Spectrophotometric investigation of the plankton pigment—Ⅲ

Relations between pigment amount and cell number of phytoplankton (in case of 1959)

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Abstract

Succeeding to two previous reports, we tried to elucidate the relation between cell number and \( E_{670} \)-value in this report. From a viewpoint monthly, proportionality existed between them generally (Tab. 1) but in each case the relation was not always so, for the relation was different considerably in every sample (Fig. 1). Therefore, to analyse in detail, the authors showed figures (Fig. 2&3) of the relation between cell number and \( E_{670} \)-value per one cell, in stead of \( E_{670} \)-value, and knew that the relation was hyperbolic (Fig. 2), experimental equation being linear in logarithmic expression (Fig. 3). But circumstances are differ by cell number; i.e. in the case of cell number less than 300,000 cells per liter, the more cell number per liter we observe the less \( E_{670} \)-value per one cell we obtain. The experimental equation is

\[
\log y_2 = -0.9675 \log x + 3.6288
\]

where \( x \) is cell number per liter and \( y_2 \) is \( E_{670} \)-value per one cell, determined by the method already described in the previous reports. Consequently, it will be clear that the less cell number per liter we observe the more \( E_{670} \)-value per one cell we obtain; this is, minimum cell number agrees with maximum \( E_{670} \)-value per one cell. Therefore, in the coastal region, the authors guessed that during the plankton desert period or interval term of the two succeeding prosperities of population \( E_{670} \)-value per one cell becomes rather plentiful.

Preface

In the previous reports\(^{12)}\), the authors elucidated that spectral absorption curves of phytoplankton collections in the coastal region were grouped into 3 types and determined that efficient and appropriate sampling interval to secure the variations of plankton pigment amount in this field was probably twice a week. In this report we tried to elucidate the correlations between pigment amount and cell number of phytoplankton. Data were as same as in the previous reports collected in surface layer of Sakibe Inlet, Sasebo Bay, from April 20 to December 31, 1959. Five and one liter sea water, respectively, to extract pigment and to count cells were collected simultaneously in same place, and the former samples were proceeded as already described and every absorbency was determined at 10m\( \mu \) interval from 460 to 550m\( \mu \), especially at 5m\( \mu \) interval in two main absorption band from 430 to 445 and from 660 to 670m\( \mu \), by means of spectrophotometer. We used only \( E_{670} \)-values, showing the
absorbency at 670nm, by reason of being considered to express relatively the chlorophyll amount; i.e. we were not concerned with absolute value of chlorophyll. After formalin-fixing, the latter samples were condensed into 25 ml by settling and centrifuging. Thereafter we counted cell number in 0.1 ml of it 5 times and finally converted into cell number per one liter. In these procedures, 63 pairs of data about E₆₇₀-value and cell count were collected during the period. To analyse the correlation between pigment amount and cell number in detail, we considered from 3 different points, namely relation between E₆₇₀-value and cell number, E₆₇₀-value per one cell and cell number, and E₆₇₀-value per one cell and rise-and-fall of population, respectively, where E₆₇₀-value per one cell is the quotient of E₆₇₀-value divided by total cell number of phytoplankton (including dinoflagellates and silicoflagellates) and rise-and-fall of population means the fluctuation of cell number composing the community. In this case, it was assumed that all the each cell contained the same pigment amount, disregarding species composition, magnitude, physiological condition and career of each cell and all the environmental factors. As all factors as mentioned above bring indeed some differences on the pigment amount of each cell in natural condition, we do not consider this procedure to be sufficient. Some discrepancies occurred, of course, in analysis of results and we shall try to correct this point in future.

**Result and consideration**

The monthly occurrences of E₆₇₀-value and cell number on the average, were as follows (Tab.1).

All over the period, the maximum occurrence of E₆₇₀-value was appeared in July and from April to July it exceeded the average and in other months it was below the average. In the period from April to July the occurrences of first three months increased slowly on the whole, increasing sharply in July. Immediately after it, the occurrence decreased extremely in August and attained to the minimum all over the period. Afterward, in the period from September to December the occurrences were constant on the whole. According to cell

| Tab. 1 Monthly relation between E₆₇₀-value and phytoplankton cell number |
|-------------------------------|------------------|-----------------|
| f : numbers of collection     |                  |
| E₆₇₀                         | cells/L (×10⁶)   |
| Apr. 0.085                   | 133              | 7               |
| May 0.082                    | 1,105            | 22              |
| June 0.073                   | 1,580            | 22              |
| July 0.141                   | 1,364            | 12              |
| Aug. 0.027                   | 377              | 3               |
| Sept. 0.040                  | 499              | 7               |
| Oct. 0.036                   | 13               | 7               |
| Nov. 0.048                   | 50               | 6               |
| Dec. 0.045                   | 130              | 9               |
counting, the maximum occurrence appeared in June and minimum in October and the maximum of cell number appeared one month early compared with the E$_{670}$-value, being as same as the result by W. T. EDMONDSON & Y. H. EDMONDSON(2) in this point only, who observed in the aquarium the maximum of cell number preceding to the maximum of pigment amount. It may be allowed to say that rise-and-fall of E$_{670}$-value and cell number agreed with each other on the whole. As the relation between pigment amount and cell number was complicated, however, we didn't think that the relation mentioned above was able to be affirmed completely. In all the each collection, the relation between E$_{670}$-value and cell number was considerably variable. Though we showed the relation by the figure (Fig. 1), the distribution

![Graph showing the relation between pigment amount (E$_{670}$-values) and cell number.](image)

**Fig. 1** The relation between pigment amount (E$_{670}$-values) and cell number $x$ and $y_1$ of linear equation in the figure are cell number ($\times 10^{-9}$) per liter and E$_{670}$-value ($\times 10^3$), respectively.

![Graph showing the relation between pigment amount (E$_{670}$-values) per one cell and total cell number.](image)

**Fig. 2** The relation between pigment amount (E$_{670}$-values) per one cell and total cell number — (1)
Fig. 3 The relation between pigment amount (E<sub>670</sub>-values) per one cell and total cell number—(2)

To determine the linear equation in the figure, values of 28 samples except 5 shown by sign of ◊ were used. x and y<sub>2</sub> of the equation are cell number (×10<sup>-3</sup>) per liter and E<sub>670</sub>-value (×10<sup>8</sup>) per one cell, respectively.

being extensive. Nevertheless, it will be able to say that the more cell number we observe the higher E<sub>670</sub>-value we obtain, the relation being not so clear as we expected. The experimental equation was as follow,

\[
\log y_1 = 0.0662 \log x + 1.5664
\]

where x was phytoplankton cell number × 10<sup>-3</sup> per liter and y<sub>1</sub> was E<sub>670</sub>-value × 10<sup>8</sup>. Hereupon, we studied in detail the relation by using E<sub>670</sub>-value per one cell instead of E<sub>670</sub>-value and the figures showing the relation were prepared (Fig. 2&3). According to Fig. 2, the relation was hyperbolic and there was the inflexion area of hyperbola between cell number from 30×10<sup>3</sup> cells per liter to 350×10<sup>3</sup>. The same relation was in the logarithmic expression in Fig. 3, too. Of course, the relation became linear but the circumstances were differ before and behind of 20,000 cells per liter. In the ease of cell number less than 300,000 cells per liter the decrease of E<sub>670</sub>-value per one cell corresponded to the increase of cell number was linear, the equation being as follow,

\[
\log y_2 = -0.9675 \log x + 3.6258
\]

where x was as same as mentioned above and y<sub>2</sub> was E<sub>670</sub>-value × 10<sup>8</sup> per one cell and the equation was derived from 28 collectoins except 5, being shown by sign of ◊ in Fig. 3. In
the case of cell number more than 300,000 cells per liter, the relation didn't be clear but the equation may be able to apply on the whole and so we showed it by a dotted line in the figure. In the Sakibe region, the average cell number of phytoplankton in this year was approximately 600,000 cells per liter, so 300,000 cells per liter was a half of the average and it should have recognized as being rather sparse condition. Therefore, the condition less than 300,000 cells per liter will probably be said as being scanty and it was necessary to be noticed that the less cell number we observe the more plentiful E₈₇₀-value per one cell we obtain under the such scanty condition. This meant in other words that E₈₇₀-value per one cell was more plentiful during the plankton desert period or interval term of the two succeeding prosperities of population. In fact, according to Figs. 4&5 it was recognized that the relation between E₈₇₀-value per one cell and rise-and-fall of population was an inverse proportion on the whole. All over the period, we observed the 3 plentiful periods of E₈₇₀-value per one cell, the first being from May 2 to 10, the second from July 14 to 20 and the last from early October to early November. Each period was different in character in one-self; namely, the first having the character that the plentiful period of E₈₇₀-value per one cell happened in the first decade of May after the long scanty period of plankton population from March to April and immediately after it the plankton population began to increase and flourished until attaining the maximum cell number, approximately 4,600,000 cells per liter, all over the period. The second happened under the circumstance which plankton population disappeared temporarily from the surface layer probably from a result of heavy rainfall amounting to 234.5 mm in total from July 13 to 14 and began to increase after a week with vanity of the precipitation effect and flourished again in the end of July. The last agreed with the desert period after the long-term flourish from early summer to early autumn. In the preceding two cases, such phenomenon was usual as what the increase of population happened immediately after appearing of the plentiful period of E₈₇₀-value per one cell. In spite of the large scale of appearance, we didn't recognized such a common phenomenon as previous two in the latter case and it was not until December that the next increase appeared at last.

Though we were not able to elucidate why the plentiful period of E₈₇₀-value per one cell happened occasionally and why E₈₇₀-value per one cell was abundant at the time being less in cell number, we have some opinions about those as follows: the pigment amount per one cell being plentiful means in other words the activity of cell being strong and the cell-group, in which retained such a plentiful pigment amount, being able to withstand to the environmental difficulties for existence. Therefore, such a cell-group only can retain the life against the wrong condition as the plankton desert period or interval term of the two succeeding prosperities and such a cell-group only may succeed to flourish in future. From this view point, the plentiful pigment amount per one cell will be one of the indispensable conditions for maintenance of species and there happens some possibility which the population increase appear after the plentiful period of pigment amount per one cell. We obtained only 3 terms being plentiful in pigment amount all over the period and were not always able to affirm our opinions in all the cases and so we shall try to analyse in detail by means of collecting the many of practical examples about that.

References

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3) W. T. Edmondson & Y. H. Edmondson : Measurements of production in fertilized salt-water
Fig. 4 The seasonal variations of pigment amounts (E<sub>670</sub>-values), cell numbers of Diatoms, Dinoflagellates and Silicoflagellates and pigment amount (E<sub>670</sub>-values) per one cell from April 20 to July 31 at Sakibe Inlet, Sasebo Bay; surface collections—(I)

Fig. 5 The seasonal variations of pigment amounts (E<sub>670</sub>-values), cell numbers of Diatoms, Dinoflagellates and Silicoflagellates and pigment amount (E<sub>670</sub>-values) per one cell from August 20 to December 31 at Sakibe Inlet, Sasebo Bay; surface collections—(II)