企画立案

②庶務担当：

【企画】

招聘文書の作成
プログラム原案の作成
日仏会館との交渉（協力要請も含む）
アルバイトの役割分担と指示
会場準備（会場借り上げから当日の準備まで）
ミニシンポジウム当日の準備と雑務（会場設営，受付など）
配付資料の作成と印刷
アペリティフ・パーティの準備

【研究】

プログラム原案の作成
講演者の決定と交渉
講師招聘に係る雑務（宿泊，交通，食事，その他）
招聘文書の作成
ミニシンポジウムにおける総括の準備
報告書作成
La mer原稿の作成と投稿
成果公表（2006年度新規予算）

【広報】

ミニシンポジウムの広報（La mer，研究発表会，ＨＰ，日仏会館経由など）

【記録】

ミニシンポジウムの記録（音声，映像，DVD等）

【通訳】

招聘講演者の通訳
会議通訳
原稿の翻訳（外注の翻訳については予算計上済み）

6．招待講演者（候補者）：

Hubert J. CECCALDI博士(基調講演)
フランス高等研究院名誉教授，同名誉所長
フランス科学アカデミー

Bernard SALVAT 博士
フランス高等研究院名誉教授，同名誉所長

Jean Pierre FERAL博士
C.N.R.S.（フランス高等学術院）研究部長
C.N.R.S. 研究部門総括

徳山英一 博士
東京大学海洋研究所 教授
海洋底科学部門，海洋底地質学分野

小松輝久 博士
東京大学海洋研究所 助教授
海洋生命科学部門，行動生態研究分野

石黒直子 博士
岡山大学自然科学研究科　日本学術振興会特別研究員

7．プログラム

09：00	開場
09：30	午前の部開会

09：30-09：45	開会の言葉（日仏海洋学会会長）
09：45-10：45	基調講演　「海洋・水産分野における日仏交流の意義と今後の展望」（H.J. CECCALDI，フランス・エックス・マルセイユ第Ⅲ大学）
10：45-11：30	「海洋生態系における日仏共同研究の成果，サンゴ礁保全研究の立場から」（B. SALVAT，フランス・ペルピニョン大学）
11：30-12：15	「日仏研究交流，沿岸生態系の保全と修復を目指して」（小松輝久, 東京大学海洋研究所）
12：15-14：00	昼食
14：00	午後の部開会
14：00-14：45	「海洋底科学からの展望」（徳山英一，東京大学海洋研究所）
14：45-15：30	「海洋学分野における日仏交流，ケルゲレン諸島周辺海域の共同研究の展望」（J-P. FERAL，フランス・CNRS）
15：30-16：15	特別講演「フランス留学への道」（石黒直子，岡山大学）
16：15-16：30	閉会の言葉（日仏海洋学会副会長）
16：30-16：45	休憩
16：45-18：00	アペリティフ・パーティー（無料）

8．活動記録

2005年４月	招待講演予定候補者との交渉と日程調整
	日程決定
５月	プログラム原案（第１案）の作成
	予算原案の作成
	第１回実行委員会開催（５月20日の日仏海洋学会幹事会・評議員会の前）
	招聘状の発送（評議員会での承認後）
６月	日仏海洋学会総会で承認
	フランスにおいてフランス側招待者と内容について打ち合わせ（６月13，14日）
	第２回実行委員会の開催（６月16日）プログラム原案（第２案）の作成
	ミニシンポジウムの広報開始
７～９月	
	事前準備開始
	（会場予約，原稿作成，各種印刷，ホテル予約等の雑務）
	講演要旨・原稿〆切　９月30日
	案内状印刷・送付（出席者の把握）
10月	配付資料原稿作成（翻訳を含む）
	フランス側と最終確認（10月上旬）
	第３回実行委員会の開催（10月上旬）（進捗状況確認・役割分担確認）
	配付資料・原稿等について実行委員会で承認後　印刷
11月	日仏会館に実行委員会室設置　11月１日
	第４回実行委員会の開催　11月１日　（最終確認）
	東京海洋大学でのシンポジウム　11月４日（金）
	会場設営　11月４日（金）
	会場機器の確認　11月４日（金）
	ミニシンポジウム開催　11月５日（土）
12月	日仏会館への報告書の作成開始（翻訳原稿の依頼を含む）
	DVDの作成開始
	日仏海洋学会誌への投稿原稿作成開始
2006年１月	実行委員会の開催（報告書の内容検討）
２月	日仏海洋学会への投稿予約
３月	成果公表資料（DVDも含む）作成開始
	日仏会館への報告完成

9．講演内容

(1)ご挨拶と日仏海洋シンポジウム開催趣旨（日仏海洋学会会長・須藤英雄）

本日は日仏海洋シンポジウムにご参集くださいましてまことにありがとうございました。財団法人日仏会館ご後援のもとに本シンポジウムを開催できますことを誠に光栄に存じます。水産・海洋学分野における日仏協力は1960年代から続いてまいりましたが，最近はこの日仏海洋研究の協力関係がやや停滞ぎみだと思われます。現在，第三世代注）ともいえる世代が積極的な活動を行っておりますが，これからの日仏の協力関係を担う第四世代といえる若年層が日仏ともに育っておりません。この原因は日仏水産・海洋研究分野での情報交換不足や日仏間を取り持つ人材育成の遅れなどが挙げられると思います。　そこで，今回，水産・海洋研究における日仏間の協調の重要性や日仏協力の実現可能分野を明らかにして，日仏間の協力関係を再構築することを目的としたシンポジウムを開催することにいたしました。現状の日仏間において共同で解決すべき課題や，日本でできること，フランスでできることなどが明確になり，また，これから先，日仏の水産・海洋分野の若手研究者の中からひとりでも多く日仏共同研究に携わっていただくことを期待しております。

日仏海洋学会は，今後，若手研究者交流のために，日本から渡仏およびフランスから来日を希望する若手研究者のサポート体制を強化していきたいと考えております。

なお，本シンポジウム開催にあたり，日仏海洋学会の趣旨に快くご賛同いただき，遠くフランスから私たちのためにご来日していただきました，H.J.セカルディ先生，B.サルバ先生，J-P.フェラル先生に心よりお礼申し上げるとともに，日本側からは日仏共同研究を積極的に推進されておられる徳山英一教授，小松輝久助教授，石黒直子特別研究員の皆さまのご講演に対しまして深謝いたします。さらに，このシンポジウムを開催するにあたり，個人および団体から多大なご支援を頂きました。ここに厚くお礼申し上げます。

注）日仏間の水産・海洋研究において，次の世代に分類しました。

第一世代　フランス深海潜水艇バチスカーフなどを招聘して日仏間の研究交流を開始した1960年代の黎明期。

第二世代　日仏の水産・海洋研究責任者等が往来して日仏共同の基礎を築いた1970年代の発展期。

第三世代　第二世代の援助を受け若手研究者として日仏交換学生が互いに長期に滞在し，日仏共同研究を実働した70年代後半から80年代の充実期。KAIKO計画などもこの時期に行われました。この世代が現在日仏両国で研究の中心的な年齢層になっています。

第四世代　これからの日仏共同研究を担う若い世代です。

(2)基調講演（ユベール・ジャン・セカルディ）

「海洋・水産分野における日仏交流の意義と今後の展望」

海洋科学・技術は歴史的に根付いており、著しく進歩してきたが、それに続く科学的知識・技術の力強い変化過程および社会の急速な進展に関連している。研究という面では、異なる研究分野間で、複数の分野にまたがる研究チームから利益と効率を高めるような強い結びつきを確立することが必要である。また、国際的なチームで取り組むことで、新しい科学的知識を取り入れるだけでなく、文化の交流を豊かにするという大きな利益が得られる。特に、人類と自然との関係の将来を明確にするというフランス―日本の枠組みに当てはまる。

(3)講演（ベルナール・サルバ）

「海洋生態系における日仏共同研究の成果，サンゴ礁保全研究の立場から」

フランスのサンゴ礁は、7海外県・海外領土に存在する。すなわち、大西洋カリブ海西インドのマルティニークおよびグアドループ、インド洋のレユニオン島およびマイヨット、太平洋のニューカレドニア、ワリス＝エ＝フトゥナ、およびフランス領ポリネシアである。これらの地域は、住民の文化が異なるため、生物地理、動物相および植物相の豊富さ、サンゴ礁の構造、資源の利用および開発に関して異例な多様性がみられる。

150人を超えるフランスの研究者および経営者がサンゴ礁で仕事をしている。これらの人々は、フランスまたはその海外県・領土での、大学、多数の研究およびまたは開発機関、水産または環境の行政機関、非政府機関および民間分野のメンバーである。その地理的分布およびテーマからみた専門分野について概観する。その大部分は、「フランスサンゴ礁研究および持続性開発専念協会」(ACOR)のメンバーである。

1994年にフランスが創設メンバーとなり、1999―2000年にはフランスに事務局がおかれた「国際サンゴ礁イニシアティブ」(ICRI)後援のもとに、「フランスサンゴ礁イニシアティブ」(IFRECOR)が2000年に5か年計画で開始され、第2期が2010年まで続く。どの海外県・領土でも実施されているこのIFRECOR計画について述べる。

「南太平洋サンゴ礁イニシアティブ」(CRISP)は、南太平洋15か国のサンゴ礁保護および持続性のある開発をめざして2004年初めに開始された。フランス開発庁(AFD)後援のもとに、この計画は、地域生態保護戦略、海洋保護区、総合的な沿岸管理、情報および資源管理、劣化したサンゴ礁の回復、進行中の海洋の実体および地域的なデータベースを含む。多数の研究機関が、コンサベーション・インターナショナル、ペナンの世界水産センター、フィジーの南太平洋大学、国際サンゴ礁行動ネットワーク、国連基金などこの計画に協力している。CRISPは、太平洋コミュニティ(CPS)およびも南太平洋環境計画(SPOREP)のような地域研究機関と連携して実施されている。

フランスと日本のサンゴ礁研究者および経営者間の協力を発展させるために、現在および望ましい共同研究を一覧する。

(4)講演（小松輝久）

「日仏研究交流，沿岸生態系の保全と修復を目指して」

演者は，1991年7月から1992年12月までフランス政府給費留学生(Haut niveau)としてNice-Sophia Antipolis大学理学部沿岸海洋環境研究室において「地中海に侵入した熱帯性緑藻イチイヅタの生態」というテーマでPost-docの研究を行った。潜水による現場での観察とインキュベータによる培養を行い，夏季にはイチイヅタの匍匐枝の先端が1日で1cm以上生長すること，致死温度が10℃以下，31℃以上であり，潜在的には地中海西部のすべての沿岸で生育が可能であることを明らかにした。さらに，フランス滞在中に多くの研究者と交流する中で，将来の持続的な発展のためには沿岸生態系の修復と保全が重要な課題であることを認識できた。この経験をもとに，帰国後数次にわたって沿岸環境の保全と修復に関する日仏交流をシンポジウムや研究交流の面で進めてきた。また，フランス人の若手研究者の受け入れも積極的に行っており，日仏研究協力をさらに深めたいと考えている。

(5)講演（徳山英一）

「海洋底科学からの展望」

1984年度から2003年度まで4期にわたり実施された日仏”ＫＡＩＫＯ”計画（1984-1986，1987-1990，1993-1997，1999-2003）によって，日本列島周辺の海溝，特に南海トラフ東部の地形，地質構造，メタンハイドレート，テクトニクス，地震発生帯について，世界に類例がないほどに詳しく解かってきました。今回の講演では．研究成果の概要を報告致します。また，2007年1月～2月にかけて我が国の研究船白鳳丸が東地中海まで出向き，フランスを中心としたEUと共同で海洋調査を実施します。その内容も併せて報告いたします。

(6)講演（ジャン・ピエール・フェラル）

「南大洋における沿岸無脊椎動物の発生，群集構造および進化の様式」

南大洋で生活している無脊椎動物種の50～70%は、発生が保護されてきており、先験的にその分散が限られている可能性がある。多分野からの取り組みでこの前提は確認され、この海域を特徴づける大きな生物多様性を説明することができた。しかし、今のところ、幼生期をもつ種が支配的であるようである。仮説の確証には海洋学的な研究航海が必要である。

(7)特別講演（石黒直子）

「フランス留学への道・これからフランス留学を考えられている皆様へ」

フランス政府の給費留学生としては97-98年に渡仏させていただきました。多くの国の政府給費が分野毎に1名程度しか採用しないのに対し，フランスの政府給費は科学技術部門で数名の採用があるため，採用の可能性が高いと思います。科学技術系の研究者の場合，フランス語を履修することが少ないですが，政府給費留学のように専門分野で留学する場合には語学力よりも専門の研究が重要視されます。私自身も給費留学の試験を受けるときにはほとんどフランス語が喋れず語学試験をされている先生に困った顔をされるほどでした。しかし大使館の方に，フランス語でなくても英語でも受け入れ研究者の先生と研究交流が出来ることが重要と言われました。つまり，採用のためにはまず何よりも研究計画が重要となると思います。フランス語があまりできないことは気にせずに，自分のやりたい研究をしっかりアピールすることが大切だと思います。アピールの仕方としては，“どうしてフランスなのか？”“何が目的なのか？”を考えておくとよいと思います。そこに行かねば出来ないことがあると強いと思います（特に海洋学の分野ではフィールド観測が多いので，それも重要なアピールポイントです)。そして，その留学が実現したらばこんなことが得られますということを言えるといいと思います。あとは，採用に際して，フランス側の受け入れ研究者との連絡が取れていることも重要です。日本の指導者から紹介してもらうのもいいですし，もしそのような手段がなくても自

分で連絡を取ってみることも出来ます。私はそのようなつながりがなかったので，フランスの学術雑誌に掲載されている興味深い論文の著者に手紙を書いて連絡を取りました。そのような手紙はフランスの先生にとても喜んでもらえました。フランス政府の給費留学は，修士課程（フランスのDEA課程）で留学できることも魅力です。フランスのDEA課程は1年間で修了なので（語学のハンディもあるため）とても大変ですが，ドクターコース（3年間）でなく1年ほどの留学で多くのことを吸収することができます。

最後に，フランス大使館の方からも受験前に言われましたが，一度で諦めず，何度も受けてみるとよいと思います。Bonne chance!

La mer 44: 53, 2006
Société franco-japonaise d'océanographie, Tokyo

学会記事

1. 2006年1月30日平成18・19年度評議員選出
下記の通り

青木三郎　荒川久幸　有元貴文　有賀祐勝
石丸　隆　和泉　充　石戸谷博範　井上敏彦
市川　香　磯田　豊　今脇資郎　岩田静夫
内海真生　奥田邦明　神田穣太　岸野元彰
木谷浩三　北出裕二郎　河野　博　小池勲夫
小池康之　小林雅人　小松輝久　斎藤誠一
櫻本和美　須藤英雄　関根義彦　千手智晴
平　啓介　多田邦尚　高橋正征　田中祐志
谷口　旭　寺崎　誠　中田英昭　長島秀樹
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森永　勤　門谷　茂　柳　哲雄　八木宏樹
山口征矢　山崎秀勝　吉田次郎　和田　明
渡邊精一

2. 2006年2月20日　会長選挙結果　須藤英雄前会長が引き続再選

3. 新入会員

氏　名	所　属	紹介者
ウイヨノ　エコ　スリ（Wiyon eko sri）	東京海洋大学大学院 海洋科学技術研究科 〒108-8477 東京都港区港南4-5-7	吉田次郎

日仏海洋学会誌「うみ」投稿規定

1. 「うみ」（欧文誌名 La mer）は日仏海洋学会の機関誌として，和文または欧文により，海洋学および水産学ならびにそれらの関連分野の研究成果を発表する学術雑誌であり，同時に研究者間の情報交換の役割をもつことを目的としている。
2. 「うみ」は，原則として年4回発行され，投稿（依頼原稿を含む）による原著論文，原著短報，総説，学術資料，書評その他を，編集委員会の審査により掲載する。これらの著作権は日仏海洋学会に帰属する。
3. 投稿は日仏海洋学会会員，および日仏海洋学会正会員に準ずる非会員からとする。共著者に会員を含む場合は会員からの投稿とみなす。
4. 用語は日，仏，英3カ国語のいずれかとする。ただし，表および図の説明の用語は仏文または英文に限る。原著論文には約200語の英文または仏文の要旨を別紙として必ず添える。なお，欧文論文には約500字の和文要旨も添える。ただし，日本語圏外からの投稿の和文要旨については編集委員会の責任とする。
5. 原稿はすべてワードプロセッサを用いて作成し，本文・原図とも2通（正，副各1通）ずつとする。副本は複写でよい。本文原稿はすべてA4判とし，白紙にダブル・スペース（和文ワープロでは相当間隔）で記入する。表原稿および図の説明原稿は本文原稿とは別紙とする。
6. 投稿原稿の体裁形式は「うみ」最近号掲載論文のそれに従う。著者名は略記しない。記号略号の表記は編集委員会の基準に従う。引用文献の表示形式は，雑誌論文，単行本分載論文（単行本の一部引用も含む），単行本などの別による基準に従う。
7. 原図は版下用として鮮明で，縮尺（版幅または1/2版幅）に耐えられるものとする。
8. 初稿に限り著者の校正を受ける。
9. すべての投稿原稿について，1編あたり5万円の論文掲載料を申し受けます。
10. 会員に対しては10印刷ページまでの掲載を無料とする。会員の投稿で上記限度を超える分および非会員投稿（依頼原稿を除く）の印刷実費はすべて著者負担（1万円/ページ）とする。ただし，カラー印刷を含む場合には，別に所定の費用（1ページあたり9万円）を著者（会員，非会員とも）負担とする。
11. すべての投稿原稿について，1編あたり別刷り50部を無料で請求できる。50部を超える分は請求により50部単位で有料で作製される。別刷り請求用紙は初稿校正と同時に送付される。
12. 原稿の送り先は下記の通りとする。なお著者（共著の場合は代表者）連絡先のe-mailアドレス並びにFAX番号を付けることとする。

〒108-8477 東京都港区港南4-5-7
東京海洋大学海洋科学部海洋環境学科（吉田　次郎気付）
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執筆要領

1. 原稿

⑴ 和文原稿の場合：ワードプロセッサを使用し，A4版の用紙におよそ横30字，縦25行を目安に作成すること。

⑵ 欧文原稿の場合：ワードプロセッサを使用し，A4版の用紙にダブルスペース25行でタイプし，十分な英文添削または仏文添削を経て提出すること。

⑶ 和文原稿，欧文原稿いずれの場合も，要旨，表原稿および図版説明原稿はそれぞれ本文原稿とは別紙とする。

⑷ 最終原稿提出の際に，印刷原稿とともに原稿，表，図版が保存されたフロッピーディスク，CD-R/RW，MO等での提出を依頼する。この場合，原稿はMicrosoft WORD，Just System 一太郎，PDFの原稿のみに限る。また，表，図版はこれら原稿ファイルの中に取り込むか，bmp，jpg等の一般的な画像ファイルに保存したものに限る。なお，電子媒体は返却しない。

2. 原稿記載の順序

(1) 原著（和文原稿）：原稿の第1ページ目に表題，著者名，研究の行われた所属機関，所在地，郵便番号を和文と英文で記載する。研究終了後所属機関が変わった場合は現所属機関も記載する。連絡先（共著の場合は連絡先とする著者を明示する）の住所，電話番号，ファックス番号，E-mailアドレスも記す。最後にキーワード（4語以内），ランニングヘッドを英文で記載すること。第2ページ目に欧文要旨（欧文表題，著者名を含む）を200語以内で記す。本文は第3ページ目から，「緒言」「資料」「結果」「考察」「謝辞」「文献」「図版の説明」などの章立てあるいは項目で順に記載する。基本的には最近号掲載論文の体裁形式を参考にして投稿原稿を作成すること。原稿には通しのページ番号を記入すること。

(2) 原著（欧文原稿）：原稿の第1ページ目に表題，著者名，研究の行われた所属機関，所在地，郵便番号を記載する。研究終了後所属機関が変わった場合は現所属機関も記載する。最後にキーワード（4語以内），ランニングヘッドを記載すること。第2ページ目に欧文要旨（欧文表題，著者名を含む）を200語以内で記す。本文は第3ページ目からとする。「Introduction」「Data」「Results」「Discussion」「Acknowledgement」「References」「Figure Caption」などの章立てで順に記載する。基本的には投稿原稿の体裁形式は最近号掲載論文を参考にして作成すること。最終ページに和文の表題，著者名，連絡先著者住所，電話番号，ファックス番号，E-mailアドレスおよび約500字以内の和文要旨を添える。原稿には通しのページ番号を記入すること。

(3) 原著短報，総説：和文ならびに欧文原稿とも原著論文に準ずる。

(4) 学術資料，書評：特に記載に関する規定はないが，すでに掲載されたものを参考にすること。

3. 活字の指定

原稿での活字は10.5pt～12ptを目安に設定し，英数字は半角フォントを用いること。学名はイタリック，和文原稿での動植物名はカタカナとすること。句読点は（。）および（，）とするが，文献リストでは（.）および（,）を用いること。章節の題目，謝辞，文献などの項目はボールドまたはゴシックとする。

4. 文献

文献は本文および図表に引用されたもののすべてを記載しなければならない。和文論文，欧文論文共に筆頭著者のアルファベット順（同一著者については，単著，共著の順とし，それぞれ発表年の古い順）にまとめ，以下の例に従って記載する。

(1) 論文の場合

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

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

(2) 単行本分載論文（単行本の一部引用の場合）

村野正昭（1974）：あみ類と近底層プランクトン.海洋学講座10　海洋プランクトン（丸茂隆三編），東京大学出版会，東京，p.111–128.

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

(3) 単行本の場合

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

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

(4) 本文中での文献の引用

本文中での文献の引用方法はすでに発行された雑誌を参考にするが，基本的には次の形式に従う。

①GREVE and PARSONS(1977)

②（AVIAN and SANDRIN, 1988),

③YANAGI *et al.*（1997）は……（3名以上の共著の場合）

④……示されている（例えば，YANAGI *et al.*, 1997)（3名以上の共著の場合）

5. 図，表および写真

(1) 図，表および写真とその説明はすべて英文または仏文を用いる。

(2) 図，表はそのまま写真製版用の草稿となるような明瞭なもので，A4版の上質紙に作製したもの（写真は，正原稿についてもオリジナルとは別にA4版の用紙にコピーしておくことが望ましい）のみを受け付ける。カラー図を希望する場合はその旨明記する。この場合，別に所定の費用を著者負担とする。

(3) 写真は光沢平滑印画紙に鮮明に焼き付けたものを受け付ける。カラー写真の印刷を希望する場合はその旨明記する。この場合，別に所定の費用を著者負担とする。

(4) 図，表および写真は刷り上がり時に最大横が14cm，縦が20cm（説明文を含む）以内であることを考慮して作製すること。

(5) 図（写真を含む）には，Fig. 1, Fig. 2, ……のように通し番号をつけ，一つの図中に複数の図を含む場合はFig. 3 (a), Fig. 3 (b), ……のように指定する。本文中での引用は和文原稿の場合も「Fig. 1にみられるように……」のようにすること。

(6) 表には，表題の次（表の上のスペース）に説明をつけ，表ごとに別紙とし，Table 1, Table 2,.....のように通し番号をつけること。

(7) 図，表および写真は1枚ごとに著者名，通し番号をつけること。また，本文中での挿入箇所を最終提出原稿の該当箇所右欄外に朱書きすること。

(8) 図，写真の説明は別紙にまとめること。

(9) 地図にはかならず方位と縮尺または緯度，経度を入れること。

6. 単位系

原則としてSI単位を用いること。塩分は実用塩分単位（Practical Salinity Unit： psuまたは PSU）を用いる場合は単位なしとする。

Information for Contributors

1. The scientific journal,"La mer," the official organ of Japanese-French Oceanographic Society (JFOS), is published quarterly. "La mer" is open to all researchers in oceanography, fisheries and related sciences in the world. The journal is devoted to the publication of original articles, short contributions, reviews, book reviews, and information in oceanography, fisheries and related fields. Submission of a manuscript will imply that it has not been published or accepted for publication elsewhere. The editorial board decides the acceptance of the manuscript on the basis of peer-reviews and is responsible for its final editing. The Society reserves the copyright of all articles in the Journal.
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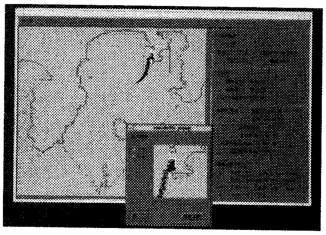

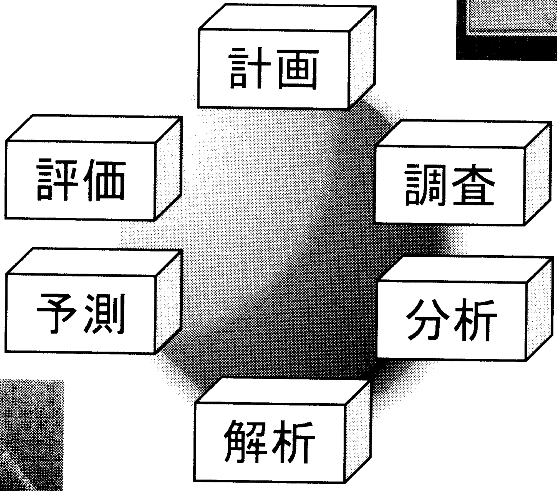
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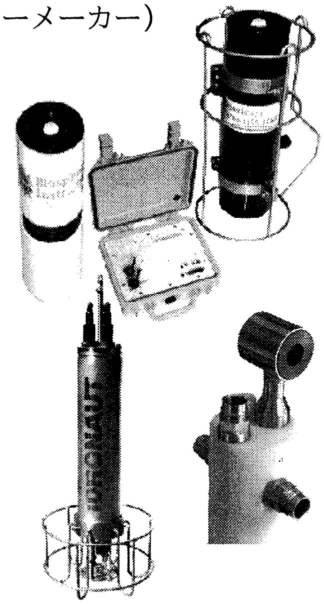
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