1973年、博多湾箱崎港において発生した赤潮、増殖プロセスとクロロフィル含量

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A Red Tide Occurred at the Hakozaki Fishing Port, Hakata Bay, in 1973

—The growth process and the chlorophyll content—

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Abstract

Red tide consisting of two peaks took place in the Hakozaki fishing port, Hakata Bay, between late May and early June, 1973. A predominant organism was identified temporarily as Heterosigma sp., genus Heterosigma HADA, Dinoflagellida.

The maximum cell density and chlorophyll-a concentration recorded at the time of the red tide were $83.5 \times 10^7$ cells/liter and 1,628 $\mu$g chl-a/liter, respectively. The average chlorophyll-a concentration per one cell was about $2.46 \times 10^{-6}$ $\mu$g, and growth rate ($k'/\text{day}$) of the red tide was calculated as 0.405. Although non-motile cells, non-flagella and global, were observed during early growth phase of the red tide, it could not be confirmed whether the non-motile cells were a form of early state of Heterosigma sp. or not.

Introduction

In the study of the mechanisms of red tide occurrence, it is important to find the actual state of the growth process of red tide organism in the field. Although there are many growth-physiological studies of red tide organisms, especially flagellates, under various culture conditions (IWASAKI, 1969; 1971-a; 1971-b; 1973; IWASAKI and SASADA, 1969; IWAKAKI, et al., 1968; 1969; OKAICHI, 1969-a; 1969-b; OKAICHI and YAGYU, 1969; HIRAYAMA and NUMAGUCHI, 1972; HIRAYAMA, et al., 1972; NUMAGUCHI and HIRAYAMA, 1972; HONJO and HANAOKA, 1973), the studies do not seem to have completely revealed the growth process of the organism which caused red tide in the field.

The present authors investigated daily changes in cell density of each species found in the surface water of the Hakozaki fishing port, Hakata Bay, from early May to late June, 1973, with the purpose to find the change of phytoplankton composition and the characteristics.

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1) 1973年，博多湾箱崎港において発生した赤潮。增殖プロセスとクロロフィル含量。 Contribution from the Tokai Regional Fisheries Research Laboratory, B, No. 643.
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during red tide season (HONJO, et al., 1978). And we encountered fortunately an intense flagellate red tide during the period. In the present paper, the observed results of the intense red tide are described on especially the growth process and chlorophyll content.

Methods

In accordance with the methods reported by HONJO, et al. (1978), daily changes in cell density of Heterosigma sp. were determined.

Chlorophyll-a concentration was estimated spectrophotometrically using Strickland and Parsons’s method (1968), on the extracts with 90% acetone of the residue which were obtained by filtering the water samples with membrane filter (0.45 µm in pore size). Chlorophyll-a concentration was calculated by using Strickland and Parsons’s formula.

Furthermore, water temperature and chlorinity were observed by the authors.

Data of Fukuoka Regional Meteorological Observatory were utilized to analyse weather conditions during the period of the red tide.

Results and Discussion

An intense red tide in surface water was observed with two peaks from 31 May to 6 June and from 9 to 12 June, 1973. Predominant red tide organism was 20-25 µm in length, 18-20 µm in width, 7-8 µm in thickness. Because the shape is the same as the species described by HONJO and HANAOKA (1973, see Figure 6, 1, a–c) which was identified as resembling species of Heterosigma inlandica, genus Heterosigma HADA, Dinoflagellida (HADA, 1968), the organism was identified temporarily as Heterosigma sp.*

The first peak was maintained under 17-18 Cl %o and about 20-22°C, and the second peak under 16-18 Cl %o and 23-25°C (Figures 1 and 2). At the first peak, the maximum cell density was $3.65 \times 10^7$ cells/liter, and chlorophyll-a concentration $1,628 \mu g/liter$. At the second peak, cell density was $8.35 \times 10^7$ cells/liter and chlorophyll-a concentration $1,526 \mu g/liter$. This red tide with two peaks was of extreme intensity compared with the Heterosigma sp. red tide, the mixed red tides of Heterosigma sp. and Gymnodinium sp. observed in eastern Hakata Bay (HONJO, 1974), and some red tides reviewed by HANAOKA (1972).

Growth rate ($k'/\text{day} = \frac{\log N_2}{\log N_1}$, where $N_2$ and $N_1$ are the number of cells on the day $t_2$ and $t_1$,) between 24 and 31 May was calculated as 0.405 (1.35 divisions per day). Since this growth rate is estimated with cell densities of Heterosigma sp. of only surface water at one station, effects of vertical migration and cell loss or gain from or to the sampling station are neglected. Nevertheless, the growth rate approximates to those (average growth rate, ca. 0.4) which were obtained in culture media wherein “mud supernatant” was added (HONJO and HANAOKA, 1973). This value is larger than those which were estimated by laboratory incubations of red tide organisms composed of Gymnodinium sp. and Coch-

* There are some uncertainties for the organism and some taxonomists temporarily classify as a species of Olisthodiscus sp., genus Olisthodiscus CARTER, Xanthophyceae.
Fig. 1. Chlorinity, water temperature, and meteorological parameters during the period of *Heterosigma* sp. red tide.

Fig. 2. Daily changes in cell density of *Heterosigma* sp. red tide and the growth rate.
lodinium sp. (0.55-0.77 divisions per day; HOLMES, et al., 1967). F. UYENO (cited from HANAOKA, 1972) has observed, however, 2-4 divisions per day of Ceratium furca red tide in Ago Bay.

On 7 June, the first peak expired suddenly. The expiration seemed to be a temporary one because of the scattering of cells due to intense turbulence by wind velocity of about 5 m/sec and escaping from the surface water due to abrupt decline of chlorinity by precipitation. And the second peak appears due to recrowding of the cells on the surface water as soon as the wind abated and chlorinity became better. Thereafter, the second peak disappeared within a short time.

The regression line between cell densities of Heterosigma sp. and chlorophyll-a concentrations during red tide is shown in Figure 3, that is $2.46 \times 10^{-6}$ µg chl-a per one cell. This is a considerably small value compared with $39 \times 10^{-6}$ µg of Gonyaulax polyedra and other dinoflagellates (HOLMES, et al., 1967), $21.85 \times 10^{-6}$ µg of Gymnodinium sp. (IIZUKA and IRIE, 1966), about $6 \times 10^{-6}$ µg of Gymnodinium sp. (HICKEL, et al., 1971), about $5 \times 10^{-6}$ µg of Olisthodiscus sp. (SAZUKI, et al., 1971), and $4.9 \times 10^{-6}$ µg of Heterosigma sp. in culture (T. HONJO, unpublished manuscript).

Before 26 May, cell densities of Heterosigma sp. were counted as motile cell below $0.4 \times 10^7$ cells/liter, but suddenly from 28 to 29 May non-motile cells (non-flagella, global, and about 20 µm in size),* were observed ($0.5-3.5 \times 10^7$ cells/liter). However, on 31 May this non-motile cell population disappeared and changed into a motile cell population. On the other hand, it was reported that the non-motile cell population was observed at 4 m above oxygen deficient layer on 22 July, 1969, in eastern Hakata Bay. This population developed into red tide of Heterosigma sp. comprising of motile cell at 2 m in depth on 4 August (HONJO, 1974). The coincidence of these two phenomena suggests that the non-motile cell may be an early form of Heterosigma sp. in red tide. However, no conclusive evidence was obtained whether

* The shape is similar to that in Figure 6-4 from HONJO and HANAOKA (1973).
or not the non-motile cell that originated from a dormant seed population in the sediment changed into motile cell. If the non-motile cell population could be confirmed to be one form (or one generation) of *Heterosigma* sp. life cycle, the non-motile cell population may serve as a diagnostic indicator to predict the occurrence of *Heterosigma* sp. red tide.

To elucidate the mechanisms of red tide occurrence, it seems essential to study the life cycles and the growth rates of various red tide organisms, and to observe the actual states of the growth process of red tides in the field.

**References**


IWASAKI, H. and K. SASADA, 1969: Studies on the red tide dinoflagellates. II. On *Heterosigma*