The Phytoplankton Zooplankton Relationships in Two Paddy Fields in Central Japan

By

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(*With 4 Text-figures*)

The purpose of this paper is to determine the quantitative relationships between phytoplankton and zooplankton in two paddy fields in Central Japan noted during the vegetative period of summer of 1950 and 1955. Many papers have appeared concerning the antagonistic correlation between phytoplankton and zooplankton. Two explanations of these relationships have been advanced by Harvey et al. (1935) and Hardy and Gunther (1935). One is that the grazing effect of the herbivorous zooplankton is sufficient to limit the phytoplankton population, the other is that the zooplankton move from or die within the dense area of phytoplankton. Ryther (1954) has recently related that reproduction and growth in *Daphnia* can be inhibited by a senescent *Chlorella* population. Anderson et al. (1955) stated that a control of phytoplankton population size is due to the grazing activity of the zooplankton. But these results were determined only by the variation of plankton population, and not studied on the basis of weight or productivity. So this work was also devoted to a study on the relationship in weight between phytoplankton and zooplankton, with special reference to the weekly changes of phytoplankton productivity.

The two paddy fields studied are in Narashino City, Chiba Pref. and Ono Vill., Nagano Pref. of Central Japan. The former is in plain district near Tokyo Bay and the latter in montane district at the altitude of 900 m. The paddy field observed of Chiba has an area of 200 m^2 with water 2–5 cm deep and Nagano 980 m^2 with 5–15 cm. At middle of June the rice plants (20 cm high) are transplanted to paddy fields and kept up to grow to about 1.1 m high late in August. The water temperature of the both paddy fields was ca. 25°C at 3 p.m. and the pH value near 7 during the vegetation period. Samplings of plankton were made weekly at 3 p.m. in clear daytime. Surveys of plankton weight and productivity were made only in Nagano paddy field. Paddy field waters (2–5 *l*) were filtered with a suction apparatus through filter paper (Toyo filter papers No. 5c). After the filtration, sediments on the filter paper was dried at 70°C, weighed and ignited. The dry matter minus ash content was taken as a measure of standing crop of plankton. The weight of each species of zooplankton was computed by multiplying the body weight (Kurasawa et al. 1952) by the individual number. The organic matter in sediment minus total weight of zooplankton was regarded as a weight

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of phytoplankton. The measurement of photosynthetic activity of phytoplankton was determined by the oxygen bottle method by G.L. Clark (1934). The light intensity on the surface of water was measured with a selenium photoelectric cell, and nutritive salts dissolved in water (PO_4, and NH_4-N) were determined by the usual methods.

In Nagano the phytoplankton appears in tremendous abundance after about a week from the day of transplanting rice plant and we have found it begin to decrease in a good speed but again slightly develop till early in August (Fig. 1). Since then it reduces gradually to September. Thus there are two maxima in the phytoplankton population, one at middle of June, dominated by *Cosmarium* sp. and *Nitzschia obtuza* and the other early in August, by *Melosira granulata*.

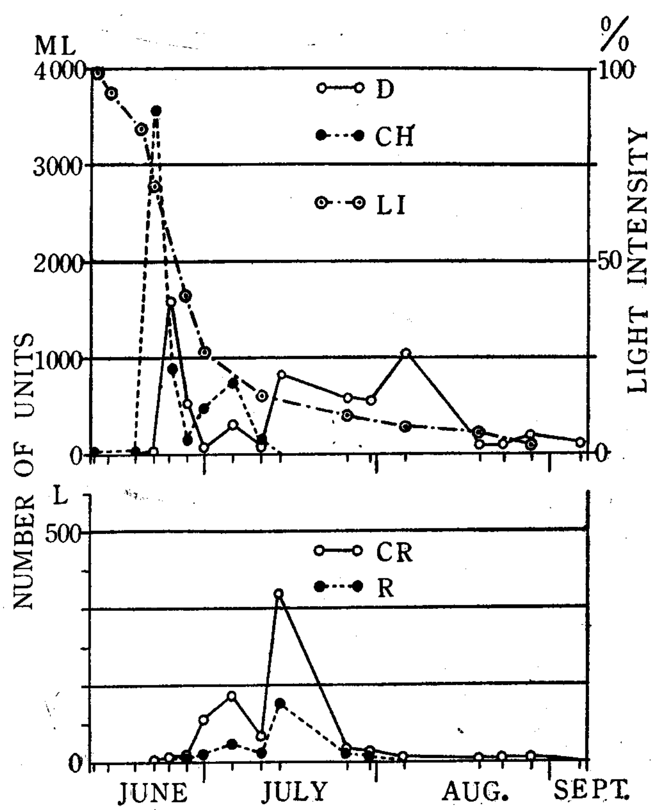

Fig. 1. Weekly succession in population numbers of phytoplankton and zooplankton and changes of light intensity at the water surface of the paddy field, Ono, Nagano, observed in summer of 1950. D..Diatomaceae, Ch.. Chlorophyceae, LI..Light intensity, CR..Crustacea, R..Rotifera,

The maximum population at middle of June rapidly declined to the minimum at beginning of July, during this period there was a large increase in the copepod and nauplii populations. At the time of maximum copepod abundance, there were also dense population of *Daphnia pulex* and *Keratella* sp. These zooplankton declined rapidly late in July, reaching a minimum in middle and latter part of August. During this period of decline the phytoplankton consisted mainly of diatoms, which grew rapidly, achieving the second peak to population abundance early in August. So there is no agreement between maxima of phytoplankters and that of zooplankters. The standing crop of phytoplankton began to increase

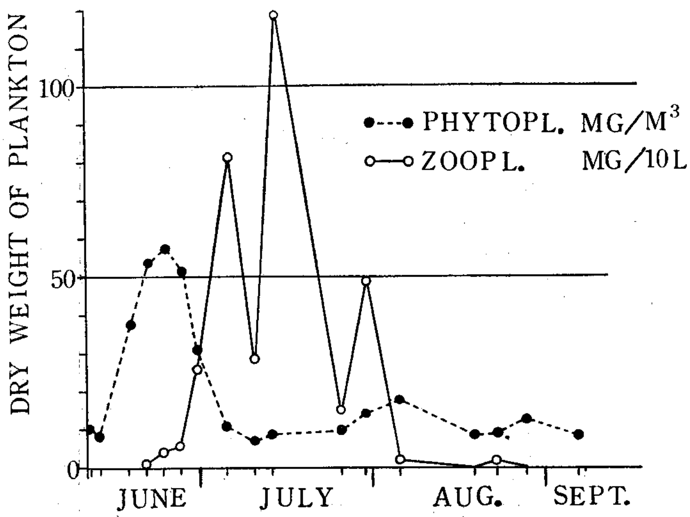

Fig. 2. Weekly changes of dry weight of phytoplankton and zooplankton in the paddy field of Nagano, observed in summer of 1950.

at middle of June and reached its maximum late in June (Fig. 2). After reaching the maximum, it declined steeply early in July, and during the declining period there are a large value in zooplankton weight, and again phytoplankton slightly increased early in August. Namely these features of the changes in plankton weight are much the same as that of population.

In Chiba the phytoplankton population began to increase in June and became the most abundant after about a month from the day of transplantation. The maximal population decreased rapidly at latter part of July, reaching a minimum early in August and September (Fig. 3). The maximum of the phytoplankton population was dominated by diatoms (mainly *Navicura* sp.). During the period of two minimal population of phytoplankton late in June and in July, there were two maxima in zooplankton population, and the copepod population reached its maximum abundance late in June. At the same time the population of *Daphnia pulex* and *Brachionus* sp. became large. At the beginning and latter part of July when the copepod population had reached a low level there was a resurgence of the phytoplankton population. Zooplankton maximum in June was seen before the phytoplankton abundance, for which two reasons are supposed as follows. One is that zooplankton grew by feeding mainly nonliving organic matter and the

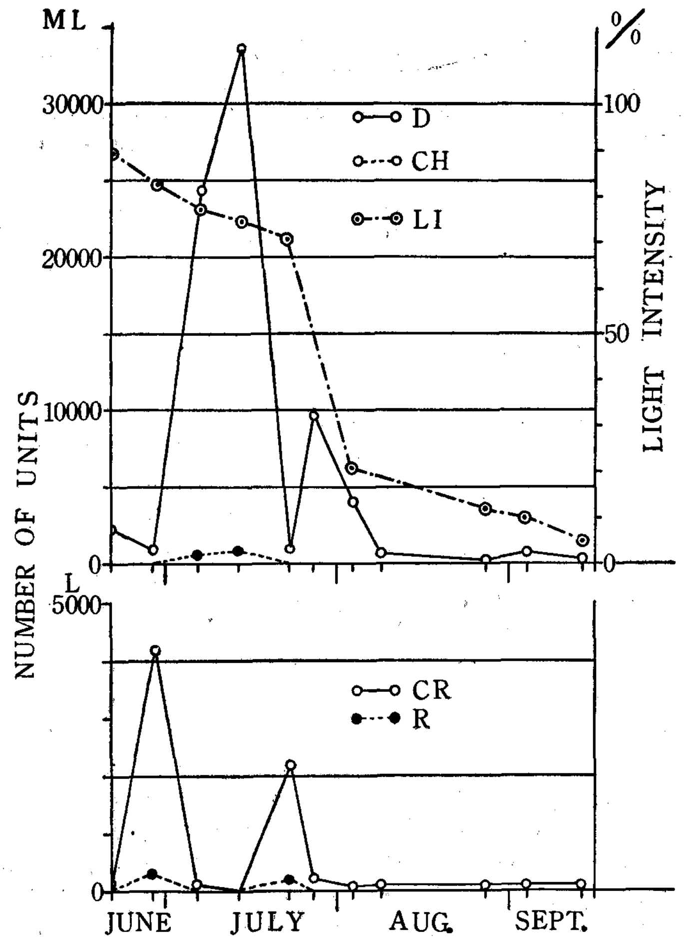

Fig. 3. Weekly succession in population numbers of phytoplankton and zooplankton, and changes of light intensity at the water surface of the paddy field, Narashino, Chiba, observed in summer of 1955. D.: Diatomaceae, CH.: Chlorophyceae, LI.: Light intensity, CR.: Crustacea, R.: Rotifera.

other is that a phytoplankton increase may occur before we start investigation. In Chiba, irrigation has continued from the beginning of June. On the contrary it was made just before transplantation of the rice plants in Nagano. Thus it was clarified that there was a clear reciprocal relationship between the population densities of zooplankton and phytoplankton. Also it was noticed that Rotifera and Chlorophyceae appear or disappear at the same time between June and July. The same phenomena was observed in the case of Nagano. This fact may show a close food relationship between Chlorophyceae and Rotifera. In consequence it is given as a probable explanation that the pulse of phytoplankton is due to the grazing activity of the zooplankton. Hardy and Ryther state that animal exclusion is caused by too dense phytoplankton population to the feeding of zooplankton. In both paddy fields the appearance of a small population of zooplankton by the time the phytoplankton maximum occurred may be able to suggest that this effect acted on remarkably. If the changes stated here can be imputed to zooplankton exclusion cannot be fixed from our results. However, under any circumstances it cannot be deny that feeding of zooplankton is the important cause of the changes.

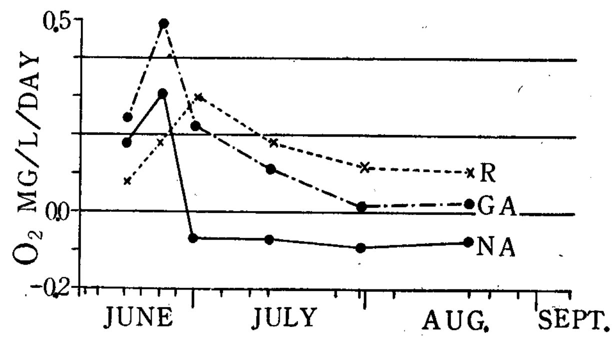

Fig. 4. Weekly changes in the productivity of the water of the paddy field of Nagano under natural condition, observed in summer of 1950. NA..Net assimilation, R..Respiration, GA..Gross assimilation.

The recent works of Ichimura (1954) and Kurasawa (1956) have shown that in the paddy field the most important habitat factor which affects the weekly succession of phytoplankton population and productivity was the light factor. In these two paddy fields with the growth of the leaf-canopy of rice plants the light intensity was weakened to the point near or below the compensation point of phytoplankton in August (1–5% of full day light). Phytoplankton should be decreased under these light conditions (Figs. 1,3). Fortunately, data in Nagano were available on the rate of photosynthesis of the phytoplankton population (Fig. 4). The maximum of net assimilation was seen late in July, and during this period there was a sharp increase in phytoplankton population, and when the net assimilation decreased steeply early in August, the minimum of phytoplankton population appeared at the time. It has been said that the seasonal changes of phytoplankton are caused by the variation of chemical nutrients, especially of nitrogen and phosphorus factors dissolved in lake water. The concentrations of these nutrients may be fairly enough to maintain the high production in paddy fields, because a dressing of those is done usually there.

Thus it is maintained that the two factors, grazing by the herbivorous zooplankton and the decrease of light for photosynthesis of phytoplankton may be in operation simultaneously on the decrease of phytoplankton population.

Summary

The weekly succession in the phytoplankton and zooplankton population, standing crop and productivity were observed in two paddy fields in Ono, Nagano Pref. and in Narashino, Chiba Pref., Central Japan. In Nagano the phytoplankton population was large late in June, but was small at other times. The zooplankters were abundant when the phytoplankton was minimum at the middle of July. While in Chiba the maximum population of phytoplankton was seen at middle of July, and reached the minimum early in August. Late in June and latter part of July when phytoplankton was its minimum the zooplankters were commonly rich, and it became poor at the time of abundance of phytoplankters. Thus in both paddy fields a clear reciprocal relationship was observed population densities between zooplankton and phytoplankton. Also the changes in phytoplankton and zooplankton weights show much the same features as those in population number. Diatomaceae and Crustacea are commonly present throughout the period, but Chlorophyceae and Rotifera disappear at the same time in and after August, probably showing the food relation between phytoplankton and zooplankton. Light was found to be the most important habitat factor which affected the weekly succession of phytoplankton population and standing crop. Nutritive salts might give only slight effects. After all, the weekly changes of phytoplankton population were probably caused by the changes of light intensity on the surface water under rice plant leaves and the grazing activity of zooplankton.

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It is the author's great honor to dedicate this piece of work to Professor T. Uchida in celebration of his sixtieth birthday.

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