ISSN 0038-1578

Vol. 31 No. 3 20 September 1983.

The Japanese Journal of PHYCOLOGY

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Jap. J. Phycol. (Sôrui) 31 : 129-147. September 20, 1983

Phytoplankton biomass and photosynthesis in relation to the environmental conditions in Tokyo Bay[1)]

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BRANDINI, F. P. and ARUGA, Y. 1983. Phytoplankton biomass and photosynthesis in relation to the environmental conditions in Tokyo Bay. Jap. J. Phycol. 31 : 129-147.

Phytoplankton biomass and photosynthesis were investigated in relation to physico-chemical environmental conditions in Tokyo Bay from May 1979 through March 1981. Vertical and seasonal variations of chlorophyll *a*, photosynthetic and respiratory activity, and environmental conditions were investigated mainly at Stns. A and T-4 in the inner part of the bay. Seasonal measurements were carried out from the inner part of the bay to Uraga Strait. At Stn. A, phytoplankton cell number varied from 5.3×10^3 to 8.2×10^4/m*l*; high in May, August and February but low in June and July. *Skeletonema costatum* and *Prorocentrum* spp. dominated during most of the period. Surface chlorophyll *a* ranged from 2.7 to 175 mg/m^3 with the maximum in September 1980 and lower values in October to January. Light-saturated gross photosynthesis showed a maximum of 2.98 mgO_2/*l*/hr in September 1980 and a minimum of 0.08 mgO_2/*l*/hr in January 1981 in surface samples. It was high in surface samples and low in deeper samples. On a chlorophyll *a* basis, light-saturated gross photosynthesis of surface samples was low during winter and high during summer in the range of 9.5–80 mgO_2/mgChl.*a*/hr. Although chlorophyll *a* concentration and photosynthetic rates were low during the low temperature period and high during the high temperature period, their relationships to temperature were not clear. Chlorophyll *a* concentrations were generally high when salinity was low, but no definite relationship was observed between photosynthesis and salinity. No clear relationship was observed between chlorophyll *a* and nutrient concentrations.

Key Index Words: *biomass*; *chlorophyll* a; *environmental conditons*; *nutrients*; *photosynthesis*; *phytoplankton*; *respiration*; *Secchi disc depth*; *Tokyo Bay*.

Since the initial work of HOGETSU *et al.* (1959) in the estuarine region off Haneda, many studies about phytoplankton productivity in Tokyo Bay have been published in the two decades. Observations on the seasonal changes of photosynthesis rate and biomass were made by ICHIMURA and KOBAYASHI (1964) and ICHIMURA and ARUGA (1964). ICHIMURA (1967) observed the horizontal distributions of primary production in relation to environmental gradients in the bay. MARUMO and MURANO (1973), MARUMO *et al.* (1974) and MARUMO (1975) studied succession of diatoms and FUNAKOSHI *et al.* (1974), TSUJI *et al.* (1974), YAMAGUCHI and ICHIMURA (1976), ARUGA and SHIBATA (1978) and SHIBATA and ARUGA (1982) studied red tide formation and primary production in the bay. Recently, YAMAGUCHI and SHIBATA (1979) published a review of the primary productivity studies after 1970 by different

1) This study was supported by a Grant-in-Aid for Scientific Research No. 403073 from the Ministry of Education, Science and Culture, Japan.

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authors with the purpose of understanding the present status of the phytoplankton production in Tokyo Bay. They pointed out that owing to the eutrophication throughout the whole bay as the consequence of great amounts of organic and inorganic substances carried into the bay with urban and industrial effluents from the surrounding areas, the seasonal variation of phytoplankton production has gradually been more difficult to be distinguished.

Although there are some papers dealing with the physiological responses of phytoplankton photosynthesis to salinity (NAKANISHI and MONSI 1965), nutrients (NAKANISHI and MONSI 1965, ICHIMURA 1967, FUNAKOSHI *et al.* 1974), light (ICHIMURA and ARUGA 1964, ICHIMURA 1967, SHIBATA and ARUGA 1982) and temperature (SHIBATA and ARUGA 1982), clear relationships between primary productivity and such environmental factors in Tokyo Bay still remain to be understood.

The objective of the present work is to measure the phytoplankton biomass and photosynthesis at fixed stations in Tokyo Bay and to clarify their relationships to environmental factors for characterizing the coastal phytoplankton.

Material and Methods

A total of 19 cruises were made in Tokyo Bay and Uraga Strait from May 1979 through March 1981 by the T/S Seiyo Maru of the Tokyo University of Fisheries. Seven fixed stations were set up as shown in Fig. 1. Vertical water samples were obtained from various depth at Stn. A on the estuarine region off Haneda and at Stn. T-4 with plastic Van Dorn type bottles, and surface water samples were taken with a plastic bucket at 10 or 15 min. intervals from the inner part of Tokyo Bay through Uraga Strait along the cruise track to the entrance of Tateyama Bay for monthly measurements of photosynthesis, respiration, chlorophyll *a*, salinity, temperature and nutrient concentrations.

Annual changes of solar radiation were

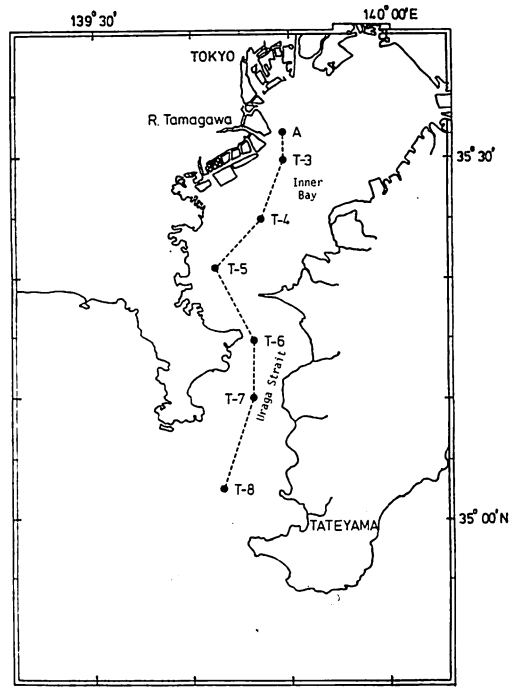


Fig. 1. Map of Tokyo Bay showing the location of stations and the cruise track.

obtained from the JAPAN METEOROLOGICAL AGENCY (1979–1981). Transparency of water was estimated by the Secchi disc. Temperature was measured with a standard type thermometer and salinity with an Autolab Portable T-S Meter on board the ship for water samples collected. For chlorophyll *a* determinations, the water samples were filtered through Whatman GF/C glass fiber filters and the pigments were extracted with 90% acetone. Extinction values of the extract were read at wavelengths of 750, 663, 645 and 630 nm with a Hitachi 101 or 100 spectrophotometer and chlorophyll concentrations were calculated by the equations of SCOR-UNESCO W.G. 17 (1966). Filtrate samples of about 500 m*l* each were placed into polyethylene bottles and kept frozen for later analyses of nutrients. Silicate, phosphate, nitrate and nitrite were determined following the techniques described by STRICKLAND and PARSONS (1972). Ammonium was estimated according to LIDDICOAT *et al.* (1975) with some modifications con-

cerning the light condition for color development; samples were exposed to fluorescent light (Toshiba FL 20S, W-DL-X/NL) of approximately 5 klux for 6 hr at room temperature.

Photosynthesis and respiration rates were measured by the light and dark bottle oxygen method. Transparent and dark bottles were filled with water samples of approximately 100 m*l* and placed in a fluorescent light incubator at about 25 klux or under natural sunlight on the ship deck at *in situ* water temperature. Photosynthesis-light curves of surface samples from Stn. A were obtained whenever possible using neutral filters consisting of transparent plastic tubes rolled up with vinyl chloride sheets to give different percentages of light. Initial and final oxygen concentrations were determined always in duplicate by means of the Winkler titrations.

Phytoplankton species composition was examined under a microscope in the laboratory after 1 *l* samples were fixed with 8-10 m*l* of glyceraldehyde.

Results and Discussions

1. *Physical and Chemical Properties*

Vertical profiles of temperature, salinity and transparency observed at Stns. A and T-4 are shown in Fig. 2. Surface temperature ranged from 8.1 to 26.3°C at Stn. A and from 8.8 to 24.9°C at Stn. T-4, with the highest value in August and the lowest in February (cf. Fig. 10(A)). Only very slight differences were found of surface temperature and its seasonal changes be-

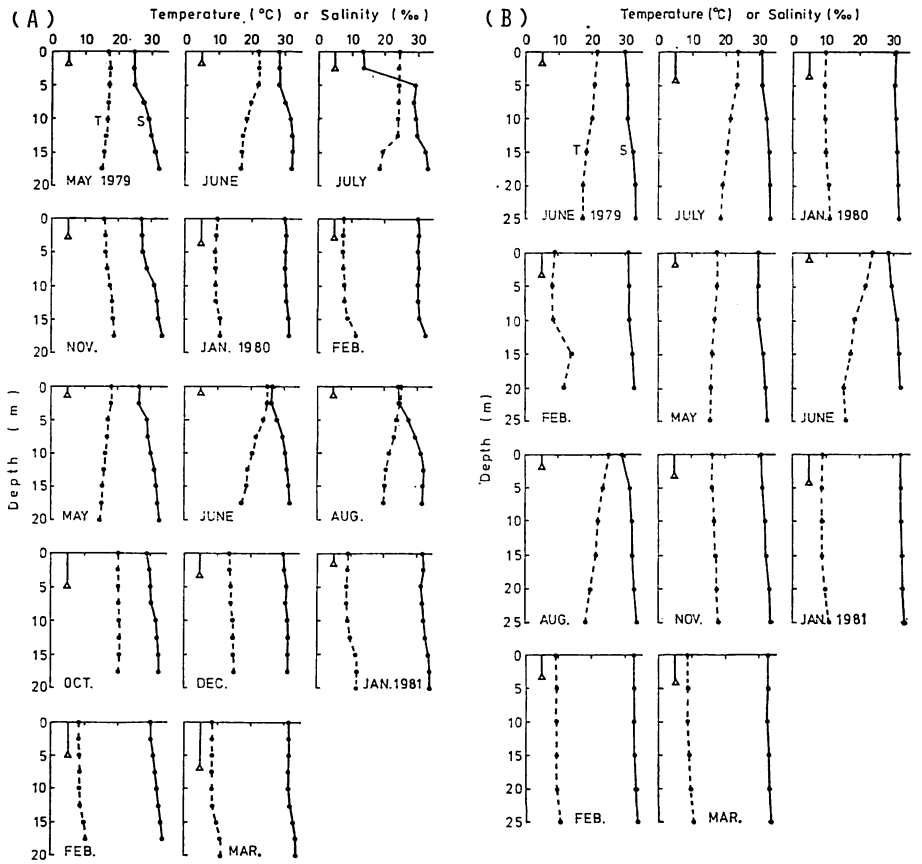


Fig. 2. Vertical profiles of temperature (dotted lines) and salinity (solid lines), and the Secchi disc depth (open triangles) at Stns. A (A) and T-4 (B) in Tokyo Bay.

tween the two stations. A not well-defined thermal stratification could be seen from May to August, breaking down during winter when vertical mixing takes place. Temperature at both the surface and the bottom was lower in the innermost part of Tokyo Bay than in Uraga Strait during winter and higher during summer. The same situation was observed by the MINISTRY OF TRANSPORTATION (1979).

Salinity of the surface water at Stn. A is influenced to a great extent by the freshwater discharged from River Tamagawa. It ranged from 13.4 to 30.8‰. Usually, less saline water was found in the upper layer and a more saline watermass of oceanic origin was always present near the bottom. During the autumn-winter period the oceanic influence seems to be stronger and salinity higher than 30‰ was measured even in more superficial layers.

The transparency at Stn. A was higher during the autumn-winter period than during the spring-summer period, varying from 1 to 5 m. It ranged from 1.5 to 6.5 m at Stn. T-4.

Fig. 3 shows seasonal variations of nutrient concentrations in the surface water at Stn. A. Total inorganic nitrogen concentration ranged from 9.9 to 73.8 μg-at./l and silicate concentration from 0 to 72 μg-at./l. Phosphate was present always in lower concentrations than inorganic nitrogen and silicate, ranging from 0.12 to 1.9 μg-at./l. Comparatively low concentrations of nutrients were found at the end of August 1979 and in June 1980 probably due to consumption by the phytoplankton population which was very large during those periods.

The vertical distribution of ammonium and nitrate was not uniform, showing a not well-defined seasonal trend (Fig. 4(A)). Nitrite and phosphate were present in small amounts and almost uniformly distributed in the water column. Silicate was always present in high concentrations in the whole water column especially in 1979 (Fig. 4(B)) with the exception of August when the diatom population was very large. In February 1980 the silicate concentration decreased to not detectable values. The seasonal trend of silicate distribution was also not defined and the vertical distribution was not uniform.

Horizontal distributions of total inorganic nitrogen, phosphate and silicate in different periods of 1980 are indicated in Fig. 5. In general, very high concentrations were observed in the inner part of the bay and the concentrations decreased in Uraga Strait toward the mouth of Tateyama Bay. A similar pattern of nutrient distribution was

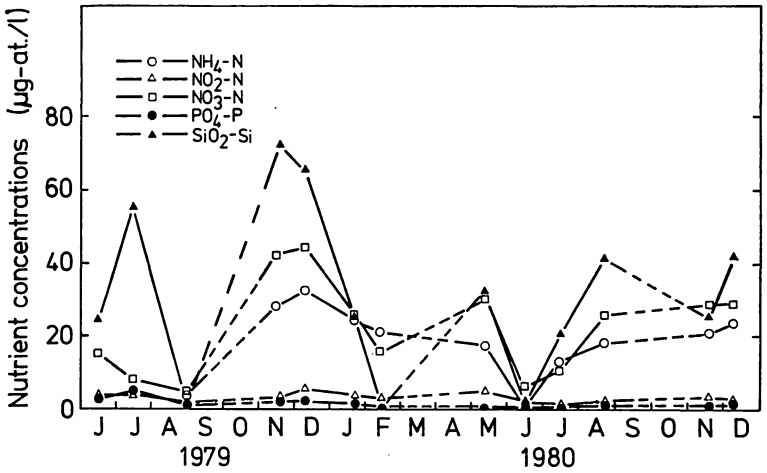


Fig. 3. Seasonal variations of nutrient concentrations in the surface water at Stn. A in Tokyo Bay.

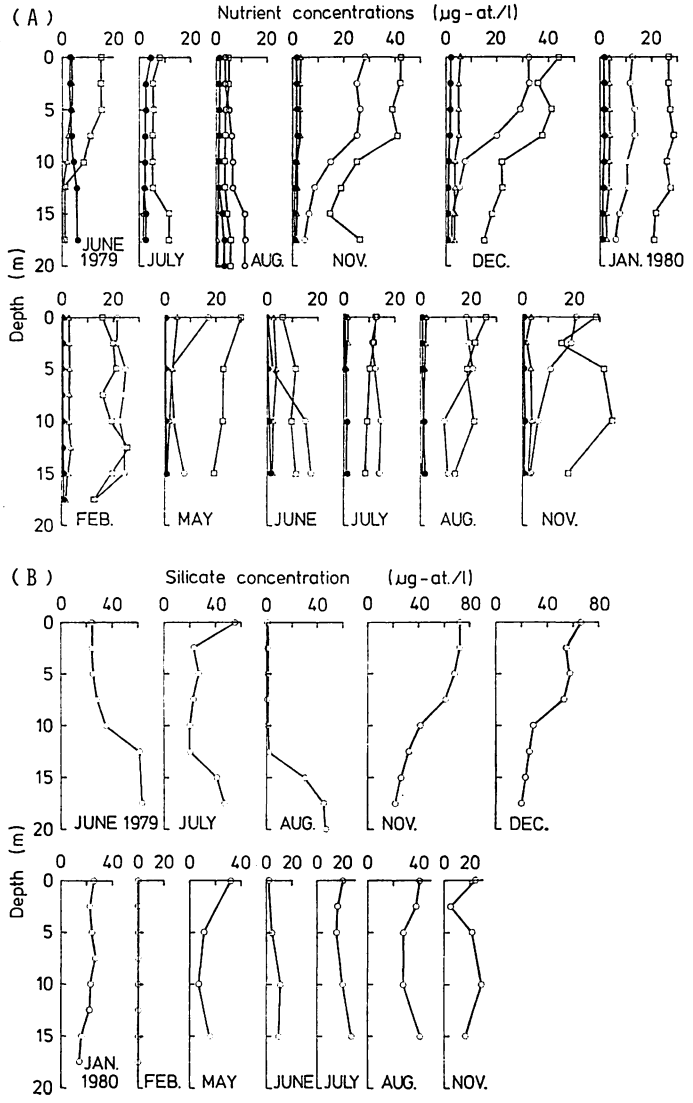


Fig. 4. Vertical profiles of ammonium (○), nitrite (△), nitrate (□) and phosphate (●) concentrations (A) and of silicate concentration (B) at Stn. A in Tokyo Bay.

observed by ICHIMURA (1967) and FUNAKOSHI (1973) in the surface water of Tokyo Bay.

2. Seasonal Variations of Phytoplankton Biomass

Seasonal variations of the cell number of phytoplankton in the surface water at Stn. A are indicated in Fig. 6. The cell number varied irregularly throughout the sampling period, ranging from 5.3×10^3 to 8.2×10^4/m*l*. It was high in May, August and February, but low in June and January. From May 1979 until February 1980, 39 species of diatoms and 24 species of dinoflagellates were observed, but only the frequent groups are indicated in Table 1. Some Chlorophycean, Euglenophycean and Crysophycean algae were also present but in small number. Except in May and July, diatoms dominated over dinoflagellates and the most frequent species was *Skeletonema costatum*, occurring abundantly in different periods of the year; e. g. 4.97×10^4/m*l* in August and 4.95×10^4/m*l*

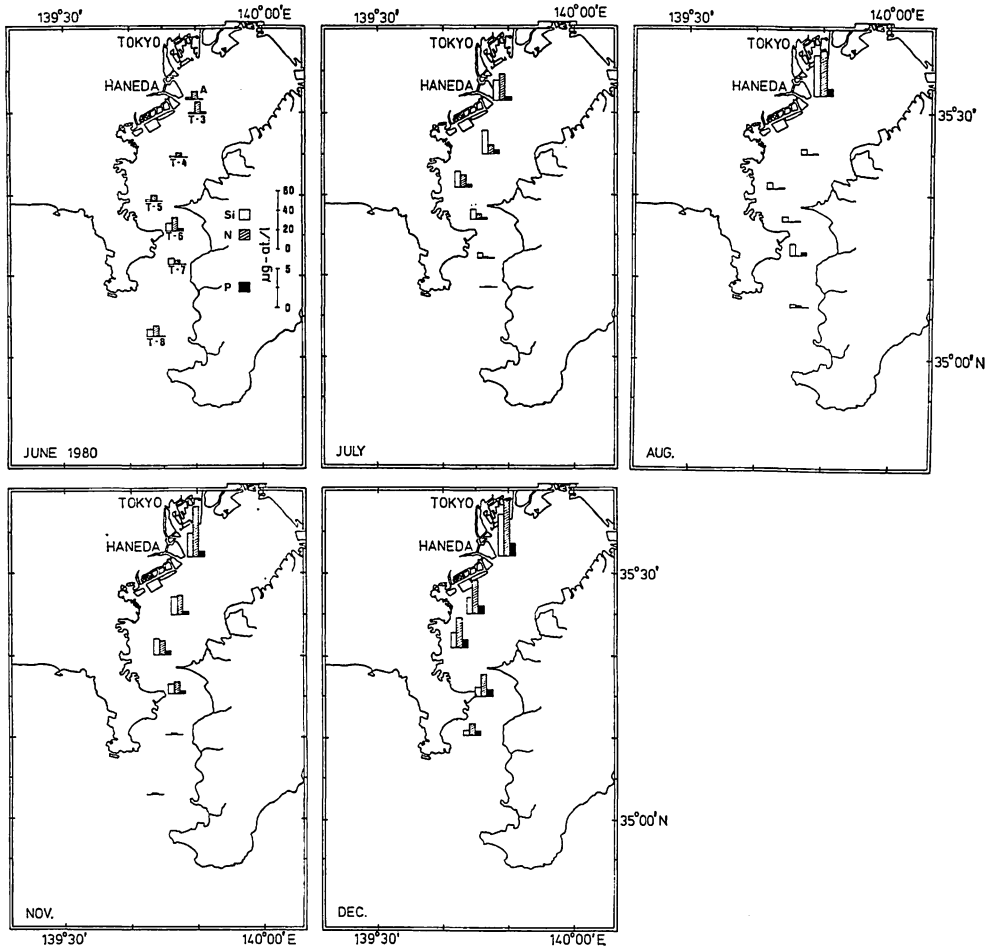


Fig. 5. Horizontal distributions of total inorganic nitrogen, phosphate and silicate in the surface water of Tokyo Bay (June—December 1980).

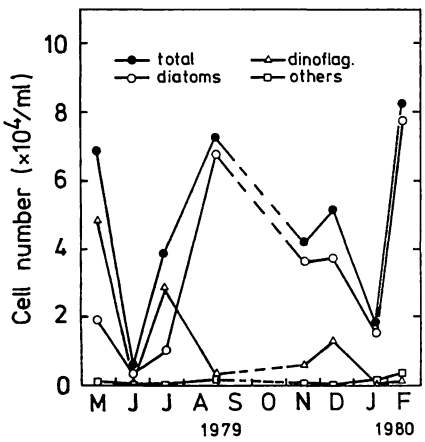


Fig. 6. Seasonal variations of the phytoplankton cell number in the surface water at Stn. A in Tokyo Bay.

in February. These values are very similar to $5\times10^3-10^4$/m*l* reported by MARUMO *et al.* (1974) for maximal growth period in June and August of 1972. In November 1979 the dominance was replaced by *Chaetoceros curvisetum*. Both *S. costatum* and *C. curvisetum* dominated the diatom population in January, but in February *S. costatum* again became the most frequent species followed by *Thalas siosira decipiens* and *T. anguste-lineata*. Among the dinoflagellates, *Prorocentrum minimum* was the dominant in May being replaced by *Prorocentrum triestinum* from July until January. In February *Peridinium* spp. were the most abundant.

The chlorophyll *a* concentration in the surface water of Stn. A (cf. Fig. 10(A)) was

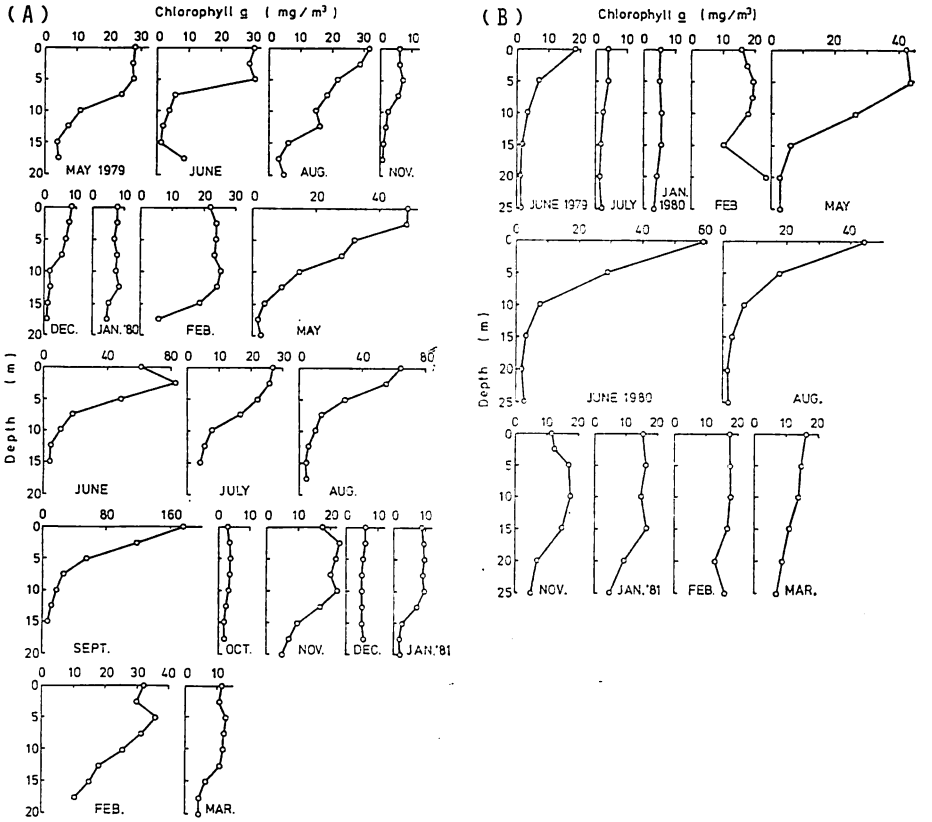


Fig. 7. Vertical profiles of chlorophyll *a* concentration at Stns. A (A) and T-4 (B) in Tokyo Bay.

high during summer except in July and low from October through January, ranging from 2.72 to 175 mg/m³ throughout the year. The maximum value of 175 mg/m³ was obtained in September 1980.

The vertical profiles of chlorophyll *a* at Stns. A and T-4 are illustrated in Fig. 7. It was high at the surface during the warm seasons with decrease toward the bottom, while during the vertical circulation periods of winter it was comparatively low and uniformly distributed in the water column. Subsurface peaks were observed in June 1979 and 1980. A careful comparison of Fig. 7 with Fig. 2 indicated that the surface layer with high chlorophyll *a* concentrations became thicker from May to September as the thermocline became deeper. This trend seems to be closely related to the vertical mixing of water between the surface and the deeper layers.

In the same area in Tokyo Bay, ICHIMURA and KOBAYASHI (1964) obtained chlorophyll *a* concentrations of 10-200 mg/m³ and ICHIMURA (1967) found concentrations higher than 100 mg/m³ during summer 1963. Similar concentrations of chlorophyll *a* were obtained 10 years later by YAMAGUCHI and ICHIMURA (1976), and a maximum of 104.7 mg/m³ was reported in summer of 1978 by SHIBATA and ARUGA (1982). The range of chlorophyll *a* concentration observed during the present work was similar to those reported by these authors.

The horizontal distributions of chlorophyll *a* in the surface water from the inner bay through Uraga Strait are shown in Fig. 8. In general, independent of the seasons, higher concentrations of chlorophyll *a* were found in the inner bay, decreasing rapidly

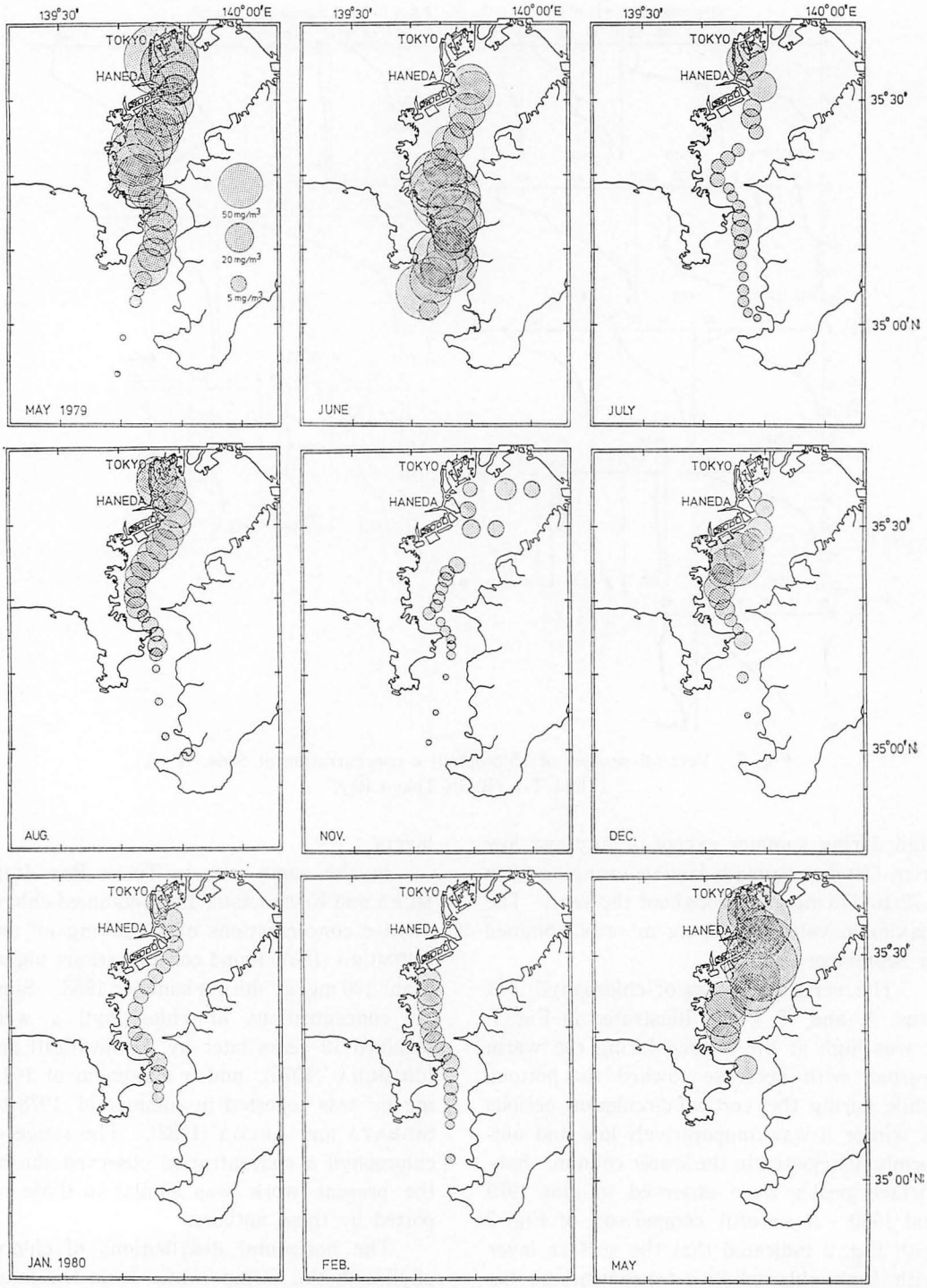
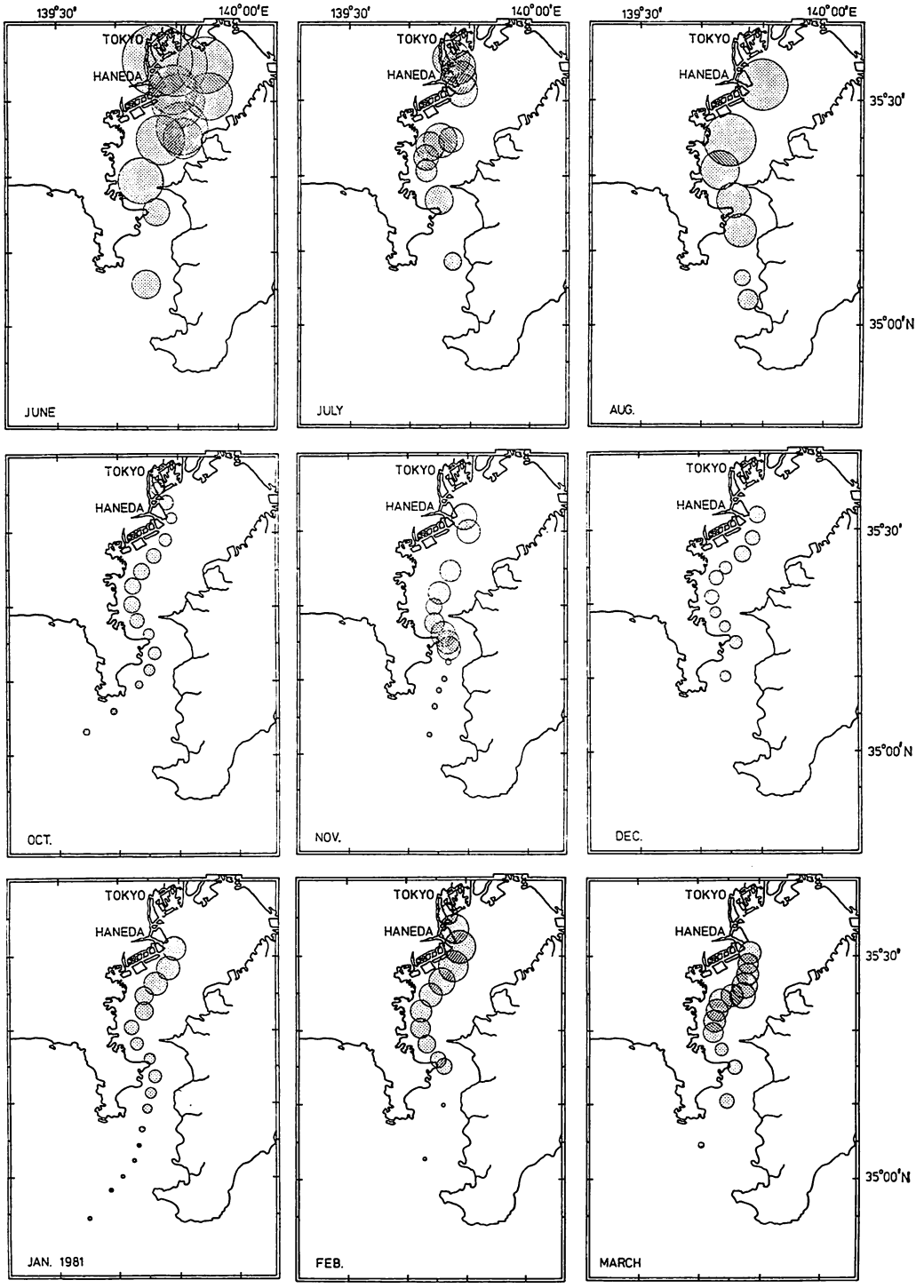


Fig. 8. Horizontal distributions of chlorophyll *a* concentration in the surface water of Tokyo Bay (May 1979—March 1981).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MARCH

Table 1. Abundance of phytoplankton species in the surface water at Stn. A from May 1979 to February 1980 ($\times 10^3$ cells/ml).

Species	1979 May	June	July	Aug.	Nov.	Dec.	1980 Jan.	Feb.
Chaetoceros curvisetum				3.6	**29.5**	r	5.4	
C. decipiens				1.9				
C. didymus				0.5				1.3
C. spp.							0.9	0.5
Coscinodiscus spp.				0.6	r	r	0.1	
Cyclotella sp.		0.6						
Ditylum brightwelii				0.2			0.4	0.3
Eucampia zoodiacus			1.8		0.1		0.35	1.6
Nitzschia closterium				1.1				0.2
N. seriata	0.75			6.1		0.4	0.3	
N. sp.	0.13							1.5
Rhizosolenia fragilissima							0.3	0.3
Skeletonema costatum	**17.5**	1.8	7.6	**49.7**	4.4	**35.5**	5.3	**49.5**
Thalassiosira anguste-lineata					r			6.5
T. binata				1.8				
T. decipiens				0.2	1.3		0.9	**10.8**
T. rotula					r	r		2.4
T. spp.	1.0	1.15		1.0		1.2		1.9
Dinophysis sp.		0.1		0.3				
Gymnodinium sp.	0.6	0.05						0.4
Peridinium minusculum	0.13		0.1	0.1				0.2
P. spp.	0.13	0.15	2.3	0.2	r	0.1		1.8
Phalacroma sp.	0.25	0.15						0.1
Prorocentrum micans	0.25	0.45						
P. minimum	**46.7**	0.25			0.7	0.5	0.1	0.5
P. triestinum			**26.4**	2.0	5.1	**12.9**	0.7	0.1
Dictyocha fibula				0.1			0.2	
Distephanus speculum							1.3	3.5
Euglena sp.	0.25			1.9				
Eutreptiella sp.	0.6	0.45	0.1					

r: rare

from Uraga Strait toward the open sea. The geographical as well as seasonal patterns of distribution of the phytoplankton biomass were not so clear. Although very high and variable concentrations of chlorophyll *a* were observed during the warm seasons and comparatively low and uniform concentrations in the cold periods of the year, high concentrations of chlorophyll *a* could be observed sometimes in winter and low concentrations in summer.

SHIBATA and ARUGA (1982) also found a great variability in the surface chlorophyll *a* concentrations over the whole area of the bay and YAMAGUCHI and SHIBATA (1979) recognized no definite pattern of horizontal chlorophyll *a* distribution in the bay. YAMAGUCHI and ICHIMURA (1976) reported that the chlorophyll *a* concentrations were 10 to 50 times more variable than those previously obtained in the region off Haneda (ICHIMURA 1967) due to the increasing eutrophication of the bay.

3. *Seasonal Variations of Phytoplankton Photosynthesis*

Photosynthesis-light curves of the surface phytoplankton samples obtained at Stn.

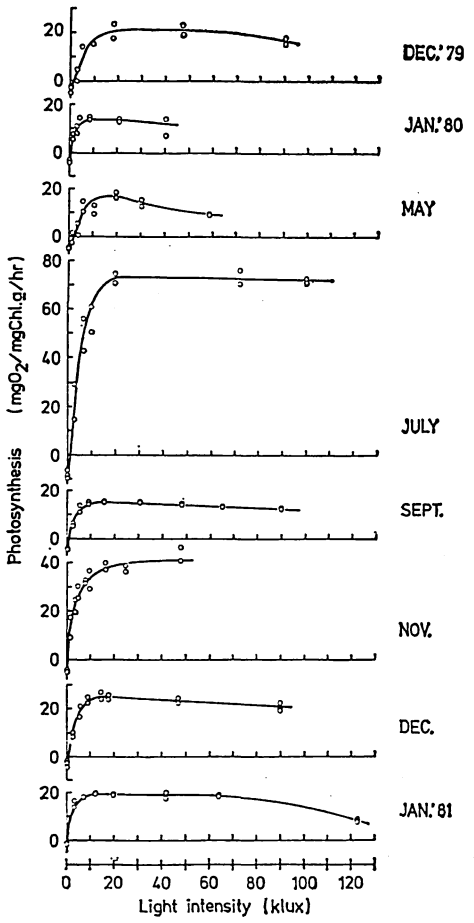

Fig. 9. Photosynthesis-light curves of the surface phytoplankton samples collected at Stn. A in Tokyo Bay.

A are illustrated in Fig. 9. The light-saturated net photosynthetic rate (P_n^{max}) varied from 15 to 72 mgO_2/mgChl.*a*/hr with the minimum occurring during winter and the maximum during summer. In January 1980 a shade type photosynthesis-light curve was obtained reaching the P_n^{max} at approximately 6 klux, while in July a sun type curve was obtained reaching the P_n^{max} at about 20 klux without the inhibition of photosynthetic rate even at very high light intensities. In September the photosynthesis-light curve showed the shade type, but in November and December the curves were something between shade and sun type. In January 1981 again the photosynthesis-light curve became the shade type with the P_n^{max} at 10 klux.

Using the Winkler method, HOGETSU *et al.* (1959) obtained P_n^{max} of 24-45 mgO_2/mgChl.*a*/hr with surface samples of *Skeletonema* in the region off Haneda. They did not observe the inhibition of photosynthesis at high light intensities up to 140 klux. ICHIMURA and ARUGA (1964) reported a photosynthesls-light curve of *Thalassiosira* and *Skeletonema* bloom in Tokyo Bay which had no inhibition of photosynthesis. FUNAKOSHI (1973) also obtained the photosynthesis-light curves of phytoplankton without intense light inhibition in Tokyo Bay. However, SHIBATA and ARUGA (1982) reported the inhibition of photosynthetic rate in their phytoplankton samples from the surface water off Haneda especially during summer.

Although only a few curves were obtained during the present work, they showed similar seasonal characteristics in comparison with those reported previously by other workers in Tokyo Bay concerning the range of P_n^{max} values (HOGETSU *et al.* 1959, FUNAKOSHI 1973, SHIBATA and ARUGA 1982), no inhibition of photosynthesis at high light intensities during summer (HOGETSU *et al.* 1959, ICHIMURA and ARUGA 1964, FUNAKOSHI 1973) and the differentiation of photosynthetic pattern into sun and shade types in different periods of a year (ICHIMURA and ARUGA 1964).

Fig. 10 (B and C) shows the seasonal variations of photosynthesis and respiration of the surface phytoplankton samples obtained at Stn. A. Gross and net photosynthetic rate both on a water volume basis and on a chlotophyll *a* basis showed a similar pattern of seasonal variations. Gross photosynthetic activity on a water volume basis showed a maximum of 2.98 mgO_2/l/hr in September 1980 and a minimum of 0.08 mgO_2/l/hr in January 1981. Respiratory activity on a water volume basis was fairly high during the warmer seasons (May-October). Gross photosynthetic rate on a chlorophyll *a* basis ranged from 9.52 to 80 mgO_2/mgChl.*a*/hr; the highest value was obtained in July 1980 and the lowest in January 1981.

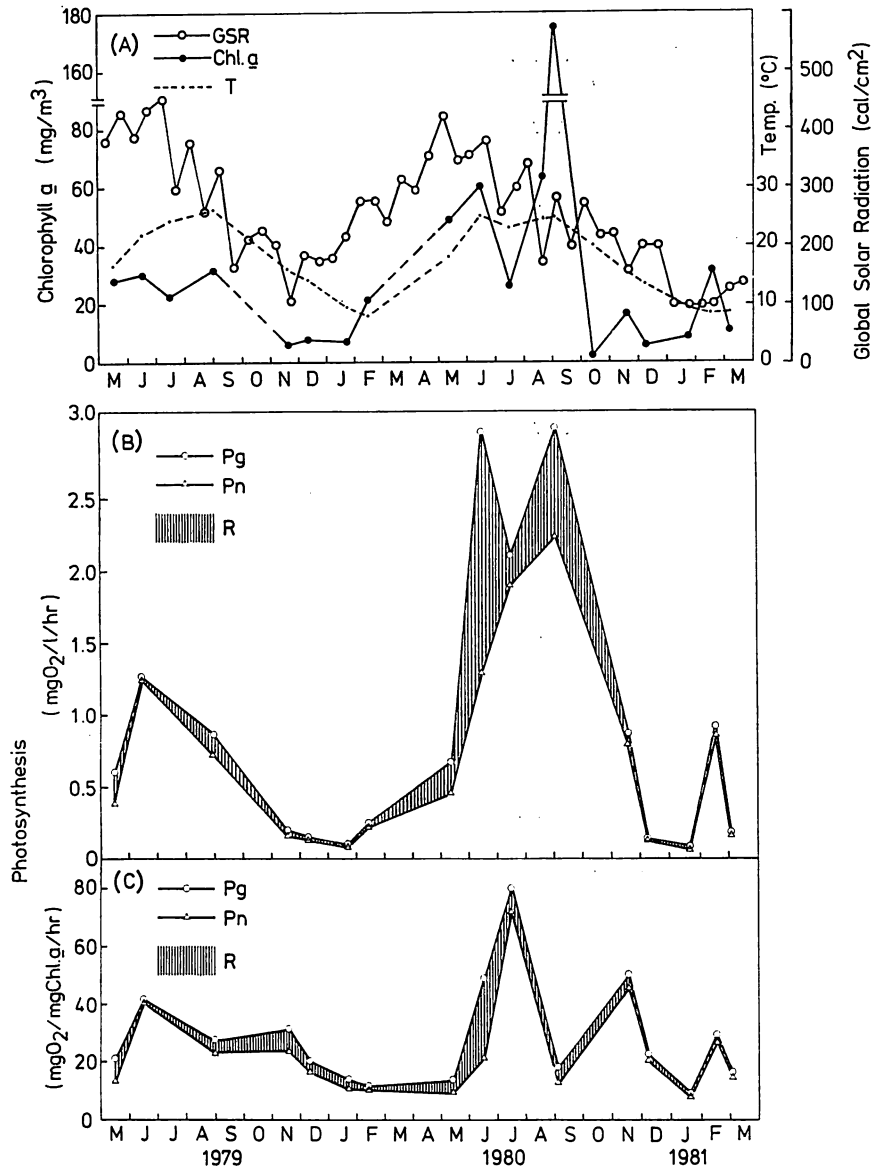

Fig. 10. Seasonal variations of chlorophyll *a* concentration (A), light-saturated photosynthesis and respiration activity (B and C) of phytoplankton from the surface water of Stn. A in Tokyo Bay. P_g, gross photosynthesis; P_n, net photosynthesis; R, respiration. Surface water temperature (T) and global solar radiation (GSR) are also illustrated. GSR data are averaged for each half-month period in Tokyo based on JAPAN METEOROLOGICAL AGENCY (1979-1981).

The horizontal distribution of gross photosynthetic rate was obtained only in the inner bay from June to December 1980 (Fig. 11). Gross photosynthetic rates were high and varied from 15.3 to 71.9 mgO_2/mgChl.*a* /hr during summer and from 11.0 to 46.2 mgO_2/mgChl.*a*/hr during autumn-winter period, showing no definite pattern of distribution. FUNAKOSHI *et al.* (1974) obtained values of 1.5-15 mgO_2/mgChl.*a*/hr in the areas from the innermost part of the bay to the outside oceanic region. In recent

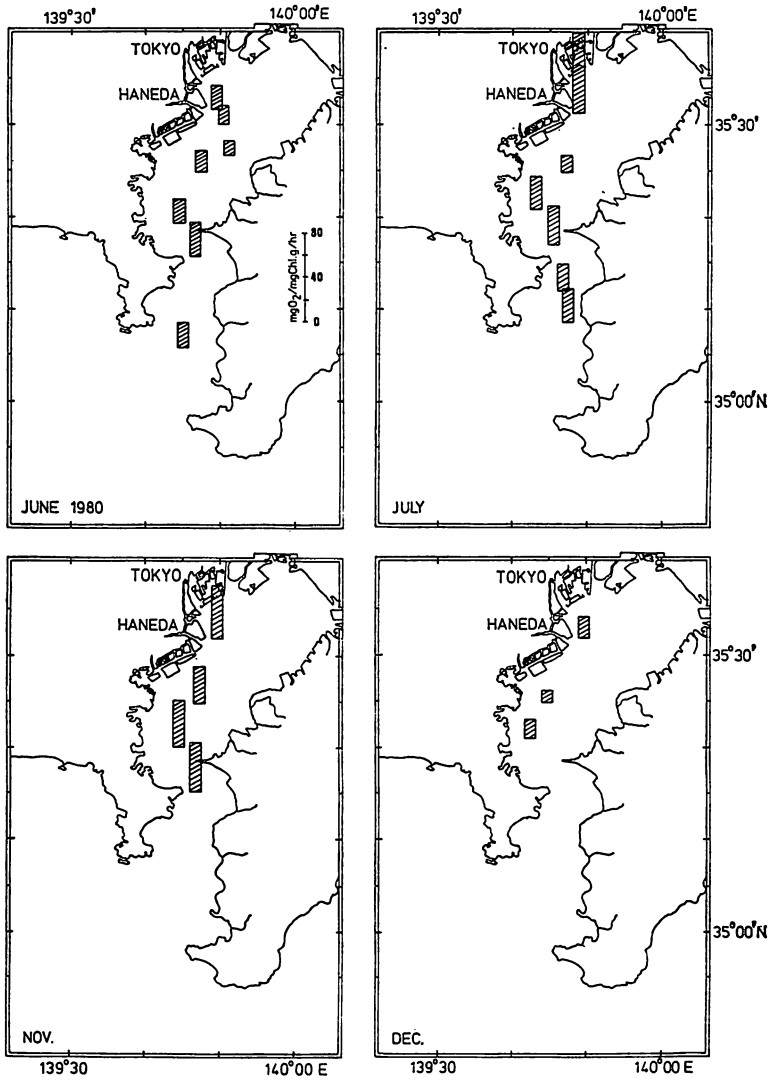

Fig. 11. Horizontal distributions of light-saturated gross photosynthesis of surface phytoplankton samples in Tokyo Bay (June—December 1980).

years the light-saturated net photosynthetic rates from 7.4 to 56 mgO_2/mgChl.*a*/hr were reported for the surface samples in Tokyo Bay by ARUGA and SHIBATA (1978) and SHIBATA and ARUGA (1982).

The vertical distributions of light-saturated photosynthesis and respiration at Stn. A are shown in Fig. 12. In general, the photosynthetic activity on a water volume basis was high in surface samples and low in deeper samples, decreasing with depth. The pattern of vertical distribution mostly followed that of chlorophyll *a*. Gross and net photosynthesis ranged from 0.014 to 2.95 and from 0.0044 to 1.88 mgO_2/l/hr, respectively. On a chlorophyll *a* basis, light-saturated gross and net photosynthesis ranged from 3.21 to 80 and from 1.69 to 72 mgO_2/mgChl.*a*/hr, respectively. In some cases they decreased with depth, but in general they were vertically at a similar level even in deeper samples. During the periods of vertical circulation, both the photosynthesis activity on a water volume basis and that

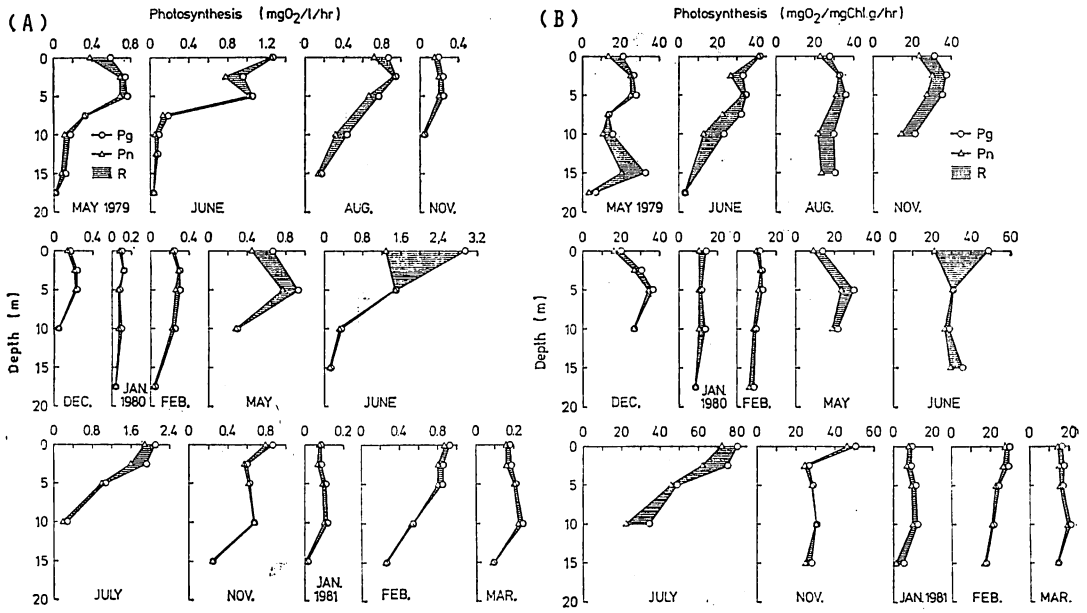

Fig. 12. Vertical profiles of light-saturated photosythesis and respiratory activity of phytoplankton samples collected from different depths at Stn. A in Tokyo Bay. P_g, gross photosynthesis; P_n, net photosynthesis; R, respiration. (A), on a water volume basis and (B), on a chlorophyll *a* basis.

on a chlorophyll *a* basis were almost uniformly distributed in the water column. Subsurface maximum of photosynthesis activity was sometimes observed even in winter samples.

The respiratory rate obtained in the present study, of course, includes zooplankton and bacterial respiration which is reported to be very high during summer (TSUJI *et al.* 1974, SEKI *et al.* 1974). In the present study, as indicated in Fig. 10, it was also higher during the warm seasons than in winter, ranging from 0.015 to 1.66 $mgO_2/l/hr$. The seasonal variations of respiratory activity on a chlorophyll *a* basis were not so clear; the rate ranged from 0.75 to 27.49 mgO_2/mgChl.*a*/hr. In the vertical profiles (Fig. 12), the respiration activity was usually higher on a water volume basis in the surface samples especially during summer, but on a chlorophyll *a* basis higher rates were often observed in deeper samples.

4. *Relationships of Phytoplankton Biomass and Photosynthesis to Environmental Factors*

(a) Temperature and Solar Radiation

It is very difficult to analyse the relationships between phytoplankton production and environmental factors especially in highly eutrophic areas such as Tokyo Bay. The results obtained in the present investigation clearly indicated that chlorophyll *a* concentrations and photosynthetic rates tend to increase during summer and to decrease during winter. Although comparatively large quantities of chlorophyll *a* were measured in February 1980 and 1981, chlorophyll *a* concentrations lower than 20 mg/m^3 were never observed from May to August 1979 and from May to September 1980 (Fig. 10(A)).

The role of temperature in controlling the seasonal variation of phytoplankton primary production in shallow and temperate eutrophic estuaries has been pointed out by several workers (WILLIAMS and MURDOCH 1966, EPPLEY 1972, HARRIS and PICCININ 1977). However, the dependency of primary production on temperature in the region off Haneda in Tokyo Bay is still not completely clear presumably due to the extremely advanced eutrophication making the seasonal

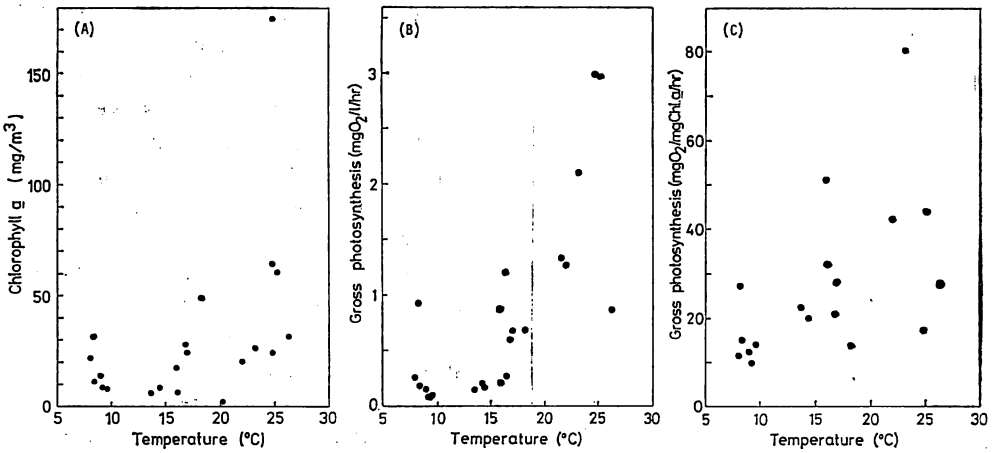

Fig. 13. Relationship of chlorophyll *a* concentration (A) and light-saturated gross photosynthesis (B and C) to temperature of the surface water at Stn. A in Tokyo Bay.

variation of phytoplankton production difficult to be detected (YAMAGUCHI and SHIBATA 1979).

Fig. 13 shows the relationships of chlorophyll *a* concentration, gross photosynthesis on a water volume basis and gross photosynthesis on a chlorophyll *a* basis to temperature in the surface water at Stn. A. Relatively higher correlation in the case of photosynthesis on a water volume basis (Fig. 13(B)) might have resulted from compound effects of temperature and chlorophyll *a* concentrations. The scattering of points in Fig. 13 may be interpreted as the result of interference by environmental factors other than temperature; e.g. SINCLAIR *et al.* (1981) observed that short-term variations of phytoplankton biomass may be related to changes in the density profiles of the water column in many estuaries during periods in which growth is not limited by light. HARRIS *et al.* (1980), who also did not observe a clear relationship between P^{max} and temperature, pointed out that photosynthetic rate responds better to the changes in the ratio of the depth of euphotic zone to the depth of mixed layer (Z_{eu}/Z_m) than to only temperature. It is clear from Fig. 13(C) that the correlation between both parameters is less pronounced during the warm periods of a year. According to HARRIS *et al.* (1980), the unstable meteorological conditions during summer in Hamilton Harbour (L. Ontario) probably affect the physical regimes of the water column and consequently rapid changes in the Z_{eu}/Z_m ratio may occur followed by changes in P^{max}. If this is also the case in Tokyo Bay, the absence of a clear correlation between photosynthesis activity of phytoplrnkton and temperature observed in the present study as well as by other workers (cf. SHIBATA and ARUGA 1982) could be partially explained.

The seasonal variations of surface chlorophyll *a* concentration at Stn. A and solar radiation showed a fairly good correlation as can be seen in Fig. 10(A). It seems that not only temperature but also the yearly changes of solar radiation may affect the seasonal variations of phytoplankton growth in Tokyo Bay. It would probably be more reasonable to consider the combined effects of light and temperature regimes in controlling the seasonal changes of phytoplankton biomass in the region off Haneda, instead of analysing the relationships of these environmental factors to phytoplankton production separately. Correlations of phytoplankton production to both solar radiation and temperature changes have also been found by other workers in estuaries (SCOTT 1979) and freshwater environments (JONES 1977a, b).

(b) Salinity

Clear relationships could not be observed

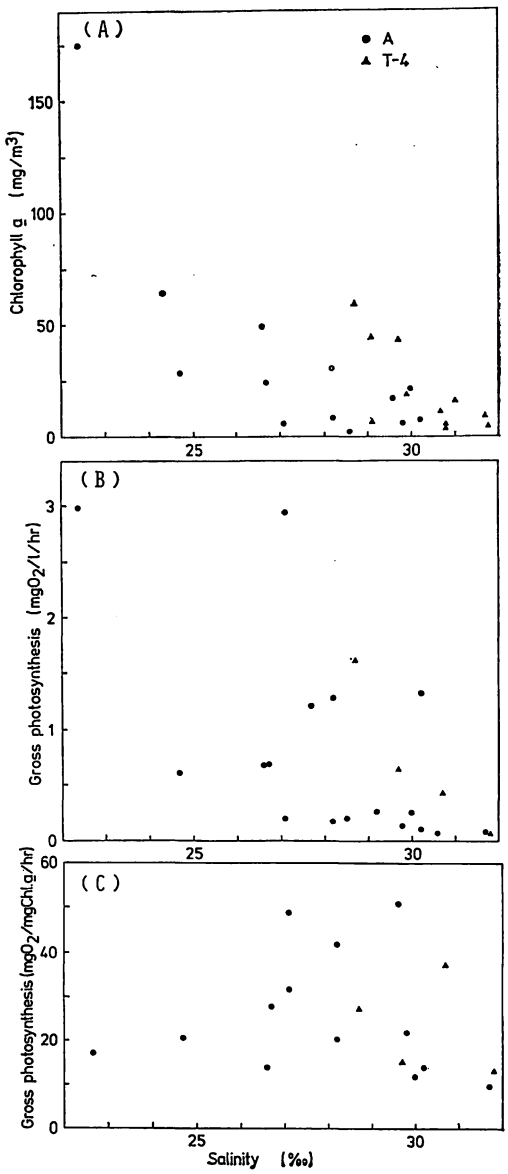

Fig. 14. Relationships of chlorophyll *a* concentration (A) and light-saturated gross photosynthesis (B and C) to salinity of the surface water at Stns. A and T-4 in Tokyo Bay.

of chlorophyll *a* concentrations and gross photosynthesis to salinity of the surface water at Stns. A and T-4 in the present study (Fig. 14). An optimum salinity of 25‰ was reported by NAKANISHI and MONSI (1965) for phytoplankton growth in Tokyo Bay. SHIMURA *et al.* (1979) found a tolerance of *Skeletonema costatum* and *Chaetoceros* sp. to salinity variations in the range of 4.4 to 40.0‰. A similar range of tolerance was observed for *Thalassiosira decipiens* by TAKANO (1963). These species were the principal components of the diatom population at Stn. A from May 1979 through February 1980 in the present investigation (cf. Table 1). With the exception of July 1979, the range of salinity variation in the surface water at Stn. A was from 22.4 to 30.8‰. These values are consistent with the favorable salinity ranges reported by the authors mentioned above. Therefore, it may be considered that the salinity was adequate for the development of phytoplankton population in the area concerned during most of the period of the present work.

Relationship between chlorophyll *a* concencentration and salinity of the surface water in the inner part of Tokyo Bay and Uraga Strait is shown in Fig. 15. Chlorophyll *a* concentration tended to decrease as the salinity increased; the concentration was higher in the inner part of the bay than in Uraga Strait and the salinity was lower in the former than in the latter. SHIBATA and ARUGA (1982) observed higher photosynthetic rates followed by lower salinity in the inner part of Tokyo Bay and lower photosynthetic rates followed by higher salinity in Uraga Strait. A similar trend was obtained by TERADA *et al.* (1974) in the eutrophic estuary of Shimoda Bay. During the present work, however, higher salinities were associated with the low temperature periods and also with the lowest concentrations of nutrients in the mouth of the bay (cf. Fig. 5). Therefore, the relationships of biomass and photosynthesis to salinity obtained in the present work should be carefully examined in due consideration of the interactions of other environmental factors. Unfortunately, photosynthesis-salinity curves were not obtained in the present study, but certainly they would have been helpful for a more precise comprehension of these relationships.

(c) Nutrients

No correlation was observed between seasonal changes in the chlorophyll *a* con-

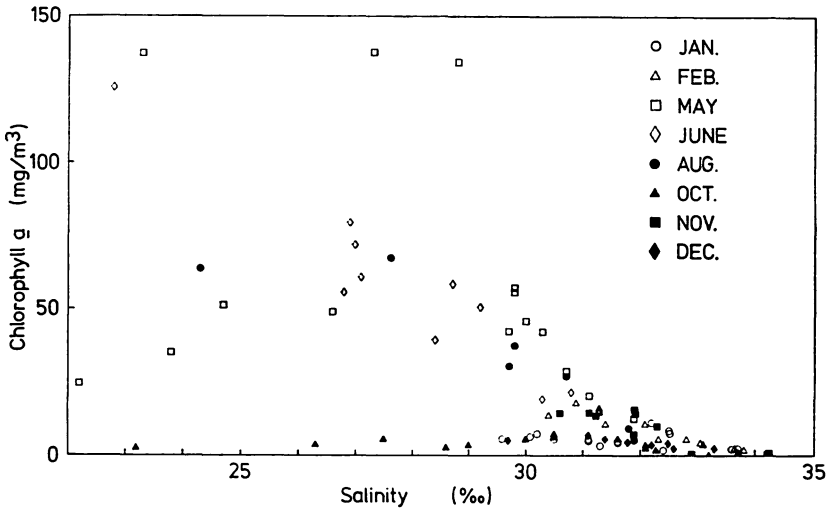

Fig. 15. Relationship between chlorophyll *a* concentration and salinity of the surface water in Tokyo Bay and Uraga Strait.

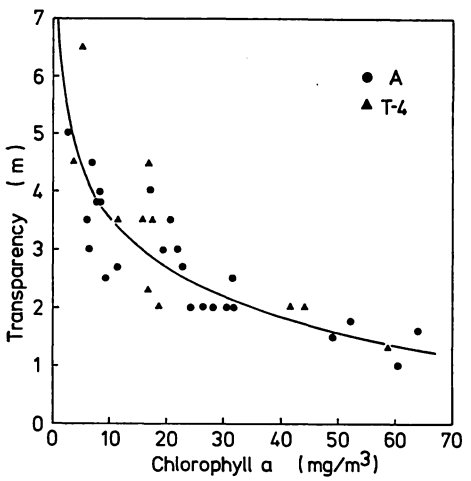

Fig. 16. Relationship between surface chlorophyll *a* concentration and transparency (Secchi disc depth) at Stns. A and T-4 in Tokyo Bay.

centrations and nutrients as well as between those in the photosynthetic rates and nutrients (cf. Figs. 3 and 10). There were not well-defined annual variations of total inorganic nitrogen, phosphate and silicate concentrations which were always high enough to support well-growing phytoplankton populations in the estuarine region off Haneda throughout the year (cf. NAKANISHI and MONSI 1965, ICHIMURA 1967, FUNAKOSHI *et al.* 1974) with the exception of silicate which might have been limiting the diatom development in August 1979 and February and June 1980.

(d) Transparency

A very clear hyperbolic relationship was obtained between transparency (Secchi disc depth) and chlorophyll *a* concentration in the surface water at Stns. A and T-4 (Fig. 16). A similar relationship was reported by SHIBATA and ARUGA (1982) with the data from the whole area of the bay and also by TOYOTA and NAKASHIMA (1979) with the data from Uraga Strait and Sagami Bay. It is evident that the transparency is strongly affected by the amount of chlorophyll in water (cf. ICHIMURA 1956, SAIJO and ICHIMURA 1960).

(e) Tide

Unfortunately, the effect of tide on the diurnal changes of chlorophyll *a* concentrations in water was not studied in the present work; however, it should be taken into account especially in estuarine regions. Short-term temporal variations of chlorophyll *a* concentration have been noted together with changes in physical and chemical properties in Tokyo Bay (ARUGA and SHIBATA 1978, MINISTRY OF TRANSPORTATION 1979); the concentration of chlorophyll *a* tended to

be higher during high tide and to be lower during low tide at a fixed station. These changes followed by the change in tide level might be related to the supply of river water, to the outflow of inner bay water into Uraga Strait, or to the inflow of open sea water into the inner bay.

Concluding Remarks

The results obtained in the present investigation are consistent with those reported previously by many investigators. Chlorophyll *a* concentrations found in the inner bay were by far higher than those reported for coastal areas adjacent to the Kuroshio Current and oceanic areas of the Pacific Ocean (SHIMURA and ICHIMURA 1972, TAKAHASHI *et al.* 1972, ICHIMURA 1980). The high levels of chlorophyll *a* concentration and of photosynthetic activity of phytoplankton observed from May 1979 to March 1981 reflect the eutrophic conditions in Tokyo Bay. Highly productive periods showed higher phytoplankton biomass and photosynthetic activity in 1980 than in 1979.

Acknowledgements

We express our sincere thanks to the Captain T. ISOUCHI and the officers and crew of the T/S Seiyo Maru, Tokyo University of Fisheries, for their kind assistance in providing all the facilities for the work on board. Grateful thanks are due to the colleagues of the Laboratory of Phycology, Tokyo University of Fisheries, for their kind help during the analytical work in the laboratory.

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F. P. ブランジーニ・有賀祐勝：東京湾における植物プランクトンの現存量および光合成活性と環境条件

1979年5月～1981年3月に東京湾内湾と浦賀水道で19回の調査を行った。Stn. Aでは，植物プランクトン細胞数は 5.3×10^3～8.2×10^4/ml で，5，8，2月に多く，6，7月に少なかった。主な優占種は *Skeletonema costatum* と *Prorocentrum* spp. であった。表面水中のクロロフィル *a* は 2.7～175 mg/m³ で，1980年9月に最大値が得られ，10～1月には比較的少なかった。光飽和総光合成は 0.08～2.98 mgO_2/l/hr (9.5～80 mg O_2/mg Chl. *a*/hr) で，水体積当りでは1980年9月に最高，1981年1月に最低であったが，クロロフィル *a* 当りでは夏季に高く，冬季に低かった。クロロフィル *a* 濃度と光合成活性は，高温期に高く，低温期に低い傾向があるものの，温度との相関はあまり明確でなかった。クロロフィル *a* 濃度は，低塩分の内湾で高く，高塩分の浦賀水道で低かったが，光合成活性と塩分の関係は明らかでなかった。また，クロロフィル *a* 濃度と栄養塩濃度との間にも明確な関係は認められなかった。 （〒108 東京都港区港南 4-5-7 東京水産大学水産植物学教室）

Jap. J. Phycol. (Sôrui) 31 : 148-155. September 20, 1983

Distribution of *Ulva pertusa* and amount of nitrogen in Yamaguchi Bay

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UNO, S., SAKAI, Y. and YOSHIKAWA, K. 1983. Distribution of *Ulva pertusa* and amount of nitrogen in Yamaguchi Bay. Jap. J. Phycol. 31 : 148-155.

It is said that *Ulva pertusa* has increased in abundance with the progression of eutrophication in the Seto Inland Sea. The authors drew distribution maps of *U. pertusa*, and estimated the quantity of total nitrogen in *U. pertusa*, seawater (DIN, DON, and PON), and sediment (solid and liquid fractions) in Yamaguchi Bay in July and November 1976. *U. pertusa* existed thickly at the middle part of both east and west sides of the bay. The highest standing stock was 5.3 kg (wet weight)/m^2 in November. The total amount of nitrogen in *U. pertusa* in the bay was estimated to be about 3.8 and 12.1 tonnes in July and November, respectively. The analyses of the other materials showed that the sum of nitrogen in the sediment exceeded that in any other component. The total amount of nitrogen in *U. pertusa* in the bay greatly exceeded that in the seston including phytoplankton. It is thought that *U. partusa* holds the most important position among living materials in the nitrogen cycle in the bay.

Key Index Words: *nitrogen cycle*; *nitrogen distribution*; Ulva pertusa.

Recently, for understanding the eutrophication in estuarine or coastal regions, studies of nitrogen or phosphorus cycles in the sea have been carried out at many research bodies. Nitrogen and phosphorus seem to be the main factors involved in eutrophication. It is thought that plants in large seaweed beds play an important role in the nitrogen and phosphorus cycles. Recent works on nutrient cycles in the sea have concentrated on phytoplankton, the predominant life in the sea, and have not paid much attention to the seaweeds. However, some recent investigators (IIZUMI 1975, PENHALE *et al.* 1977, etc.) studied the ecocystem of the eelgrass (*Zostera marina*) beds.

The present authors have studied the nitrogen stock in *U. pertusa* beds in Yamaguchi Bay. *U. pertusa* is ordinaly seen on any shore of the Seto Inland Sea and is said to have increased in abundance with the progression of eutrophication in the sea.

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Study area

Yamaguchi Bay is situated in the western part of the Seto Inland Sea. It is a secondary slender bay which is separated from Aio Bay by Iwaya Peninsula. The mouth of the bay is about 4 km wide and its length is about 8 km. The area discussed in this paper is 15.18 km^2 and is indicated by stippling in Fig. 1. The deepest point at the mouth exceeds 10 m, and the 5 m depth line extends into the bay parallel to the peninsula. The average depth of the bay is 1.04 m at mean level.

As five small rivers are flow into the bay, chlorinity of the water is low: the chlorinity of the surface water at Stn. 2 varied from 8.3 to 17.1‰. The maximum current speed was 25 cm/sec at the mouth

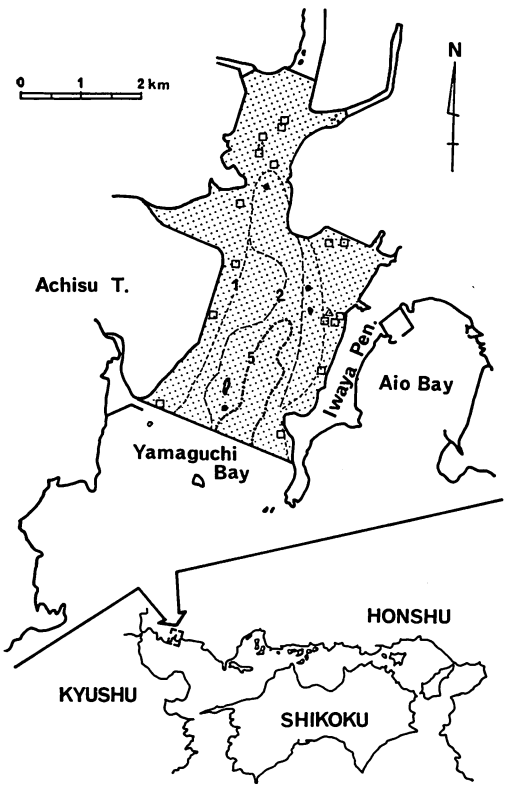

Fig. 1. Maps of Yamaguchi Bay and the Seto Inland Sea. Solid circles: stations for seawater and sediment analyses. Open triangle: a station for sediment analysis. Open square: stations for the determination of standing stock of *Ulva pertusa*. Numerals at isodepth contours are in meter.

of the bay in November. The grain size composition of the surface sediment in the bay widely varied with time and sampling stations. The main components of the sediment were silt and sand.

Methods

Field observations were carried out on July 13 and November 24, 1976. The distribution of *U. pertusa* in the bay was observed by naked eyes and minutely recorded on the map. *U. pertusa* in the quadrat of 50 cm × 50 cm was sampled for the estimation of total amount of the plant in the bay. Then standing stock of *U. pertusa* were determined at seventeen stations on the intertidal zone. While *U. pertusa* in the deep water were sampled by nets, or counted by diving observation.

Determinations of organic carbon and nitrogen in *U. pertusa* and sediment were carried out by a Yanagimoto CN Coder MT-500 with measurement error less than 2%. Sediment samples collected in July were weighed and then centrifuged to separate theoretically liquid (dissolved) from solid (particulate) fraction. The deposited solid materials were weighed again and then dried. Finally, they were tared to determine dry/wet weight ratio of the sediment.

Seawater was sampled from surface and bottom layers at high and low tides. They were also sorted into two parts: particulate matter collected on Whatman GF/C glass fiber filters and the rest dissolved matter passed through the filters. A Yanagimoto CHN Corder MT-2 was employed to determine particulate organic nitrogen (PON). Dissolved inorganic nitrogen (DIN) is the integrated value of nitrate, nitrite, and ammonium nitrogen, determined by the methods of SOLÓRZANO (1969), BENDSCHNEIDER and ROBINSON (1952) and WOOD *et al.* (1967), respectively. Dissolved organic nitrogen (DON) was analysed with Kjeldahl digestion method based on STRICKLAND and PARSONS (1968).

The large tidal range cause remarkable variation of the volume of seawater in Yamaguchi Bay. For convenience, the authors estimated the nitrogen stock in the water at the mean tidal level for assessing the role of *U. pertusa* in the nitrogen cycle in seaweed beds.

The nitrogen in *U. pertura* (N_u) in the whole bay, is expressed as equation (1):

$$N_u = U \cdot f_u \cdot F, \quad (1)$$

where U is the total amount (wet weight) of *U. pertusa* in the bay, f_u is the ratio of dry to wet weight of *U. pertusa*, determined as 0.15 in the present experiment, and F is the ntrogen content on a dry weight basis of *U. pertusa* determined as 0.037 here.

Each of the nitrogen as DIN, DON, and

PON, in seawater of the bay (N_w), is obtained by equation (2):

$$N_w = \sum_n \cdot d_w \cdot S/p\,, \qquad (2)$$

where n is the nitrogen concentration of each sample in gN/m^3, d_w is the mean water depth of the bay in meter, S is the area of the bay concerned in this paper in m^2, and p is the number of samples collected.

In July, nitrogen in the sediment was divided into two parts: the solid fraction (sediment completely excluding water), the liquid fraction (all the volume of interstitial water). Total nitrogen in the solid fraction (N_s) and in the liquid fraction (N_i) of the sediment in the bay are calculated by equations (3) and (4).

$$N_s = \sum_{ns} \cdot V_s \cdot d_c \cdot S/(V_s + V_{si}) \cdot p\,, \qquad (3)$$

$$N_i = \sum_{ni} \cdot (V_i + V_{si}) \cdot d_c \cdot S/(V_s + V_i + V_{si}) \cdot p, \qquad (4)$$

where ns is the nitrogen content of dried sediment in μgN/g and ni is the nitrogen concentration of liquid fraction in gN/m^3 at each station sampled, d_c is the thickness of the sediment core concerned with nitrogen cycle in the bay (assumed to be 0.1 m), V_s, V_i and V_{si} are volumes of the dried sediment, interstial water taken by centrifuging, and the water contained in the sediment after centrifuging. These values are obtained by the solution of following equations:

$$V_s + V_i + V_{si} = V$$

$$\rho_m = (V_i + V_{si}) \cdot \rho_i + V_s \cdot \rho_s$$

$$r_1 = V_s \cdot \rho_s / \rho_m$$

$$r_2 = V_s \cdot \rho_s / (V_{si} \cdot \rho_i + V_s \cdot \rho_s)\,,$$

where V is unit volume of the whole sediment in 0.1 m^3, ρ_s, ρ_i, and ρ_m are specific gravities of the solid fraction (determined as 2.6 as the average of all the three stations), liquid fraction (calculated as 1.02 at σ_{15}), and the whole sediment, respectively, r_1 and r_2 are weight ratios of solid fraction to the whole sediment determined as 0.61 as the average), and to the sediment after centrifuging (determined as 0.73).

Nitrogen of the whole sediment in November is expressed by the sum of N_s plus N_i in equations (3) and (4).

Results and Discussion

Figs. 2 and 3 show distributions of *U. pertusa* in the bay in July and November, respectively. In July *U. pertura* was found most densely at the middle part of the both east and west sides of the bay. The highest standing stock was about 2 kg/m^2 in wet weight. At the central part of the bay *U. pertusa* existed thinly with the value from 0.5 to 10 g (wet weight)/m^2. In November the areas of high density were also located at both sides of the middle part of the bay. The highest standing stock was 5.3 kg/m^2 in the month. The total amounts of *U. pertusa* in the bay were 684 tonnes in July and 2187 tonnes in November.

Fig. 2. Distribution of *Ulva pertusa* (wet weight) in Yamaguchi Bay in July 1976.

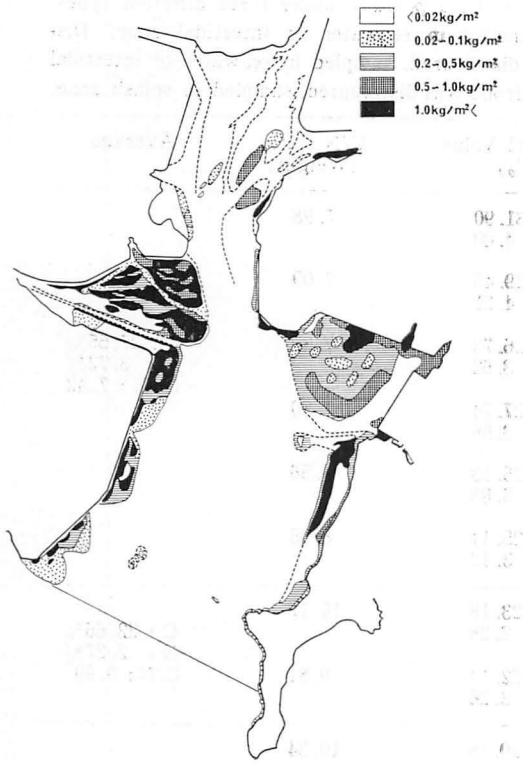

Fig. 3. Distribution of *Ulva pertusa* (wet weight) in Yamaguchi Bay in November 1976.

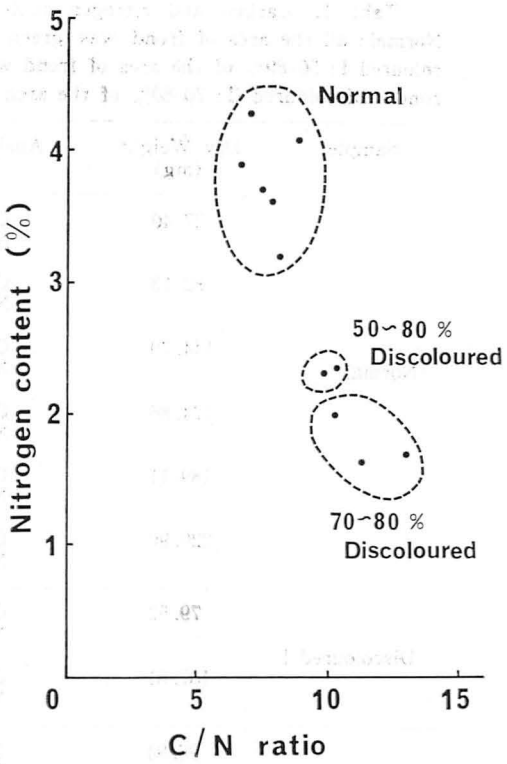

Fig. 4. Relationships between nitrogen content (% dry weight) and C/N ratio in *Ulva pertusa* of three different discolouration types.

Organic carbon and nitrogen of *U. pertusa* are shown in Table 1. The average carbon and nitrogen contents of healthy growing *U. pertusa* were 7.6 and 3.7% dry weight respectively. Nitrogen content of *U. pertusa* was about half that of *Porphyra yezoensis* in which it varied from 6.2 to 7.9% in a day (OOHUSA *et al.* 1978). The present figures of *U. pertusa* did not differ very much from that of *Zostera marina* (1.9–4.3 %, after HARRISON and MANN 1975).

The average carbon/nitrogen ratio of *U. pertusa* was 7.42 by weight. Both of the carbon and nitrogen contents gradually decreased with decline of the growth of *U. pertusa*. Nitrogen content decreased at quicker rate than did carbon, so the C/N ratio of *U. pertusa* tended to rise with decline of the growth as indicated in Fig. 4. Such values of the C/N ratio have been also recognized in phytoplankton. REDFIELD (1934) and FLEMING (1940) showed a C/N ratio of 7.0 based on the number of carbon and nitrogen atoms (the ratio by weight is about 6.0) for natural phytoplankton. UNO (1974) indicated that the average C/N ratio of the diatom *Skeletonema costatum* in continuous culture was 5.75 by weight. Furthermore, UNO (1978) also found that many organic materials in the sea showed a tendency to increase the C/N ratio as nitrogen content decreased.

Table 2 shows the total amount of nitrogen in six components in the bay. Almost all the nitrogen in the bay existed in the solid fraction of the sediment with the value of about three order of magnitude higher than that of any other component. Values of nitrogen existed in the other components did not much differ from each other. *U. pertusa* in the whole bay comprised 3.80 tonnes of nitrogen in July and 12.14 tonnes

Table 1. Carbon and nitrogen content in *Ulva pertusa* under three different types. Normal: all the area of frond was green, sampled in seawater or intertidal zone. Discoloured I: 50-80% of the area of frond was discoloured, sampled in seawater or intertidal zone. Discoloured II: 70-80% of the area of frond was discoloured, sampled in splash zone.

Sample	Dry Weight (mg)	Analyzed Value (%)	C/N Ratio (Weight)	Average
Normal	27.40	C : 31.90 N : 4.00	7.98	C : 27.55% N : 3.72% C/N : 7.42
	82.13	C : 29.45 N : 4.21	7.00	
	144.70	C : 26.73 N : 3.62	7.39	
	174.86	C : 27.74 N : 3.56	7.80	
	189.11	C : 25.13 N : 3.83	6.56	
	220.90	C : 25.14 N : 3.12	8.05	
Discoloured I	79.52	C : 23.18 N : 2.28	10.17	C : 22.66% N : 2.27% C/N : 9.99
	187.81	C : 22.14 N : 2.26	9.81	
Discoloured II	96.94	C : 20.18 N : 1.95	10.34	
	108.31	C : 17.98 N : 1.60	11.27	C : 19.99% N : 1.73% C/N : 11.6
	125.53	C : 21.80 N : 1.65	13.24	

Table 2. The estimated amounts (in tonnes) of nitrogen in *Ulva pertusa*, seawater, and sediment in Yamaguchi Bay, July and November 1976.

Components		July	November
Ulva		3.80	12.14
Seawater	DIN	2.06	1.63
	DON	6.88	5.37
	PON	0.89	1.27
Sediment	Solid	1,395.10	1,333.11
	Liquid	6.74	
Total		1,415.47	1,343.52

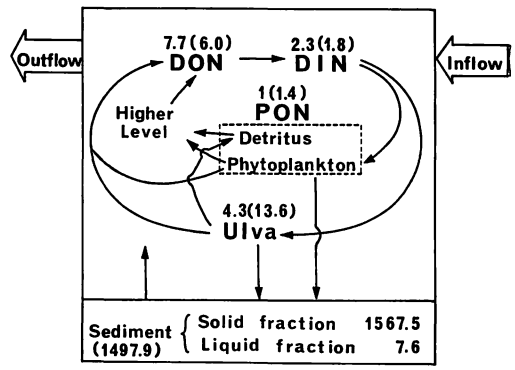

Fig. 5. Schematic diagram of the nitrogen cycle in Yamaguchi Bay. Each values in relative to PON in July. In parentheses are shown the November values.

in November. Fig. 5 express schematically the nitrogen cycle in the bay, taking the value of PON in July as the standard.

The column thickness of seawater in the present study was ten times greater than the core thickness of sediment samples. Nevertheless, nitrogen stock in the sediment exceeded that in all other components of

the bay, due to the remarkable difference of nitrogen concentration of sediment (ca. 700 ppm) from that of the others (e.g., ca. 60 $\mu g/l \fallingdotseq 0.06$ ppm as PON). The nitrogen content in the sandy sediment of Yamaguchi Bay was lower than that of Harima-Nada, in the eastern part of the Seto Inland Sea, which was 1630 ppm in average at 46 stations (UNO 1978). In the sediment of the East China Sea, HAMADA and HAMADA (1963) found that the nitrogen content varied from 300 to 700 ppm.

For convenience the present authors selected a sediment core thickness of 10 cm, even though nitrogen should exist in the sediment below 10 cm depth. IIZUMI (1975) indicated that nitrate, nitrite, and phosphorus in the interstitial water from the sediment of an eelgrass bed decreased below 10 cm of core depth, but ammonia increased. According to him water content and ignition loss of the sediment did not changed vertically. Living organisms in the sediment usually exist in a thin layer at the surface. PERKINS (1974) and TEAL and WIESER (1966) pointed out that meiobenthos are commonly most abundant in the upper 1-2 cm layer of the sediment. Additionally, TANIDA and OKUDA (1958) indicated that more than 90% of macrobenthos have been found within the upper 10 cm core depth. Consequently, the layer of sediment appears the most important for the nitrogen cycle. The amount of nitrogen in interstitial water of the sediment represented only 0.48% that of solid fraction, but its nitrogen concentration was twenty time shigher than the dissolved nitrogen in seawater.

In Table 2, nitrogen contained in phytoplankton was included in the PON calculation because of the difficulties of separating it from the other particulate materials in the seawater. Usually phytoplankton is attributed to the most abundant living organism in the sea. However, in the shallow waters of Yamaguchi Bay *U. pertusa* was the most dominant living organism in the nitrogen cycle. The amount of nitrogen in a water column is directly dependent on the thickness of water column. If the mean depth of the bay were 10 m, the amounts of DIN, DON, and PON would be about ten times greater than the present results.

In 1981, meiobenthos of Yamaguchi Bay was observed and the biomass was varied from 20-2645 and 157-2333 mg/m^2 in July and December, respectively. In Oumi Bay, the next bay at east side of Aio Bay, macrobenthos existed with the value from 714 to 3450 g/m^2 in June and from 270 to 2340 g/m^2 in November 1982, while meiobenthos also existed from 223 to 1080 mg/m^2 in June and from 159 to 581 mg/m^2 in November.

TANIDA and OKUDA (1958) showed that the biomass of macrobenthos in Matsushima Bay was 2.28 kg/m^2 (average value of three stations). This value is fairly close by its weight to the higher values of standing stock of *U. pertusa* in the coastal zone of Yamaguchi Bay. Usually, the macrobenthos have 10-100 times more biomass than the meiobenthos (FENCHEL 1969). However, if the almost components of macrobenthos are bivalves, the biomass of macrobenthos in weight will be much higher than that of the meiobenthos just like as Oumi Bay. We have no numerical data on the macrobenthos in Yamaguchi Bay, but have recognized many bivalves there. Therefore the biomass of benthos in Yamaguchi Bay would be equivalent to the standing stock of *U. pertusa* in the bay.

In Yamaguchi Bay the total nitrogen decreased by 92 tonnes from July to November. This was mainly caused by a change in the sediment nitrogen. However, variation of the sediment nitrogen between July and November was smaller than that of other materials. The values of nitrogen in Table 2 were all determined based on many assumptions and definitions. The nitrogen in *U. pertusa* would be closest to the actual value. On the other hand, the estimate of nitrogen in seawater was based on the mean value of the surface and bottom samples at three stations during low and high tides. The nitrogen in the sediment of various stations changed from sample to sample, but

was based on the mean value of four stations at low tide. It will be necessary to take more samples to improve the accuracy of the nitrogen estimation.

In estuaries, especially where algal beds are present, seaweeds could play a predominant role in the nitrogen cycle by virtue of its quantity. It is thought that *U. pertusa* occupies the most important position among the living materials in the nitrogen cycle in Yamaguchi Bay. As such, it must perform a role of buffer for nutrients in estuarine water.

Acknowledgements

The authors wish to express their sincere thanks to Drs. Yunosuke SAITO and Akio MURAKAMI, who gave them an opportunity to carry out this study. They are most grateful to Mr. Thomas B. MCCORMICK III and Dr. Sigeiti HAYASI for their interest and critical reading of the manuscript. Thanks are also extended to Miss Harumi MURAKAMI for her assistance in preparation of the manuscript.

They are indebted to Yamaguchi Naikai Fisheries Experimental Station of Yamaguchi Prefecture for the cooperation to this study.

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宇野史郎・酒井保次*・吉川浩二*：山口湾におけるアナアオサの分布と窒素の量

近年，瀬戸内海では富栄養化の進行と共にアナアオサの量は増大しつつあると言われる。1976年7月，及び11月に山口湾におけるアナアオサの分布を調べ，また湾内のアナアオサ，海水（DIN, DON, 及び PON），底質（泥粒及び間げき水）の窒素量を推定した。アナアオサは湾両岸の各々中央部に高密度で分布し，現存量最大値は11月の 5.3 kg（湿重量）/m^2 であった。この湾内のアナアオサ中の窒素の総量は7月に 3.8 ton 11月に 12.1 ton であった。窒素の総量は底質において著しく多かった。アナアオサ中の窒素量は，ここでの水深が浅い為に植物プランクトンを含む懸濁物などよりもはるかに卓越していた。この湾においては，アナアオサは窒素循環の中で最も重要な生物としての役割を果たしているであろうことが推察された。(424 清水市折戸 5-7-1 遠洋水産研究所 * 739-04 広島県佐伯郡大野町 7782 南西海区水産研究所)

Jap. J. Phycol. (Sôrui) 31 : 156-160. September 20, 1983

Batrachospermum kushiroense, sp. nov. (Rhodophyta, Nemalionales) from Kushiro Moor in cool temperate Japan

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KUMANO, S. and OHSAKI, M. 1983. *Batrachospermum kushiroense*, sp. nov. (Rhodophyta, Nemalionales) from Kushiro Moor in cool temperate Japan. Jap. J. Phycol. 31 : 156-160.

Batrachospermum kushiroense is described here as a new species of the section *Contorta* of genus *Batrachospermum* from Kushiro Moor in the eastern part of Hokkaido. This species resembles *B. capensis* STARMACH and *B. basilare* FLINT et SKUJA in having the loose agglomeration of gonimoblasts, but differs from them in the size of carpogonia, gonimoblasts and carposporangia.

Key Index Words: Batrachospermum kushiroense; *Nemalionales*; *Rhodophyta*; *section* Contorta; *Taxonomy*.

The section *Contorta* of genus *Batrachospermum* is characterized by the twisted carpogonium-bearing branch. SKUJA (1931) established this section based on *Batrachospermum procarpum* from tropical Brazil. As to tropical and subtropical species belonging to this section, STARMACH (1975) described *B. capensis* from the Seychelles in the Indian Ocean. *B. tortuosum* was described by KUMANO (1978), *B. tiomanense* and *B. hirosei* by RATNASABAPATHY and KUMANO (1972a, b) from tropical Malaysia. From subtropical Japan, *B. tortuosum* var. *majus* and *B. iriomotense* were described by KUMANO (1982). *B. basilare* was described by FLINT (1953) from Louisiana and reported from Florida in the United States of America. On the other hand, some species have been described from temperate regions and highlands in tropical region. For example, *B. intortum* was described from temperate China by JAO (1941); *B. lusitanicum*, *B. heriquesianum* and *B. pseudocarpum* from Portugal by REIS (1965, 1972 and 1973); *B. woitapense* from the Papuan highlands by KUMANO (1983). The specimen collected from Kushiro Moor in cool temperate Japan is found to belong to the section *Contorta* of genus *Batrachospermum*, and is described in the present paper as a new species of this section.

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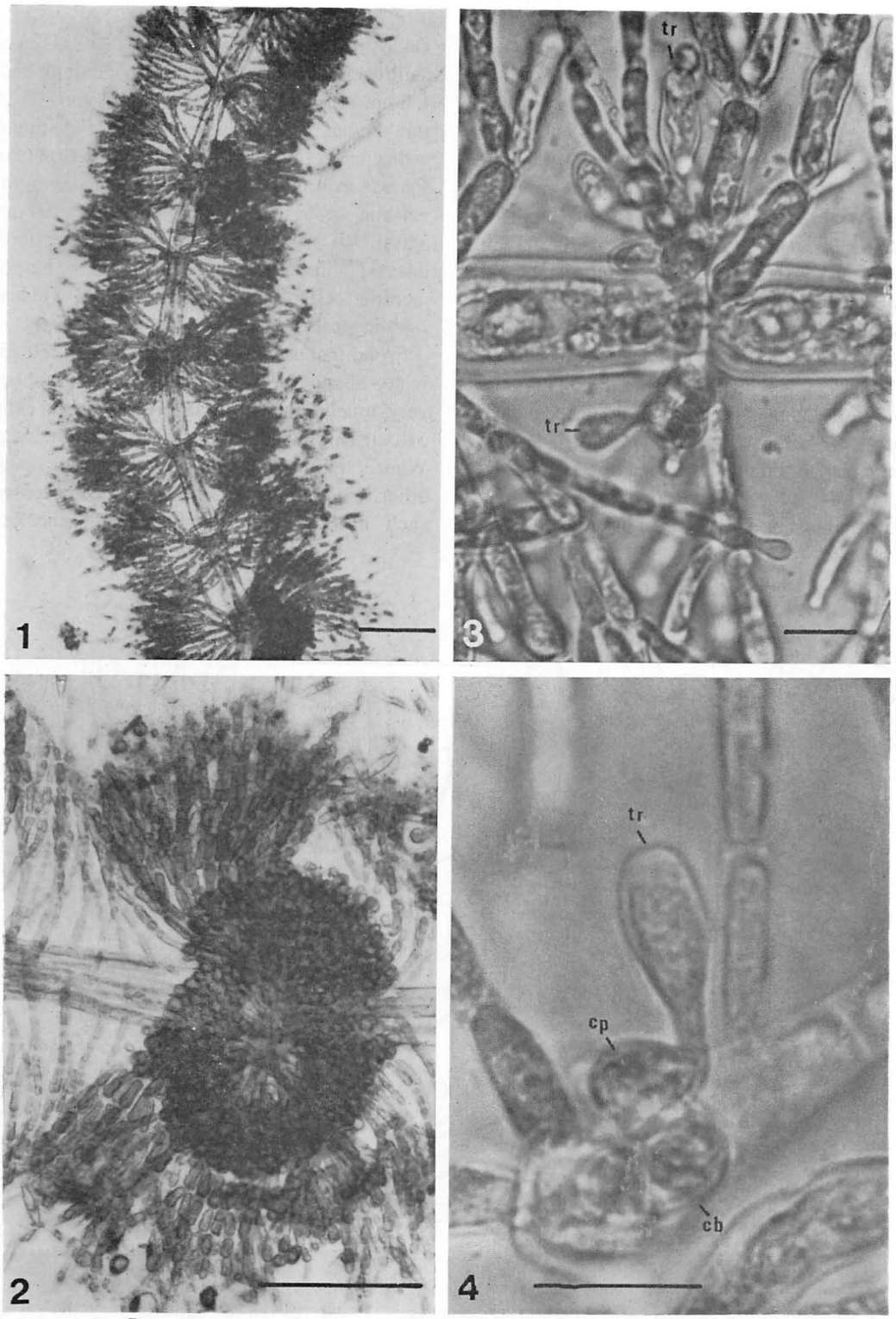
Kushiro Moor in Hokkaido

The Kushiro Moor, one of the largest moors in cool temperate Japan, is about 226 km^2, and situated at latitude 43°N and at an alluvial plain along the south-eastern coast of Hokkaido in Japan. The specimens of *Batrachospermum* were collected from an oxbow stagnant pond in the back-swamp along the Kushiro-gawa in this moor on 10th September 1981 by OHSAKI. At the time of collecting the specimens, the water temperature was 20.6°C and pH value was 6.9.



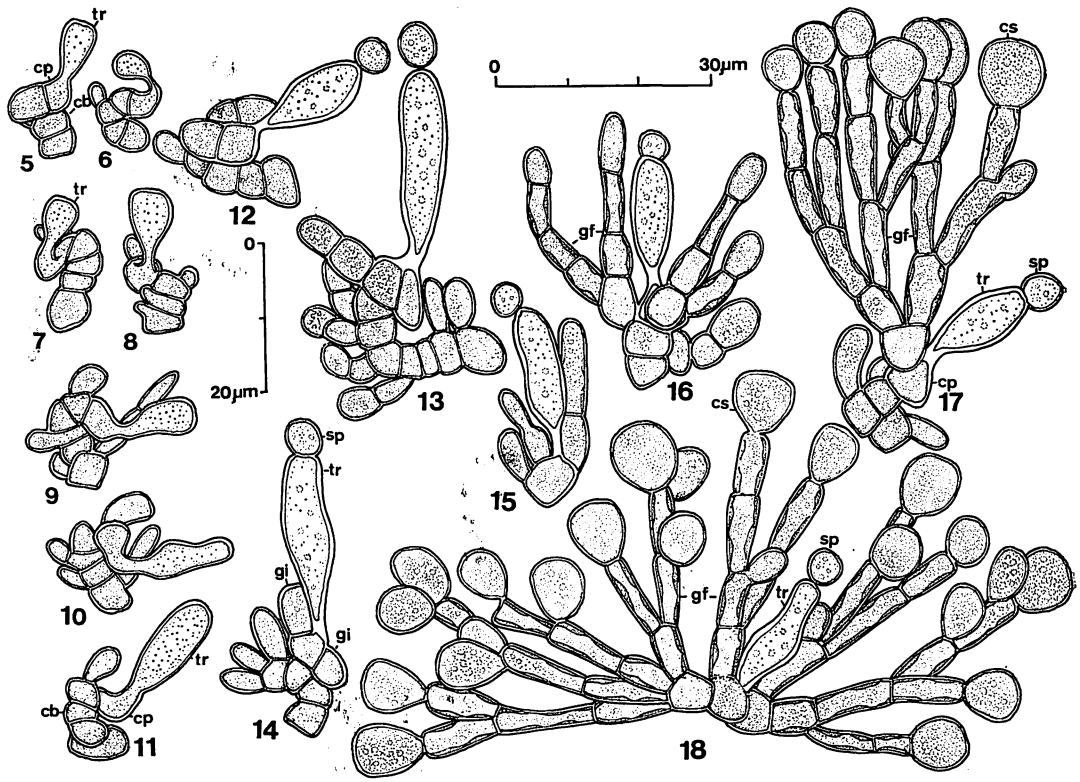
Figs. 1-4. *Batrachospermum kushiroense* KUMANO et OHSAKI, sp. nov. 1. Structure of whorls showing axial cells, primary branchlets, cortical filaments and gonimoblasts inserted centrally; 2. A part of thallus showing two semiglobular gonimoblasts; 3. Two carpogonium-bearing branches arising from the basal cells of primary branchlets, a fertilized carpogonium and an unfertilized carpogonium are shown; 4. A young carpogonium-bearing branch. (cb: carpogonium-bearing branch, cp: carpogonium, tr: trichogyne). (Scale: 100 μm for Figs. 1-2, 10 μm for Figs. 3-4).

Description of Species

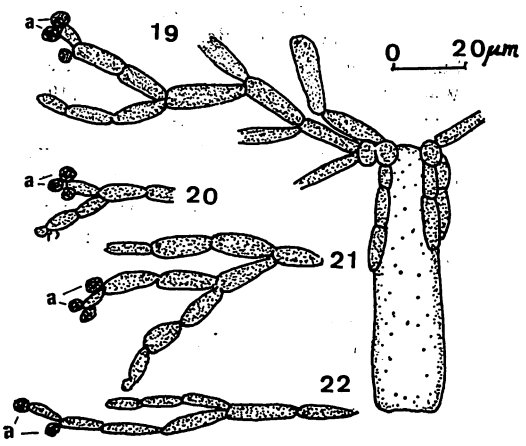
Batrachospermum kushiroense KUMANO et OHSAKI, sp. nov. (Figs. 1-22)

Frons monoica, 4.5 cm alta, 300-350 μm crassa, abundanter et irregulariter ramosa, parum mucosa, aeruginosa. Cellulae axiales cylindricae, 18-50 μm crassae, 70-300 μm longae. Verticilli distantes et ellipsoidei, vel contigui et plus minusve compressi. Ramuli primarii abundanter ramificantes, ex 7-12 cellulis constantes; cellulae fasciculorum cylindricae vel fusiformes, 2-8 μm crassae, 10-20 μm longae; pili nuli. Ramuli secundarii sparsi. Antheridia rari, globosa, 4-7 μm diametro, in ramulis primariis et secundariis terminalis. Ramuli carpogoniferi e cellulis basi ramulorum primariorum orientes, breves, valde tortuosi, ex cellulis 3-7 disci- vel doliiformibus constantes; carpogonium basi 4-6 μm crassum, apice 4-7 μm crassum, 17-34 μm longum; trichogyne urnformis, indistincte pedicellata, ad basim saepe flexa. Bracteae sparsae et brevissimae. Gonimoblasti singuli vel duo, globosi vel semiglobosi, 80-190 μm crassi, 40-130 μm alti, in centro verticilli inserti; fila gonimoblastorum laxe agglomeratia. Carposporangia globosa vel ovoidea, 7-9 μm crassa, 7-11 μm longa.

Frond monoecious, 4.5 cm high, 300-350 μm wide, abundantly and irregularly branched, very mucilaginous, bluish green. Axial cells cylindrical, 18-50 μm wide, 70-300 μm long. Whorls ellipsoidal and distant from each other, sometimes touching and compressed each other (Fig. 1). Primary branchlets



Figs. 5-18. *Batrachospermum kushiroense* KUMANO et OHSAKI, sp. nov. 5-11. Early stages in the development of twisted carponium-bearing branches; 12. A fertilized carpogonium; 13-16. Early stages in the development of gonimoblast filaments; 17-18. Carposporangia terminated on gonimoblast filaments. (cb: carpogonium-bearing branch, cp: carpogonium, cs: carposporangium, gf: gonimoblatt filament, gi: gonimoblast initial, sp: spermatium, tr: trichogyne).



Figs. 19-22. *Batrachospermum kushiroense* KUMANO et OHSAKI, sp. nov. 19. Structure of a whorl showing an axial cell, cortical filaments and antheridia terminated on primary branchlets; 20-21. Antheridia terminated on primary branchlets; 22. Antheridia terminated on a secondary branchlet; (a: antheridium).

abundantly branched, consisting of 7-12 cell-stories; cells of fascicles cylindrical or fusiform, 2-8 μm wide, 10-12 μm long; hairs racking. Secondary branchlets sparse. Antheridia rare, globose, 4-7 μm in diameter, terminal on primary (Figs. 19-21) and secondary branchlets (Fig. 22). Carpogonium-bearing branch (Figs. 3-14) arising from the basal cell of the primary branchlets, short, twisted very much, consisting of 3-7 disc- or barrel-shaped cells; carpogonium 4-6 μm wide at the base, 4-7 μm wide at the apex, 17-34 μm long; trichogyne urn-shaped, indistinctly stalked, often bent at the base (Figs. 3-18). Bracts sparse and very short. Gonimoblasts (Figs. 1-2) single or couple, globular or semiglobular, 80-190 μm wide, 40-130 μm high, inserted centrally; gonimoblast filaments loosely agglomerated (Figs. 2, 17 and 18). Carposporangia (Figs. 17-18) globular or ovoidal, 7-9 μm wide, 7-11 μm long.

Holotype: OHSAKI No. 810910, 10/IX 1981, Herbarium of Faculty of Science, Kobe University. Isotype: OHSAKI No. 810910b (SAP 043462), Herbarium of Department of Botany, Faculty of Science, Hokkaido University, SAP.

Type localoty: An oxbow pond, Kushiro-gawa, Kushiro Moor, Hokkaido, Japan.

Habitat: This species lives on submerged macrophytes and molluscs in stagnant pools in an oxbow of Kushiro-gawa in the moor.

Distribution: Known from the type locality only.

This species resembles *B. iriomotense* KUMANO 1982, *B. capensis* STARMACH 1975 and *B. basilare* FLINT et SKUJA 1953 in the loose agglomeration of the gonimoblast filaments. However, *B. kushiroense* differs from *B. iriomotense* in the length of carpogonium-bearing branches. The carpogonium-bearing branch of *B. kushiroense* consists of 3-7 cells, while 8-12 cells for *B. iriomotense*. *B. kushiroense* differs from *B. capensis* and *B. basilare* in the size of their reproductive organs. Carpogonia of *B. kushiroense* are 17-34 μm long, while those of *B. basilare* are 45-65 μm long and those of *B. capensis* are 40-63 μm long, respectively. The size of gonimoblast was not described by FLINT and SKUJA (1953) for *B. basilare*. The gonimoblasts of *B. kushiroense* are 80-190 μm in diameter, while those of *B. capensis* are 600-850 μm in diameter. Carposporangia of *B. kushiroense* are 7-11 μm long, while those of *B. basilare* are 29-31 μm long and those of *B. capensis* are 11-15 μm long, respectively. Hence, *B. kushiroense* can be distingushed from the above-mentioned three species.

Acknowledgements

The authors wish to express their sincere thanks to Dr. H. HIROSE, Professor Emeritus of Kobe University and Professor M. KUROGI of Hokkaido University for the critical reading of the manuscript.

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熊野　茂*・大崎万治：日本冷温帯の釧路湿原に産する *Batrachospermum kushiroense*, sp. nov.（紅藻，ウミゾウメン目）**

北海道東部の釧路湿原にある釧路川のメアンダーの止水池からカワモヅク属の1新種 *Batrachospermum kushiroense* を記載した。本種はコントルタ節に属し，まばらに集合した嚢果をもつ点で *B. capensis* STARMACH 1975 および *B. basilare* FLINT et SKUJA 1953 に最もよく似るが，造果器・嚢果および果胞子の大きさによってこれらの種と区別できる。（*657 神戸市灘区六甲台　神戸大学理学部生物学教室．**001 札幌市北区北10条西8丁目　北海道大学大学院環境科学研究科分類学講座：現住所 478 愛知県知多市金沢字大知山　県立知多高等学校）

Jap. J. Phycol. (Sôrui) 31: 161-166. September 20, 1983

Diurnal vertical migration and dark uptake of nitrate and phosphate of the red tide flagellates, *Heterosigma akashiwo* HADA and *Chattonella antiqua* (HADA) ONO (Raphidophyceae)[1)]

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WATANABE, M. M., NAKAMURA, Y. and KOHATA, K. 1983. Diurnal vertical migration and dark uptake of nitrate and phosphate of the red tide flagellates, *Heterosigma akashiwo* HADA and *Chattonella antiqua* (HADA) ONO (Raphidophyceae). Jap. J. Phycol. 31: 161-166.

Diurnal vertical migration of *Heterosigma akashiwo* and *Chattonella antiqua*, which form heavy red tides during the summer periods, when the thermal stratification is striking, was observed in laboratory cultures. These species concentrated at the surface in the daytime and at the bottom at night. The timing of descent and ascent did not coincide exactly with the onset or end of the light phases. Dark uptake by *H. akashiwo* was 41-100% NO_3^- and 43-100% PO_4^{3-} of that in the light, whereas that by *C. antiqua* was 49-100% NO_3^- and 75-100% PO_4^{3-} of that in the light. Nitrate and phosphate uptakes were less affected by light conditions in these species than in coastal diatoms. The combination of diurnal vertical migration and the ability to take up nitrate and phosphate at night probably gives these species double ecological advantages over the coastal diatoms in the thermally stratified waters. The migratory ascent at daytime maintains them in the euphotic zone and the descent at night makes sufficient nutrients available to them from the nutrient-rich bottom water.

Key Index Words: Chattonella antiqua; *diurnal vertical migration*; Heterosigma akashiwo; *nitrate and phosphate uptakes*; *red tide*.

The raphidophycean flagellates, *Heterosigma akashiwo* HADA and *Chattonella antiqua* (HADA) ONO, have often formed extensive red tides during the summer periods, when the thermocline was observed in the water body, in the Seto Inland Sea, Japan (ONO and TAKANO 1980, YAMOCHI *et al.* 1982). As these red tides develop, the surface waters rapidly become turbid and reddish brown. Such changes often run their courses within a few days and while a dramatic increase in cell division rates does occur, such high concentration of organisms must be explained by other mechanisms as well.

Many red tide flagellates migrate vertically (HASLE 1950, 1954, EPPLEY *et al.* 1968, BLASCO 1978, STAKER and BRUNO 1980, HEANEY and EPPLEY 1981, KAMYKOWSKY 1981, CULLEN and HORRIGAN 1981). Their ascent during the daytime usually results in more rapid increases of the cell concentrations in surface waters than can be accounted for by cell division (cf. IWASAKI 1979). Furthermore, the ability to assimilate nitrate at night observed in *Gonyaulax polyedra*, together with the capacity to migrate between the euphotic zone and the nutrient-riched bottom, has been recognized as possibly giving *G. polyedra* an ecological advantage over coastal diatoms and allowing growth of its population to bloom dimensions (EPPLEY and HARRISON 1975, HARRISON 1976).

This paper describes the diurnal vertical migration and dark uptake of nitrate and

[1)] Dedicated to Prof. Munenao Kurogi on the occasion of his academic retirement.

phosphate of *Heterosigma akashiwo* and *Chattonella antiqua* in laboratory cultures and discusses the ecological role of diurnal vertical migration in the development of red tides caused by these species in the Seto Inland Sea.

Materials and Methods

Axenic clones of *H. akashiwo* (OHE-1) and *C. antiqua* (Ho-1), used in the previous studies (WATANABE *et al.* 1982a, NAKAMURA and WATANABE 1983a, b), were maintained under a light intensity of 0.04 ly·min^{-1} and a photoperiod of 12 : 12 LD (lights on at 0800 and off at 2000), at 22.5 and 25°C, respectively, throughout the course of the present experiments.

Diurnal vertical migration: Each organism was cultured in two sets of 1000 m*l* Erlenmeyer flasks with 500 m*l* f/2 medium (GUILLARD and RYTER 1962). A 1000 m*l* culture of exponentially growing cells of *H. akashiwo* (cell concentration=ca. 1×10^4 cells ·ml^{-1}) or *C. antiqua* (cellc oncentration=ca. 1×10^3 cells·ml^{-1}) was transferred into a cylindrical glass tube 25 cm high by 8 cm internal diameter, whose sides and bottom were blackened. After the cultures had settled for 3 hrs, 2 m*l* water samples from 3 depths were taken every 1-3 hrs over the diel cycle. Cell concentrations were measured under a microscope (WATANABE *et al.* 1982a).

Nitrate and phosphate uptakes: *H. akashiwo* was cultured in 1000 m*l* Erlenmeyer flasks with 500 m*l* N- or P-limited modified ASP-7 medium (WATANABE *et al.* 1982a) containing 100 μM nitrate or 10 μM phosphate, respectively, and *C. antiqua* with 500 m*l* N- or P-limited H medium (NAKAMURA and WATANABE 1983a) containing 50 μM nitrate or 5 μM phosphate, respectively. When the cell concentrations of *H. akashiwo* reached ca. 2×10^4 cells·ml^{-1} and of *C. antiqua* ca. 1×10^3 cells·ml^{-1}, the exponential phases, samples were taken every 3 hrs over the diel cycle. Sampling procedures and analytical methods were the same as those previously reported (WATANABE *et al.* 1982a).

Results

Diurnal vertical migration: *H. akashiwo* and *C. antiqua* concentrated at the surface in the daytime and at the bottom at night (Figs. 1 and 2). Maximum cell concentrations of *H. akashiwo* and *C. antiqua* were 1×10^5 cells·ml^{-1} and 7.8×10^3 cells·ml^{-1}, respectively, at the surface in the daytime. These reached 2.5×10^5 cells·ml^{-1} and 6×10^3 cells·ml^{-1}, respectively, at the bottom at night, whereas cell concentration at the surface dramatically decreased. The timing of descent and ascent did not coincide exactly with the onset or end of the light phases but, rather, began to descend from the surface before the light was extinguished and ascended before the light came on.

Nitrate and phosphate uptakes: Cell division of *H. akashiwo* occurred between 0500-1100 and of *C. antiqua* 0200-0800 (Figs. 3-6). Ambient nitrate or phosphate concentration in the cultures of both species decreased monotonously throughout the light and dark periods. Light and dark uptake rates of nitrate and phosphate were determined by the following equation;

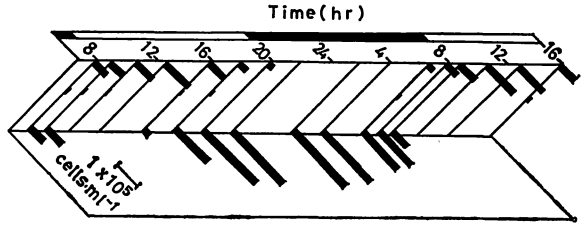

Fig. 1. Diurnal vertical migration of *Heterosigma akashiwo*.

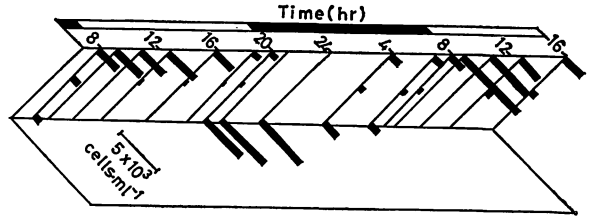

Fig. 2. Diurnal vertical migration of *Chattonella antiqua*.

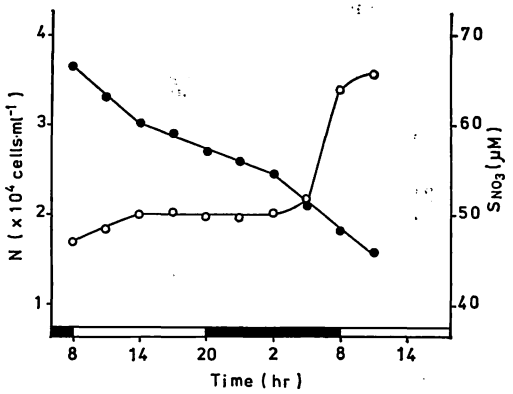

Fig. 3. Increase of cell concentration of *Heterosigma akashiwo* and decrease of ambient NO_3-N concentration under a light-dark cycle. ○ : cell concentration. ● : ambient NO_3-N concentration.

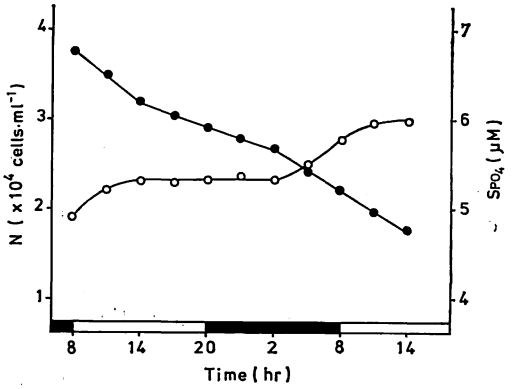

Fig. 4. Increase of cell concentration of *Heterosigma akashiwo* and decrease of ambient PO_4-P concentration under a light-dark cycle. ○ : cell concentration. ● : ambient PO_4-P concentration.

$$V=-\frac{dS}{dt}/N,$$

where V=uptake rate, $-\frac{dS}{dt}$=disappearence rate of nitrate or phosphate, and N=cell concentration. The results are summarized in Table 1. These two species took up nitrate and phosphate in both light and dark. The dark/light uptake ratios were estimated at 41-100% NO_3^- or 43-100% PO_4^{3-} in *H. akashiwo* and at 49-100% NO_3^- or 75-100% PO_4^{3-} in *C. antiqua*.

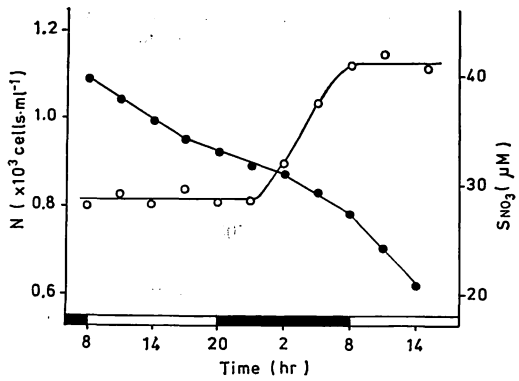

Fig. 5. Increase of cell concentration of *Chattonella antiqua* and decrease of ambient NO_3-N concentration under a light-dark cycle. ○ : cell concentration. ● : ambient NO_3-N concentration.

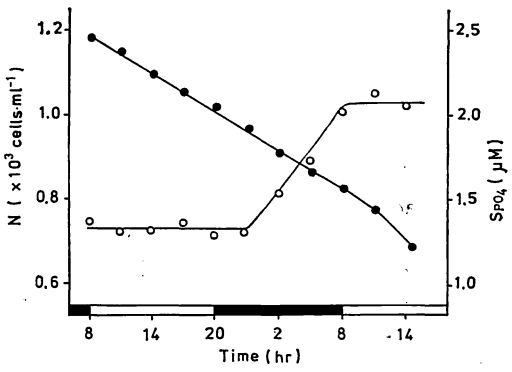

Fig. 6. Increase of cell concentration of *Chattonella antiqua* and decrease of ambient PO_4-P concentration under a light-dark cycle. ○ : cell concentration. ● : ambient PO_4-P concentration.

Discussion

Vertical distribution of flagellates is a function not only of their migration patterns but also of other factors such as zooplankton grazing and tidal transport (cf. SOURNIA 1974). Experiments with pure cultures demonstrate that flagellates migrate vertically according to a diurnal rhythm. The patterns of diurnal vertical migration of cultures of *H. akashiwo* and *C. antiqua* correspond well with the periodic changes of vertical distribution of the natural popu-

Table 1. Uptake rates of nitrate (V_N) and phosphate (V_P) of *Heterosigma akashiwo* and *Chattonella antiqua* at the light (L) and dark (D).

Species	hrs	L or D	V_N ($fmol \cdot cell^{-1} \cdot hr^{-1}$)	V_P ($fmol \cdot cell^{-1} \cdot hr^{-1}$)
H. akashiwo	0800—1100	L	59	4.7
	1100—1400	L	54	4.2
	1400—1700	L	24	2.0
	1700—2000	L	24	2.0
	2000—2300	D	24	2.0
	2300—0200	D	24	2.0
	0200—0500	D	52	3.1
	0500—0800	D	39	2.8
C. antiqua	0800—1100	L	791	51
	1100—1400	L	791	51
	1400—1700	L	791	51
	1700—2000	L	409	51
	2000—2300	D	409	51
	2300—0200	D	389	48
	0200—0500	D	655	43
	0500—0800	D	586	38

lations of these species observed in the Seto Inland Sea (YAMOCHI *et al.* 1982, HAMAMOTO *et al.* 1979). In nature they concentrate at the surface during the daytime and at lower zones at night. This suggests that the diurnal changes of vertical distribution in the natural population of these species were mainly due to their movement.

The migratory descent and ascent of some dinoflagellates preceded light changes (EPPLEY *et al.* 1968, HEANEY and FURNASS 1980, KAMYKOWSKI 1981, CULLEN and HOLLIGAN 1981). The importance of circadian rhythms in the diurnal vertical migration of the dinoflagellates, *Cachnia niei* and *Ceratium hirundinella,* seems clear, because in continuous dark they migrated with a similar periodicity to that in the light-dark cycle. In continuous darkness, *H. akashiwo* and *C. antiqua* migrated with not only a different periodicity from that of a light-dark cycle but also different from each other (WATANABE *et al.* in press., NAKAMURA and WATANABE in press.). Further metabolic studies are necessary to explain these results.

Red tides caused by flagellates are commonly associated with nutrient-depleted surface waters and steep, shallow thermoclines, below which nutrients are rich (HOLMS *et al.* 1967). This is true in the case of *H. akashiwo* or *C. antiqua* red tide (MURAKAMI 1978, SATO *et al.* 1979). Under such conditions, it has been reported that diurnal vertical migration gives flagellates double survival opportunities. The migratory ascent in the daytime places them in the euphotic zone and the descent at night positions them in the nutrient-rich bottom waters (HOLMS *et al.* 1967, EPPLEY *et al.* 1968, EPPLEY and HARRISON 1975, HARRISON 1976). Descent is advantageous only if the organisms can take up nutrients at night. Since N or P is limiting nutrient in the Seto Inland Sea (YAGI *et al.* 1982, NAKAMURA and WATANABE 1983b), dark uptake of these nutrients should be a significant adaptive feature for *H. akashiwo* and *C. antiqua.* As shown in the results, the dark/light ratios of nitrate or phosphate uptakes were 41-100% NO_3^- or 43-100% PO_4^{3-} in *H. akashiwo* and 49-100% NO_3^- or 75-100% PO_4^{3-} in *C. antiqua.* On the other hand, nitrate or ammonium uptake and nitrate reductase activity in natural assemblages of marine diatoms showed maximal activity about noon and minimal activity about

midnight and the amplitude of the variation from day to night was 5 to 10 fold (EPPLEY and HARRISON 1975). *Skeletonema costatum*, which often competes with *H. akashiwo* or *C. antiqua* in the Seto Inland Sea (MURAKAMI 1978, YAMOCHI *et al.* 1982), assimilated less nitrate at night than in the daytime (EPPLEY *et al.* 1971) and did not take up phosphate at night (WATANABE *et al.* 1982b). It seems that nitrate or phosphate uptake of *H. akashiwo* and *C. antiqua* is less affected by light conditions than that of the diatoms. These findings provides a basis for speculating that diurnal vertical migration provides *H. akashiwo* and *C. antiqua* an ecological advantage over the coastal diatoms.

Acknowledgement

The authors wish to express their thanks to Prof. L. B. LIDDLE, Southampton College of Long Island University, for critical readings of the manuscript and to Dr. M. WATANABE, the National Institute for Environmental Studies, for his encouragement.

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渡辺 信・中村泰男・木幡邦男：赤潮鞭毛藻，*Heterosigma akashiwo* と *Chattonella antiqua* の日周垂直移動と夜間における硝酸塩，燐酸塩の摂取

瀬戸内海にて夏期，成層が発達した時に赤潮を形成する *Heterosigma akashiwo* と *Chattonella antiqua* の日周垂直移動と硝酸塩・燐酸塩摂取の経時変化を純粋培養下で観察した。両種とも日中は表層に，夜間は底層に集積し，その上下の移動は明暗切り換え時刻に先行して行われた。*H. akashiwo* の夜間における硝酸塩，燐酸塩の摂取速度は日中のそれの各々 41～100%，43～100% であり，*C. antiqua* では各々 49～100%，75～100% であった。この値は，これらの種と競合関係にある硅藻と比べると大きく，従って両種の硝酸塩，燐酸塩の摂取は明暗条件で硅藻ほど影響をうけていないといえる。

H. akashiwo と *C. antiqua* に確認された有光層と栄養塩を豊富に含む底層の間を日周期的に移動しうる能力と夜間に硝酸塩，燐酸塩を摂取しうる能力は，成層期においてこれら2種の個体群の発達に大きな役割を果すものであることが推論された。(305 茨城県筑波郡谷田部町小野川 国立公害研究所水質土壌環境部)

Jap. J. Phycol. (Sôrui) 31 : 167-172. September 20, 1983

Morphological observations on *Acrothrix gracilis* KYLIN (Chordariales, Phaeophyta) newly found in Japan[1),2)]

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Hiroshi KAWAI. Morphological observations on *Acrothrix gracilis* KYLIN (Chordariales, Phaeophyta) newly found in Japan. Jap. J. Phycol. 31 : 167-172.

Morphological observations are made on the plant identified as *Acrothrix gracilis* KYLIN (1907), newly found at Akkeshi, Pacific coast of Hokkaido. Among the morphological features, the length of assimilatory filaments, shape and number of their cells are shown to be remarkably variable mainly according to the age of the plant. The assimilatory filaments are relatively long, isodiametric and composed of symmetric cells in younger plants, whereas in mature plants, they are relatively short, composed of asymmetric upper cells and symmetric lower cells and often unisodiametric. Among the 4 species described in the genus until now, *A. pacifica* was the only species reported in Japan and is clearly distinguished from the others in the morphological features of assimilatory filaments. *A. novae-angliae* and *A. norvegica* resemble *A. gracilis*, the type species of the genus, in their habits and morphological features of assimilatory filaments. A taxonomic reexamination of these species seems to be needed.

Key Index Words: Acrothrix; A. gracilis; *Chordariales*; *morphology*; *phytogeography*; *Phaeophyta*; *taxonomy*.

Acrothrix gracilis KYLIN (1907) was newly collected at Akkeshi, Pacific coast of Hokkaido. In the genus *Acrothrix*, *A. pacifica* OKAMURA et YAMADA was the only species known in Japan until now. Morphological observations on the plant of *A. gracilis* and a taxonomical discussion are presented.

Materials

The specimens observed were collected in Akkeshi (43°02′N, 144°52′E) at Cape Aikappu on June 28, 1980 and at Cape Aininkappu on June 29, 1980 and June 27, 1982. Some specimens were dried on herbarium sheets, and others were preserved in 10% formaldehyde-seawater for morphological observations with the light microscope.

A comparison with *Acrothrix pacifica* was also made. The materials of *A. pacifica*, which were also preserved in 10% formaldehyde-seawater, were collected at the following localities in Japan:

July 20, 1978, Abashiri (Okhotsk coast of Hokkaido); July 11, 1982, Ofuyu, July 6, 1982, Oshoro (Japan Sea coast of Hokkaido); May 10, 1982, Kikonai (In Hokkaido facing Tsugaru Strait); July 3, 1982, Miyako, July 3, 1980, Ohtsuchi (Pacific coast of northeastern Honshu); May 16, 1982, Mifunezaki (Japan Sea coast of Noto Peninsula).

1) Dedicated to Professor Munenao KUROGI on the occasion of his academic retirement.

2) This work was supported by a Grant-in-Aid for Scientific Research (No. 58540440) from the Ministry of Education, Science and Culture of Japan.

Results

Morphological observations on *Acrothrix gracilis*

The plants grow on rocks or on *Corallina pilulifera* POSTELS et RUPRECHT, together with *Eudesme virescens* (CARMICH.) J. AGARDH and *Chordaria flagelliformis* (MÜLL.) C. AGARDH in the upper subtidal zone to 1 meter deep under M. L. L. in rather sheltered areas. The thalli (Fig. 1; 2, a-d) are irregularly alternately branched to 2-3 orders, up to about 20 cm in height and 0.5 mm in diameter, not so slimy but smooth and rather tough, and yellowish in the living condition. They are solid in the upper part but hollow in the middle or lower parts.

The thallus is constructed of a single central axial filament with trichothallic growth, medullary layer and cortical layer. Cells of central axial filaments are long cylindrical, nearly hyaline and measure 20-43 μm and 15-30 μm in long and short diameters in cross section of the upper part of the thallus (Fig. 3c). Trichothallic hairs

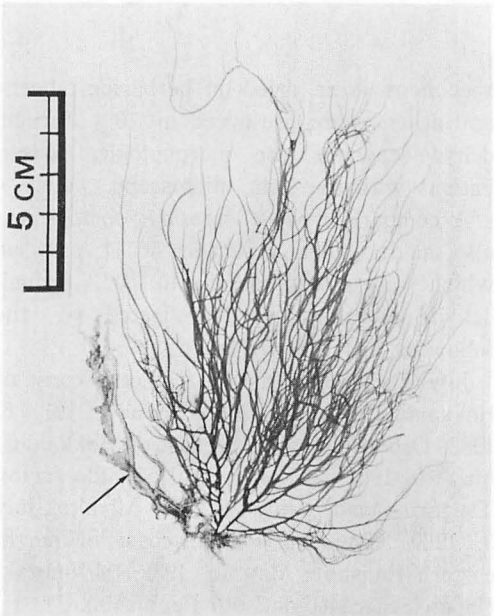

Fig. 1. *Acrothrix gracilis* KYLIN at Akkeshi. Habit, growing on *Corallina pilulifera*. Arrow shows *Eudesme virescens*.

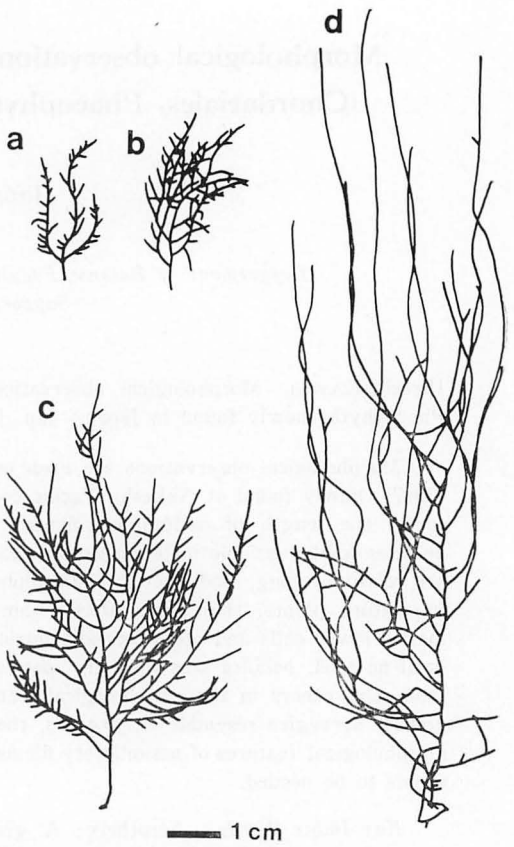

Fig. 2. *Acrothrix gracilis* KYLIN at Akkeshi, showing branching; a, b, young plants having irregular branchlets; c, d, mature plants.

measure 8-13 μm in diameter. The medullary layer is composed of 2-3 layers of large hyaline cells (Fig. 3, a-d; 4, b). Their cells measure 65-103 μm and 50-90 μm in long and short diameters in cross section. The cortical layer is composed of cortical cells, assimilatory filaments, lateral hairs and unilocular sporangia (Fig. 3, a, b, d; 4, b). Cortical cells are roundish and 8-48 μm in diameter in cross section, containing a few chloroplasts.

Assimilatory filaments are formed from a central axial filament near the apex and from cortical cells in the middle and lower parts of the thallus. Cells of the assimilatory filaments contain several chloroplasts. The number of cells and the shape of the assimilatory filaments are considerably

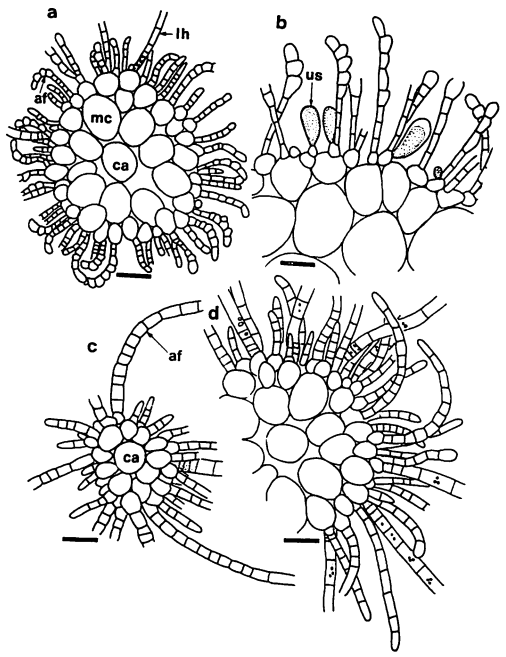

Fig. 3. *Acrothrix gracilis* KYLIN at Akkeshi. a, cross section of solid part of mature plant; b, cross section of hollow part of mature plant, showing asymmetric assimilatory filaments and unilocular sporangia; c, cross section of solid part of young plant showing long symmetric assimilatory filaments; d, cross section of upper part of young plant. (af, assimilatory filament; ca, central axial filament; lh, lateral hair; mc, medullary cell; us, unilocular sporangium) Rule: 20 μm.

variable mainly according to the age of the plant.

In mature plants, as shown in Figs. 3a, 3b, 4a, 4b, the assimilatory filaments are relatively short, 7-12 celled and 43-120 μm in length. There are two types of assimilatory filaments, symmetric ones and asymmetric ones in shape. Symmetric assimilatory filaments are more often observed in the upper part of the thallus, simple and nearly isodiametric throughout the length. The terminal cells of these filaments measure 10-15 μm in length and 5-6 μm in width. The lowermost cells of them measure 4-6 μm in length and 5-8 μm in width. On the other hand, asymmetric assimilatory filaments are more often observed in middle or lower parts of the thallus (Fig. 3, a-b). The upper part of the asymmetric assimilatory filaments are usually curved and their upper cells are often considerably swollen to one side. Their terminal cells measure 9-15 μm in length and 4-8 μm in width. The lower cells of the filaments are usually cylindrical and narrower than the other cells. The lowermost cells of the asymmetric assimilatory filaments measure 6-13 μm in length and 3-5 μm in width.

But the assimilatory filaments of young plants, which have many irregular branchlets near the apex of the thallus (Fig. 2, a-b; 4, c), are often very long, 7-19 celled and 55-300 μm in length. They are usually isodiametric, simple and composed of cylindrical cells. They often curve adaxially to envelop the apex in the upper part of the thallus (Fig. 3, c-d; 4, c-d). The assimilatory filaments are nearly uniform in morphology throughout the thallus of a young plant. Asymmetric assimilatory filaments are not observed. Their terminal cells measure 11-25 μm in length and 5-10 μm in width. Their lowermost cells measure 5-10 μm in length and 5-9 μm in width.

Phaeophycean hairs are abundant in young plants and measure 8-13 μm in diameter (Fig. 3d). They are also present in mature plants but fewer than in young plants (Fig. 3a).

Unilocular sporangia are sessile on the basal cells of assimilatory filaments, or on the cortical cells with a stalk cell and obovoid in shape (Fig. 3b). They measure 28-45 μm in length and 15-29 μm in width. The length/width ratio of unilocular sporangia is about 1.3-2.3. Plurilocular sporangia are not observed.

Morphological observations on *Acrothrix pacifica*

All the materials observed were epiphytic on *Chorda filum* (LINN.) STACKHOUSE. The thalli are irregularly alternately branched, yellowish brown and up to 8 cm in height and 0.6 mm in diameter.

The structure of the thallus agrees well with the original description by YAMADA

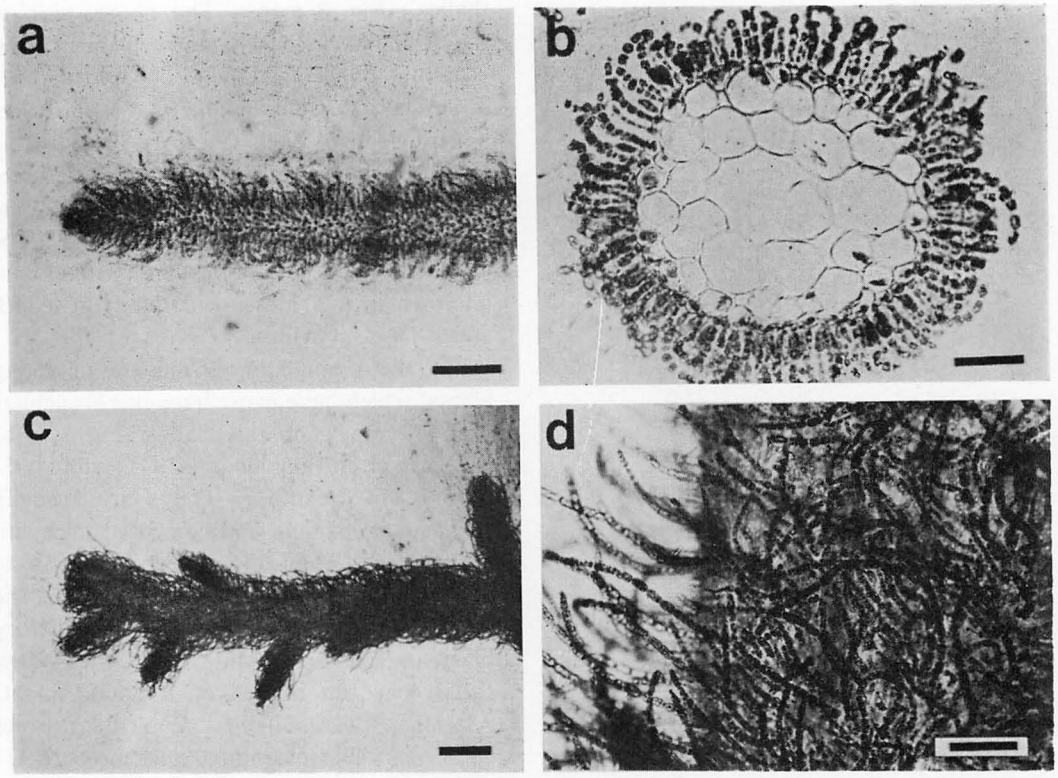

Fig. 4. *Acrothrix gracilis* KYLIN at Akkeshi. a, surface view of upper part of mature plant; b, cross section of middle part of mature plant, showing short asymmetric assimilatory filaments and unilocular sporangia; c, surface view of upper part of young plant having branchlets, showing long assimilatory filaments enveloping apex; d, surface view of lower part of young plant, showing long assimilatory filaments. Rule: a, 100 μm b, d, 50 μm, c, 200 μm.

(1932) and with the report of the species by INAGAKI (1958). Assimilatory filaments of *A. pacifica* are generally isodiametric and symmetric irrespective of the age or the part of the plant. Asymmetric assimilatory filaments as observed in the plant of *A. gracilis* are not observed. In mature plants, the assimilatory filaments are composed of 4-12 cells, 35-168 μm in length. Terminal cells of the filaments measure 10-38 μm in length and 6-20 μm in width. Their lowermost cells measure 10-28 μm in length and 6-15 μm in width.

Unilocular sporangia are obovoid, 30-55 μm in length and 23-45 μm in width. The length/width ratio of the unilocular sporangia is about 1.1-1.7. Plurilocular sporangia are not observed.

Discussion

The plant belongs to the genus *Acrothrix* in KYLIN (1907), as it has a single central axial filament with trichothallic growth, uniseriate assimilatory filaments and oniy unilocular sporangia as reproductive organ.

In the genus *Acrothrix*, four species have been described. They are the type, *A. gracilis* KYLIN (1907), *A. novae-angliae* TAYLOR (1928) and *A. norvegica* LEVRING (1937) from North Atlantic Ocean and *A. pacifica* OKAMURA et YAMADA (YAMADA 1932) from North Pacific Ocean.

Among these species, the plant at Akkeshi is most similar to the type species, *A. gracilis*. As seen in Table 1, it agrees with the species in habitat, height and diameter of thallus, diameter of lateral hair and size

Table 1. Morphological comparison of *Acrothrix gracilis* at Akkeshi and *A. gracilis* in KYLIN (1907, 1947).

		A. gracilis at Akkeshi			*A. gracilis* in KYLIN (1907, 1947)	
habitat		epilithic or on *Corallina* sp.			epilithic	
branching (orders)		2-3			1-2	
height of thallus (cm)		<20			10-40	
diameter of thallus (mm)		<0.5			0.5-1	
		a	b	c	d	e
assimilatory filament	length (μm)	55-300	43-88	53-120	—	—
	number of cells	7-19	7-10	7-12	7-10	4-7
	length × width of terminal cell (μm)	11-25×5-10	10-15×5-6	9-15×4-8	12-18×6-9	—×6-10
	length × width of lowermost cell (μm)	5-10×5-9	4-6×5-8	6-13×3-5	6-9×6-9	—×3-5
diameter of lateral hair (μm)		8-13			7-9*	
size of unilocular sporangium (μm)		28-45×15-29			35-50×18-22	

a, young plant, b, symmetric assimilatory filament in mature plant, c, asymmetric assimilatory filament in mature plant, d, primary assimilatory filament, e, secondary assimilatory filament.
* measured from Figs. 22 & 23 in KYLIN (1907).

of unilocular sporangia. KYLIN (1907, 1947) reported two types of assimilatory filaments, the primary one (formed from the central axial filament, symmetric) and the secondary one (formed from the cortical cells, asymmetric composed of thin lower cells and unilaterally swollen upper cells). Such characteristic assimilatory filaments are also observed in the mature plant at Akkeshi. The cell sizes of symmetric and asymmetric assimilatory filaments of the mature plant at Akkeshi also agree with those of the "primary" and "secondary" ones of *A. gracilis* in KYLIN. However, some differences are seen in branching of the thallus and the number of cells of assimilatory filaments between the two. The branching of the plant at Akkeshi is usually denser than in *A. gracilis* in KYLIN. In addition, the assimilatory filaments are a little longer in the plant at Akkeshi. But these differences seem to be variations within the same species. So, the plant at Akkeshi is identified as *Acrothrix gracilis* KYLIN.

Judging from the descriptions by YAMADA (1932) and INAGAKI (1958) and my observation in this paper, *A. pacifica* is clearly distinguished from *A. gracilis* especially in the morphology of the assimilatory filaments. The assimilatory filaments of *A. pacifica* are wider (the terminal cells measure 8-15 μm in diameter by YAMADA 1932) than those of *A. gracilis*. In addition, asymmetric assimilatory filaments as seen in *A. gracilis* do not occur in *A. pacifica*.

Acrothrix novae-angliae was reported from the Atlantic coast of North America by TAYLOR (1928), who distinguished it from *A. gracilis* in having denser branching and subspherical unilocular sporangia. LEVRING (1937) suggested that *A. novae-angliae* might represent a well branched form of *A. gracilis*. *A. norvegica* was described from Norway by LEVRING (1937) and characterized

by having numerous irregular branchlets in the upper part of the thallus and long assimilatory filaments attaining 15 cells in length. Asymmetric assimilatory filaments were not reported in this species. In these features, *A. norvegica* resembles the young plants of *A. gracilis* at Akkeshi. Considering the variations of branching and the diversity in morphology of assimilatory filaments in *A. gracilis*, it seems to me that a reexamination of the taxonomic interrelationships among *A. novae-angliae*, *A. norvegica* and *A. gracilis* is needed.

Acknowledgement

I am grateful to Dr. Munenao KUROGI for giving me helpful advice on the investigation and the critical reading of the manuscript. I am also grateful to Tetsu SHIMIZU, Shigeo KAWAGUCHI, Toshihiko KUDO and Mitsuru MARUI for offering me specimens of *Acrothrix pacifica*. I am again grateful to Dr. Michael J. WYNNE for his critical reading and improving the English of the manuscript.

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川井浩史： 日本新産褐藻 *Acrothrix gracilis* KYLIN（キタニセモズク；新称）の形態学的観察

北海道の太平洋沿岸，厚岸で日本新産の *Acrothrix gracilis* KYLIN を採集し，その形態学的観察を行った。本種の同化糸は主に生長の段階によりその長さ，細胞の形態と長さが著しく異なる。若い藻体では同化糸は比較的長く，等径で相称の細胞からなるが，成熟した藻体では比較的短く，非相称な上部の細胞と相称な下部の細胞からなりしばしば不等径である。本属ではこれまでに4種が記載されており，*A. pacifica* だけが本邦で報告されていた。これらのうち，*A. pacifica* は同化糸の形状で他と明らかに区別されるが *A. novae-angliae* と *A. norvegica* はこの属のタイプ種の *A. gracilis* とその外観，同化糸の形状が類似し，これら三種の分類学的な再検討が必要であると考える。(060 札幌市北区北10条西8丁目 北海道大学理学部植物学教室)

Jap. J. Phycol. (Sôrui) 31 : 173-179. September 20, 1983

The use of fluorescence staining to study nucleus development in the multinucleate dasycladalean green algae

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LIDDLE, L. and HORI, T. 1983. The use of fluorescence staining to study nucleus development in the multinucleate dasycladalean green algae. Jap. J. Phycol. 31 : 173-179.

Numbers and sizes of nuclei were established for vegetative and reproductive regions of the large cells of the three multinucleate siphonous algae, *Cymopolia van bossei*, *Halicoryne wrightii* and *Bornetella sphaerica* (Chlorophyceae, Dasycladales). Nuclei were treated with 4, 6 diamidino-2-phenylindole (DAPI) which, when combined with DNA, fluoresces under ultraviolet light. All species were characterized by having a variety of size classes of nuclei in the central siphons, and single large nuclei which migrate from the siphon into the putative gametangia where, through subsequent divisions, 1000's of small gametic nuclei are formed. DAPI staining is a useful tool to study nuclei in a variety of cell types, one of the most unusual of which is illustrated by the multinucleate members of the Dasycladales.

Key Index Words: *DAPI-staining*; *Dasycladales*; *fluorescence staining*; *nucleus development*; *siphonous green algae.*

Nucleus development in association with thallus differentiation and sexual reproduction in members of the Dasycladales has been studied in *Acetabularia* (BERGER *et al.* 1975, GREEN 1975, KOOP 1979 and SPRING *et al.* 1978), *Batophora* (LIDDLE *et al.* 1976) and *Cymopolia* (LIDDLE *et al.* 1982). However, even in these genera meaningful details are lacking. In the uninucleate *Acetabularia* and *Batophora* different stages of nuclear development have been described from light and electron microscopic observations (BERGER *et al.* 1975 and LIDDLE *et al.* 1976) and critical stages which affect the ploidy of nuclei such as mitosis and meiosis have been ovserved. Recently the site of meiosis has bee verified in *Acetabularia* by electron microscopy, genetic analysis and direct observations (KOOP 1979). In *Batophora* synaptonemal complexes were observed in the mature primary nuclei shortly before they divided to form the smaller, morphologically simpler secondary nuclei (LIDDLE *et al.* 1976).

The multinucleate members of the Dasycladales have been studied very little. Certain features of nucleus development have been reported for *Cymopolia barbata* (LIDDLE *et al.* 1982, WERZ 1953) but mitosis and meiosis are still not understood in this or any of the multinucleate genera. The siphonous structure and complex morphology of these organisms offer unique mechanical problems of distribution, localization, development and division of nuclei. In *Cymopolia* the heterogeneous population of nuclei in the large central siphon includes characteristic nuclei that migrate into lateral branches to localize in the putative gametangia (LIDDLE *et al.* 1982). One nucleus is established in each gametangium.

Electron microscopy has been an inefficient tool to study siphonous cells, which can reach lengths up to 26 cm., because of their large central vacuoles, the relatively small amount of cytoplasm and the vast amount

of cell wall material that defines several, often lime-encrusted, compartments of the thallus. Staining with DNA-specific fluorescent dyes is a useful technique that can be applied to study nuclei during differentiation (COLEMAN 1982). Stained nuclei in cytoplasm which has been expressed from the central siphon and other structures of the thalli of giant unicellular green algae can be readily counted to estimate their population sizes. Also, the sizes of individual nuclei and the intensity of their fluorescence as a function of the amount of DNA per nucleus can be measured accurately. The purpose of this preliminary study is to assess nucleus development in several genera of the Dasycladales in order to understand the basic processes which nuclei undergo during cellular differentiation.

Materials and Methods

Cymopolia van bossei SOLMS (Fig. 1) was collected from Amami-oshima and Okinawa

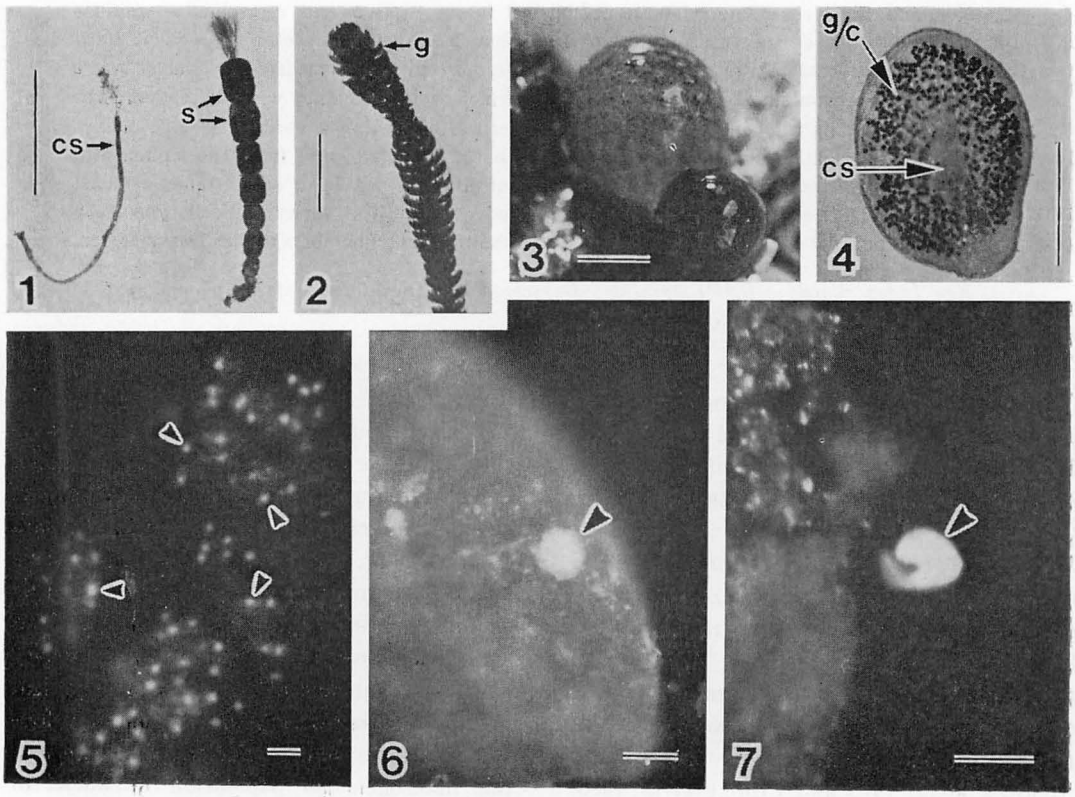


Fig. 1. *Cymopolia van bossei* SOLMS. Whole plant. Left: central siphon (c. s.) with segments (s) stripped off. Right: intact plant. Scale=1 cm.

Fig. 2. *Halicoryne wrightii* HARV. Upper part of whole plant. Lateral gametangia (g) can be removed to bare central siphon. Scale=1 cm.

Figs. 3 and 4. *Bornetella sphaerica* SOLMS. Whole plants. Fig. 3. Scale=0.5 cm. Fig. 4. Mid-longitudinal section. c. s.=central siphon, g/c=Gametangia with cysts. Scale=0.5 cm.

Fig. 5. Cytoplasm from central siphon of *C. van bossei*. DAPI-stained nuclei (arrows). Scale =10 μm.

Fig. 6. Young gametangium of *C. van bossei*. DAPI-stained single nucleus (arrow). Scale= 10 μm.

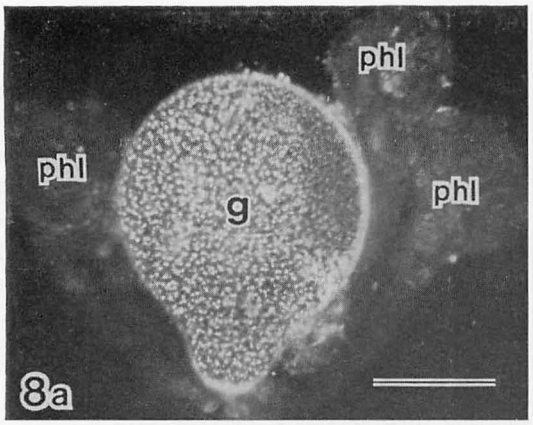
Fig. 7. Cytoplasm of young gametangium of *C. van bossei*. Single nucleus (arrow). Scale= 10 μm.

Islands throughout the year. *Halicoryne wrightii* HARVEY (Fig. 2) and *Bornetella sphaerica* SOLMS (Figs. 3, 4) were collected or sent sporadically from both islands. Plants were maintained in sterile seawater at 24°C under a 14 : 10 LD cycle with ca. 2000 lux illumination from cool white fluorescent bulbs or in an aerated aquarium at room temperature (20-25°C) under constant cool white fluorescent illumination of ca. 1500 lux.

Central siphons, cysts and gametangia were isolated from healthy thalli by gently stripping off the whorls of laterals (Fig. 1). The cytoplasm was pressed out from the cut ends of fragments or whole siphons into a drop of seawater. Cysts and gametangia were washed repeatedly to remove lime and cell wall debris. If they were calcified as in *Halicoryne*, the cysts were rapidly rinsed in sterile seawater acidified with acetic acide to pH 5.7 in order to dissolve heavy calcification without damage. Cytoplasm or whole

Table 1. Fluorescens of nuclei of *Cymopolia*, *Halicoryne* and *Bornetella* in fluorescence units (F.U.).

Source of nuclei	No. of thalli	Mean size of nucleus (μm in dia.)	Mean no. of nuclei	F.U. (Mean)	F.U. (Range)
Cymopolia van bossei					
Central siphon	20		252		
Apical	16	10.0	25	3.9	3.0-5.0
		5.0	64	2.4	2.0-3.1
		2.5	34	1.8	1.5-2.0
Middle	20	10.0	9	3.9	3.0-5.0
		5.0	28	2.4	2.0-3.1
		2.5	71	1.8	1.5-2.0
Base	15	5.0	6	2.4	2.0-3.1
		2.5	15	1.8	1.5-2.1
		1.75	3	1.6	1.5-1.8
Gametangia					
Young	20	10.0	1	3.6	3.0-4.6
Intermediate	10	5.0	112	2.5	2.1-3.1
		2.5	300	1.7	1.5-2.2
Mature	15	1.25	1180	1.1	0.9-1.2
Halicoryne wrightii					
Central siphon	7	10.0	20	3.7	2.9-4.6
		7.0	192	3.2	2.8-4.0
Gametangia					
Young	10	12.5	1	4.0	3.6-4.1
Mature	9	1.25	2000	1.0	0.9-1.2
Bornetella sphaerica					
Central siphon	10	10.0	10	3.8	3.0-5.0
		5.0	72	2.5	2.1-3.0
		3.5	20	2.0	1.7-2.2
		2.5	90	1.7	1.4-1.5
Gametangia					
Young	0				
Intermediate	15	5.0	240	2.6	2.1-2.9
Mature	8	1.25	1800	1.0	0.8-1.1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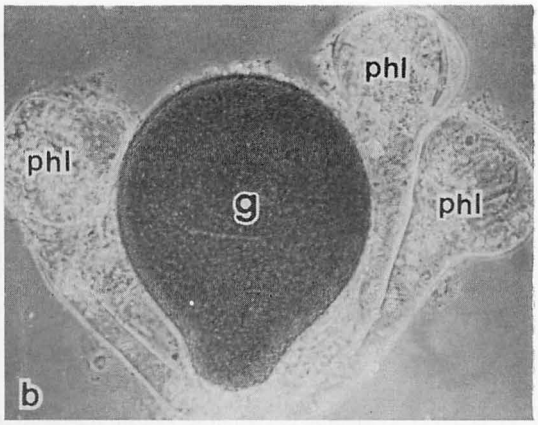
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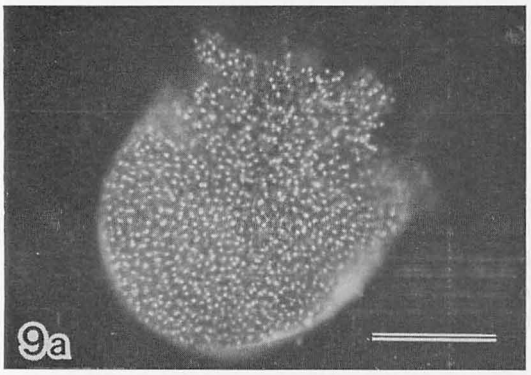
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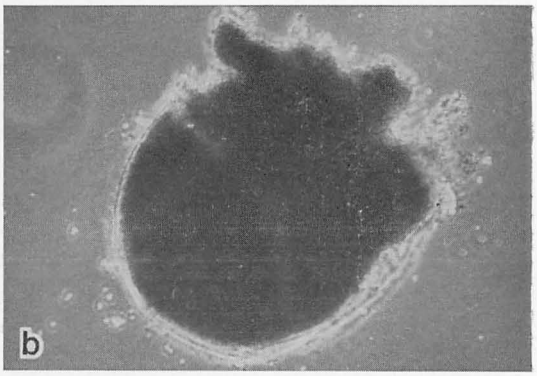
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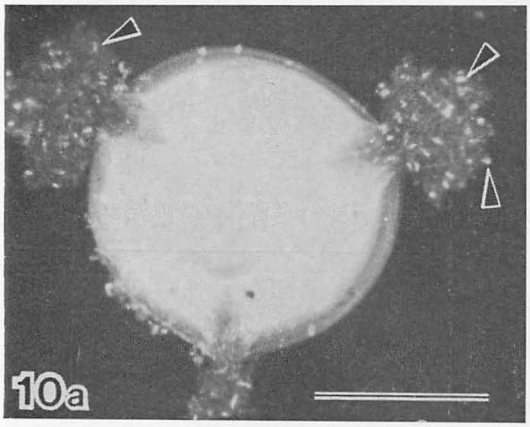
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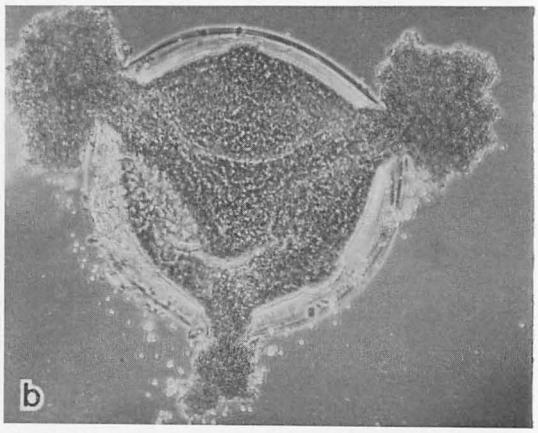
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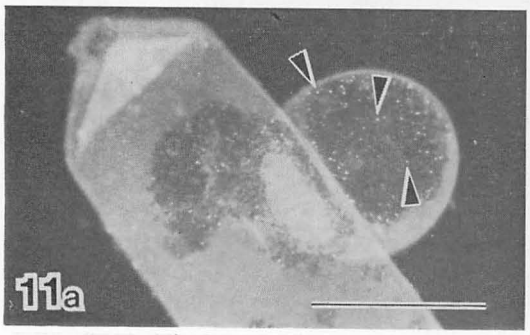
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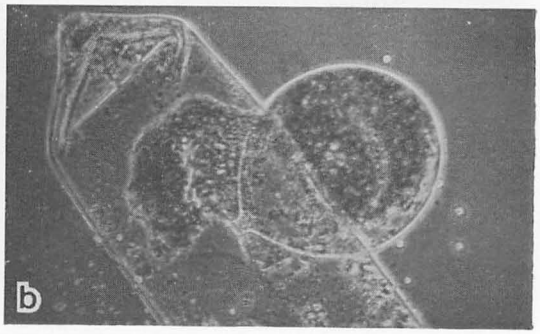
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cysts and gametangia in seawater were stained with an equal volume of 50 μg/ml DAPI (4, 6 diamidino-2-phenylindole) in S buffer (COLEMAN 1982) to a final concentration of 25 μg/ml. Slightly higher or lower concentrations of DAPI did not affect the fluorescence characteristics of the nuclei. Acid and alcohol-cleaned coverslips were used to contain suspensions of stained cytoplasm on clean glass slides or a haemocytometer.

The preparations were observed by using a Zeiss photomicrosope equipped with phase optics and an epi-illumination system which emitted an excitation beam of approximately 360 nm from an HBO 100 W Hg lamp. Fluorescence was measured by a Zeiss microspectrophotometer system which included a Hamamatsu Photomultiplier attached to a Zonax computer and printer. A range of sizes of measuring diaphragms permitted rapid measurement of fluorescence from various types of nuclei. Comparisons were frequently made with the fluorescence of healthy cultures of *Chlamydomonas sp.* To check for irregularities that might be caused by differences in stain concentration or other factors. Fluorescene of the background nearby the nuclei was subtracted from nucleus reading which were taken immediately after being exposed to excitation illumination.

Photographs were made from Kodak Tri-X using a Zeiss M35 motordriven camera with a Zeiss MC63 automatic exposure meter.

Results

Nuclei of specific size classes were localized in the various compartments of the thallus (Table 1). They were distributed throughout the central siphon of *Cymopolia van bossei* with a decrease in numbers from the apex to the base. Also the size classes of nuclei were differentially distributed. The apical region contained a higher proportion of 10 μm dia. nuclei than the middle and basal regions which contained a higher proportion of 5 and 2.5 μm dia. nuclei (Fig. 5). A single nucleus in a gametangium was also 10 μm in diameter (Figs. 6, 7). After division and just prior to gamete liberation the numerous gametangial nuclei were 1.25 μm dia. (Figs. 8a, 9a). Intermediate stages of gametangial development (Figs. 10, 11) contained nuclei of larger sizes. Each successive division of the original single gametangia nucleus resulted in a smaller product. At any point in gametangial development nuclei were markedly homogeneous in size. The fluorescent DNA content was correlated with nucleus size. Large 10 μm nuclei emitted ca. 4 fluorescent units and 1.25 μm nuclei ca. 1 fluorescent unit.

Nuclei of the central siphon of *Halicoryne wrightii* were also distributed in a decreasing apico-basal gradient although there were strikingly few in the cytoplasm of the basal one half. Sizes were also more homogeneous with two size classes, 7 μm and 10 μm dia., predominating. Mature gametangial nuclei were 1.3 μm dia. prior to gamete liberation (Table 1). The single progenitor nucleus of

Figs. 8a and b. Reproductive unit of *C. van bossei*. a. Fluorescence photograph; b. Phase contrast photograph. g=mature gametangium, phl=photosynthetic lateral, DAPI-stained nuclei are distributed throughout the gametangium. Scale=100 μm.

Figs. 9a and b. Cytoplasm of mature gametangium of *C. van bossei*. a. Fluorescent photograph. DAPI-stained nuclei are distributed throughout the cytoplasm; b. Phase contrast photograph. Scale=100 μm.

Figs. 10a and b. *H. wrightii*. Double-walled gametangium and cyst in intermediate stage. Cytoplasm being exuded. a. Fluorescence photograph. DAPI-stained nuclei (arrows); b. Phase contrast photograph. Scale 25 μm.

Figs. 11a and b. *B. sphaerica*. Young gametangium before cyst formation. a. Fluorescence photograph. DAPI-stained nuclei (arrow); b. Phase contrast photograph. DAPI-stained nuclei (arrows). Scale=50 μm.

cyts/gametangia was 12.5 μm in diameter. Approximately 2000 nuclei were formed in a mature gametangium. Similar patterns exist for *Bornetella sphaerica*, except, due to the short central siphon, it was not technically possible to make differential counts from the apex to the base. However, 2.5, 5 and 10 μm dia. nuclei were present in the cytoplasm with a lower percentage of 10 μm ones. A mature gametangium contained ca. 1800 nuclei 1.25 μm dia. (Fig. 6).

Nuclei in all species were usually oval to sphaerical although some *Cymopolia* apical regions contained decidedly spindle-shaped nuclei 2.5 μm long as well as other irregular shapes. Presumably these nuclei were undergoing synchronous division. Nuclei were in general sparsely distributed in the cytoplasm of the siphon or evenly spaced in the gametangia (Figs. 5, 8a, 9a, 10a, 11a). However, frequently in all three species nuclei were in clumps of 5-10 in the central siphon. These may have been post-division.

Discussion

The multinucleate species of the Dasycladales seem to conform to a general pattern of a limited variety of sizes of nuclei in the central siphon, large nuclei that migrate into putative gametangia and a standard (1.25 μm dia.) nucleus in the gametes. If measurements of fluorescence of DAPI-stained nuclei are extrapolated to represent amounts of DNA and further to ploidy of nuclei, the general pattern appears to be diploid and polyploid nuclei streaming throughout the siphon, a polyploid nucleus being transported to presumptive gametangia and haploid (by definition) nuclei being formed during gametogenesis. The variety of nucleus sizes can be interpreted as being stages in the formation of large (10-12 μm dia.) nuclei or self-replicating products of nuclei which were established early from the single zygote nucleus. It is clear that multinucleate species of the Dasycladales have mechanisms of nucleus continuity and distribution unique among all organisms. The usual dogma of nuclear and "cell" cycle does not interpret the patterns observed in the giant cells of *Cymopolia*, *Halicoryne* and *Bornetella*. Further investigations of nucleus development beginning with zygotes are required to characterize nuclear cycles.

Acknowledgements

The authors wish to express their thanks to Professor Mitsuo CHIHARA for his encouragement and for the use of facilities, to Dr. Yoshiaki HARA and Mr. Takeo HORIGUCHI for their useful technical advice and assistance and to Drs. Sachito ENOMOTO, Kobe University, Shintoku KAMURA, Ryukyu University, and Takaaki KOBARA, Senshu University and Mr. Hidenobu ISA, Ryukyu University, for providing specimens and advice on collecting.

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L. B. リドル*・堀　輝三: 緑藻類，カサノリ目の多核種における核分化の研究のための蛍光染色法の有用性**

緑藻，カサノリ目に属する種の多核管状種，*Cymopolia van bossei*, *Halicoryne wrightii*, *Bornetella sphaerica*, について，その栄養体および生殖器官にみられる核の数とサイズの変化を測定観察した。核の DNA を DAPI で染色し，紫外線励起蛍光を観察した。調査した全ての種で，中心管状部はいろいろなサイズの核を含む特徴がみられた。また，将来配偶子嚢になる部分には，中心管状部から移動した大きな核が存在する。それらは後に分裂して千個以上の小核になる。DAPI 染色法はいろいろな細胞タイプの核の研究に有用であり，そのことを最も特異な細胞タイプの一つであるカサノリ目の多核種で示した。(* ロングアイランド大学サウザンプトン・カレッジ，ニューヨーク，** 茨城県新治郡桜村天王台 1-1-1，筑波大学生物科学系)

Jap. J. Phycol. (Sôrui) 31 : 180-189. September 20, 1983

The life history of *Ahnfeltia concinna* J. AGARDH (Rhodophyta, Gigartinales) from Japan[1),2)]

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MASUDA, M. 1983. The life history of *Ahnfeltia concinna* J. AGARDH (Rhodophyta, Gigartinales) from Japan. Jap. J. Phycol. 31 : 180-189.

The life history of the red alga *Ahnfeltia concinna* J. AGARDH from Japan was completed in laboratory culture. Carpospores from field plants germinated to form crustose thalli. The crustose thalli bore 2-8 tetrasporangial nemathecia which bulged from the thallus surface. Intercalary tetrasporangia were formed in 2-3 successive cells of a single filament of the nemathecia. Tetrasporelings gave rise to basal discs from which upright axes developed. The upright axes became fertile before producing branches and formed spermatangia and procarps on separate plants. They continued to grow into dichotomously divided thalli similar in morphology to field plants. Spermatangia were formed in a sorus and released cylindrical spermatia. Procarps were formed in groups and each consisted of a large supporting cell, a three-celled carpogonial branch and a sterile cell. Excised vegetative apices from single field male and female plants grew well and formed reproductive structures in a manner similar to that of plants derived from tetraspores. Female plants bore cystocarps only when crossed with male plants and discharged viable carpospores through carpostomes.

Key Index Words: Ahnfeltia; A. concinna; *crustose tetrasporophyte*; *nemathecia*; *Gigartinales*; *life history*; *Phyllophoraceae*; *Rhodophyta*; *taxonomy*.

MAGRUDER (1977) described the life history of *Ahnfeltia concinna* J. AGARDH (Phyllophoraceae) from Hawaii. It involves the alternation of upright dioecious gametophytes with a crustose tetrasporophyte which forms intercalary catenate tetrasporangia in distinct sori. On west coast of the Pacific *A. concinna* has been recorded from various localities of middle to southern Japan (OKAMURA 1936). Female gametophytes with cystocarps were described by OKAMURA (1922) and MIKAMI (1965), but male gametophytes and tetrasporophytes have not been reported yet. INOH (1947) found that upright axis primordia were differentiated from carposporelings of Japanese *A. concinna*. This suggested that the alga has a direct-type of life history. The present study was conducted to clarify the life history of *A. concinna* growing in Japan and to compare it with that of the Hawaiian *A. concinna* as reported by MAGRUDER (1977).

Materials and Methods

Female plants with mature cystocarps and male plants with spermatangia were collected at Susaki (34°39′N 138°58′E), Shimoda, Shizuoka Pref. on August 2, 1980 and on April 3, 1981 and at Jogashima (35°08′N 139°38′E), Kanagawa Pref. on February 20, 1982. Carpospores were isolated into unialgal

1) This study was supported in part by a Grant-in-Aid for Scientific Research (Nos. 448018 and 57123115) from the Ministry of Education, Science and Culture, Japan.

2) Dedicated to Professor Munenao KUROGI on the occasion of his retirement.

culture using Susaki material collected on August 2, 1980 (culture nos. 653 and 654) according to methods reported for *Neodilsea crispata* (MASUDA 1973). Reproductively sterile apices of branches of female and male plants for Susaki material (nos. 666 male, 667 female, 841 male, 842 male, 843 female and 844 female) and Jogashima material (nos. 1183 female, 1184 male, 1185 male, 1186 male and 1187 female) were cleaned by Kimwipe tissues, excised about 200 μm long with a scalpel (Feather No. 15) and were introduced individually into screw cap tubes (18 mm×135 mm) containing 10 ml of PES medium. Two months after inoculation clean apices were transferred to culture vessels (65 mm×80 mm) containing 200 ml of medium.

The cultures were placed in plant growth chambers illuminated with cool-white fluorescent lamps (2500–3000 lux). The temperatures and photoperiods were regulated in the following combinations: 15°C, 16:8 LD (light and dark cycle); 15°C, 8:16 LD; 20°C, 16:8 LD and 20°C, 8:16 LD. Mixed cultures of mature female and male plants were placed on a Taiyo R-II Rotary Shaker at 90–100 rpm.

Microscopic examinations were done chiefly on living material and also sometimes on material preserved in 70% ethyl alcohol. Sections were made by hand using a straight-edge razor and pith stick and stained with 0.5% (w/v) cotton blue in a lactic acid/phenol/glycerol/water (1:1:1:1) solution. Voucher specimens are deposited in the Herbarium of Faculty of Science, Hokkaido University, Sapporo (SAP 032220–032225). Stock cultures of male (653, 666 and 1186) and female (653, 667 and 1187) are maintained in a plant growth chamber at the Center for Experimental Plants and Animals of Hokkaido University.

Results

Carpospore culture: Liberated carpospores are globular, light red in color and measure 15–20 μm in diameter (Fig. 1, A). They were first cultured at 15°C, 16:8 LD and 20°C, 16:8 LD. They attached to the substrate and divided into two cells within 2 days (Fig. 1, B). The vast majority of these cells then divided successively and formed circular crusts (Fig. 1, D–E). However, some of these bore a filamentous outgrowth (Fig. 1, C) which eventually formed crusts. The crusts grew both concentrically by a marginal meristem and upward in the central portion. They reached 300–600 μm in diameter at 15°C, 16:8 LD and 680–1150 μm in diameter at 20°C, 16:8 LD 1 month after initiation. Most formed 10–18 colorless hairs from the superficial cells during this period. These hairs were 150–500 μm in length and 5–6 μm in diameter near the proximal portion. Each of one month old cultures grown at 15°C, 16:8 LD and 20°C, 16:8 LD was divided into two groups; one group was shifted to 15°C, 8:16 LD and 20°C, 8:16 LD and the other group was maintained at 15°C, 16:8 LD and 20°C, 16:8 LD. The crusts grew well under all the culture conditions attempted and the cuticular surface peeled off but was repeatedly regenerated as did cultured foliose thalli of *Gigartina johnstonii* DAWSON (WEST and GUIRY 1982).

The crusts reached reproductive maturity and formed tetrasporangial nemathecia at 20°C, 16:8 LD (Fig. 1, F) 4 months after initiation, at 15°C, 16:8 LD (Fig. 1, G) and 20°C, 8:16 LD for 5 months after initiation, and at 15°C, 8:16 LD 9 months after initiation. The fertile crusts were 7–19 mm in diameter and 80–110 μm in thickness in the center. They were composed of a monostromatic hypothallus, which consisted of radiating filaments, and a polystromatic perithallus, which consisted of coalescent erect filamets (Fig. 1, I-J; 2, A-B). The perithallus was composed of 11–14 cell-layers at the center of the crust. Erect filaments of the perithallus were dichotomously divided (Fig. 2, A-B) and the cells of adjacent filaments were frequently connected by secondary pit plugs (Fig. 2, A-B).

Two to eight nemathecia were formed

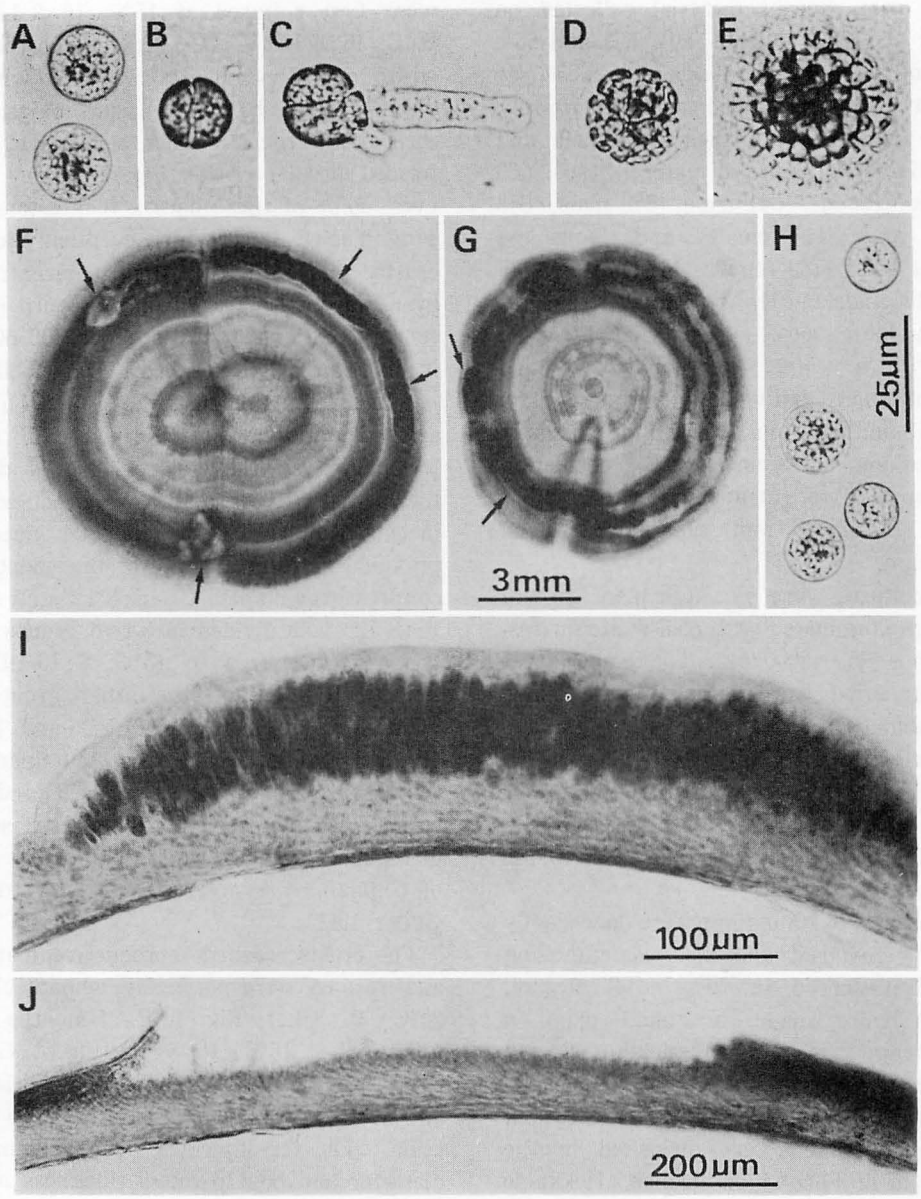


Fig. 1. Carpospores and cultured tetrasporophytes of *Ahnfeltia concinna*. A. Carpospores from a field-collected plant. B–E. Carposporelings grown at 20°C, 16 : 8 LD (culture no. 653) : B, two days old; C–D, five days old; E, ten days old. F–G. Fertile tetrasporangial crusts bearing nemathecia (arrows) : F, two coalescent crusts (4 months old) grown at 20°C, 16 : 8 LD (no. 653) ; G, five months old crust grown at 15°C, 16 : 8 LD (no. 654). H. Released tetraspores from crusts shown in F. I–J. Radial sections of crusts shown in F, indicating the nemathecium before spore release (I) and that after spore release (J). Scale in G applies also to F; scale in H applies also to A–E.

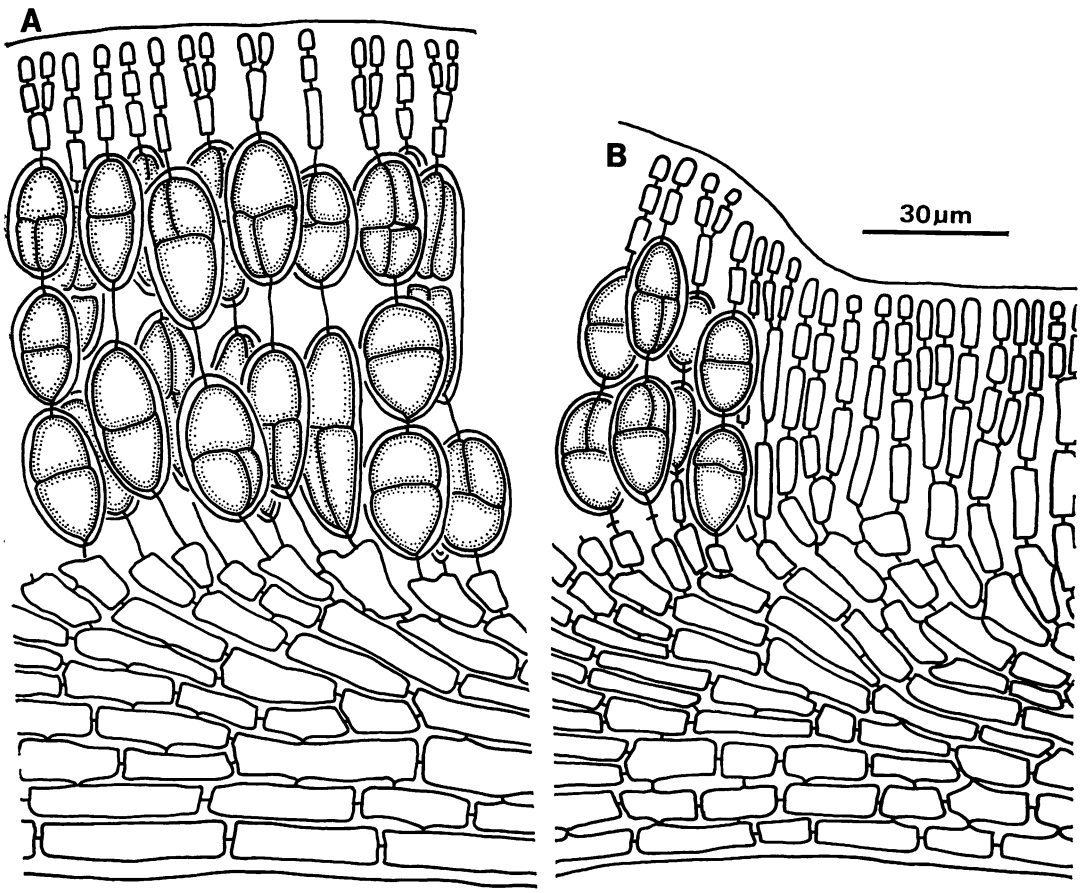


Fig. 2. Cultured tetrasporophyte of *Ahnfeltia concinna*. A-B. Radial section of a crust shown in Fig. 1, F through a nemathecium: A, central portion of the nemathecium; B, marginal portion of the nemathecium.

along a marginal concentric ring of eachcrust (Fig. 1, F-G). The majority of the nemathecia were almost circular to elliptical and 550-1400 μm in diameter. Some nemathecia were band-shaped and 5-15 mm long and 800-1400 μm wide. These band-shaped nemathecia were commonly formed on the crusts grown at 20°C, 16:8 LD (Fig. 1, F). The nemathecia were 130-200 μm thick in the center. Intercalary tetrasporangia were formed on the erect filaments of the nemathecia (Fig. 2, A-B). They were formed in 2-3 successive cells of a single filament. The terminal 2-4 cell-rows of fertile filaments remained sterile. Some of the cell-rows were branched dichotomously as were those of the Hawaiian alga (MAGRUDER 1977, Fig. 13). These sterile cells became paler in color as the tetrasporangia developed. Mature tetrasporangia were ellipsoid, 37.5-42.5 μm long and 17.5-22.5 μm wide, and divided cruciately. The tetrasporangia of each nemathecium released tetraspores almost synchronously. The tetraspores were slightly smaller than the parent carpospores at 12.5-16.3 μm in diameter (Fig. 1, H). After the spore release, the nemathecium disintegrated leaving the lower vegetative portion (Fig. 1, J).

Tetraspore culture: Tetraspores from cultured plants were grown at 15°C, 16:8 LD and 20°C, 16:8 LD. They germinated and grew into discoid thalli in a manner similar to that of carpospores described above (Fig. 3, A-C). After 3 months they

reached 4-6 mm in diameter and began to produce upright axes in a concentric ring (Fig. 3, D). The sructure of the basal discs was similar to that of the tetrasporophytic crusts. The upright axes became fertile before producing branches and formed spermatangia and procarps on separate plants 5 months after germination.

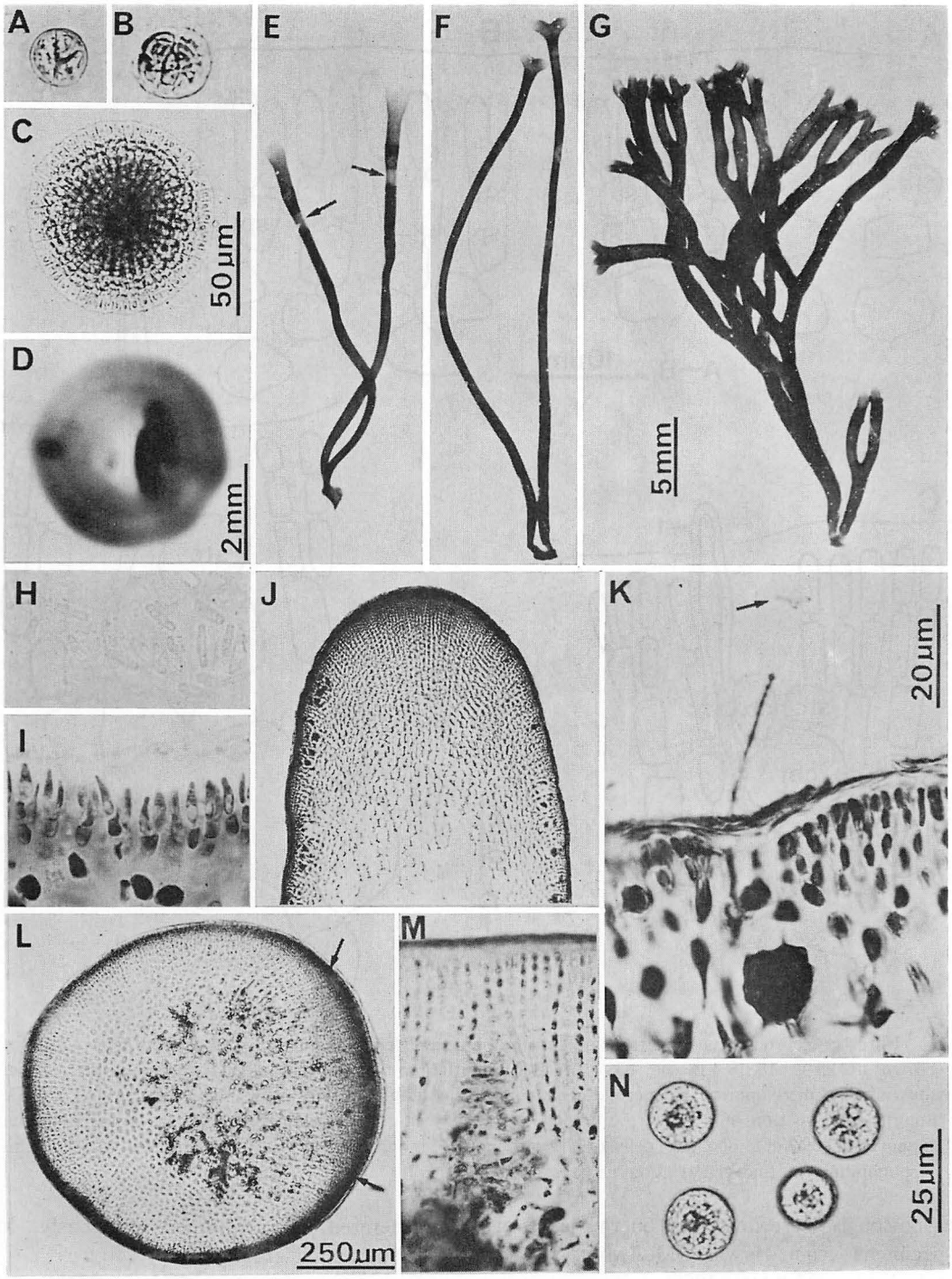
Some tetrasporelings grew into spherical masses of cells with a few rhizoidal filaments or without any rhizoidal filaments. None of these sporelings formed a marginal meristem. The sporelings attached loosely to the substrate and with the slightest mechanical disturbance they became free from the substrate. They developed single upright thalli. One month old upright thalli reached 300-500 μm in length and 190-220 μm in diameter (Fig. 5, A). They formed spermatangia and procarps on separate plants (Fig. 5, B-C) 3 months after germination. Both the detached and attached male and female thalli grew into dichotomously branched terete thalli, which were similar in morphology to those of field plants, while continuing to form reproductive structures on their upper portions. However, the upright thalli showed a somewhat different morphology according to temperature. The thalli grown at 15°C, 16: 8 LD (Fig. 3, G) were thicker and much more branched than those grown at 20°C, 16:8 LD (Fig. 3, E-F). Of 80 detached and attached plants cultured from single tetraspores, 38 were male and 42 were female.

Spermatangia were formed in a sorus near the branch apex of male thalli. One or two spermatangia were produced from a single spermatangial parent cell (Fig. 3, I; 4, A-B). Spermatia were released forming an opaque, white cloud around the sorus. The spermatia were cylindrical, 6.4-15.0 μm in length and 2.4-3.8 μm in diameter (Fig. 3, H). After release of spermatia, the sorus became paler in color than the vegetative parts and showed a banded appearance (Fig. 3, E).

Procarps were borne within the cortex near the branch apex of female thalli (Fig. 3, J). The procarps were formed in groups and each procarp consisted of a large supporting cell and a three-celled carpogonial branch. A single sterile cell was borne on the first cell of the carpogonial branch (Fig. 4, C-D) as in field plants of this species (MIKAMI 1965).

Isolated female plants did not produce cystocarps. After starting mixed cultures of female thalli with numerous procarps and male thalli with numerous spermatia on a shaker, the spermatium attached to the trichogyne (Fig. 3, K). After the trichogyne degenerated, many gonimoblast filaments issued from the supporting cell, which functioned as an auxiliary cell, and grew inward through the medulla (MAGRUDER 1977). The cortex around the fertilized procarp became thicker (Fig. 3, L). Mature cystocarps appeared on all the females after 1 month at 20°C, 16:8 LD and discharged viable carpospores (Fig. 3, N) which gave rise to crustose thalli. The cystocarps were provided with specialized pores (carpostomes) in the thickened cortex (Fig. 3, M) through which carpospores were discharged. The

Fig. 3. Cultured gametophytes of *Ahnfeltia concinna* (no. 653). A-D. Tetrasporelings grown at 20°C, 16: 8 LD: A, two days old; B, four days old; C, eighteen days old; D, three months old one issuring upright axes. E-G. Twelve months old fertile gametophytes: E, male plant grown at 20°C, 16: 8 LD (arrows indicate band-shaped spermatangial sori after release of spermatia); F, female plant grown at 20°C, 16: 8 LD; G, female plant grown at 15°C, 16: 8 LD. H. Released spermatia. I. Longitudinal section through a spermatangial sorus, showing a single layer of elongated spermatangia. J. Longitudinal section of a branch apex of a female plant, showing procarps stained with cotton blue. K. Longitudinal section of a procarpic branch, showing fertilization between a trichogyne and a spermatium (arrow). L. Cross section of a cystocarp (arrows indicate the thickened cortex). M. Carpostome formed in the thickened cortex. N. Released carpospores. Scale in C applies also to M; Scale in G applies also to E-F; scale in L applies also to J; scale in N applies also to A-B and H-I.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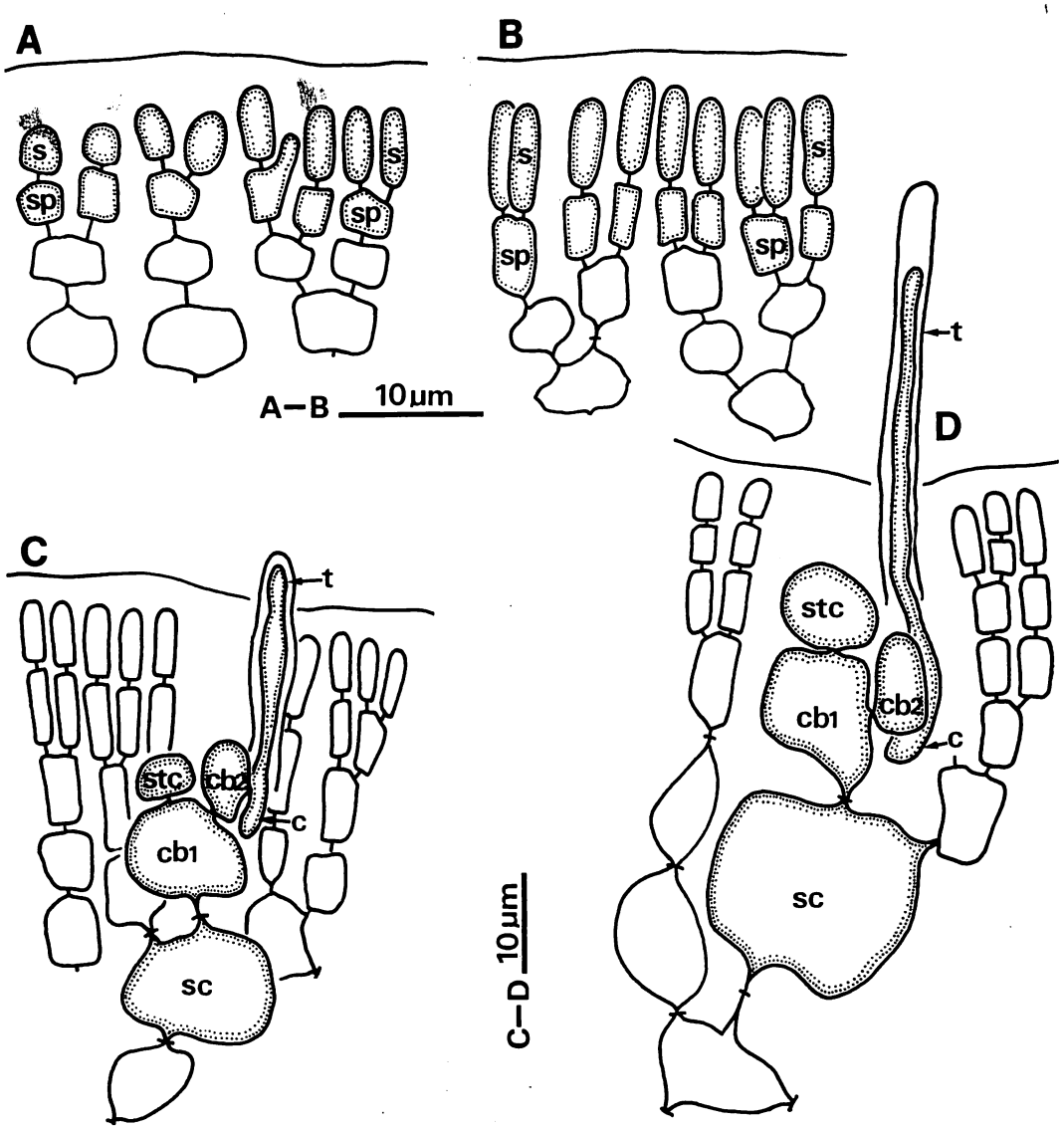

Fig. 4. Reproductive structures of cultured male and female gametophytes of *Ahnfeltia concinna* grown at 20°C, 16: 8 LD (no. 653). A-B. Longitudinal section through a spermatangial sorus, showing the development of spermatangia (sp, spermatangial parent cell; s, spermatangium). C-D. Longitudinal section of a procarpic branch, showing young (C) and mature (D) procarps; note the supporting cell (sc), the two cells of the carpogonial branch (cb_1 and cb_2), the sterile cell (stc), the carpogonium (c) and the trichogyne (t).

carpostomes were described on the basis of specimens from Hawaii (MCFADDEN 1911) and Japan (MIKAMI 1965). However, no cystocarp development was observed on the females mixed with males at 15°C, 16:8 LD for 2 months. On upright thalli and basal discs of all cultured plants the cuticular surface peeled off and it was repeatedly regenerated as mentioned previously for tetrasporangial crusts.

Branch apex culture of gametophytes: Excised vegetative apices of branches were first cultured at 15°C, 16:8 LD. Two-month-old cultures were divided into two groups and grown at 15°C, 16:8 LD and 20°C, 16:8 LD. One month later the

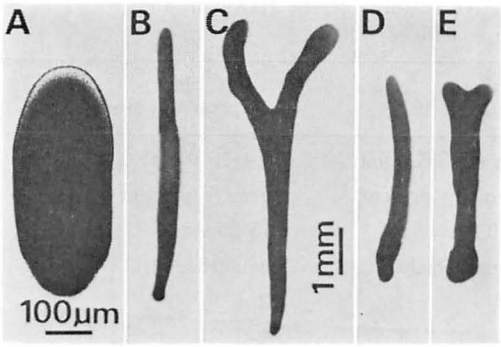

Fig. 5. Cultured gametophytes of *Ahnfeltia concinna*. A-C. Plants derived from spherical masses of cells, which originated from single tetraspores, and grown at 20°C, 16 : 8 LD (no. 653) : A, one month old tetrasporeling issuing a single upright axis; B, three and a half months old male thallus; C, three and a half months old female thallus. D-E. Three months old plants derived from excised apices of branches grown at 15°C, 16 : 8 LD : D, male thallus (no. 666) ; E, female thallus (no. 667). Scale in C applies also to B and D-E.

majority of the plants reached reproductive maturity under both regimes before producing branches and formed spermatangia and procarps on separate individuals (Fig. 5, D-E). They grew into dichotomously branched thalli in a manner similar to that of plants derived from tetraspores. All female isolates (Susaki 667, 843 and 844; Jogashima 1183 and 1187) did not produce cystocarps when they were separated from male isolates. These female isolates were crossed with male isolates derived from branch apices (Susaki 666, 841 and 842; Jogashima 1184, 1185 and 1186). Cystocarps were formed on all females of the 30 attempted crosses using these 5 female and 6 male isolates and viable carpospores were discharged within 1 month at 20°C, 16 : 8 LD.

Discussion

The life history of *Ahnfeltia concinna* studied here involves the alternation of upright dioecious gametophytes with a crustose tetrasporophyte. INOH (1947) described upright axis primordia which were differentiated from 7-day-old carposporelings of *A. concinna* collected from Shikine Island situated about 45 km to the southeast of Susaki, Shimoda. This suggests that some local populations of this species may recycle directly without bearing crustose tetrasporophytes. Further life-history studies of *A. concinna* from other localities including Shikine Island are needed to elucidate this problem.

The observed life-history pattern is similar to that reported for the Hawaiian *A. concinna* (MAGRUDER 1977). However, the following two morphological features of the alga under study do not coincide with those of the Hawaiian *A. concinna*, although other quantitative features listed in Table 1 and gross morphological features of gametophytes are similar. The procarp of the Japanese alga always possesses a single sterile cell which was "not normally present" on the procarp of Hawaiian alga (MAGRUDER 1977, p. 199). The sterile cell has been found on the carpogonial branch of several species of the Phyllophoraceae : *Ahnfeltia gracilis* (YAMADA) YAMADA et MIKAMI (MIKAMI 1965), *A. yamadae* (SEGAWA) MIKAMI (MIKAMI 1965), *A. gigartinoides* J. AGARDH (DECEW, WEST and MASUDA, unpubl.), *A. paradoxa* (SURINGAR) OKAMURA (MASUDA unpubl.), *Gymnogongrus linearis* (C. AGARDH) J. AGARDH (DOUBT 1935), *G. flabelliformis* HARVEY (TOKIDA and MASAKI 1959, MIKAMI 1965, MASUDA 1981), *G. crustiforme* DAWSON (WEST, DECEW and MASUDA unpubl.), *Stenogramme interrupta* (C. AGARDH) MONTAGNE (KYLIN 1956) and *Phyllophora antarctica* A. et E. S. GEPP (MILLER pers. comm.). This seems to be a characteristic feature of the Phyllophoraceae or at least of the species group including *A. concinna*. Further investigation of the procarps of the Hawaiian *A. concinna* is needed. The tetrasporangia of the Japanese *A. concinna* are formed in nemathecia bulging from the thallus surface, whereas those of the Hawaiian alga are embedded in the thallus. Whether or not tetrasporangial sori are

Table 1. A comparison of some reproductive features of the Hawaiian and Japanese *Ahnfeltia concinna*.

	Hawaii (MAGRUDER 1977)	Japan (present author)
Size of spermatia (length × diameter)	8-14 μm × 3.5-5.0 μm	6.4-15.0 μm × 2.4-3.8 μm
Sterile cell on carpogonial branch	not normally present	always present
Size of carpospores (diameter)	9.5-18.0 μm	15-20 μm
Tetrasporangial sorus	non-nemathecial	nemathecial
Number of sterile cap cell-rows	2-4	2-4
Number of tetrasporangia in series	2-4	2-3
Size of tetraspores (diameter)	9.5-18.0 μm	12.5-16.3 μm

nemathecial is of considerable taxonomic significance at the species level (MASUDA *et al.* 1979). On the basis of this difference it may be reasonable to segregate the Japanese alga from *A. concinna* of which the type collection was made from the Hawaiian Islands (C. AGARDH 1822, J. AGARDH 1847). Of the *Ahnfeltia* species, *A. gigartinoides* seems to be most closely allied to *A. concinna*. YENDO (1916) stated that the type specimens of both species were hardly separable one from the other. *A. gigartinoides* from Mexico possesses a crustose tetrasporophyte which bears intercalary tetrasporangia in nemathecia (DECEW, WEST and MASUDA unpubl. cf. MASUDA *et al.* 1977, p. 71). The tetrasporangia of *A. gigartinoides* are fewer and smaller than those of *A. concinna*, 1-2 sporangia on each fertile filament and 18-39 μm long and 8-13 μm wide (cf. Table 1). The elucidation of the taxonomic relationship between the Hawaiian and Japanese *A. concinna* and the Mexican *A. gigartinoides* must await further detailed investigations, including hybridization experiments.

The tetrasporophytes of *Ahnfeltia concinna*, whether or not their tetrasporangial sori are nemathecial, are characterized by the production of catenate cruciate tetrasporangia which originate from intercalary cells of the erect filaments and distinguished from those of *A. plicata* (HUDSON) FRIES, the type species of the genus, which form single zonate tetrasporangia terminally on the erect filaments (FARNHAM and FLETCHER 1976, CHEN 1977). Upright thalli of *A. plicata* bear "monosporangia", which are probably equivalent to carposporangia, in external pustule-like nemathecia (ROSENVINGE 1931, GREGORY 1934, SCHOTTER 1968, FARNHAM and FLETCHER 1976). However, those of *A. concinna* produce internal cystocarps with carpostomes. These fundamental differences are of taxonomic significance at the generic level. Taxonomic revision of the genus *Ahnfeltia* is needed. The establishment of a new genus to accommodate *A. concinna* will be proposed by DECEW and SILVA (pers. comm.) at a later date (cf. SILVA 1979).

Acknowledgements

I am deeply indebted to Professor Munenao KUROGI, Hokkaido University, for his criticism of the manuscript. I wish to acknowledge Dr. Michael D. GUIRY, University College, Galway, for his reading of the manuscript and his helpful suggestions. I am also grateful to Dr. Yasutsugu YOKOHAMA, Shimoda Marine Research Center, The University of Tsukuba, for his help in collecting materials and to Dr. Paul C. SILVA, Dr. John A. WEST and Dr. Thomas C. DECEW, University of California, Berkeley, for helpful discussions.

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増田道夫：日本産サイミ（紅藻スギノリ目）の生活史

サイミの果胞子と枝の先端部から培養を行い生活史を調査した。果胞子は発芽して殻状の四分胞子体になり，その表面に隆起したネマテシアを数個形成した。四分胞子嚢はネマテシア内の直立糸に 2-3 個連続して介生的に形成された。四分胞子の発芽体は雌雄異株の配偶体に生長し，精子嚢とプロカルプを生じた。プロカルプには1個の sterile cell が認められた。配偶体は生殖器官の形成を続けながら生長し，分枝した個体は天然産のそれによく似た形態を示した。枝の先端部の培養からも同様な生長を行う雌雄の配偶体が得られた。雌性配偶体は雄性配偶体と交配した時にのみ嚢果を形成し，果胞子を放出した。日本産のサイミはハワイ産のそれとはネマテシアを形成すること，及びプロカルプに sterile cell が存在することで異なり，今後両者の詳細な比較検討が必要である。(060 札幌市北区北10条西8丁目　北海道大学理学部植物学教室)

藻類 Jap. J. Phycol. 31: 190-195. September 20, 1983

ホンダワラ類の初期形態形成に関する研究—IV フタエモク[1)]

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TERAWAKI, T.*, NOZAWA, K.** and SHINMURA, I.*** 1983. Studies on morphogenesis in the early stages of *Sargassum* (Phaeophyceae, Fucales). IV. *Sargassum duplicatum*. Jap. J. Phycol. 31: 190-195.

This paper presents morphogenesis in the early stages of *Sargassum duplicatum* cultured in the sea. Embryos developed the first primary leaf which was subcylindrical in shape. When plants attaind about 2 cm in total length, primary leaf became dichotomous to alternate-pinnate with deeply dentate margin. These primary leaves were arranged spirally on the stem, and older ones fell off successively. When plants attained about 3 cm in total length, main branches were developed in spiral arrangement at the top of the stem. Later, primary leaves changed to rarely divided shapes with sharply serrate to double serrate margin. Leaves were formed alternately at apex of main branches. Leaves were spatulate to ovate in shape with sharply serrate and duplicate margin, and clearly different from primary leaf. When total length of plants reached 20 cm, lateral branches and vesicles were observed on main branches. Plants attained its maturity in 12 months.

Key Index Words: *Fucales*; *growth*; *morphogenesis*; *Phaeophyceae*; Sargassum; Sargassum duplicatum.
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著者らは，褐藻・ホンダワラ属のマメタワラ *Sargassum piluliferum* (TURNER) C. AGARDH (寺脇他 1982)，ヤツマタモク *S. patens* C. AGARDH (寺脇他 1983) およびアカモク *S. horneri* (TURNER) C. AGARDH (寺脇他 1983) の初期形態形成について報告し，アカモクでは他2種と比較し特異的であることを明らかにした。今回は *Eusargassum* 亜属に分類されているフタエモク *S. duplicatum* J. AGARDH について報告する。

材料と方法

培養方法および観察方法は前報 (寺脇他 1982) と同じ要領で行なった。

母藻は昭和54年7月6日に，薩摩半島南部の坊津町久志で採集したフタエモクで，多数の生殖器床を備えていた。採集した母藻を大型クーラーで保冷し，鹿児島県水産試験場へ持ち帰った。7月11日，幼胚を養殖網へピペットで採苗後4トン水槽で育苗し，7月20日 (採苗後9日) その養殖網を坊津町久志地先へ沖出しして海中養殖を開始した。

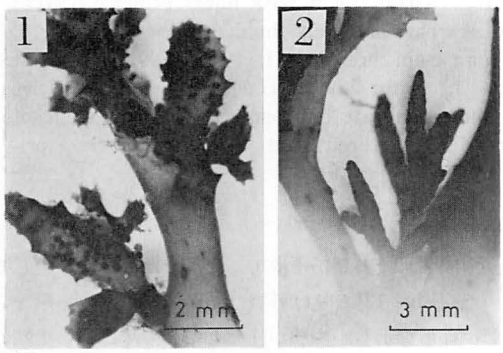
結果

母藻の特徴：母藻は黄褐色で全長約 70 cm に達す

1) 本論文は寺脇の鹿児島大学大学院修士論文の一部である。

る。付着器は盤状で，表面が平滑である。付着器から1本の直立する円柱状の茎を生じ，その頂端部から数本の主枝を各方向に発出する。主枝はやや扁圧し，幅 3 mm 程度で，2～4 cm 間隔に葉および側枝を互生する。側枝は主枝とほぼ同様の形態を示す。葉は倒卵形ないしへら形で，長さ 2.5 cm，幅 1 cm に達し，短柄を有し，膜質で，基部が不均斉，先端部が鈍頭で，縁辺に二重の鋸歯がある。中肋が半ばで消失する。毛巣が散在している。気胞は球形ないし卵形で，長さ 1 cm，直径 1 cm に達し，円頭または翼状突起を有し，やや扁圧した短柄を有する。雌雄異株。生殖器床は葉腋に形成され，数回分岐している。雌性生殖器床は長さ 5 mm に達し，扁圧して両縁に薄く，一方が隆起して三稜形を示すものもあり，縁辺に刺ないし歯状突起を有する (Fig. 1)。雄性生殖器床は長さ 8 mm に達し，円柱状で小刺を有し，雌性生殖器床より多少長い (Fig. 2)。

培養経過：採苗後の生長経過を Fig. 3 に示した。7月11日には幼胚の下端から約16本の第1次仮根が伸出していた (Fig. 4)。幼胚の30個体平均の大きさは 262(±20)×205(±16) μm であった。採苗後のタンク内育苗は，施設の制約等もあって，光，温度，流水量等に関して，必ずしも適正条件を満たしたものではなかったが，5日後 1.1 mm に達した。7月20日の沖出し後は順調な生長を示し，9月下旬に 1.5 cm に達した。その後，葉体の損傷や減少，生長停滞が認められ，魚類による食害と推察されたため，11月9日に瀬々串漁場へ移植した。移植後は生長を回復したが，9～11月に得られた試料のほとんどは先端の切れた不完全なものであった。翌年7月2日には最大 42 cm に達し，生殖器床を有する藻体が観察された。7月下旬以降は，主枝の基部を残して流失し，一方，若い主枝の萌出が



Figs. 1 and 2. 1. Female receptacle with embryos; 2. Male receptacle.

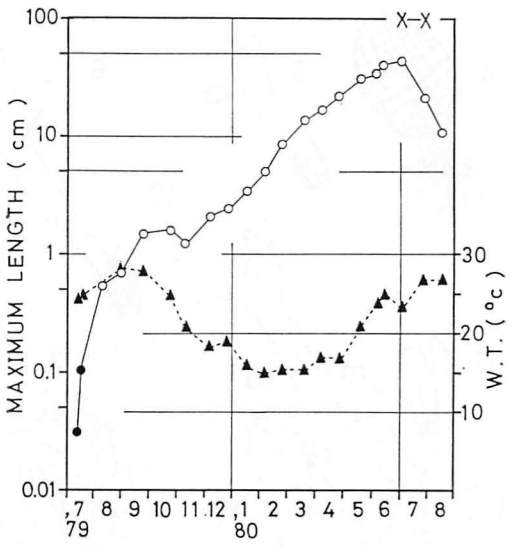


Fig. 3. Growth of *Sargassum duplicatum*. ●-●: cultured in the tank. ○-○: cultured in the sea. ×-×: receptacle formation. ▲-▲: water temerature.

認められ，2年目の生長期に入った。

観察結果：生長経過における長さ別の形態的特徴は，概略以下の通りであった。

全長約 1 mm：第1初期葉の形態は，やや扁圧した円柱形で，葉幅が 0.2 mm 程度であった (Figs. 5, 17)。

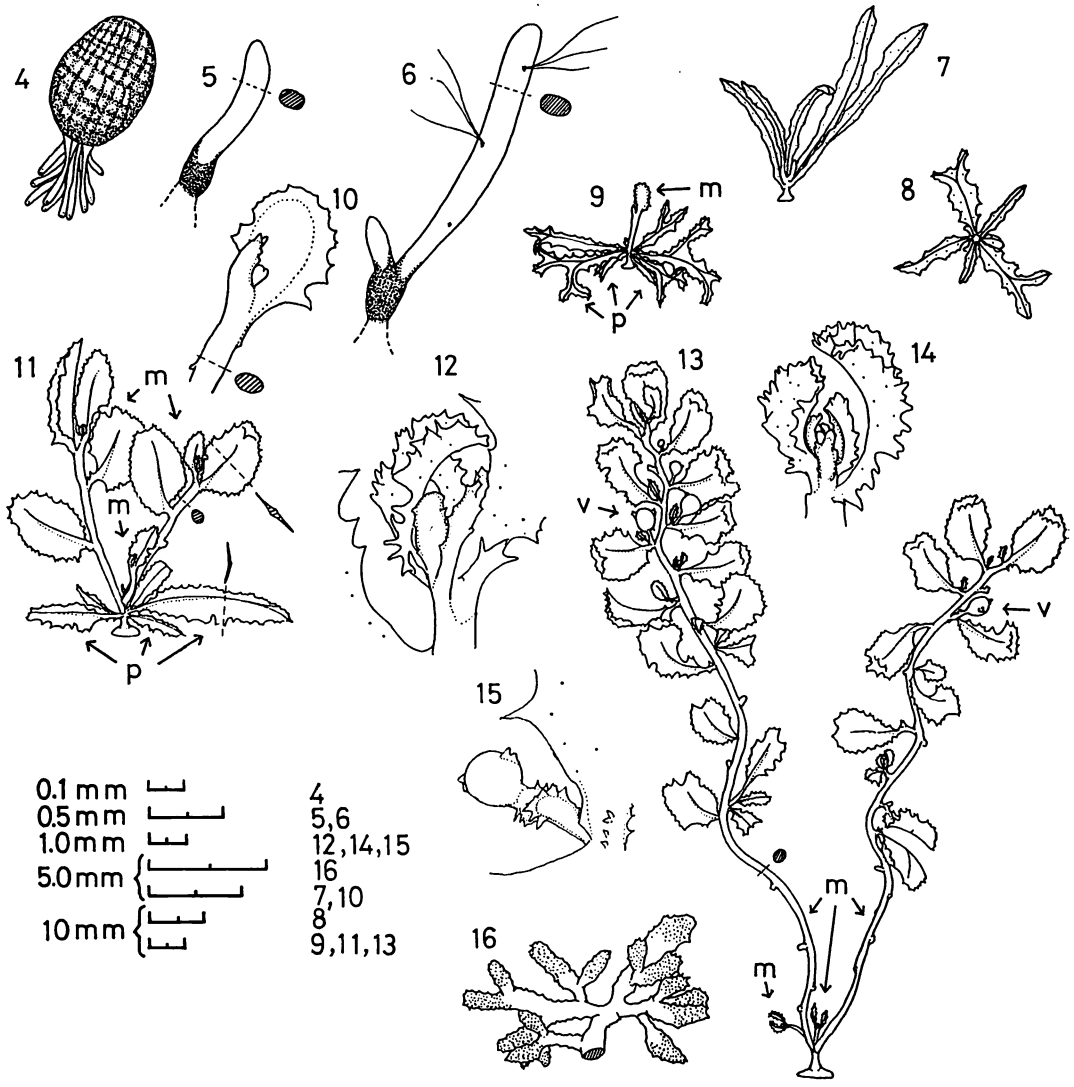
全長 2～3 mm：第1初期葉は，幅 0.2～0.3 mm の円柱形であり，その基部付近から第2初期葉が形成され始めていた (Figs. 6, 18)。

以後，全長の伸長に伴い糸状ないし線形で単条の初期葉が，茎上にらせん状に形成され，葉数が増加した。第2初期葉以降では，次第に中肋が明らかになった。

全長約 1 cm：6～7 枚の初期葉を備えているものがみられ，初期葉は葉幅 0.8～1.2 mm の線形で，縁辺が波状を呈していた (Figs. 7, 19)。

全長約 2 cm：叉状ないし互生羽状に分裂する初期葉が茎上部から形成されており，多いもので7～8枚であった (Figs. 8, 20)。それらは縁辺が深い歯状を呈し，中肋が裂片の先端近くまで明らかであった。一方，茎下部には線形で単条の初期葉がみられ，更に下部の茎面には葉痕が残っていた。

全長約 3 cm：初期葉は互生羽状に分裂し，裂片の最大幅が 2～4 mm で，縁辺の鋸歯が鋭く明瞭になっていた (Fig. 9)。茎の先端から主枝が形成され始めた。主枝はやや扁圧した円柱形で，先端に葉芽を備えていたので，初期葉とは容易に区別できた (Figs.



Figs. 4-16. Morphogenesis of *Sargassum duplicatum*. 4. Embryo with short rhizoids detached from receptacle; 5. Five days old plant after sowing, development of first primary leaf; 6. After 30 days, first primary leaf and bud of second one; 7. After 76 days, plant with linear primary leaves; 8. After 149 days, development of dichotomously to alternate-pinnately divided primary leaves; 9. After 190 days, development of main branch; 10. Young main branch; 11. After 299 days, plant with three main branches; 12. Apex of main branch; 13. After 289 days, development of vesicles and duplicate leaves; 14. Apex of main branch with some duplicate leaf buds; 15. Young stage of vesicle with small winglike spines; 16. Female receptacle of cultured plant. Main branch (m); primary leaf (p); vesicle (v).

10, 21)。

全長 5～10 cm：初期葉は広線形ないし披針形を呈し，分裂の少ないものが多くなり，長さ 4～5 cm，幅 1 cm 程度に達し，縁辺に鋭い鋸歯と，所々に細かな重鋸歯を有していた (Figs. 11, 22)。主枝は 2～3 条形成され，表面が平滑で，先端では葉芽が互生していた (Fig. 12)。葉は膜質ないし肉質で，へら形ないし倒卵形を示し，中肋が隆起して葉の半ばから先端付近まで達し，葉自体がゆるやかに波打っていた。葉は縁辺が鋭い歯状ないし鋸歯状を呈し，葉の先端の鋸歯

が外側へ開き，凹みの観察されるものもみられた。

全長約 20 cm：ほとんど全ての初期葉が脱落し果て，茎の高さは 5～10 mm となっていた(Figs. 13, 23)。主枝は3～4条で，次々と形成される様子がうかがえた。主枝上部の葉は，先端がらっぱ状に開く形態を示し，主枝先端の長さ 3～4 mm の葉芽でも，その傾向を示していた (Figs. 14, 24)。一方，主枝下部の葉は脱落し，その基部が残っていた。葉腋には気胞が形成され，気胞は球形で，直径 1～2 mm の形成初期のものも既に翼状突起を備えているのが観察された (Fig. 15)。

以上のように，全長約 20 cm に達したものは，生殖器床を除けば母藻の有する形質を表わしていた。その後，養殖によって全長約 40 cm に達する試料まで得られた。それらは，葉腋から主枝先端部と同形の側枝を伸長させた。7月に，これら養殖藻体に生殖器床が形成され，その形態 (Figs. 16, 25) が母藻のそれと一致し，フタエモクであることが確認された。一方，付着器は多数の仮根が束状ないし塊状に癒合して形成された。本種の付着器は表面が平滑な盤状であるが，全長の伸長につれ養殖網を包み込むように発達し，全長約 40 cm の試料では，着生基質の 4.2 mm ロープを，ほぼ一周していた。

考　　察

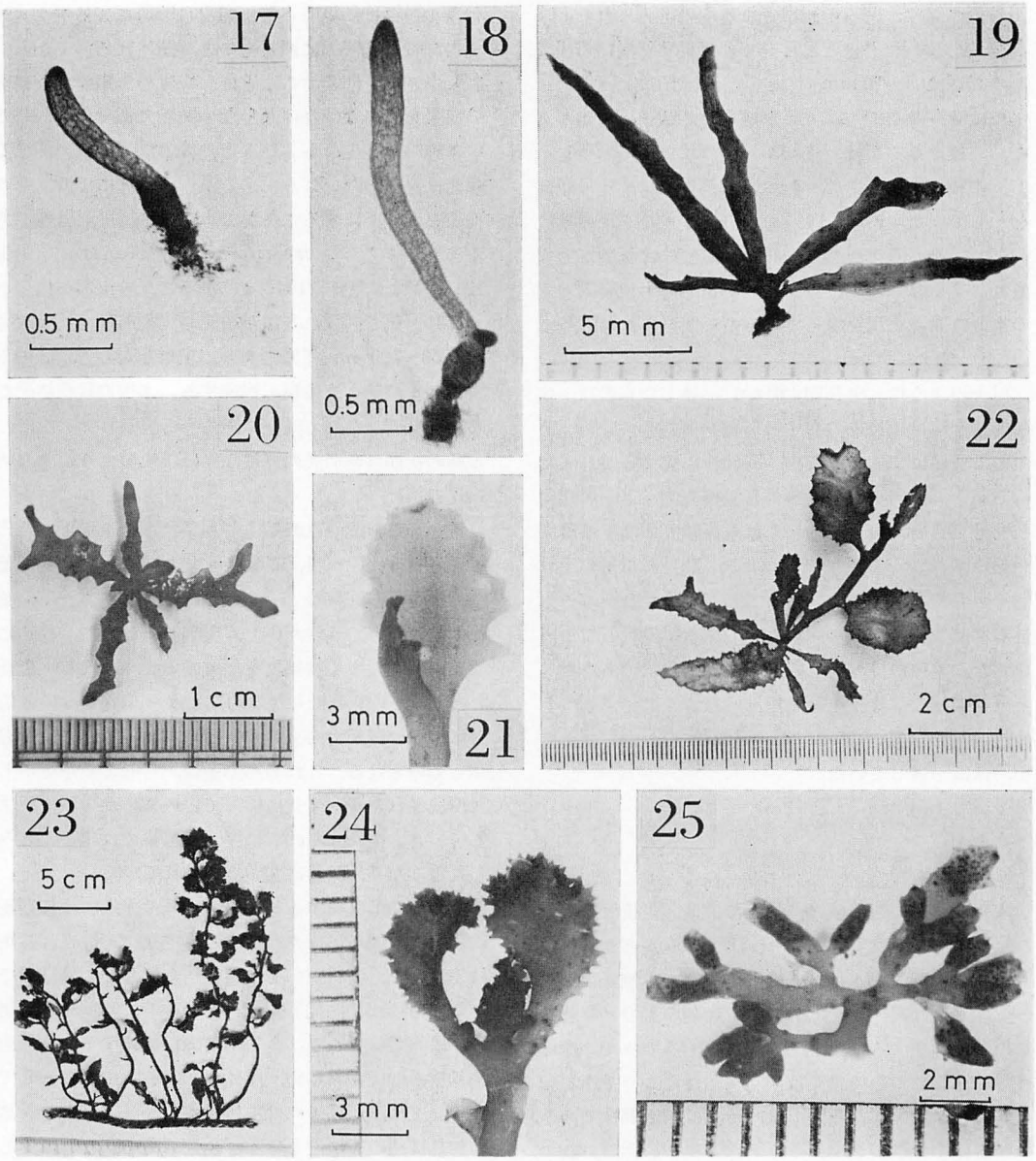
本研究に用いた母藻は，付着器，茎，主枝，葉および気胞の形態がフタエモク (岡村 1956) とよく一致した。しかし，フタエモクについては，生殖器床が同一個体または同一枝上においても無刺のものと有刺のものとが混在する (岡村 1956) とあるのみで，雌雄性等の詳細については記載が見当らないようである。これに対し，調べた範囲では，母藻は雌雄異株であり，生殖器床の特徴がナンカイモク *S. sandei* Reinbold (Yamada 1950) のそれとよく一致した。一方，ナンカイモクは，付着器が仮盤状で，茎に疣々を有することもあり，全縁の葉が混在し，葉の先端が稀に二重になる (Yamada 1950) 点が，母藻と異なっていた。いずれにしろ，本邦に産するフタエモク，ナンカイモクおよびその近縁な種類に関しては，分類学的研究が未だ不充分であり，生殖器床の特徴についてもトサカモク *S. cristaefolium* C. Agardh (岡村 1956)，フタエヒイラギモク *S. ilicifolium* var. *conduplicatum* Grunow (山田 1942b) 等明らかにされていない種が多いようである。以上の点などから，本研究に用いた母藻の特徴は，現時点では岡村(1956)によるフタエモクの記載の範囲内にあるものと判断される。しかし，これを正しく同定することは，今後の分類学的な研究の成果を待たなければならない問題であると思われる。

本種の胚発生，および，その後の形態形成に関する報告は見当らないようであるが，本研究により，その概要を明らかにすることができた。本種の近縁種であるアツバモク *S. crassifolium* J. Agardh (山田 1942a) は，猪野 (1947) によると，放出卵が他のホンダワラ属と同様に8核が散在し，楕円形で，大きさが 260×190 μm 程度であり，正常なもので幼胚の下端に16本の第1次仮根を形成する。本種の観察結果からも，ほぼ，それと同様であろうと思われた。次に，本種の初期形態形成の特徴は，ほぼ次のようにまとめられる。

幼胚から形成された第1初期葉は，やや扁圧した円柱形であった。以後，単条で糸状ないし線形の初期葉を形成するが，全長 1～2 cm に達すると，次第に葉幅が広くなり，叉状ないし互生羽状に分裂し，縁辺に深い歯状を呈する初期葉を形成するようになる。全長 5～10 cm に達したものの初期葉は，広線形ないし披針形で，分裂が少なくなり，縁辺に鋸歯や重鋸歯を有するものとなる。これら初期葉は，らせん葉序を示して形成されるが，生長に伴って古いものから順次脱落していき，全長 20 cm に達したものではほとんどみられなくなり，次第に茎が形成されていく。

全長 3 cm に達するころから，茎の先端には初期葉に代って主枝が形成され始める。主枝に形成される葉は，互生し，膜質ないし肉質のへら形ないし倒卵形で，先端がらっぱ状に開く形態へと発達し，初期葉とは明らかに異なっている。全長 20 cm に達すると，気胞や側枝が形成され始め，成体の形態的特徴を表わしてくる。主枝の形成後には主枝の伸長が旺盛であり，茎の伸長は極めて緩慢となる。全長 30～40 cm に達した個体の茎の高さは 1 cm 以下である。

本種の初期形態形成の過程，すなわち，第1初期葉がやや扁圧した円柱形であること，その後，単条または分裂する初期葉が茎上にらせん状に形成された後に主枝が形成されること，主枝に形成される葉が互生することなどの一連の過程は，マメタワラ(寺脇他 1982)のそれと同様の傾向を示している。本種とマメタワラとの相違点として，マメタワラでは主枝に形成される葉と，分裂する初期葉とが形態的に類似しているのに対し，本種ではそれらの形態が明らかに異なっている点があげられる。また，本種では，単条の後に分裂す



Figs. 17–25. Morphogenesis of *Sargassum duplicatum*. 17. After 5 days, development of first primary leaf; 18. After 30 days, first primary leaf and bud of second one; 19. After 76 days, plant with linear primary leaves; 20. After 149 days, development of dichotomously to alternate-pinnately divided primary leaves; 21. Young main branch; 22. After 211 days, plant with two main branches; 23. After 289 days; 24. Apex of main branch with some duplicate leaf buds; 25. Female receptacle of cultured plant.

る初期葉が形成されるが，主枝が形成され始めると，葉幅が広く分裂の少ない初期葉となる傾向が認められた。ヤツマタモク（寺脇他 1983）では，第1初期葉の形態にやや疑問が残るものの，主枝を形成するまでの過程は本種とよく類似している。ただ，ヤツマタモクでは，主枝が扁圧し，その両縁から分裂する葉を二列互生する点が本種と異なっている。以上のように，マメタワラ，ヤツマタモクおよび本種の3種間には，主枝形成までの過程および，主枝形成後に茎の伸長が緩慢になる点に3種の共通性が認められた。

一方，アカモク（寺脇他 1983）の場合は，第1葉がやや扁圧した円柱形を示して形成され，以後，分裂する葉が茎上にらせん状に形成される点では，上記3種と同様の傾向を示すが，その後，茎が大きく伸長し続け，側枝のみが葉腋から形成される点で異なっている。

終りに，御校閲をいただいた北海道大学理学部助教授吉田忠生博士に厚くお礼を申し上げる。また，本研究の発表の機会を与えられ御配慮をいただいた電力中央研究所生物研究所長中村宏博士および同水域部長下茂繁博士に謝意を表する。

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ホンダワラ類の初期形態形成に関する研究—V コブクロモク[1)]

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TERAWAKI, T.*, NOZAWA, K.** and SHINMURA, I.*** 1983. Studies on morphogenesis in the early stages of *Sargassum* (Phaeophyceae, Fucales). V. *Sargassum crispifolium*. Jap. J. Phycol. 31: 196-201.

This paper deals with morphogenensis in the early stages of *Sargassum crispifolium* cultured in the sea. Embryos developed into the first primary leaf which was subcylindrical in shape. When plants attained about 2 cm in length, primary leaves became divided once or twice with undulate margin. These primary leaves were arranged spirally on the stem, and the older ones fell off successively. When plants attained about 3 cm in length, main branches developed in spiral succession on top of the stem. Leaves were formed alternately at the apex of main branches. Leaves were linear to lanceolate in shape with minutely dentate and crispate margin, and clearly different from primary leaves. When the length of plants reached 20 cm, lateral branches and vesicles were observed on main branches.

Key Index Words: *Fucales*; *growth*; *morphogenesis*; *Phaeophyceae*; Sargassum; Sargassum crispifolium.
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著者らはホンダワラ類の初期形態形成に関して研究中であるが，その一部についてはすでに報告した。すなわち，マメタワラ *Sargassum piluliferum* (TURNER) C. AGARDH (寺脇ら 1982)，ヤツマタモク *S. patens* C. AGARDH (寺脇ら 1983) およびフタエモク *S. duplicatum* J. AGARDH (寺脇ら 1983) では，幼胚から単条の初期葉が数枚形成され，続いて分裂する初期葉が数枚形成された後に，茎の先端から主枝が形成される。また，初期葉および主枝が茎上にらせん状に配列されていること，そして，主枝形成後には茎の伸長が緩慢になることなどの一連の過程が同様の傾向を示すことを明らかにした。一方，アカモク *S. horneri* (TURNER) C. AGARDH では，茎が大きく伸長し続けること，また，茎先端から主枝が形成されることはなく，葉腋から側枝のみが形成されることなどの特異性を示すことも明らかにした。(寺脇ら 1983) 今回は，フタエモク同様に *Eusargassum* 亜属に分類されているコブクロモク *S. crispifolium* YAMADA について報告する。

1) 本論文は寺脇の鹿児島大学大学院修士論文の一部である。

材料と方法

培養方法および観察方法は前報 (寺脇ら 1982) と同じ要領で行なった。

母藻は昭和54年7月6日に，薩摩半島南部の坊津町久志漁港内に漂っていた寄り藻の中から採集したコブクロモクで，多数の生殖器床を備えていた。採集した母藻を大型クーラーで保冷し，鹿児島県水産試験場へ持ち帰り，水槽内で流水培養を行なった。母藻は7月12日に卵を放出した。翌7月13日，受精卵を集め，ピ

ペットで養殖網へまきつけた後，4トン水槽で育苗し，7月20日（採苗後7日）その養殖網を坊津町久志地先へ沖出しして，海中養殖を開始した。

結　　果

母藻の特徴：母藻は全長約 40 cm に達し，黄褐色で，付着器が小さな盤状である。付着器から直立する1本の円柱状の茎を生じ，その頂端部から数本の主枝を各方向に発出する。主枝はやや扁圧し，幅 3 mm 程度で，平滑であり，1～3 cm 間隔に葉および側枝を互生する。側枝は，主枝とをほぼ同様の形態を示す。葉は線形ないし披針形で，長さ 6 cm，葉幅 1.2 cm に達し，短柄を有し，膜質で，基部が不均斉，先端の鋭いものが多く，縁辺が歯状を呈し，中肋が先端近くまで明らかで，毛巣が散在している。気胞は球形ないし倒卵形で，長さ 1 cm に達し，平滑な円頭で，短柄を有する。雌雄同株で，生殖器床は葉腋に形成され（Fig. 1），長さ 5 mm に達し，数回分岐し，やや扁圧した円柱状で，稀に小刺を有しており（Fig. 2），よく発達したものでは，巣孔部を中心とした盛り上がりが認められた。

培養経過：採苗後の生経過を Fig. 3 に示した。放出卵は8核が散在しており，楕円形ないし卵形を示し（Fig. 4），30個体平均の大きさが 258(±28)×204(±23) μm であった。採苗5日後には，幼胚の下端から約16本の第1次仮根が伸出していた（Fig. 5）。採苗後のタンク内育苗は，施設の制約等もあって，光，温度，流水量等に関して，必ずしも適正条件を満たしたものではなかったが，5日後 0.8 mm に達した。7月20日の沖出し後は順調な生長を示し，9月下旬に 1.4 cm に達した。その後，葉体の損傷や減少，生長停滞が認められ，魚類による食害と推察されたため，11月9日に瀬々串漁場へ移植した。移植後には生長をやや回復したが，10～11月には先端の切れた不完全な試料が多かったうえに，それ以降には芽減りが顕著となって，形態観察に用いられる試料が少なかった。翌年7月2日に最大 20 cm に達し，その後，主枝の基部を残して藻体が流失する一方，若い主枝の萌出が認められ，2年目の生長期に入った。

観察結果：生長経過における長さ別の形態的特徴は，概略以下の通りであった。

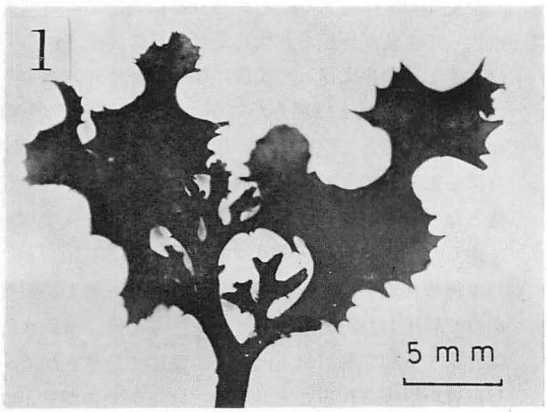
全長約 1 mm：第1初期葉の形態は，やや扁圧した円柱形で，葉幅が 0.2 mm 程度であった（Figs. 5, 16）。

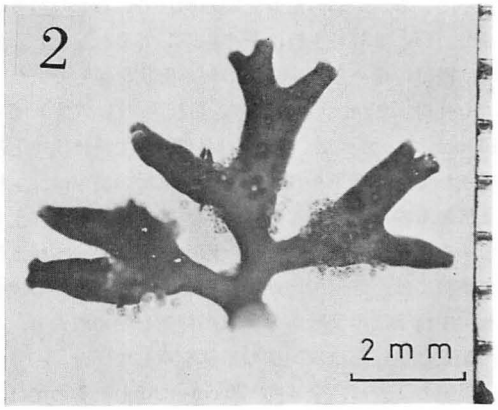
全長 2～3 mm：第1初期葉は葉幅が 0.2～0.3 mm の円柱形で，その基部付近から第2初期葉が形成され始めていた（Figs. 6, 17）。

以後，全長の伸長に伴い糸状ないし線形で単条の初期葉が，茎上にらせん状に形成され，葉数が増加した。第2初期葉以降では，次第に中肋が明らかになった。

全長約 1cm：初期葉は単条の糸状ないし線形で，葉幅が 0.5～0.8 mm であった（Fig. 7）。

全長約 2 cm：叉状に分裂する初期葉が茎上部から形成され始めているもの（Figs. 8, 18）から，1～2回分裂する初期葉を有するもの（Figs. 9, 19）までみられ，初期葉数は多いもので7～8枚であった。分裂





Figs. 1 and 2. 1. Receptacles developed from leaf axil; 2. Receptacle with released eggs.

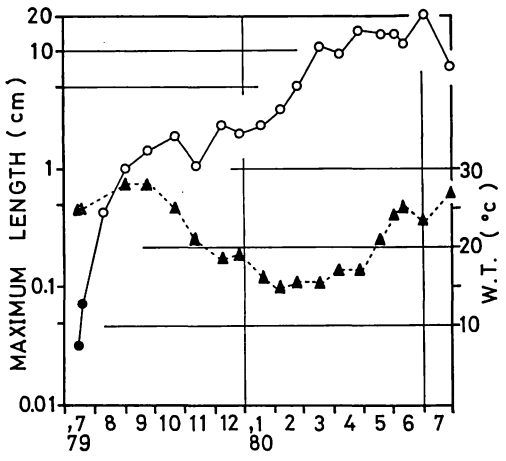


Fig. 3. Growth of *Sargassum crispifolium*. ●-●: cultured in the tank. ○-○: cultured in the sea. ▲-▲: water temperature.

する初期葉は，縁辺がやや波状を呈し，中肋が裂片の先端近くまで明らかであった。

全長約 3 cm: 初期葉は多くのものが先端の切れたものであったが，1～2回分裂し，裂片の最大幅が2～3 mm で，縁辺の波状が強くなっていた (Figs. 10, 20)。茎の先端から主枝が形成され始めていた。主枝はやや扁圧した円柱状で，先端に葉芽を備えていたので，初期葉とは容易に区別できた (Figs. 11, 21)。

全長約 5 cm: 初期葉は長さ約 3 cm，裂片の最大幅 4～5 mm となっていた (Figs. 12, 22)。一方，主枝は2～4条形成され，表面が平滑なやや扁圧した円柱状であった。葉は披針形ないしへら形で，中肋が先端近くまで明らかであり，縁辺が鋭い歯状を呈し，軽く波打っていた。

全長約 10 cm: 初期葉は次第に数が減り，1～2枚残っているが，弱ったり先端の切れているものが多かった (Fig. 13)。主枝はやや扁圧して葉を互生し，葉には皺縮が認められ，縁辺が鋭い歯状を呈していた。

全長約 20 cm: 初期葉はみられず，茎が高さ 5～10 mm なってふた (Figs. 14, 23)。主枝は次々と形成されている様子がうかがえた。葉縁の皺縮は，主枝上部のものほど甚しくなっており，主枝先端で互生している葉芽にも認められた (Figs. 15, 24)。主枝上部の葉腋には，球形で円頭の短柄を有する気胞が形成され，主枝下部の葉腋から側枝が伸長し始めており，その側枝は主枝とほぼ同様の形態を示していた。

以上のように，全長約 20 cm に達したものでは，今回観察されなかった生殖器床を除けば，母藻の有する形質を表わしていた。一方，付着器は，多数の仮根が束状ないし塊状に癒合して形成された。本種の付着器は，表面が平滑な盤状であるが，全長約 20 cmの試料では，着生基質の 4.2 mm ロープをほぼ1/3周していた。

考　　察

コブクロモクの生殖器床は，1～4回分岐し，下部では柄を有し，上部では無柄で，円柱状，瘤々をなし，稀に小刺が存する (YAMADA 1931; 岡村 1956) が，雌雄性等の詳細については記載が見当らないようである。一方，本研究に用いた母藻は，YAMADA (1931) の記載とよく一致したためコブクロモクと同定し，調べた範囲では同一生殖器床内に雌雄両生殖巣が観察され (androgynous)，雌雄同株・同床であったため，その記載も添えて母藻の特徴を示した。

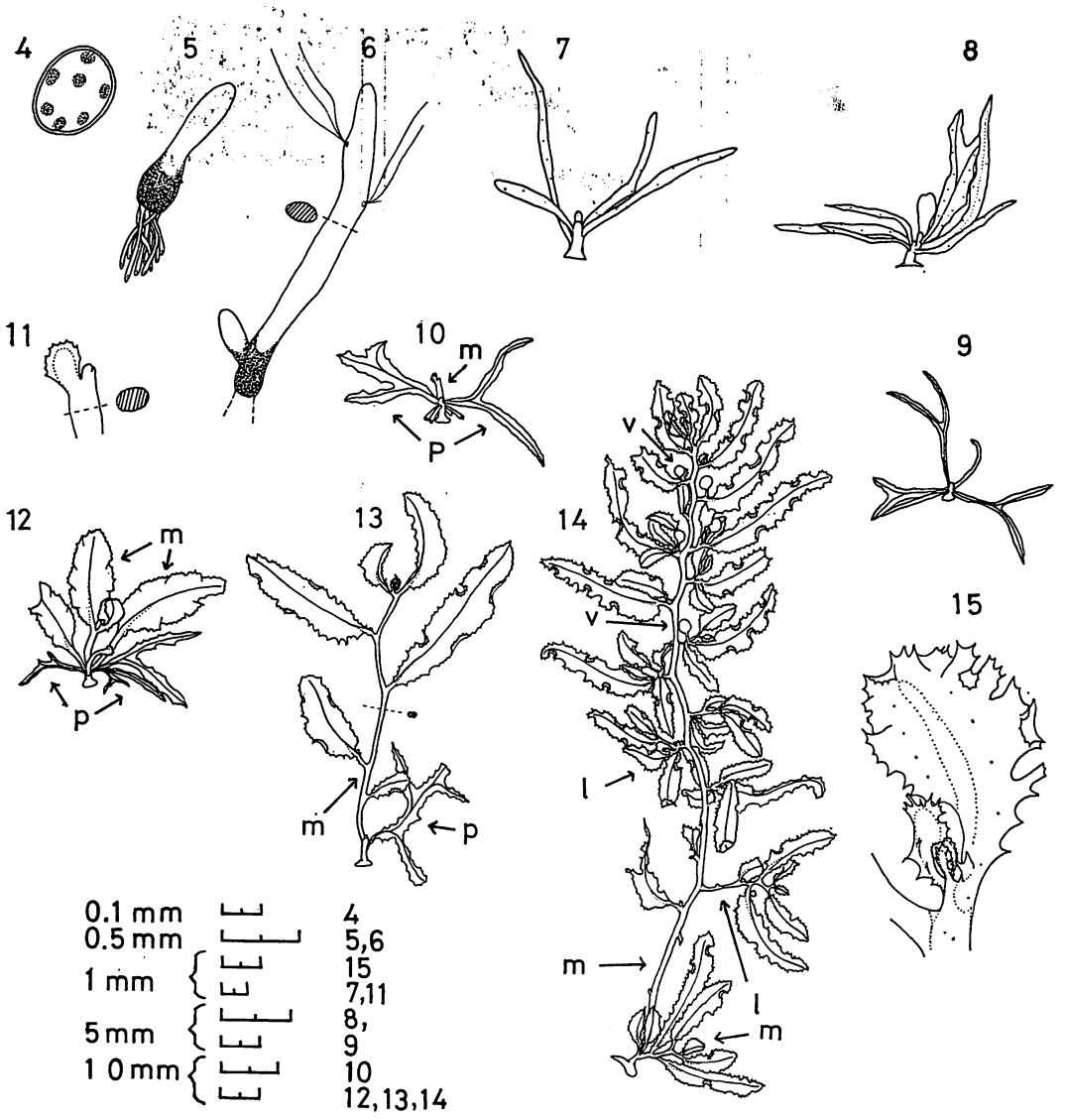
本種の胚発生，および，その後の形態形成に関する報告は見当らないようであるが，本研究によりその概要を明らかにすることができ，ほぼ次のようにまとめられる。

本種は，他のホンダワラ属同様に，放出卵が8核を有し，楕円形ないし卵形であり，正常なもので幼胚の下端に16本の第1次仮根を形成するものと思われる。

幼胚から形成された第1初期葉は，やや扁圧した円柱形である。以後，初期葉の形態は単条の糸状ないし線形で，次第に葉幅が広くなり，全長約 2 cm に達すると，1～2回分裂し，縁辺が波状を呈するようになる。これら初期葉は，らせん葉序を示して形成され，生長に伴って古いものから順次脱落していき，全長20 cm に達したものではほとんどみられない。茎は，これら初期葉が順次脱落していくことにより，次第に形成されていく。

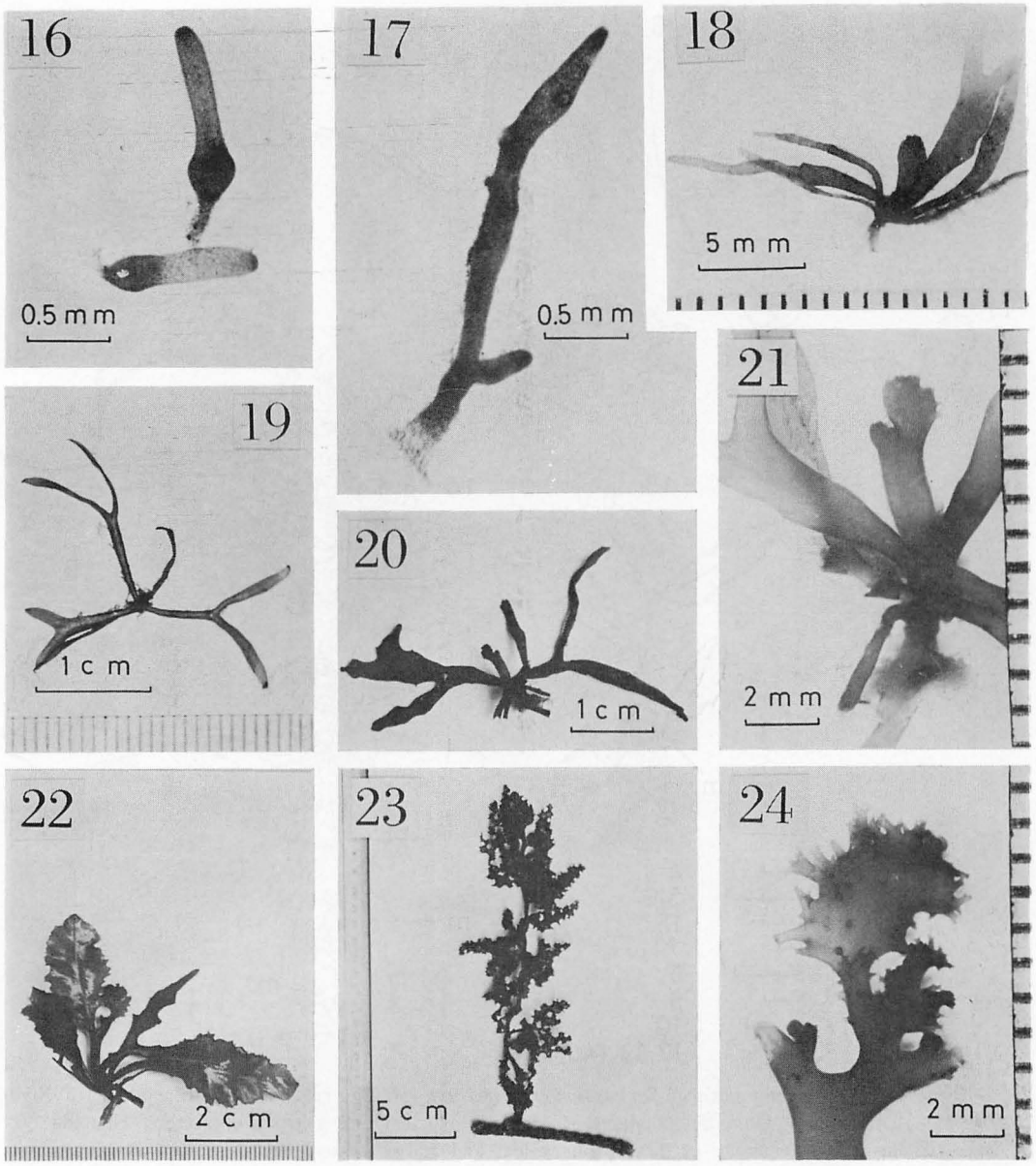
全長 3 cm に達するころから，茎の先端には初期葉に代って主枝が形成され始める。主枝に形成される葉は互生し，発達に伴って葉縁に皺縮が認められるようになり，初期葉とは明らかに異なっている。全長 20 cm に達すると気胞や側枝が観察され，成体の形態的特徴を表わしてくる。主枝形成後には主枝の伸長が旺盛となり，茎の伸長は極めて緩慢となる。全長 20 cm に達した個体の茎の高さ 1 cm は以下である。

本種の初期形態形成の過程，すなわち，第1初期葉がやや扁圧した円柱形であること，その後，単条または分裂する初期葉が茎上にらせん葉序で形成されてから主枝が形成されること，主枝には単条で初期葉とは明らかに異なった形態の葉が互生すること，および，



Figs. 4–15. Morphogenesis of *Sargassum crispifolium*. 4. Egg released from receptacle; 5. Five days old plant after sowing, development of first primary leaf and a group of sixteen rhizoids; 6. After 28 days, development of first primary leaf and bud of second one; 7. After 50 days, plant with linear primary leaves; 8. After 74 days, development of divided primary leaves; 9. After 150 days; 10. After 188 days, development of main branch; 11. Young main branch; 12. After 227 days, plant with divided primary leaves and leaves on main branches lanceolate to spatulate in shapes; 13. After 328 days, crispate leaves with minutely dentate margin; 14. After 355 days, development of vesicles and lateral branches; 15. Apex of main branch with crispate leaf buds. Lateral branch (l); main branch (m); primary leaf (p); vesicle (v).

主枝形成後には茎の伸長が緩慢となることなどの一連の過程が，同じく *Eusargassum* 亜属に分類されているフタエモク（寺脇ら 1983）のそれと同様の傾向を示している。また，フタエモクでは，主枝が形成され始めると再び分裂の少ない初期葉が形成される傾向が認められている（寺脇ら 1983）が，本種の場合，全長 5～10 cm に達した数個体の観察では，主枝の基部付近から単条で線形ないし広線形の初期葉を備えたものもみられた。しかし，それらの初期葉が，その後分裂するものなのか，単条のままであるのか分らなかっ



Figs. 16-24. Morphogenesis of *Sargassum crispifolium*. 16. Five days old plant after sowing; 17. After 28 days, development of first primary leaf and bud of second one; 18. Ater 74 days, development of divided primary leaves; 19. After 105 days; 20. After 188 days, development of main branch; 21. Young main branch; 22. After 227 days, plant with divided primary leaves and leaves on main branches lanceolate to spatulate in shape; 23. After 355 days, development of vesicles and lateral branches; 24. Apex of main branch with crispate leaf buds.

た。

本種に関しては，主枝形成開始前後の初期葉の形態変化，また，本研究においては今回観察されなかった，発生1年目での藻体の成熟現象等について，更に詳細な研究が必要であると思われる。

終りに，御校閲をいただいた北海道大学理学部助教授吉田忠生博士に厚くお礼を申し上げる。また，本研究の発表の機会を与えられ御配慮をいただいた電力中央研究所生物研究所長中村宏博士および同水域部長下茂繁博士に謝意を表する。

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藻類 Jap. J. Phycol. 31: 202-207. September 20, 1983

紅藻ニセカレキグサの生活史

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The life history of *Farlowia irregularis* YAMADA was investigated by periodic samplings of plants at its type locality, Akkeshi, east coast of Hokkaido in Japan and by laboratory culture experiments. This alga has morphologically similar upright gametophytic and bisporophytic thalli, both of which are perennial. Reproductive structures are formed in branches issuing at the upper portion of the thalli. Female gametophytes bearing carpogonial branches and auxiliary cell branches were found from August to December and those with cystocarps were seen from February to April. Bisporangial primordia appeared in August, cut off as side branches from the third cell from the distal end of cortical filaments, and grew slowly from October to December. Mature bisporangia were found during March and April. After spore release, cystocarpic and bisporiferous branches of gametophytic and sporophytic thalli distintegrated leaving their proximal sterile portions, respectively. Proliferous branches issued from the uppermost portion of these surviving sterile portions during May and June. However, male gametophytic thalli have not been detected in the field. Bispores were isolated into unialgal culture with Provasoli's ES medium and maintained in freezer-incubators illuminated with cool white fluorescent lamps (2000-2500 lux) at 10°C, 16: $\overline{8}$ (light-dark cycle). Isolated bispores germinated and grew into plants similar in morphology and anatomy to field-collected *F. irregularis*. Apical segments of branches of 2-month-old plants were excised 0.5-1.0 cm in length and cultured at six conditions: 5°C, 16: $\overline{8}$; 5°C, 8: $\overline{16}$; 10°C, 16: $\overline{8}$; 10°C, 8: $\overline{16}$; 15°C, 16: $\overline{8}$; 15°C, 8: $\overline{16}$. Of these, plants transfered to 10°C, 8: $\overline{16}$ reached reproductive maturity within 4 months after the excision and formed spermatangia and carpogonia in separate individuals. Thus, the life-history pattern of *F. irregularis* is of the *Polysiphonia*-type and differs from that of the Pacific North American *Farlowia* species which possess upright gametophytes and crustose tetrasporophytes. These results suggest that taxonomic revision of the genus is needed.

Key Index Words: *Cryptonemiales*; *Dumontiaceae*; Farlowia; F. irregularis; *life history*; *Rhodophyta*; *taxonomy*.

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紅藻ニセカレキグサ *Farlowia irregularis* (カクレイト目リュウモンソウ科) は YAMADA (1933) によって南千島国後島と北海道厚岸を生育地として記載された。北海道大学理学部標本室に保管されている基準標本 (SAP 14034, YAMADA 1933, pl. XI) の産地は厚岸である。その後, 本種は南サハリン(TOKIDA 1954), ウラジオストック (舟橋 1966) および北海道の北見枝幸から知床半島, 根室半島を経て日高に至る沿岸(川井・黒木 1982, 黒木ら 1979, 三上 1957) に生育することが報告されている。この分布域はMICHANEK (1979) によって区分された冷温帯に含まれる。本種の雄性配偶体に関する報告はないが, 雌性配偶体は TOKIDA (1954) と三上 (1957) によってそれぞれ南サハリンと日高から, 四分胞子体は舟橋 (1966) によってウラジオストックから報告されている。これらの報告はニセカレキグサの生活史がイトグサ型であることを示唆している。しかしながら, 本属の北米太平洋沿岸に生育する3種, *Farlowia compressa*, *F. conferta* および *F. mollis* の生活史は盤状の四分胞子体をもつカギケノリ型であることが最近報告されている (DECEW and WEST 1981)。ニセカレキグサの生活史が前述した報告から想定しうるようにイトグサ型

であるのか，あるいは北米太平洋沿岸産の種と同じカギケノリ型を示すのかを確認する必要がある。本種の type locality である厚岸で定期的な標本採集を行い，得られた標本の観察および室内培養を行って，生活史を調べた結果を報告する。

材料と方法

1976年4月から1977年8月にかけて北海道東岸の厚岸でほぼ2カ月ごとに定期的な採集を行い，多数のニセカレキグサの標本を得た。観察は生体材料を用いて行い，必要に応じて10%ホルマリン海水液で固定しコットンブルーで染色した。腊葉標本は北海道大学理学部標本室（SAP 043079-043091）に保管されている。

培養材料は1977年4月7日に厚岸で採集した二分胞子体である。二分胞子の培養を MASUDA (1973) によって記述されている方法によって最初に 10°C 16時間明期8時間暗期で行った。2カ月後に直立体の枝から切り取った先端部の培養を 5°C, 10°C, 15°C の16時間明期8時間暗期ならびに8時間明期16時間暗期の6条件（光源は白色螢光灯，照度は 2000-2500 lux の培養庫）で行った。

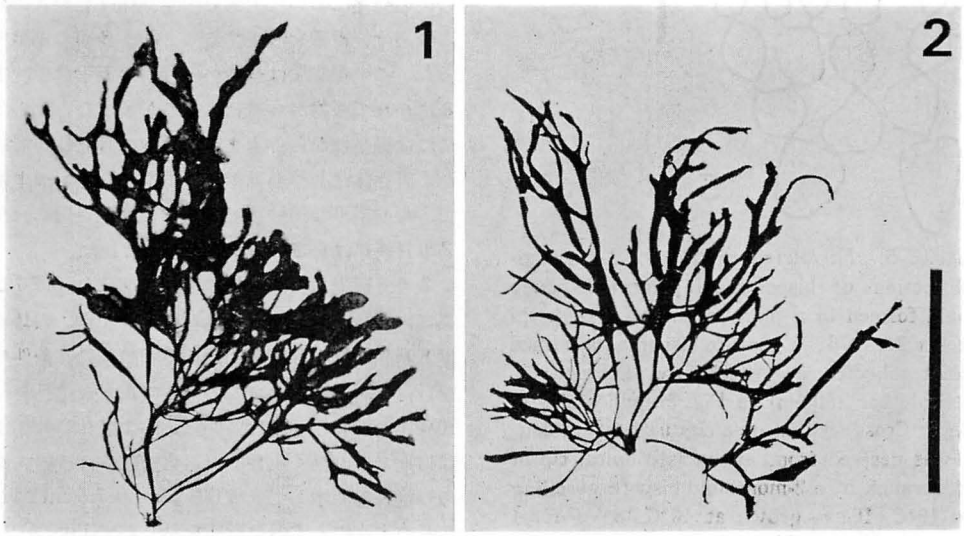
結　　果

天然産の個体の観察

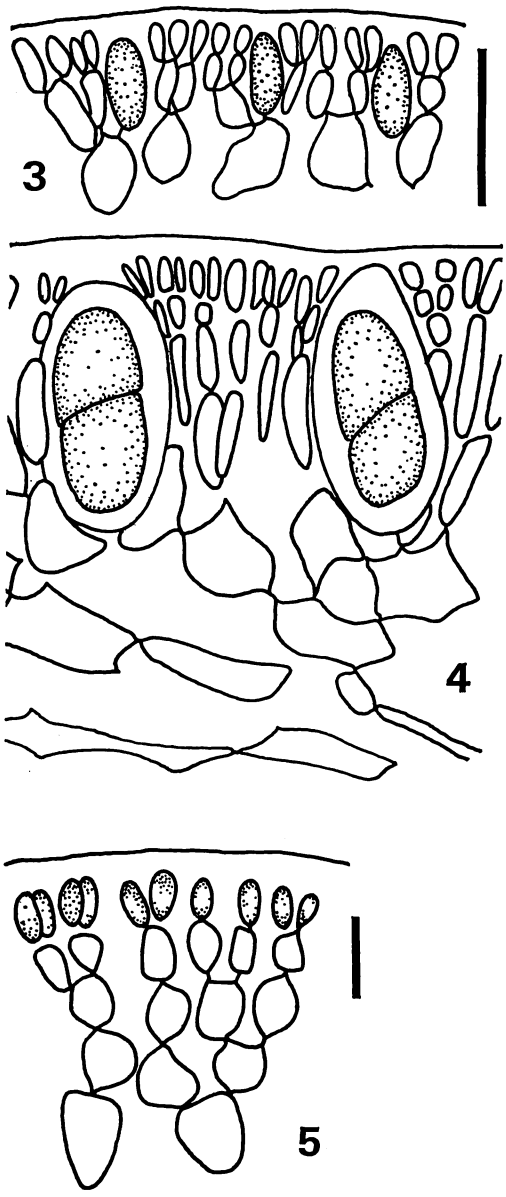
ニセカレキグサは潮間帯下部の岩上に生育しており，1年中直立体がみられる。YAMADA (1933) によって記載されているように，不規則な分枝をする数本の直立体が同一の基部組織から生じる。若い直立体の先端部の表面観（Fig. 9）で1個の半球形の頂端細胞が観察されるように直立体の内部構造は単軸型である。厚岸で行ったほぼ2カ月ごとの定期的な採集で，雌性配偶体と胞子体が生殖器官を形成する時期およびその後の直立体の生長様式が明らかになった。しかしながら，雄性配偶体のそれらについては不明である。

造果枝と助細胞枝を形成した雌性配偶体は8月，10月および12月に，嚢果を形成したそれは2月と4月に採集された。造果枝と助細胞枝は藻体の上部の枝に形成され，その枝においては求基的に形成される。造果枝，助細胞枝および果胞子体の発達過程は三上(1957)の記載したそれと一致する。成熟した嚢果は髄層中に散在し，直径 0.5-1 mm の球状で肉眼で識別できる (Fig. 1)。果胞子は4月下旬に放出され，平均直径 43.4 μm（標準偏差 ±6.6，測定数400個）の球形で濃赤色を呈する。果胞子を放出した部分の枝の組織は崩壊して流出する。6月には枝の残った部分の最上部から多数の再生枝が発出する。

生殖器官を形成した胞子体は，8月から4月にかけて採集された (Fig. 2)。胞子嚢原基は皮層を形成する細胞枝の末端から3個目の細胞の側枝として形成される (Fig. 3)。胞子嚢原基は藻体の上部の枝に求基的に形成され，10月から12月にかけて分裂しないで生長する。10月には 25-43 μm×15-23 μm の大きさで



Figs. 1-2. *Farlowia irregularis*. 1. A cystocarpic plant collected at Akkeshi on April 6, 1977 (SAP 043085); 2. A bisporangial plant collected at Akkeshi on February 2, 1977 (SAP 043079). Scale bar (5 cm) in Fig. 2 applies also to Fig. 1.



Figs. 3-5. *Farlowia irregularis*. 3-4. Longitudinal sections of bisporangial plants: 3, young sporangia formed in a plant collected at Akkeshi on October 24, 1976; 4, mature bisporangia formed in a plant collected at Akkeshi on February 3, 1977. Scale bar (50 μm) in Fig. 3 applies also to Fig. 4; 5. Cross section of a cultured male plant, which was derived from an cxcised apical tip of a single branch of a 2-month-old bispore germling kept at 10°C, 16: $\bar{8}$, grown at 10°C, 8: $\overline{16}$ for 4 months. (Scale bar=10 μm)

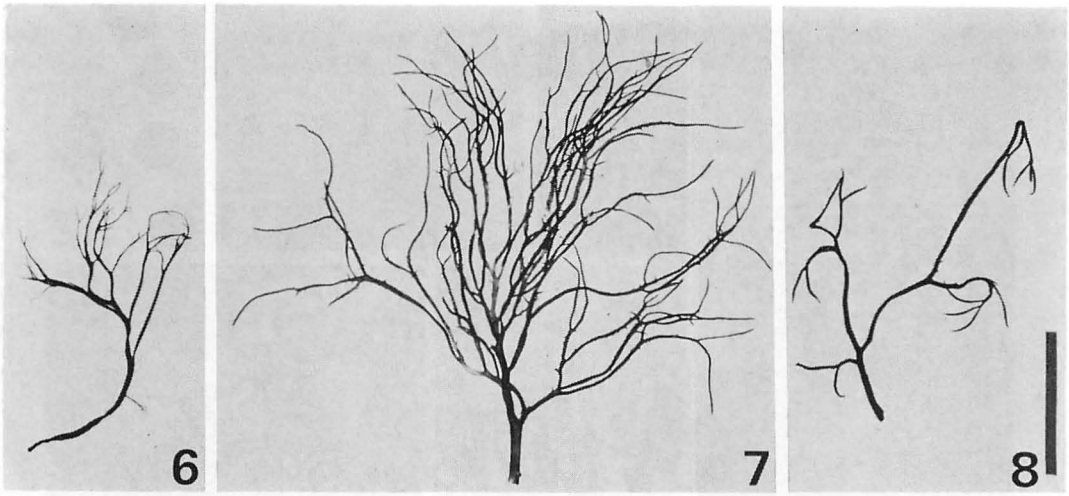
12月には 38-55 μm×20-30 μm である。2月に長軸に対し垂直にまたはやや斜めに1回分裂するが，その後は分裂しないで二分胞子を4月上旬に放出する (Figs. 11-12)。二分子に分裂した胞子嚢の大きさは 73-103 μm×35-50 μm である (Figs. 4, 10)。胞子体は胞子嚢群を形成することなく，散在した二分胞子嚢を形成するので外観では未成熟体と区別できない。胞子を放出した枝の部分は雌性配偶体と同様に流失し，5月から6月にかけて残った部分の最上部から多数の再生枝が発出する。

再生枝は叢生して生じるのが特徴で，YAMADA (1933) の原記載にある "branches in the upper part of the frond often fasciculate" に一致する。本種の基準標本 (SAP 14034, YAMADA 1933, pl. XI) の観察結果，YAMADA によってこのように記載された部分の枝は正常な分枝によるものではなく，再生枝が集合して形成されていることが確認された。

培養実験

胞子体からの二分胞子は2個連なった状態で放出されて (Fig. 11) 放出後に分離する。胞子は平均直径 49.6 μm (標準偏差 ±6.8, 測定数510個) の球形で (Fig. 12)，濃赤色を呈している。二分胞子は最初10°Cの16時間明期8時間暗期の下で培養された。胞子は直接盤状型 (猪野 1947) の発生を行い，1週間後に3～5本の透明な毛が発出されているのが観察された。その後の発達において大部分の発芽体は放射状に発達する縁辺分裂組織を形成することなく多層の細胞塊となった。この細胞塊は基物への付着が不十分で，生長するにつれて基物から離れるものが多くなった。3週間後には細胞塊から1本または2本の直立体が形成された。直立体は一つの半球形の頂端細胞をもつ単軸構造で，やや扁平な円柱状で互生または不規則に分枝し，2ヵ月後には長さ 1.0-2.9 cm になった。

2ヵ月経過した直立体の枝の先端部を 0.5-1 cm の長さに切断して 5°C, 10°C および 15°C の16時間明期8時間暗期と8時間明期16時間暗期の6条件で培養を行った。直立体は全ての条件で正常な生長を行い，10°C の8時間明期16時間暗期および16時間明期8時間暗期でより早く生長した。培養個体は枝の先端部からの培養を開始して3ヵ月後に 4.0-7.5 cm になり天然産のそれによく似た形態を示した (Fig. 6)。この時期に 10°C 8時間明期16時間暗期で雄性配偶体が成熟し，不動精子を放出した (Figs. 7, 13)。精子嚢形



Figs. 6-8. *Farlowia irregularis*. Cultured gametophytes derived from excised apical tips of branches of 2-month-old bispore germlings grown at 10°C, 16 : $\bar{8}$. 6. A vegetative gametophyte maintained at 10°C, 16 : $\bar{8}$ for 4 months after the excision; 7-8. Fertile gametophytes, a male plant (7) and a female plant (8) both of which were grown at 10°C, 8 : $\overline{16}$ for 4 months after the excision. Scale bar (2 cm) in Fig. 8 applies also to Figs. 6-7.

成に先立って精子嚢母細胞が皮層細胞から斜めに切り出される。精子嚢は精子嚢母細胞の頂端に多くの場合2個まれに1個形成される (Fig. 5)。精子嚢は楕円体で 5-7 μm×3-4 μm の大きさであり (Fig. 5)，色素体は認められなかった。

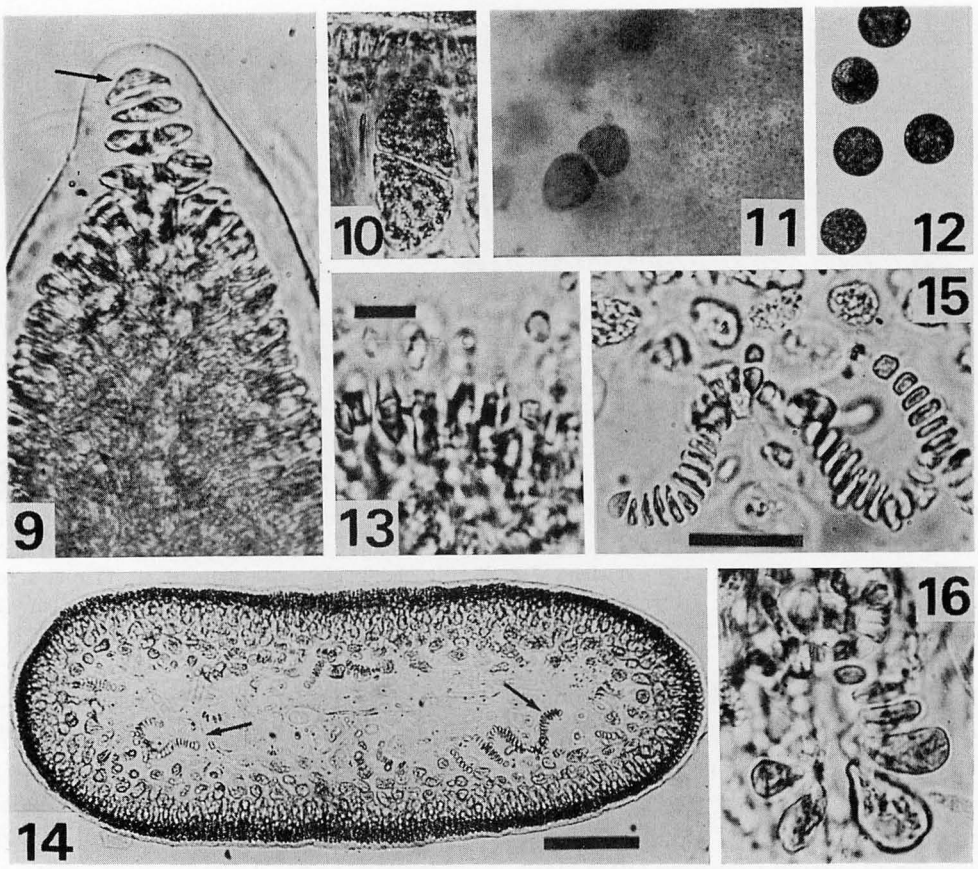
枝の先端部からの培養後4カ月で雌性配偶体が10°C，8時間明期16時間暗期の条件で成熟し (Fig. 8)，造果枝 (Fig. 16) と助細胞枝 (Figs. 14-15) を形成した。造果枝と助細胞枝は皮層最下部の細胞から形成され (Fig. 14)，造果枝の細胞数は 8-11 (Fig. 16)，助細胞枝のそれは 10-16 (Fig. 15) であった。雌雄の配偶子を受精させ，その後の発達過程を調べるために雌雄の配偶体を同一の大形シャーレ (12 cm×10 cm，培養液 800 ml) に移して3カ月間培養を行った (最初の1カ月間は1日1回スターラーで培養液を撹拌した) が果胞子体は形成されなかった。

5°C ならびに 15°C の16時間明期8時間暗期と8時間明期16時間暗期および 10°C の16時間明期8時間暗期の条件では，枝の先端部からの培養を6カ月間続けたが，いずれの個体にも生殖器官は形成されなかった。

考　　察

ニセカレキグサの雌性配偶体と胞子体の生殖器官は，ともに夏に形成を開始し，秋から冬にかけて発達し，早春に果胞子または二分胞子の放出を行う。これは TOKIDA (1954) が南サハリンの標本で9月に助細胞枝，12月に若い嚢果をもつ雌性配偶体を報告したことと一致する。このように生殖器官の形成開始から胞子放出までの期間が長いことがニセカレキグサの生物季節の特徴である。リュウモンソウ科で同じく冷温帯に生育するリュウモンソウ属 *Dumontia* (TOKIDA *et al.* 1964, KILAR and MATHIESON 1978) とアカバ属 *Neodilsea* (TOKIDA 1943, MASUDA 1973) では生殖器官形成から胞子放出までの期間が短い。それに対して，オキツバラ属 *Constantinea* では非常に異なった生物季節が報告されている。雌雄配偶子の受精は春に行われ，夏季休眠を経て，嚢果は秋の終りから冬にかけて成熟して果胞子を放出する (LINDSTROM 1981)。四分胞子嚢が形成される時期については記述されていないので，四分胞子体が同様な生物季節を示すか否かは明らかではない。ニセカレキグサにおいては休眠期は認められず，夏に形成された生殖器官は徐々に生長する。その要因を今後詳しく調査する必要がある。

本藻の胞子体は二分胞子嚢を形成することによって特徴づけられる。二分胞子嚢は真正紅藻綱において Acrochaetiaceae，テングサ科，サンゴモ科，およびイギス科で報告されている (GUIRY 1978, for review)。これらの二分胞子嚢には単核二分胞子と二核二分胞子を形成するものがみられる (BAUCH 1937)。SUNESON



Figs. 9–16. *Farlowia irregularis* 9. Apical portion of a young plant collected at Akkeshi on June 29, 1976, showing a single dome-shaped apical cell (arrow); 10. Cross section of a bisporangial plant collected at Akkeshi on April 6, 1977, showing a mature bisporangium; 11. A pair of bispores released on thallus surface; 12. Bispores; 13. Cross section of a 7-month-old male plant grown at 10°C, 8: $\overline{16}$ for 4 months after the excision. (Scale bar=10 μm); 14. Cross section of a female plant grown at 10°C, 8: $\overline{16}$ for 4 months after the excision, showing auxiliary cell branches (arrows) which issue from the innermost cells of the cortical layer; 15. Auxiliary cell branches; 16. A carpogonial branch. Scale bar (100 μm) in Fig. 14 also applies to Figs. 11–12. Scale bar (30 μm) in Fig. 15 applies also to Figs. 9–10 and 16.

(1950) は後者の形成時には減数分裂が行われるが，前者の形成にはそれがともなわないことを細胞学的に証明した。サンゴモ科のイボモカサ *Fosliella farinosa* と *Dermatolithon litorale* の単核二分胞子の培養実験で，それらが二分胞子体世代を繰り返すことが示されている (CHAMBERLAIN 1977, SUNESON 1982)。一方，*Gardneriella tuberifera* (ミリン科) の二核二分胞子は配偶体世代に生長することが確認されている (GOFF 1981)。ニセカレキグサの二分胞子は核の数が確認されていないが，培養実験で雄性配偶体または雌性配偶体に生長したので，*Gardneriella tuberifera* と同じ減数分裂によって形成された二核二分胞子 (GOFF 1981) と考えられる。なお1981年1月17日に採集した網走産のニセカレキグサでは不規則に十字状に分裂した四分胞子嚢がみられた (未発表)。本種には二分胞子嚢と四分胞子嚢を形成する異なった個体群が存在することが予想される。この問題については今後異なった生育地から多くの個体群を得て解析する必要がある。

天然産の個体の調査と培養実験の結果から厚岸産のニセカレキグサは雌雄異株の配偶体と同形の直立した二分胞子体をもつことが明らかになり，その生活史は基本的にイトグサ型と同じである。この生活史型は北米太平洋岸の *Farlowia* 属3種，*F. compressa*, *F.*

conferta および *F. mollis* で報告された直立する配偶体と殻状の四分胞子体をもつ型 (DECEW and WEST 1981) とは異なる。ところが, *F. conferta* では直立体に四分胞子嚢が形成されることも報告されている (ABBOTT 1968)。真正紅藻綱には同一属内の種によって, あるいは同一種においても個体群によって異なった生活史型を示す例がいくつか知られている (UMEZAKI 1977, for review)。生活史型の違いを, ただちに属あるいは種の区別とすることには問題があると思われる。ニセカレキグサと北米太平洋岸の *Farlowia* 属3種は藻体の内部構造, 雌雄生殖器官の形態および果胞子体の発達過程において極めて類似している (三上 1957, ABBOTT 1962, 1968)。四分胞子嚢が直立体に形成される個体群があるとされる *F. conferta* (ABBOTT 1968) においては, さらに多くの個体群でその生活史が調べられるべきである。*Farlowia* 属の分類学的改訂はその詳細が明らかにされてから行われるべきと筆者らは考える。

本稿のご校閲を賜わった北海道大学理学部黒木宗尚教授に深謝申し上げる。標本採集にご協力載いた北海道大学理学部厚岸臨海実験所の方々に御礼申し上げる。

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藻類 Jap. J Phycol. 31: 208-216. September 20, 1983

ミツイシコンブの子嚢斑形成[1)]

川嶋昭二

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KAWASHIMA, S. 1983. Sporangial sorus formation of *Laminaria angustata* KJELLMAN. Jap. J. Phycol. 31: 208-216.

The occurrence and subsequent development of sporangial sori of *Laminaria angustata* collected from Erimo and some other points of Hidaka Province, Hokkaido, were studied.

The sori were recognized on the first year blades from August to April of the next year, and on the renewed second year blades from June to December. They were formed first on under surface of the blades, the median fascia on that surface being projected, but from two or three months after formed on upper surface, too.

The sori on each surface extended their outlines successively in a fixed mode with their development, representing very distinctive features. Consequently, they were divided into three types on the under surface and into seven on the upper one. Development of the sori on the upper surface showed a tendency to accelerate on the blades bearing the superior sorus type on the under surface.

Key Index Words: *blade surface forming sorus*; *combination of sorus type*; Laminaria angustata; *sporangial sorus*; *sorus formation period*; *sorus type*.
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ミツイシコンブを新種 *Laminaria angustata* とした KJELLMAN (in KJELLMAN och PETERSEN 1885) はその原記載中で遊走子嚢斑（以下単に子嚢斑と称する）について「葉状部の一面にのみ，縁辺に沿って断続した細帯状に形成する」と述べている。しかしこの子嚢斑の形成面について，その後のわが国の多くの研究者による記述は必ずしも KJELLMAN のそれと一致せず，また斑紋の形や形成の様子などの記録にも混乱が認められる（川嶋 1979)。

著者はミツイシコンブの子嚢斑を季節を追って調査し，その出現時期，形成面，斑紋形成の特徴などをほぼ明らかにし，既往の二，三の知見とも比較検討したのでここにその結果を報告する。

材料と方法

この報告に用いたミツイシコンブは主として北海道日高支庁管内えりも町歌別の水深約 3m の海底に設置されたコンクリート礁およびその附近の天然岩礁に着生した葉体で，1977年5月から12月までは毎月1回，1978年は2月と4月に1回ずつ，計10回採集したものである。また1977年中に同支庁管内浦河町（2月），様似町（4月，7月）および三石町（10月）の各漁場（いずれも水深約 3m）から採集したものも用いた。さらに1977年11月から1983年2月までの間にえりも町と様似町で計5回にわたり漁業者により採取された流れコンブについても記録し参考とした。

上記の各材料のうち各地のコンクリート礁と天然岩礁から直接採集したものは年齢別に 30-60 本の範囲内で葉長，葉幅などの一般測定を行ったほか，子嚢斑についてはその形成面（うら，おもて面の別），形成範囲（葉状部下端から斑紋の上限および下限までの距離），斑紋の形（類型は後述）および葉面上の位置（中帯部，両縁部の区別）などを記録した。また流れコンブについては毎回50本を抽出し形成面と斑紋の形のみを記録した。

コンブの年齢については直接採集した葉体は事前に発芽期が調査されたものであったため1年目，2年目に明確に区別された。他方，流れコンブは11月から4

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月にかけてのもので新旧両葉を持つ再生葉体が多かったが，その年齢査定は困難であり，ここでは旧葉部は1年目，新葉部は2年目として扱った。したがって本論中では HASEGAWA (1962) の報告した3年目，または4年目葉体や佐々木ら (1973) の言う若2年目葉体は含まないものとする。

なお，以下の記述中に用いる葉状部の「うら面」とは遠藤 (1910, 1911) の規定した中帯部のふくらんだ側，「おもて面」とはくぼんだ側を指す。また「片面」と呼ぶ場合はすべてうら面を指すように統一した。

結　　果

(1) 子嚢斑の形成時期と葉状部の各面への形成割合の季節的変化

1年目葉体には8月末に，片面にのみ子嚢斑を形成したものが16%出現し，10月中旬には66%に増加した。次いで11月初めに14%の葉体に両面形成が認められた。その後は片面形成の葉体は次第に減少し，反対に両面形成葉体の比率が高まって翌年4月下旬には92%に達した。また，いずれの面にも子嚢斑を形成しない葉体も8月末以後順次減少したが12月から2月の間に15～20%ほどは残っており，4月下旬に至ってなくなった (Fig. 1A)。

2年目葉体には5月中旬に全く子嚢斑が認められなかったが，6月下旬に35%の葉体に片面形成が現れ，その後7～8月にほぼ55%に増加した。しかし9月中旬に両面形成葉体が6%出現してからは両者の比率は急速に逆転し，12月上旬には片面形成が3%，両面形成が97%になった。子嚢斑を全く形成しない葉体は8月末に45%も残っていたが，11月初めに至って全くなくなった (Fig. 1B)。

(2) 子嚢斑の形成範囲と長さ

1年目，2年目葉体ごとに子嚢斑が葉状部のどの位置に，どれだけの長さで形成されたか，これらの季節的変化を Fig. 2 に示した。子嚢斑の長さは，それが連続するか否かにかかわらず斑紋の最下端から最上端までの距離とした。なお，1年目葉体は10月から再生期に入ったので葉長も新旧両葉部を区別して画いた (Fig. 2A)。

1年目葉体：うら面では8月下旬に基部から葉長の5分の1ほどの部分に長さ 28 cm (葉長の 11%) にわたって子嚢斑が形成されていた。この時期の葉体は末枯れ期に入って11月まで葉長は短くなったが，10月から始まった新葉部のつき出しによって1年目部分はその上部におし上げられながら翌年4月下旬まで末枯れを続けた。この間，子嚢斑の範囲は次第に上下に拡大し，2月には長さ 86 cm になった。しかし，この時すでにその上端は末枯れしていたので実際の子嚢斑の最大長は不明である。

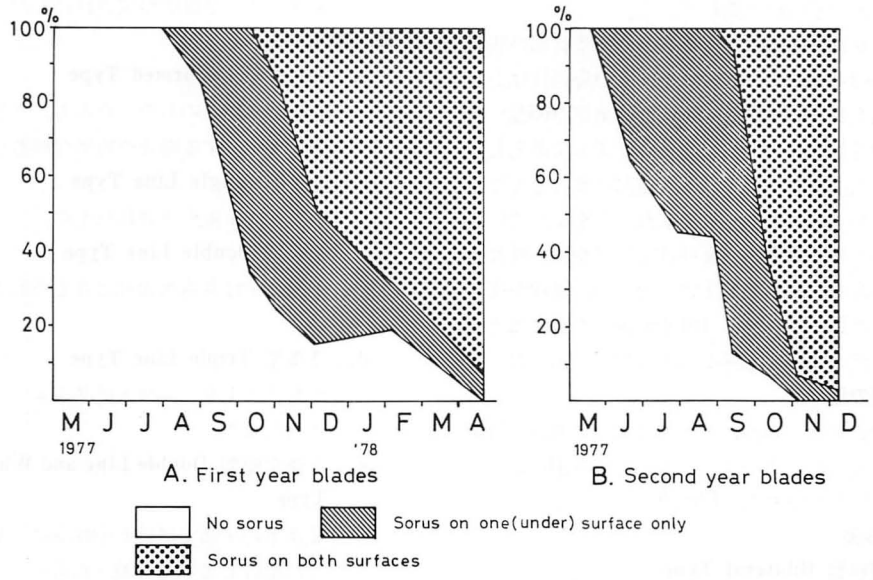

Fig. 1. Seasonal change of the formation of sporangial sorus on each surface of the blades of *Laminaria angustata*.

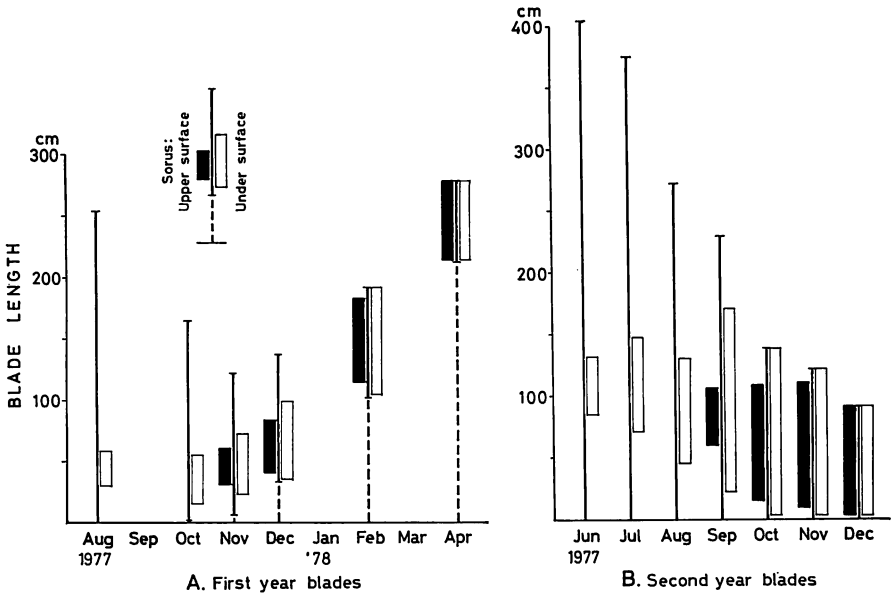

Fig. 2. Seasonal change of the blade length and relationship between the positions of the sporangial sorus formed on upper and under surfaces of the blades. Broken lines in A show the renewed blade length.

おもて面の子嚢斑は常にうら面のそれより短く，うら面の形成範囲内のやや下寄りの位置を占めていた。両面の子嚢斑ともに末枯れ部分にかかっていない12月のおもて面の斑長は，うら面のそれの68%であった。

2年目葉体：子嚢斑が形成されているのは葉長が最大に達した後の末枯れの期間である。

うら面の6月下旬における形成部分は葉状部の基部から葉長の約4分の1ほどの所で，その後斑紋は上下に向って拡大し，9月には 148 cm（葉長の65%）に達した。10月以後その上端は末枯れによって流失しているが，下端はほとんど葉状部の基部にまで達しており，子嚢斑がこの頃に良く成熟したことを示している。

おもて面での子嚢斑形成範囲は1年目葉体の場合と同様にうら面のそれのやや下寄りを占め，斑紋が完全に残っていた11月で長さは 101 cm あった。またその下端が葉状部の基部まで達したのは12月であった。

(3) 子嚢斑の型

子嚢斑の斑紋はうら面，おもて面ごとに非常に特徴的な形として現れ，次のようにうら面で3型，おもて面で7型に類型化された（Fig. 3）。

I. うら面

A. 両縁型 Bilateral Type
中帯部を除き，両縁部に各1条，幅広い帯状に形成されたもの。

B. 両縁全幅型 Bilateral and Whole Width Type
両縁型の下部で斑紋が中帯部にも形成され，全幅を被ったもの。

C. 全幅型 Whole Width Type
斑紋全体が全幅に形成されたもの。

II. おもて面

a. 未形成型 Unformed Type
斑紋が未形成のもの（ただし，うら面に必ず子嚢斑を有する場合の特別な類型）。

b. 1条型 Single Line Type
中帯部に1条形成されたもの。

c. 2条型 Double Line Type
中帯部をはさみ両縁部に各1条形成されたもの。

d. 3条型 Triple Line Type
中帯部に1条，両縁部に各1条，計3条形成されたもの。

e. 2条全幅型 Double Line and Whole Width Type
2条型の下部で斑紋が中帯部にも形成され，互に融合して全幅を被ったもの。

f. 3条全幅型 Triple Line and Whole Width Type

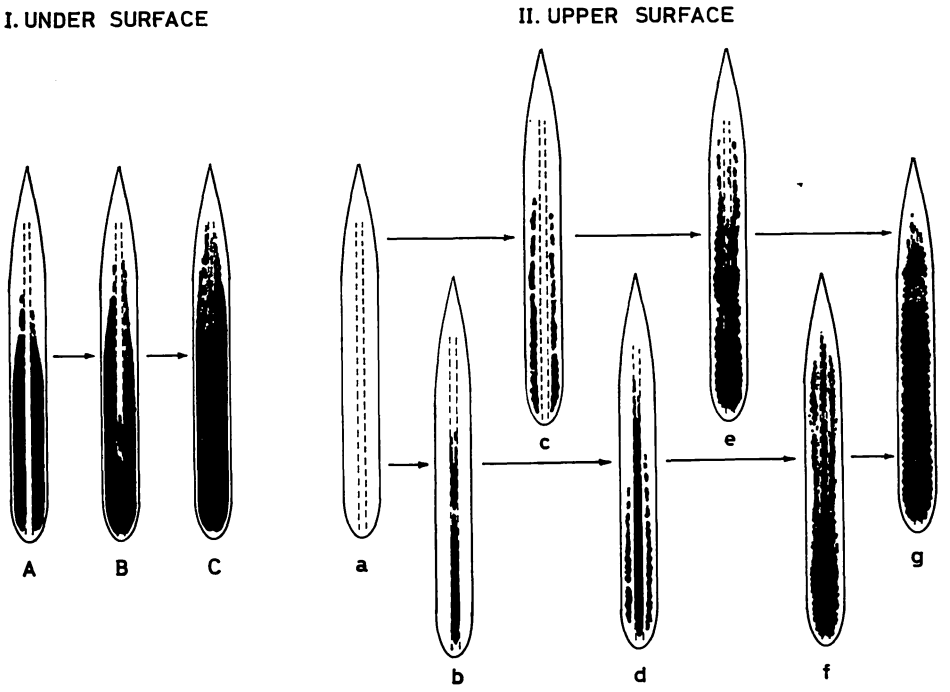

Fig. 3. Diagramatic representation of the sporangial sorus types and their developmental processes in *Laminaria angustata*. I. UNDER SURFACE. A. Bilateral Type; B. Bilateral and Whole Width Type; C. Whole Width Type; II. UPPER SURFACE. a. Unformed Type; b. Single Line Type; c. Double Line Type; d. Triple Line Type; e. Double Line and Whole Width Type; f. Triple Line and Whole Width Type; g. Whole Width Type.

3条型の下部で各斑紋の間にも斑紋が形成され，互に融合して全幅を被ったもの。

g. 全幅型 Whole Width Type

斑紋全体が全幅に形成されたもの。

(4) 各斑紋型の形成順序と特徴

葉状部のうら面とおもて面での斑紋形成には Fig. 3に矢印で示したようにそれぞれ一定の順序が認められた。

うら面：斑紋の形成は両縁型から始まる。その始源は中帯部に沿った両縁部上に幅のせまい不規則な線状や断続した大小の点として現れるが次第に明らかな直線状の輪郭をもった幅広い帯状に発達し，遂には中帯部と両縁辺 2～3 mm ほどの極くわずかな部分を除く全面を被うようになる。そして斑紋が葉状部の基部まで広がり完成するとその下端は縁辺に沿った鮮明な曲線状を呈する (Fig. 4A)。

両縁型はやがて両縁全幅型に移行する。すなわち下部の方から両側の斑紋同志の接触，融合が起こり，その部分は結果として斑紋が全幅にわたって形成される (Fig. 4B)。この場合，両者が中帯部内にせり出して接触，融合することもあるが，これとは別に全く新しい小斑が中帯部の各所に現れ，それらが拡大し両側の旧斑とのつなぎの役割りを演ずることもある。融合は順次に下部から上部に向って進むので両縁全幅型の期間は比較的長く，上端に達して全幅型となる。すなわち両縁全幅型は両縁型と全幅型をつなぐ移行型である。

おもて面：おもて面にはすでに述べたようにうら面への子嚢斑形成後も暫くは斑紋が現れない。ここではこのような状態を特別に未形成型と呼んだ。

未形成型の葉面に最初に現れる子嚢斑は1条型または2条型であるが，そのいずれがより早いか今回の調査では明らかにできなかった。しかし形成状況から見ると両者はほとんど同時期に生ずるように思われる。1条型も2条型も最初は小斑の連なりとして現れるが，前者はほぼ中帯部の幅に沿ったリボン状になり (Fig. 4C)，後者は両縁部上で不規則な形の線状，帯状を呈して，互の間には形成位置だけでなくその形状に著しい差異が認められる。

3条型は必ず1条型から生じ，2条型から生ずるものは発見されなかった。1条型の両側に新しく生ずる

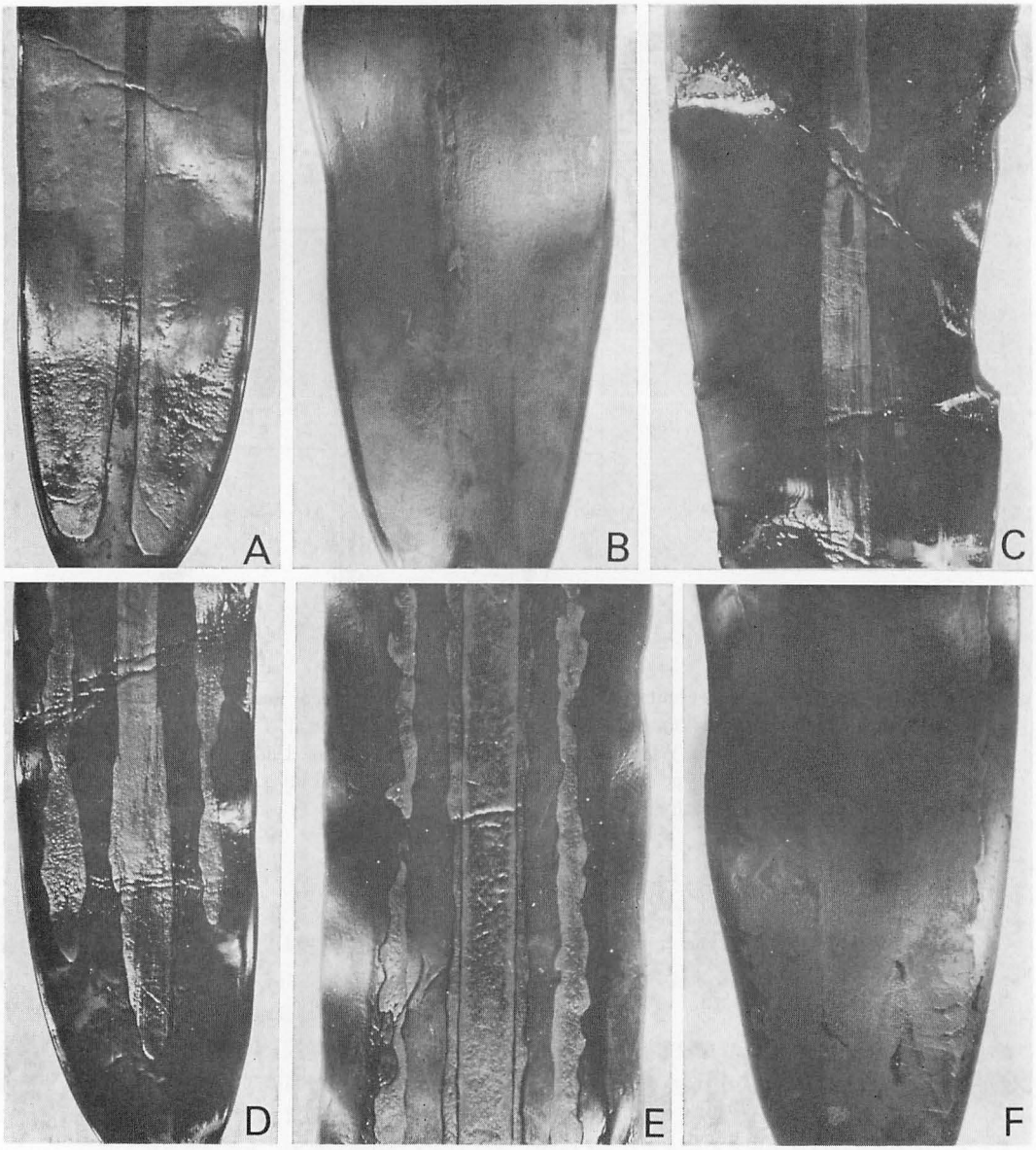

Fig. 4. Detail of five types of the sporangial sorus. A. Bilateral Type; B. Whole Width Type; (A and B are of the under surface.) C. Single Line Type; D-E. Triple Line Type; F. Basal portion of Double Line and Whole Width Type; (C-F are of the upper surface.) A and D, as well as B and F, are shown the opposite locations each other of the same blade.

2条の斑紋は葉状部の基部に近い部分に小斑となって現れ上下に伸長するが，2月末頃の良く発達した時期でもその長さは中央の1条の3分の2くらいにしかならない。また，その斑紋は2条型と同様に不規則な形を呈する（Fig. 4 D, E)。

2(3) 条型から2(3) 条全幅型を経て全幅型に達した葉体は3，4月頃の流れコンブの旧葉上に見られるだけで，うら面の全幅型の出現よりはかなり少ない。3条型が3条全幅型に移行する前に中帯部上の斑紋の両側に接して細線状の新しい斑紋が生ずるが，これは他には見られない特徴である（Fig. 4E)。また，1条型が3条型を経ずに全幅型に発達することはないようである。

おもて面の斑紋の共通的特徴は中帯部の1条が直線

的なリボン状であるのに対し，両縁部に生ずる斑紋はすべて不整形で輪郭が凹凸を呈することである(Fig. 4D, E, F)。このことはまた，うら面のそれが常に直線的であることとも著しく対照的な性質である (c.f. Fig. 4A, B)。

(5) 斑紋型の季節的出現傾向

うら，おもて両面における各斑紋型の季節的出現傾向をえりも町歌別から得られた着生コンブにより各葉面別，年齢別に整理し Figs. 5～7 に示した。

うら面：Fig. 5 に示したように1年目葉体では各月とも両縁型が主体を占め，両縁全幅型は10月から見られたが，11月から2月まで約30%を限度に出現したに過ぎなかった。また，全幅型まで発達したものはなかった。

2年目葉体でも6月から10月までの5か月間は両縁型が多かった。両縁全幅型は8月から出現したが10月までは30%未満に止まった。しかし11月になって75%に急増し，さらに全幅型に進んだものも12%あった。12月には全幅型は32%まで増加した。その後の資料は得られなかったが，このような推移から見ておそらく最後には両縁型はほとんどなくなったものと推測される。

おもて面：Fig. 6 と Fig. 7 にはそれぞれうら面に両縁型または両縁全幅型をもつ葉体の，おもて面における斑紋型の季節的変化を示した。

うら面が両縁型の葉体 (Fig. 6) は1，2年目ともにほぼ同様の傾向が見られ，いずれも未形成型100%が3か月ほど続いた後に1条型と2条型が同時に現れた。3条型の形成はこれらよりさらに1か月ほど遅く，1年目で12月から，2年目で10月から始まった。これらの各斑紋は未形成型の減少に伴ってその後月ごとに多くなったが，全体として3条型は1年目で30% (4月)，2年目で22% (12月) に止まり，1条型と2条型の占める割合が大きかった。

うら面が両縁全幅型に発達した葉体 (Fig. 7) は1年目，2年目とも初めの1か月ほど未形成型100%を保ったが，その後はいずれも急速に1条型，2条型が現れ，短期間に全葉体の両面に子嚢斑が形成されたことが判る。さらに3条型や2(3)条全幅型などの出現は，1年目では1月と3月の資料が欠けるので不確かであるけれども，少なくとも年を越してからと見られるのに対して，2年目では10月から始まっている。総体的におもて面の斑紋の発達速度はうら面が両縁型の葉体群よりも，両縁全幅型に進んだ葉体群の方がより促進される傾向が現れていた。

最後に，うら面が全幅型になった2年目葉体では11月，12月ともにおもて面はすべて2(3)条全幅型を示した。

考　　察

(1) 子嚢斑の形成期

HASEGAWA (1962) は三石町の平磯地帯のミツイシコンブの子嚢斑形成期について，1年目葉体は10月初旬から翌年3月末まで，2年目葉体は7月から翌年2月まで，また3年目葉体では6月から翌年1月までと報告している。

著者の調査したえりも町歌別の1年目葉体では8月

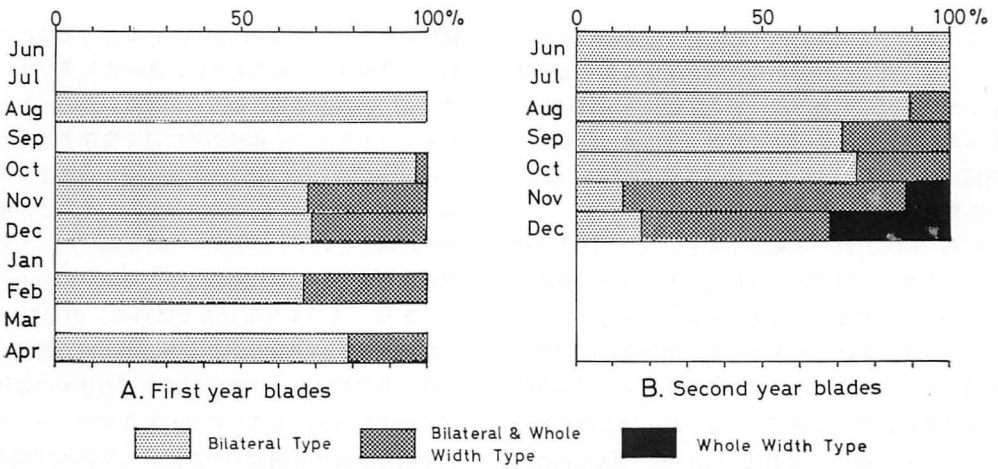

Fig. 5. Seasonal appearance of the sporangial sorus types on under surface of the blades.

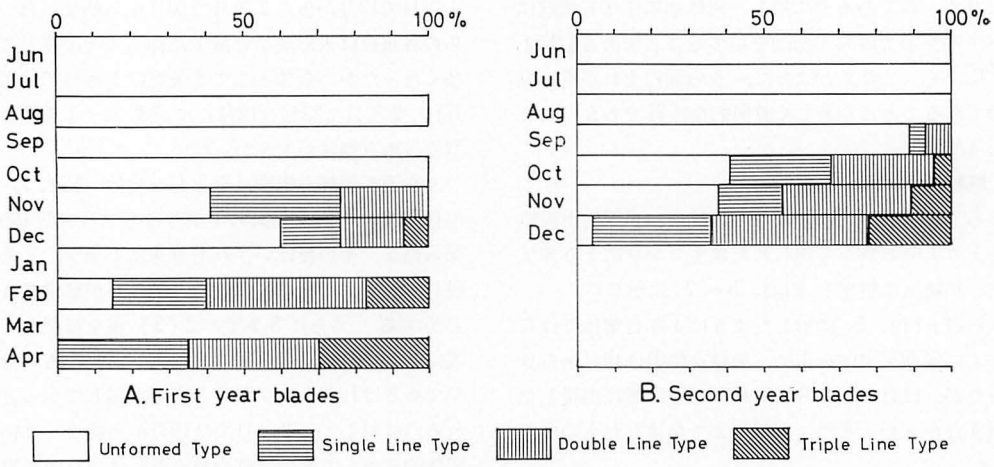

Fig. 6. Seasonal appearance of the sporangial sorus types on upper surface of the blades bearing the sorus of Bilateral Type on under surface.

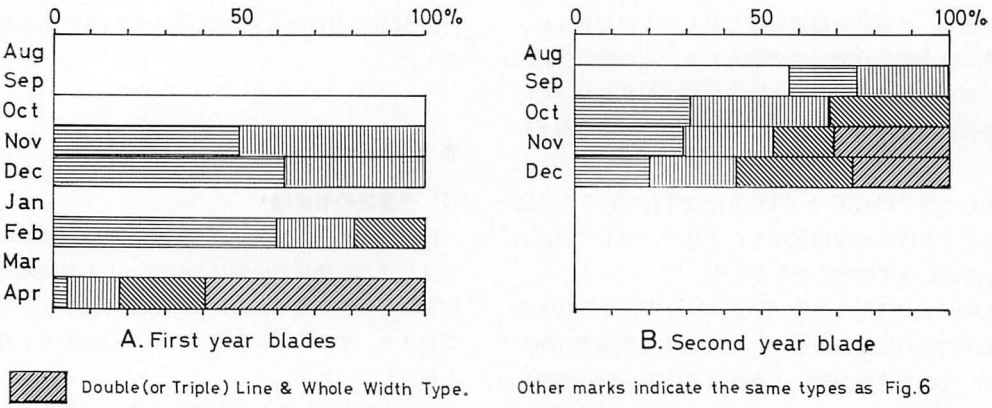

Fig. 7. Seasonal appearance of the sporangial sorus types on upper surface of the blades bearing the sorus of Bilateral and Whole Width Type on under surface.

下旬に15%に子嚢斑が認められ翌年4月まで残っていた。この間，葉体は10月から再生を始め1年目部分は新生した2年目部分の先端にあって次第に末枯れし短くなった。また2年目葉体は6月下旬にすでに35%に子嚢斑が形成されており，12月上旬まで確認したが，その終期は調査できなかった。

中村ら（1955）は「従来，ミツイシコンブは7月初旬頃から葉体に子嚢斑ができ初め，8～9月に最高に達し，10月下旬頃までに遊走子を放出するものと考えられていたが，既に3～4月の候，葉体先端部附近に子嚢斑をもったものがあり，このようなコンブが各地で多数認められた」と述べている。彼らはこの記述の中でコンブの年齢には触れていないが，HASEGAWA (l. c.) や著者の結果から判断すると，7月初旬頃に子嚢斑を形成し始めるのは明らかに2年目葉体のことを指し，3～4月の候のものは，第一に再生葉体の頂部に残っている旧葉部分のものが考えられる。しかしながらこの旧葉上の子嚢斑が特に良く発達すると，時々その下端が再生部の境界を越えて新葉部にまで入りこみ，次第に拡大していることがあるので，この季節にすでに再生を終了した新葉のみの葉体では，その先端部に子嚢斑が形成されていることは充分に有り得ることである。このような見方とは別に，中村ら (l. c.) の指摘した子嚢斑形成期と葉面上の形成位置は，その葉体の発芽期または子嚢斑形成に至るまでの生活とも深いかかわりがあるように思われるので，コンブの生活を明らかにする研究の一課題として改めて取り上げる必要がある。

ミツイシコンブは他のコンブと同様に年齢によって子嚢斑形成期がやや異なり，齢期の高いものほどその始期，終期とも早い。すなわち上に述べたことから，まず2(3)年目葉体には6～7月頃から，次いで1年目葉体には8～10月頃から形成されて，いずれの年齢でも斑紋が認められるようになるが，3月以降は原則として再生中の葉体の旧葉部にしか見られないと言うことができる。そしてこれらの形成期間はいずれも9か月前後の長期に及ぶ。また冬期間，葉状部の先端に子嚢斑が形成されていても，その多くはやがて末枯れによって流失し，形成期間は短いものと考えられる。

(2) 子嚢斑の形成面

本種の子嚢斑の形成面に関する既往の報告は，まず片面とするものはKJELLMAN (l. c.)のほかにKANDA (1941)，NAGAI (1941)，山田・木下 (1949) があり，片面のほか，時々または稀れに両面とするものに宮部 (1902)，遠藤 (1910, 1911)，岡村 (1916)，OKAMURA and UYEDA (1925)，川嶋 (1965, 1972) が，そして両面とするものに岡村 (1902)，佐々木ら (1973) などがある。

しかしこのことについて著者は Fig. 1 に示したように1年目，2年目いずれの葉体も必ずうら面から形成が始まり，ある期間を経て順次におもて面にも形成され，遂には両面形成が圧倒的多数を占めることを明らかにした。また特定の生育地や流れコンブで観察すると全葉体が両面形成に達する場合もある。

KJELLMAN (l. c.) が記載した標本の採取時期や場所はその記述からは特定できないが，これらは函館でJ. WILSON[1] から贈られたもので，輸出用集荷品の中で特に良く保存された品であったという。そしてそれらの多くのものに子嚢斑が形成されていたことから，彼はこのコンブは多分収穫の後期に採られたものらしいと記している。また産地として十勝 (Tokatsu)，様似 (Shamani) および浦河 (Uragiva) をあげているが，明治中期における日高地方の採取期は，通例夏の土用入り後1週間以内に始まり，その後数日または十数日以内に最も多量に採取した (和田・野沢 1892) ことから推定すればKJELLMANの記載した標本はおそらく7月下旬からおそくとも8月下旬までの候のものであったと考えられる。

著者の歌別での調査によれば収穫の対象となる2年目葉体は8月末まで子嚢斑はうら面形成のみに限られ，1年目葉体でも両面形成に入るのは10月以降であるから，KJELLMANの観察した標本の採取期が上述の時期とすれば子嚢斑は当然うら面にのみ形成されていたと考えることができる。

しかし一方，遠藤 (1910) は静内郡捫別村 (現静内町東静内) と井寒台 (浦河町) において7月下旬にすでに両面形成のコンブがあったことを述べている。彼の記録によりその比率を計算すると両地平均9％で高い割合とは言えないが，このことは子嚢斑の形成始期やその後の発達が年や場所などの生育環境の変動によって相当に遅速を生ずることを示している。多くの報告に見られる形成面に関する記述の違いはこのような観察時期や生育場所の相異などの事情によるほか，観察の頻度にも起因するのではないかと思われる。

(3) 子嚢斑の型

KJELLMAN (l. c.) は子嚢斑について「中帯部よりも縁辺に近い部分に広がり，断続した帯状に形成され，連なる斑紋は時に小さく，また時に大きな面積を占める」と述べている。また宮部 (1902)，遠藤 (1903) ら多くの日本人研究者も中帯部を除く両縁部に帯状に生ずると述べ，かつ縁辺のごくせまい部分には決して生じないことを特徴にあげている。このことは著者の提案した類型にあてはめるならば，うら面の両縁型を指すものであるが，さらに岡村 (1916)，KANDA (1941)，佐々木ら (1973) はこの型はやがて両縁全幅型や全幅型になることを認めている。他方，おもて面の斑紋については宮部 (l. c.) が初めて1条型があることを記載し，川嶋 (1972) は1条型と2条型について，また佐々木ら (l. c.) は1条型は3条型になることを述べている。しかしこれらはいずれも断片的な観察記録である。

斑紋型について上に掲げた既往の報告以外に今日まで最も詳細な記録を残したのは遠藤 (1910) である。彼は著者の提案した型に従えば本種はうら面の両縁型に対し，おもて面には未形成型，1条型，2条型および3条型の4型があることを認め，しかも7月と10月におけるそれぞれの型の出現数を示している。すなわち7月の斑紋はうら面の両縁型に対し，おもて面は未形成型，1条型および2条型の3型だけであったが，10月には3条型が加わり，かつ未形成型の比率が減少して1，2および3条型が増加したことがうかがわれる。このことは著者の示した各斑紋型の季節的出現状

1) John Andrew WILSON 英国人，1866年（慶応2年）頃，上海より来函し貿易商ハウル社に入社。1902年（明治35年）頃まで硫黄，昆布を輸出し，砂糖，石油を輸入する事業に従事。1916年（大正5年）函館で死去，74歳。（函館市立図書館，千代肇氏私信による）

況と多少のずれはあるものの傾向としては同一の結果と見られる。

著者は今回，これらの斑紋型をさらに詳細に観察し，うら面の3型に対しおもて面を7型に類形化し，これらの型の発達の経路についても明らかにした。さらにこれらの季節的な出現傾向を調査し，特に先行して出現するうら面の斑紋の発達に応じておもて面に現れる型の組み合せと各型の比率の変化について検討を加えた。その結果，うら面では1年目葉体が両縁型から両縁全幅型までしか発達しなかったのにくらべて2年目葉体ではさらに全幅型にまで進んだものが32%に達した。またおもて面では暫時，未形成型を保った後に1条型と2条型が現れるが，1条型はやがて3条型に移行し，2条型とは別の経路を経てそれぞれが全幅型に移行することが明らかにされた。しかし，おもて面で完全に全幅型に発達した葉体は春先頃の流れコンブだけで見られたことから，多くの着生葉体はそれまでに枯れたり流失するのではないかと考えられる。またおもて面への季節的出現傾向はうら面の斑紋型の発達に対応してその進行が加速されると言え，コンブの年齢による違いはむしろ少ない。

うら面の両縁型とおもて面の2条型は共に葉面の縁辺部に形成される点では似ているが，前者の斑紋がより幅広く，その輪郭が葉の縁に沿った非常にきれいな直線を画くのに対し，後者では複雑な凹凸状の輪郭をもった斑紋となる点で著しく異なっている。また，このことは両面における全幅型についても同様に認められる性質である。

この調査には北海道日高東部地区水産技術普及指導所の元所長坂本富蔵氏，現所長岩岸清志氏，えりも町水産課三戸　充氏らの協力をいただいた。ここに深く感謝の意を表する。

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西澤一俊： XI回国際海藻シンポジウム（青島）委員会報告 Kazutosi NISHIZAWA: Information of International Advisory Committee of International Seaweed Association

去る6月19日から25日にわたる一週間青島でXI International Seaweed Symposium (ISS) が開催されたことは既報の通りである。このISSには，予想通りに31ケ国から計400余名（中国約150名，アメリカおよび日本からそれぞれ60-70名ほど，その他）の参加者があった。4題の合同講演，6セッション36題のミニシンポジウムと大まかにわけて3区分（有用海藻生物学約101題，海藻の化学，生化学領域約35題，海藻養殖関係約30題）計約166題の一般講演と約83題を含むポスター講演がこの間発表され，盛会のうちに終了した。

一方委員会 International Advisory Committee (IAC) すなわちISS運営の本体は19日から26日にわたり毎日昼食後の休憩時間および夕食後と2回づつ開かれた。そこで議せられたことや決定した事項のうち，日本藻類学会に多少なり関係していると思われることをまとめて報告したい。

［I］ ISSに関する規約の確認

1) ISSの性格と目的：ISSはInternational Seaweed Association (ISA) の行事として3年に1度適当な国で開かれ，1回目の (1952) Edinburgh以来今回で11回目の開催である．ISAはInternational Association of Biological Oceanography (IABO) の1部門とされた。ISAの本来の目的は広い意味で応用藻学の振興にある。しかし，当面としては研究対象は海藻およびその成分にあるが，他の藻やその成分をも対象に含まれることは勿論である。従って具体的には，利用価値のあるまたはありそうな藻について，基礎的な生物学および化学の研究を促進させ，藻資源の確保とその水産環境を保存維持し，藻類の収獲，養殖その成分の加工の改良を探索することなどが当面の仕事である。

2) 会員：ISAの目的に関心を持っている人々に常に歓迎される。それで，その都度開催されたISSに正式に参加した人全員が次回のISSまで会員としての資格をもっている。

3) IACの構成：IACは今後8～12名で運営するが，決定については国とかその専攻分野を考慮してIACが選ぶ。IACには委員長副委員長を置くが同一国からは選出しない。委員長はIABOの部外員としての資格をもつ。IACにはIAC委員以外の者で別に定める職務をもつ秘書を置く。IACには別に定める職務を行う実務小委員会を設ける。それは正副委員長と前委員長から成り，ISS開催予定国の国内組織委員会と協力し乍ら実務を行う。正副委員長の職務は別に定める。

4) 国内組織委員会：IACの中で自国でISSを開催する場合には国内委員長を選び，委員会を作る義務がある。職務内容は別に定める。

5) その他：プロシーディングスは毎回のISSにつき有料で発行するが，その編集委員にはIACがその責任において委嘱する。ISAにこれに類似する他の組織例えば国際藻類学会 (IPS)，Marialg（業界の海藻産業振興のための組織），UNESCO, ITC, FAOなどと特別な関係を保持する必要があり，IACの誰かがこれらの組織と有機的な関連をもつことが望ましい。ISS運営資金獲得のために，当事国で賄えない時には国外募金委員会を置く。ISS開閉会に関する具体的事項は別に定める。その他に，IACの正副委員長やIAC委員の任期などに関しても別に定める。IACには別に定める規定に従いIAC以外の名誉IAC委員を置く。また次期ISSに関しては，その開催ISSで別に定める細則に従い決定し，その際に次ぎつまり6年後のISS開催予定の国についてもその際に決める。

［II］ XI ISS会期中の主な報告と議題

1) 国外募金委員会において集められた金額は，欧米諸国において20,000$，日本から8,809$中国から若干（明確でない）であった。正規の収入は約400名の参加者の登録料とプロシーディングスの代金計約18,000$。すなわち，計46,808$のほかに中国募金ということになる。

2) NorwayのKristensen氏(IACの一員で今回は欧州募金委員）がIACを辞任した。その欠員に二，三の候補者が挙げられたが，いずれ文書により IAC間で決めることになり，この時点ではIACは10人となった。

3) IPSとの関係をISA側ではどうしたらよいか，ということがたびたび話題に出た。Santa Barbara ISS

(IX回) 以来，IPS 創立に絡み，ISS としては，IPS とできるだけ密接な関係を保ちながら，それ自身の存続も有意義であるよう何かと苦心しているかのようにみえる。現存は，Hawaii 大学の Doty 氏が窓口となり，Canada の New Brunswick 大学の Taylor 氏や Chile の Pontificia 大学の Santelices氏(IAC の一員)などを通じて IPS の連絡を取っている。そこでまず，次回 IPS (1985, Denmark) に，ISS によるミニシンポジウム部会を設けて貰い，また逆に次回 ISS (1986, Brazil) の中にも IPS の部会を入れて貰うよう ISS 側から働きかけることなど決めた。ISS と IPS は本来の目的は違うが，内容的にはかなり重複する部分もあり，両者に参加することは，内容的にも資金的にも参加者の不便になりはしないか，それを防ぐ方法は何か，など論議された。

4) FAO の発展途上国に対する海藻資源の収獲と利用面の援助に，IAC もできるだけ応援する意見が皆の賛同を得た。FAO では有用海藻の名称と特質のリスト作製など計画している (FAO 代表として米国の Caddy 氏が説明した)。

5) IAC が，業界の Whitney氏や Stancioff 氏などを昼食に招待し，種々 ISS のあり方運営その他につき意見を聞いた際に，やはり IAC が業界のために役立つことが希望された。具体的には Marinlg 当りの希望でもあるが，海藻成分の利用限度の研究やマクロ藻養殖と収獲のための生理学も重要だし，養殖に関する相互の情報およびデータ修復機構の必要性など論議された。ついでながら，講演の中に国の政策的色彩の濃いものがあったが，そのようものは IAC で予め篩にかけるべきだとの意見が一致した。

6) 22日の委員会で，次回 ISS (1986) は Sao Paulo 大学 (de Oliveira 氏が国内委員長になるはず)で，その次のには (1989) Vancouver で行われる予定が決定された。1989 ISS は France か Chile という案も出た。次回の IAC 委員長は Norway の Jensen 氏が McLachlan 氏に代り，また副委員長は Moss 氏がなることが決った。

7) 青島 ISS の国内組織委員長の Tseng(曾)氏から，UNESCO の仕事として明年青島で養殖に関する講習会を開き，外国からも参加できるようにし，その経費は UNESCO から援助するようにする計画が発表された。また FAO との関連強化に IAC 側では委員の Delepine 氏(仏)，Doty 氏(米)，Moss 氏(米)，Tseng 氏(中)などが Caddy 氏と連絡に当ることが決った。

8) 25日以降の会議には筆者は帰国のため出席できなかったが，そのうち主なことは，今回の ISS プログラム作製 (専門的区分けなど) は満足すべきものではなく，将来は例えば生物学や化学の領域ではさらに細く区分けすべきであるという意見がでた。また ISS に学会賞を置く案も議論されたという。発表講演 116 の要旨が集ったが，そのうち68が受理され，修正，却下17件であった。Tseng 氏から今回の青島 ISS の会計につき，詳細は1ヶ月後に Trondheim ISA 本部に連絡するという報告がなされた。

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——学 会 録 事——

1. 日本藻類学会第7回大会

昭和58年7月25～26日の両日，北海道室蘭市・室蘭プリンスホテルにおいて第7回大会が開催された。本大会は北海道大学理学部附属海藻研究施設50周年を記念して開催されたものである。他の記念行事については別項に記した。北海道での大会開催は初めてのことで，当初準備委員会では地理的不便さによる参加者数の減少を危惧したが，日を経るにつれて申込み数が増え，最終的には参加者111名，講演数54題 (一般講演50題，シンポジウム4題) となった。

大会第1日目，一般講演終了後に昭和58年度総会と懇親会が開かれた。懇親会には103名出席，舘脇正和氏司会のもとに岩本康三学会会長の挨拶，阪井與志雄大会会長の乾杯で始まり千原光雄氏の閉会の挨拶で終るまでの約2時間，余興のカラオケをも混じえて極めて盛会かつ豪華であった。

本大会の会場が会員の所属機関を離れてホテルに設営されたのは今回が初めてである。大会，懇親会の開催準備と運営に加え，会場設営にも多大の尽力をされた北大理学部海藻研究施設並びに植物学教室の方々に深く感謝致します。

大会参加者：秋岡英承，秋山 優，鰐坂哲郎，阿部英治，安部 守，飯間雅文，井浦宏司，石川依久子，石光真由美，市村輝宣，庵谷 晃，巌佐耕三，井鷺裕

司，岩本康三，尹　夏鏞，内田卓志，梅崎　勇，榎本幸人，大谷修司，大野正夫，大森長朗，奥田一雄，長田敬五，大島海一，垣内政宏，角田修次，加崎英男，笠原和男，梶村光男，梶原忠彦，片野　登，金子　孝，香村真徳，川井浩史，川口栄男，川嶋昭二，加藤秀夫，笠井文絵，黒木宗尚，工藤利彦，高原隆明，小林　弘，今野敏徳，斉藤英三，斉藤捷一，阪井輿志雄，佐々木茂，佐藤恭成，佐藤輝夫，沢崎達孝，三本菅善昭，清水　哲，鈴木秀和，竹田信一，田沢伸雄，舘脇正和，田中次郎，千原光雄，辻　寧昭，寺脇利信，出井雅彦，徳田　廣，中島秀明，長島秀行，中野武登，中原紘之，中村泰男，中村義輝，南雲　保，名畑進一，新原義昭，新山優子，西浜雄二，西沢一俊，野崎久義，能登谷正浩，芳賀　卓，浜田　仁，原　慶明，P.S. パンディー，福士由紀子，富士川龍郎，藤田大介，船野　隆，舟橋説往，堀　輝三，堀口健雄，前田昌徹，玉置富太郎，増田道夫，松江和則，真山茂樹，三浦昭雄，水野真，宮地和幸，ミン・タイン，本村泰三，森　宏枝，本吉　博，山岸高旺，山田家正，山本虎夫，山本弘敏，横田雅之，横浜康継，吉崎　誠，吉田忠生，渡辺仁治，渡辺恒雄，渡辺　信，渡辺真之

2. 評議員会・編集委員会合同会議

第7回大会第1日の7月25日（12：10～13：00），室蘭プリンスホテルで評議員会・編集委員会合同会議が開催され，昭和58年度総会に提出される報告事項と議題によって審議された。審議内容は後述の総会報告と重複するので，その項を参照されたい。

出席者：岩本康三会長，三浦昭雄編集委員長。秋山優，千原光雄，堀　輝三，巌佐耕三，西沢一俊評議員・編集委員。市村輝宣，阪井輿志雄，梅崎　勇，山本弘敏各評議員。黒木宗尚，小林　弘，正置富太郎，吉田忠生各編集委員。今野敏徳，庵谷　晃，高原隆明，本吉　斉各幹事。

3. 昭和58年度総会

昭和58年7月25日，室蘭プリンスホテルにおける第7回大会第1日目（18：10～18：40）に総会が開催された。岩本康三会長の挨拶に続いて，正置富太郎氏（北大・水産）を議長に選出して議事に入った。

Ⅰ．報告事項

1．庶務関係

(1) 会員状況（58年5月現在）：名誉会員3名。普通会員496名。学生会員67名。団体会員42名。賛助会員13名。外国会員80名。(2) 昭和57年度文部省科学研究費補助金「研究成果刊行費」98万円を受けた。また昭和58年度分として105万9千円の補助金を申請した。(3) 日本学会事務センターに58年度学会業務の一部を委託する契約が締結された。(4) 第48回日本植物学会大会会期中（10月3～5日，京都工芸繊維大）に秋季集会（講演会と懇親会）を開く計画がある。

2．会計関係

(1) 昭和57年度会費の納入状況は良好で，普通会員，学会会員ともに納入率が90％を超えている。(2) 昭和57年度一般会計，山田基金決算報告は昭和58年2月18日，猪川倫好（筑波大・生物科学系）および渡辺　信（国立公害研）の両監事により適正であることが認められた。

3．編集関係

(1) 昭和57年度に発行された第30巻1～4号は，総頁数348頁，掲載論文37編，短報16編，広告14頁（16件）であった。(2) 昭和58年度既発行分の第31巻1～2号の掲載論文数は21編，126頁。3号以下に掲載予定の論文は審査中，改筆中のものを含めて12編である。

Ⅱ．審議事項

1．昭和57年度一般会計決算報告・同監査報告。

表-1のとおりで，承認された。

2．昭和57年度山田幸男博士記念事業基金特別会計決算報告・同監査報告。

表-2のとおりで，承認された。

3．昭和58年度一般会計予算案

昭和58年度予算案（表-3）についての説明がなされ，質疑の後原案どおり承認された。

4．会計関係

(1) 山田基金の活用について。これまで山田基金については，基金総額が100万円に達した時にその預金利子で賄う，ということが基本的な案として了解されてきた。基金総額は表-2のとおり100万円を超えているので，この活用に関する原案の検討を北大理学部黒木宗尚氏に委嘱したいとの提案がなされ，承認された。(2) 印刷費高騰の折から別刷代金の個人負担額を再検討することとした。(3) 昭和59年度文部省科学研究費補助金「刊行助成金」の申請を行う。

5．編集関係

文部省科学研究費補助金を受けるについての「藻類」第31巻1－4号の責任頁数は272頁とされている。現時点では論文数が不足気味なので，奮って投稿して欲しい旨要望された。

6．昭和58・59年度事業計画

以下のことが承認された。(1) 昭和58年10月3日から京都工芸繊維大学で開催予定の日本植物学会大会の折に秋季集会（講演会・懇親会）を開く。世話人は梅

崎　勇氏（京大・農）。(2) 昭和59年度 日本藻類学会　　第8回大会および総会を東京学芸大学で開催する。

表-1　昭和57年度　一般会計決算報告　(57. 1. 1～57. 12. 31)　　日本藻類学会

収入の部	(円)	支出の部	(円)
会費	3,712,113	印刷費	5,006,753
普通会員	2,539,000	印刷代30巻1～4号	4,180,253
学生会員	255,500	別刷代	826,500
団体会員	303,800	学会事務センター扱い分	1,233,379
外国会員	393,813	業務委託費，会誌発送費	
賛助会員	220,000	請求書発送費，コピー代他	
販売	857,889	発送費	9,590
定期	483,289	編集費	236,400
バックナンバー	374,600	論文審査料，英文校閲謝礼	
別刷代	793,623	編集補助費，通信費	
超過頁負担金	545,000	庶務費	188,480
広告代	369,430	事務用品費，会議費	
文部省刊行助成金	980,000	事務補助費，通信費	
預金利息	22,920	雑印刷費，事務局移転費	
		幹事手当	90,000
		幹事旅費補助	12,000
		春季大会運営補助	32,287
		選挙費用	76,360
小計	7,280,975	小計	6,885,249
前年度繰越金	808,746	次年度への繰越金	1,204,472
合計	8,089,721	合計	8,089,721

昭和58年2月18日

本決算報告は適正であることを認める
昭和58年2月18日

日本藻類学会　会長　千原光雄　㊞
日本藻類学会　会計幹事　田中次郎　㊞
日本藻類学会　会計監事　渡辺信　㊞
日本藻類学会　会計監事　猪川倫好　㊞

表-2　昭和57年度　山田幸男博士記念事業特別基金会計決算報告　(56. 1. 1～57. 12. 31)　日本藻類学会

収入の部	(円)	支出の部	(円)
山田追悼号売上金（4冊）	22,000		
学会出版物売上金	15,500		
コンブ論文集（5冊）	3,500		
日米セミナー（4冊）	12,000		
預金利息	19,250		0
小計	56,750	小計	0
前年度繰越金	1,095,507	次年度繰越金	1,152,257
合計	1,152,257	合計	1,152,257

昭和58年2月18日

本決算報告は適正であることを認める
昭和58年2月18日

日本藻類学会　会長　千原光雄　㊞
日本藻類学会　会計幹事　田中次郎　㊞
日本藻類学会　会計監事　渡辺信　㊞
日本藻類学会　会計監事　猪川倫好　㊞

表-3　昭和58年度　一般会計予算案　　日本藻類学会

収入		支出	
会費	3,772,000	印刷費	4,650,000
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外国 〃 (78)	468,000	編集費	330,000
団体 〃 (42)	336,000	論文審査料	65,000
賛助 〃 (14)	280,000	英文校閲料	75,000
販売	878,000	編集補助費	90,000
定期購読	528,000	通信連絡費	100,000
バックナンバー	350,000	会誌発送費	304,000
別刷代	800,000	庶務費	660,000
超過頁負担金	550,000	事務用品費	80,000
広告代	320,000	会議費	48,000
利子	20,000	通信・印刷費	132,000
雑収入	1	事務整理補助費	90,000
刊行助成金	1,000,000	諸雑費	200,000
		幹事旅費補助	35,000
		幹事手当	90,000
		学会センター業務委託費	700,000
		第7回大会補助金	100,000
小計	7,340,001	小計	6,759,000
前年度繰越金	1,204,472	予備費	1,785,473
合計	8,544,473	合計	8,544,473

4. 北海道大学理学部附属海藻研究施設創設50周年記念行事

1. 公開講演会と映画会（昭和58年7月24日）12：30～15：00；室蘭市労働会館）

演題並びに講師

(1) 海藻研究施設50年の歩み
　　中村義輝（前海藻研究施設長）

(2) 海藻の色は語る
　　横浜康継（筑波大学）

(3) ホタテガイを毒化させるプランクトン
　　西浜雄二（道立栽培漁業総合センター）

映画：　　（山本海苔研究所提供）

2. 記念式典と祝賀会

(1) 記念式典（昭和58年7月24日 16：00～16：40；室蘭プリンスホテル金枝の間）

海藻研究施設長阪井與志雄氏の開式の辞ののち，伊藤英治北大理学部長の式辞，松下政雄北大理学部事務長による施設の沿革報告がある。そのあと，有江幹男北大学長，岩田弘志室蘭市長，北林　浩胆振支庁長，岩本康三日本藻類学会長の祝辞があり，出席者約120名の盛会のうちに閉式となる。

(2) 祝賀会（同上17：00～19：00；同上銀枝の間）

上記式典につづいて，海藻研究施設の舘脇正和氏の司会で，立食パーティー形式で行われた。伊藤理学部長の開会のあいさつ，辻野　勇北大水産学部長の音頭による祝杯のあと，なごやかに，賑かに会は進行し，途中，故山田幸男先生の御夫人及び故神田千代一先生の御夫人の挨拶もあり，中村義輝施設長の乾杯で祝賀会はしめくくられた。

投　稿　案　内

Ⅰ．編集の方針　本誌には藻学と応用藻学に関する会員の**未発表**の，論文・総説・短報（速報・短い調査報告など）雑録（抄録・採集地案内・分布資料・ニュース・所見・新刊紹介など）を掲載します。論文はデータや考察の独創性の有無に重点を置いた編集委員会の審査を経たのち受理されます。原稿の取捨掲載順序，体裁などは編集委員会および編集幹事で決めます。原稿は**和文**または**英文**とし，論文と総説は刷上り6頁，短報は2頁，雑録は1頁以内を無料とします。頁の超過は制限しませんが，頁の超過分，折込み，色刷りなどの費用は著者負担となります。和文原稿では5枚が，英文原稿では2枚が刷上り1頁となる見当です。

Ⅱ．報文の書き方　和文原稿は400字詰原稿用紙（横書きB5またはA4）に，当用漢字，新仮名使い（生物名は片仮名）を用い楷書体で書いて下さい。英文原稿は厚手タイプ用紙を用い，ダブルスペースで28行にタイプで打ち，十分な英文添削または校閲を経たのち提出して下さい。新種の発表や学名の記載に当っては国際植物命名規約に従って下さい。なお，アラビア数字・メートル法・摂氏温度を用い，学名などのイタリック体には下線1本，人名などのスモールキャピタルには下線2本，ゴジック体には波状線1本を記入して下さい。

例： Batrachospermum ectocarpum Sirod., Summary, sec, min, hr, nm, μm, mm, cm, m, μl, ml, l, μg, mg, g, N, M, ppm, lux, g(gravity), 25°C など.

原稿は，標題・英文要約（和文・英文原稿共）・本文・引用文献・和文摘要（英文原稿のみ）・表と図とその説明（英文）の順にまとめて1組とし，コピー共2組（写真は現物2組）にしてお送り下さい。

(1) **標題と要約**　英文原稿では，欄外見出し・標題・著者名・要約の順に，和文原稿では，欄外見出し（英）・標題と著者名（和と英）・要約（英）の順に記入して下さい。要約は著者名・標題・雑誌名・まとめ（200字・必要に応じて400字まで）・著者と宛先の順に記入し，研究費に対する謝辞は脚注に入れて下さい。

(2) **本文**　標題紙に記した以外の謝辞は，なるべく本文の末尾に入れて下さい。表と図は必ず本文中に引用(Fig. 1, Table 1 のように）し，文献の引用は次の例にならって，著者名と出版年および必要に応じて頁（単行本の場合）を明示して下さい。

例： ····aquatic ecosystems (WELCH 1972, 1974), Liebig's (1840 p. 23) "low of the minimum" is····, ····が知られている (YAMADA 1949), 岡村 (1907 p. 56) は,

(3) **引用文献**　本文中で引用した文献のみを，別紙にアルファベット順に列挙して下さい。引用は，①原著の引用と，②図書目録を見て目的の書物を捜し当てるための引用の2本立てとし，それぞれが イ）著者名 ロ）出版年 ハ）標題（巻次を含む） ニ）対照事項（頁・図など） ホ）出版事項（出版者・出版地）のうちの必要部分からなるよう順を追って下例にならって記入して下さい。

（単行本） ①，②共通　広瀬弘幸ｲ) 1959.ﾛ) 藻類学総説。ﾊ) 内田老鶴圃，東京ﾆ).

（単行本中の1章） ①DREBES, G.ｲ) 1977.ﾛ) Sexuality.ﾊ) p. 250-283.ﾆ) ②*In* D. WERNER [ed.]ｲ) The biology of diatoms.ﾊ) Blackwell Sci. Pub., London.ﾎ)

（叢書中の分冊） ①HUSTEDT, F.ｲ) 1930.ﾛ) Bacillariophyta.ﾊ) ②*In* A. PASCHER [ed.]ｲ) Sübwasser-Flora Mitteleuropas. ed. 2. No. 10.ﾊ) Gustav Fischer, Jena.ﾎ)

（雑誌の中の1論文） ①森　通保ｲ) 1970.ﾛ) *Batrachospermum ectocarpum* SIROD. の分類学的研究。ﾊ) ②藻類 8ﾊ): 1-8.ﾆ)

①MORI, M.ｲ) 1975.ﾛ) Studies on the genus *Batrachospermum* in Japan.ﾊ) ②Jap. Journ. Bot. 20ﾊ): 461-485.ﾆ)

(4) **和文摘要**　英文原稿の場合のみ，和文で，著者名・標題・宛先も入れ400字以内にまとめて下さい。

(5) **表と図およびその説明**　英文で書き，表と図は**印刷頁**の寸法（14×20.5 cm），特に横幅（全幅 14，片段 6.6 cm）を考慮し，原寸大または縮小したとき**印刷頁**におさまる大きさに仕上げ，図には倍率を示すスケールを入れ，線や記号，文字，数字はタイプライター，レタリング用具などを用い黒インキで鮮明に記入し，そのまま印刷に廻せるようにして下さい。なお，特に表の組版を希望の場合はその旨明記して下さい。表と図の裏には著者名・番号・希望縮尺を記入して下さい。表と図の説明は別紙とし，それを入れる場所を本文原稿左欄外に明示して下さい。

Ⅲ．校正と別刷　著者校正は初校のみとし，編集幹事から送りますので，3日以内に校正して同封の別刷申込書に所定の事項を記入して返送して下さい。別刷は，論文・総説・短報に限って50部を学会で負担します。

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The manuscript should conform exactly to the following instructions. The **manuscript** should be typewritten, double-spaced, on thick paper of 21.5×28 cm or A4 size. Each typewritten page usually consists of 28 lines. Symbols, units and nomenclature should conform to international usage. The S. I. metric system should be used for all numerical data. Words to be printed in italics should be underlined. The original copy and one duplicate are required. The first page should have only the title, name(s) of the author(s) and institution with address, and any necessary footnote. A short running title should be included. Acknowledgements preferably follow the text but precede the references. Tables and legends for figures should be on separate pages and be placed after the references.

An **abstract** of not more than 200 words is required. At the end of the abstract, 5-10 Key Index Words should be given alphabetically for aid in indexing. A Japanese abstract will be provided by the Editor from translation of the abstract.

References. Citations in the text should read thus: LIEBIG's (1840 p. 23)…… or ……(WELCH 1972, 1974). In the list at the end of the paper, references should be typed in alphabetical order. Each reference should be given in the following order: Name, Initials, Date, Title, Journal Volume: first page-last page. Example:

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A book title should be followed by the name of publisher and place of publication. Example:

> ABBOTT, I. A. and HOLLENBERG, G. J. 1976. Marine algae of California. Stanford Univ. Press, Stanford.

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Figures. whether line drawings or photographs, should be numbered consecutively in Arabic numerals, and referred to in the text. The maximum size for a full page figure is 14×20.5 cm. Line drawings should be made with black ink on white paper or blue-lined graph paper. Letters and numerals should not be made by hand, but should be made neatly with a lettering device (not a typewriter) and be of such size that the smallest character will not be less than 1 mm high when reduced. The original drawing and one set of clear copies are required. Photographs must be of good quality. They should be grouped to conform to the page style and format of the Journal and preferably be submitted at a size that permits reproduction without reduction. Photographs should be submitted in duplicate. Coloured plates may be printed at the expense of the author. The insertion of tables and figures in the text should be indicated on the right-hand margin of the sheet.

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3. 山田幸男先生追悼号 藻類25巻増補. 1977. A5版，xxviii+418頁. 山田先生の遺影・経歴・業績一覧・追悼文及び内外の藻類学者より寄稿された論文50編 (英文26，和文24) を掲載. 価格5,500円.

4. 日米科学セミナー記録 Contributions to the systematics of the benthic marine algae of the North Pacific. I. A. ABBOTT・黒木宗尚共編. 1972. B5版，xiv+280頁，6図版. 昭和46年8月に札幌で開催された北太平洋産海藻に関する日米科学セミナーの記録で，20編の研究報告 (英文) を掲載. 価格3,000円.

5. 北海道周辺のコンブ類と最近の増養殖学的研究 1977. B5版，65頁. 昭和49年9月に札幌で行なわれた日本藻類学会主催「コンブに関する講演会」の記録. 4論文と討論の要旨. 価格700円.

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2. Index of the Bulletin of Japanese Society of Phycology. Vol. 1 (1953)-Vol. 10 (1962) Price 1,500 Yen for member, 2,000 Yen for non member, Vol. 11 (1963)-Vol. 20 (1972), Price 2,000 Yen for member, 2,500 Yen for non member. Vol. 1 (1953)—Vol. 30 (1982). Price 3,000 Yen for member, 3,500 Yen for non member (incl. postage, surface mail).

3. A Memorial Issue Honouring the late Professor Yukio YAMADA (Supplement to Volume 25, the Bulletin of Japanese Society of Phycology). 1977. xxviii+418 pages. This issue includes 50 articles (26 in English, 24 in Japanese with English summary) on phycology, with photographies and list of publications of the late Professor Yukio YAMADA. ¥6,000 (incl. postage, surface mail).

4. Contributions to the Systematics of the Benthic Marine Algae of the North Pacific. Edited by I. A. ABBOTT and M. KUROGI. 1972. xiv+280 pages, 6 plates. Twenty papers followed by discussions are included, which were presented in the U.S.-Japan Seminar on the North Pacific benthic marine algae, held in Sapporo, Japan, August 13-16, 1971. ¥4,000 (incl. postage, surface mail).

5. Recent Studies on the Cultivation of *Laminaria* in Hokkaido (in Japanese). 1977. 65 pages. Four papers followed by discussions are included, which were presented in a symposium on *Laminaria*, sponsored by the Society, held in Sapporo, September 1974. ¥700 (incl. postage, surface mail).

昭和58年9月10日 印刷
昭和58年9月20日 発行

編集兼発行者 三 浦 昭 雄
〒108 東京都港区港南4—5—7
東京水産大学 植物学教室内

印 刷 所 学術図書印刷株式会社
〒176 東京都練馬区豊玉北2丁目13番地

発 行 所 日 本 藻 類 学 会
〒108 東京都港区港南4—5—7
東京水産大学 植物学教室内
振 替 東京 4 1 3 9 1 7 6

Printed by GAKUJUTSU TOSHO Printing Co.

本誌の出版費の一部は文部省科学研究費補助金 (研究成果刊行費) による。

第31巻　第3号　昭和58年9月20日

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