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INFLUENCE OF FLOW CONDITION AND TEMPERATURE ON NUMBERS AND SPECIES OF PHYTOPLANKTON IN THE KINOKAWA RIVER

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SYNOPSIS

Under both stagnant and flowing water conditions in the Kinokawa River, the number of phytoplankton and their species were analyzed. Under flowing water conditions phytoplankton activity was found to be small in spite of water temperature change. When water temperature was less than 25 degrees centigrade, phytoplankton activity was low. However, when water temperature was over 25 degrees centigrade, phytoplankton activity became high under stagnant condition. The number of blue-green algae increased with each increase in water temperature and a decrease in the river flow. As the river flow rate decreased in summer, the ratios of Merismopedia sp. in blue-green algae, Nitzschia sp. in diatom, and Scenedesmus sp. in green algae increased. The blue-green algae showed a sudden increase in stagnated areas of the river whereas the number of diatom and green algae increased slowly when water temperature was high.

INTRODUCTION

The purpose of the study is to clarify the increase in phytoplankton in summer and the relationship between the water quality and the number of phytoplankton in the Kinokawa River. Therefore, sampling sites were selected at the Funato station for a flowing condition and the upper of the Kinokawa flood gate for a stagnant condition. A water environmental problem must be considered from a wider viewpoint, so that the water system and the basin include a material migration from a mountain to a river and the sea. Recently, mass balance from land to a sea area is important for a global problem (ecological correctness and the issue of biodiversity(1). In addition, the stagnated areas are important for mass balance because biological activity is high in stagnated areas and thus can change water quality consuming nutrients. Consumption of silica in stagnated areas causes silica deficiency and, as a result, silica deficiency also changes sea environments because river water with little silica content flows into the sea(2).

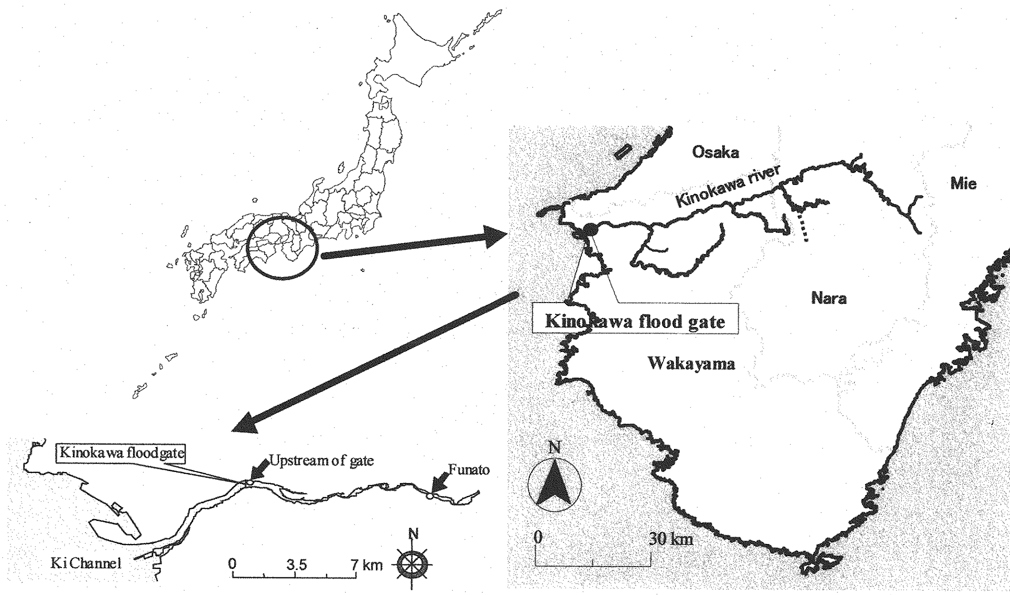

Fig. 1 A map of the Kinokawa down stream reach

Many dams and weirs, slated for river improvement and water utilization, have been built. As a result, many stagnated areas have appeared. This is similar in the Kinokawa River. Phytoplankton is sensitive to water quality and acts as a producer in the ecosystem. Therefore, investigations of phytoplankton are important because a change in species composition is thought to affect the whole ecosystem. Therefore, investigation of the upper area of the Kinokawa flood gate with stagnation was carried out in 2004. Increase in blue-green algae and a diatom in the upper area of the Kinokawa flood gate without flow can be observed when water temperature increased in July 2004(3). However, it was impossible to grasp phytoplankton species composition change period of time because observation frequency was low (once every two weeks). It has not been clarified to what extent flowing water condition and water quality has had an influence on species composition of phytoplankton. Therefore, water sampling and in-situ measurements were performed every day in the summer to clarify the species composition of phytoplankton of the summer and the relationship between water quality and species composition. A comparison between the Funato site with flowing water condition and the upstream of Kinokawa flood gate, with no flow, was also made to determine the influence of flowing water conditions on phytoplankton activity.

SUMMARY OF INVESTIGATION

Area of study

The investigation was carried out from March 15th to July 25th, 2005. Two sampling points of the Funato flow area and the upper area of the Kinokawa flood gate (stagnated areas of the water) were chosen to clarify the difference in species composition of phytoplankton between flowing water condition and stagnant conditions(Fig. 1). The Funato is located at the upstream of the Kinokawa flood gate, and the distance between the two stations is about 10km. Furthermore, there is no weir and gate in the Funato area. Periodical samplings and measurements were taken every month from March to July 2005 and intensive samplings and measurements were taken from 13th to 19th April and 13th to 25th July. The Kinokawa river is 136km long and has catchments of 1,750km^2.

Kinokawa flood gate

The Kinokawa flood gate operation started in June, 2003. The total water storing capacity of the Kinokawa flood gate is 5,100,000m^3. The Kinokawa flood gate is a movable weir which has seven gates. The maximum flow rate is more than 40m^3/s. About 1m^3/s is usually discharged from the path of the fish at both sides of the gate.

Determining sampling and measurement days by rain conditions

Figure -2 shows AMeDAS precipitation data in the Gojo and Nara cities located in the Kinokawa midstream. It was necessary in this study to avoid the days with heavy rain because the quantity of flowing water disturbs stagnation conditions and thus proliferated phytoplanktons flowed out.

SUMMARY OF WATER QUALITY ANALYSIS

An investigation method

Vertical distributions of pH, TB, chlorophyll (Chl. a, intensity of fluorescence method), water temperatures and dissolved oxygen (DO) were measured by means of portable multi sensors (AAQ1183, Aleck product made in electronic company) and also the electric conductivity (EC) was measured by a portable instrument (D-24, product made in Horiba, Ltd.). Water samplings from only the surface layer, in depth less than 0.25m, were taken at the right bank side of the upstream of Kinokawa flood gate and left bank side of the Funato.

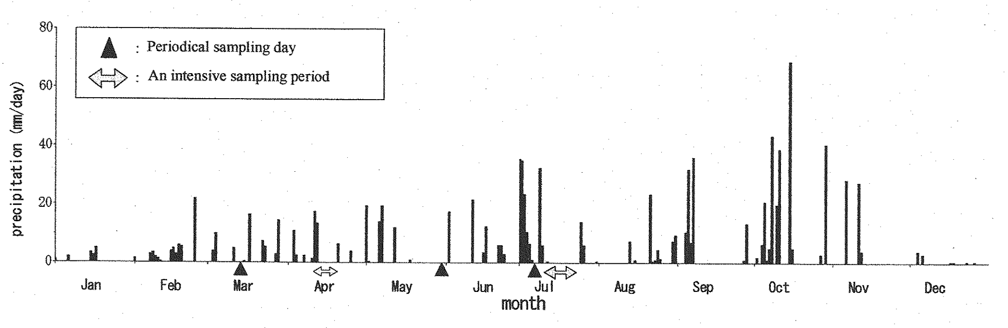

Fig 2. An AMDAS precipitation change of Gojo, Nara City

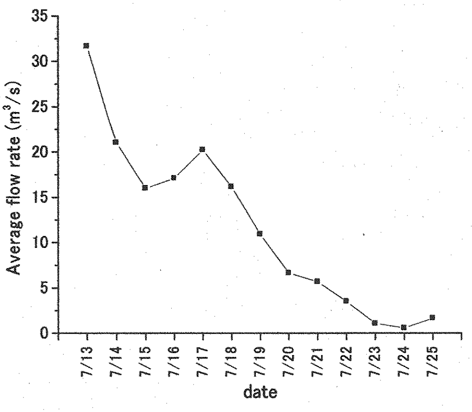

Fig. 3 Flow rate in Funato (From 13 to 25 on July in 2005)

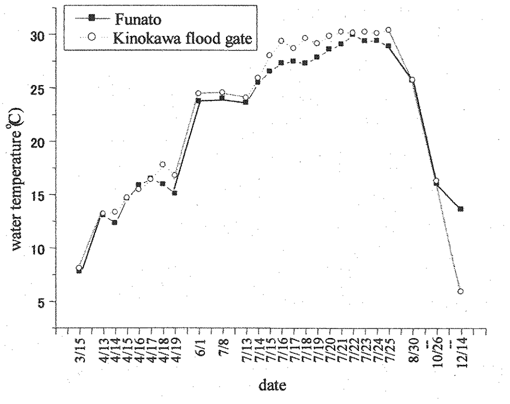

Fig. 4 A water temperature change in Funato and the Kinokawa flood gate

An analytical method

Concentrations of Nitrate Nitrogen (NO_3^--N), Nitrite nitrogen (NO_2^--N), Ammonia nitrogen (NH_4^+-N), the total Nitrogen (T-N), dissolved silicon (DSi), chlorophyll-a (Chl. a), and pheophytin-a (Pheo. a) of sampled water were measured. NO_3^--N, NO_2^--N, NH_4^+-N and DSi were directly measured by an absorptiometer (DR/2500, a product made in HACH company). The organic nitrogen in sampled water perfectly changed into nitrate and then the nitrate concentration was measured by absorptiometer as a T-N. Dissolved nitrogen (DN) of sampled water after filteration with 0.45㎛ was measured by the absorptiometer. Particle organic nitrogen (PON) is to substract DN from T-N. Dissolved organic nitrogen (DON) is to substract inorganic nitrogen (NO_3^--N, NO_2^--N and NH_4^+-N) from DN. The sampled water was filtered with glass fiber filter paper(GF/B, Whatman company and, with pore size 1㎛) and then the residual substance was soaked into N-N- dimethylformamide (DMF). Next, photosynthesis pigment of photoplankton in the solution was extracted and the absorbance of the extracted was measured with DR/2500(4)

Calculation and an identification method of plankton

25cc picric formalin was placed into the 500cc sampled water for fixation of phytoplankton in the field(5). A fixed sample was brought into a laboratory and was concentrated by the still standing deposition method and also concentrated from 500ml to 10ml(5). The total number of phytoplankton and its species in the concentrated 10ml were investigated by the phase contrast microscope (a product made in Co. , Ltd. ECLIPSE E200 Nikon) using the Japanese fresh water product zooplankton and phytoplankton picture book(6)

RESULTS OF WATER QUALITY CHANGE

Flow rate change in the Funato

Figure 3 shows a change in flow rates at the Funato. During July 13th to July 25th, there was no rain in the catchment area and flow rate decreased completely, especially after July 17th the flow rate decreased from 20 m^3/s to less than 2 m^3/s and after 23rd, the flow rate was less than 5 m^3/s.

Water temperature change in the Funato and the Kinokawa flood gate

Figure 4 shows changes in water temperature at the Funato and the Kinokawa flood gates. Water temperatures rose from 13. 2 degrees centigrade to 17.7 degrees centigrade both in the Funato and Kinokawa flood gates during April and it rose from 24.0 degrees centigrade to 30.4 degrees centigrade during July. The difference between both stations was a few degrees centigrade and usually downstream was a little high.

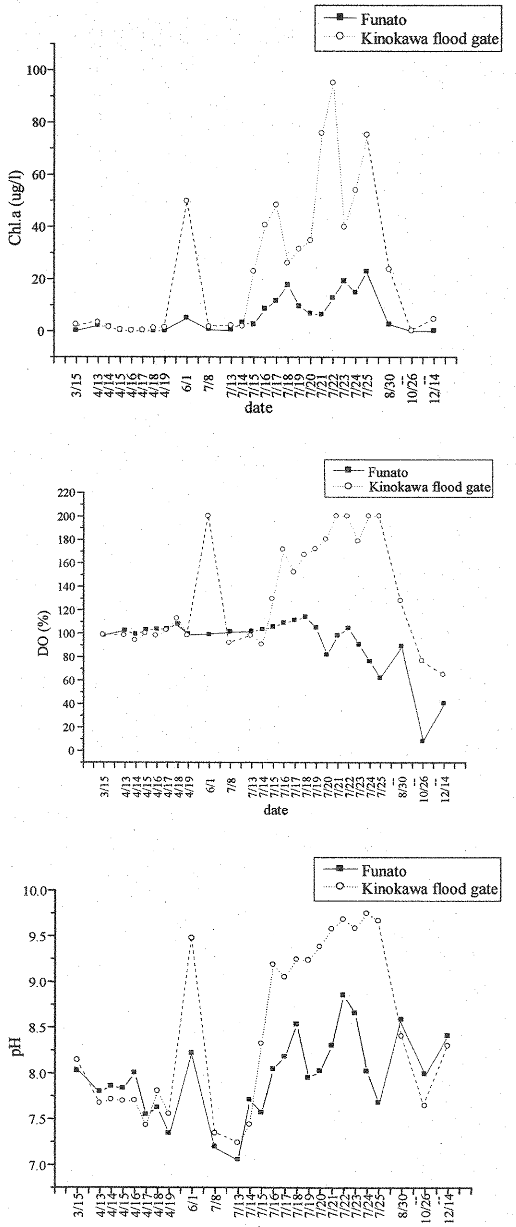

Fig. 5 Time series of Chl. a, DO and pH in sampling water at the Funato and the Kinokawa flood gate

Changes of Chl. a, pH and DO at the Funato and Kinokawa flood gates

Figures 5 shows changes in Chl. a, pH and DO at the Funato and the Kinokawa flood gates. Except for the period between June and July 14th until autumn, the differences in Chl. a, pH and DO values between two stations were very small but large in June and from July 14th till autumn. The difference depended on increase of chl. a, pH and DO at the Kinokawa flood gate. Chl. a at the Kinokawa flood gate reached the maximum value, 95μg/l in July 22nd although Chl. a at the Funato reached maximum values, 23μg/l. After July 25th, Chl. a at the Kinokawa flood gate decreased and coincided with that at the Funato.

DO values at the Funato were stable from April to mid July, but after mid July the values became smaller, and finally, depleted (0 %). On the other hand, DO values at the Kinokawa flood gate were over 100 % and then reached 200 % in June and from mid July to the end of August. Over 100 % in DO is supersaturated with normal oxygen content, 21 % in the air indicates that partially the water is saturated with over 21 % oxygen content in air. At the same time, pH values at the Kinokawa flood gate increased and was over 9. 5. The pH gaps between the Kinokawa flood gate and Funato reached over 1 and pH values at the Funato changed but it was 8 on an average. After July 25th, both DO and pH values at the Kinokawa flood gate decreased and then pH values at the Kinokawa flood gate coincided with that at the Funato. Therefore, pH and DO values at the Kinokawa flood gate increased remarkably from July 13th to 16th and then values remained high. After July

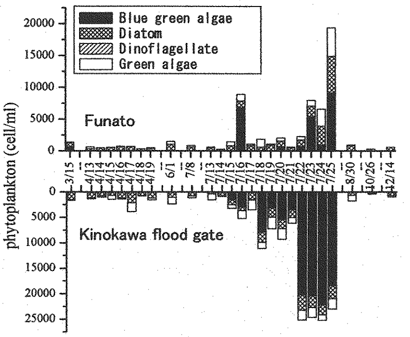

Fig. 6 Species composition of phytoplankton change in Funato and the Kinokawa flood gate

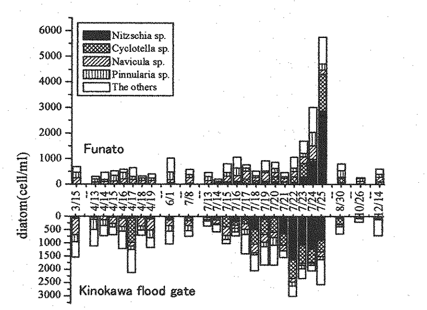

Fig. 7 Species composition of diatom change in Funato and the Kinokawa flood gate

25th, pH and DO values decreased.

Generally, photosynthesis reaction can be described by the following equation (1).

$$106CO_2 + H_3PO_4 + 122H_2O + 16H^+ + 16NO_3^- = (CH_2O)_{106}(NH_3)_{16}H_3PO_4 + 138O_2 \qquad (1)$$

From the equation, phytoplankton activity increased DO and pH values because oxygen produced by photosynthesis makes excess over 100% in DO and consumption of H^+ by photosynthesis increases the pH. As phytoplankton activity becomes high, many organic compounds, which phytoplankton consists of, are produced and then Chl. a in water also increases. Therefore, the increase in Chl. a, pH and DO in June and July was thought to indicate a high activity of photosynthesis. Photosynthesis activity depends on temperatures, the weather and flowing water conditions. The difference in temperature between the Funato and the Kinokawa flood gate was small as can be seen in Fig. 4 but flowing water conditions was quite different. River water at the Funato flows except after July 23rd to 25th from Fig. 3, but the Kinokawa flood gate had no rain and the river flow stopped. Therefore, river flow was thought to be in a critical condition. After August 30th, a swell of river stream caused by rain created a flow at both the Funato and Kinokawa flood gate and so it was thought to reduce phytoplankton activity. Then, after August 30th, Chl. a, pH and DO values were low and the differences between both stations were small.

PHYTOPLANKTON

Species composition of phytoplankton

Figure 6 shows a species composition of phytoplankton. Before July 14th, the total numbers of phytoplankton at both stations were very small but after the 15th, the number of phytoplankton at the Kinokawa flood gate increased and decreased till August 30th. At the Funato, during July 23rd to 25th, flow rate reached less than 5 m^3/s and number of phytoplankton increased as well as the Kinokawa flood gate. Therefore, the number of phytoplankton was in line with the results of Chl. a, DO and pH values completely. However, although Chl. a, DO and pH in June at the Kinokawa flood gate was high, the number of phytoplankton did not increase.

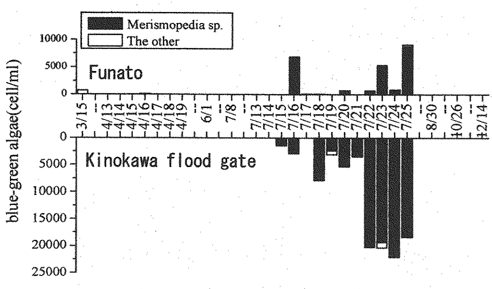

Fig. 8 Species composition of Blue algae change in the Funato and Kinokawa flood gates.

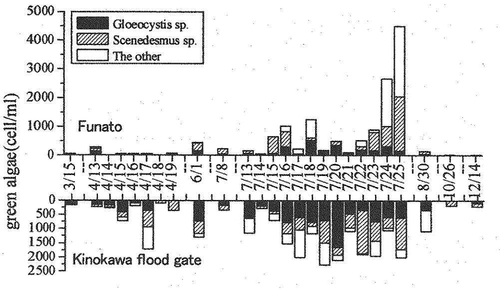

Fig. 9 Species composition of Green algae change in the Funato and Kinokawa flood gates.

Blue green algae and dinoflagellate were not frequently observed, but diatom and green algae were the main constitutions. However, when the numbers of phytoplankton increased in July, blue green algae was observed and became the main constitution. In particular, at the Kinokawa flood gate, the increase in total number depended on number of blue green algae. On the other hand, dinoflagellates were not observed in any season.

A change in species composition of phytoplankton depends on generally water temperature. High water temperature prefers diatoms to blue algae(7). However, after July 16th, water temperature reached over 28 degree centigrade and uniform but in July 22nd the number of blue green algae increased remarkably. After June, the water temperature was higher than 23 degrees centigrade but species composition did not change till 22nd July remarkably.
On the other hand, after July 22nd the flow rate at the Funato remained at fewer than m^3/s and the number of blue green algae at the Funato also increased. Therefore, flowing water conditions was thought to be important for determining species composition, especially the number of blue green algae was sensitive to change of river flow conditions.

Species composition of diatom

Figure 7 shows species composition of diatom in the Funato and the Kinokawa flood gate. From March to June, Navicula sp. and Pinnularia sp. were the main species and the number was uniform all season. When the total number of diatoms increased after mid July, Nitzschia sp. increased and became main the species. Cyclotella sp. as well as Nitzschia sp. changed.

Species composition of blue algae and green algae

Figures 8 and 9 show species composition of blue green algae and green algae. Blue algae increased at the Kinokawa flood gate in July and the main species was Merismopedia sp. When water temperatures reached 25 degrees Centigrade, blue algae were very active. Although the difference of water temperature between the Funato and Kinokawa flood gate was small, the number of blue green algae was quite different, suggesting that flowing water conditions were important for blue green algae activity.

Gloeocystis sp. and Scenedesmus sp. were the main species of green algae all season and after mid July the number of Gloeocystis sp. and Scenedesmus sp. increased. Because the change of the total number of blue green algae was clear in the Kinokawa flood gate, blue green algae was very sensitive to river flow condition.

RELATION BETWEEN PHYTOPLANKTON AND NUTRIENT

Relation between Diatom and DSi concentration

Figure 10 shows DSi concentration change in the Funato and Kinokawa flood gates. Since diatom activity in July at the Kinokawa flood gate was higher than that at the Funato, DSi concentrations at the Kinokawa flood gate were thought to be lower than those at the Funato. DSi concentrations at the Kinokawa flood gate were lower all season than those at the Funato and then decreased gradually from mid July. The concentration difference between the two stations increased from mid July. Therefore, diatom activity consumed the silica in the river.

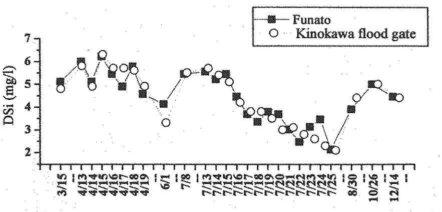

Fig. 10 DSi density change in Funato and the Kinokawa flood gate

Relation between phytoplankton and nutrient

Figure 11 shows nutrient concentration changes at the Funato and Kinokawa flood gates. In June and mid July, Total nitrogen and nitrate nitrogen decreased but PON increased with each increase in the number of phytoplankton at both stations. In particular, at the Kinokawa flood gate, the change was significant and thus phytoplankton activity at the Kinokawa flood gate was higher than that at the Funato.

CONCLUSION

Under both stagnant and flowing water conditions, the species composition and nutrients were studied. Table.1 is summary of the study. Under flowing water conditions phytoplankton activity was found to be low from results of species composition before 22nd July at the Funato, even if water temperature reaches over 25 degrees centigrade. The number of phytoplankton, even at the Funato, increased after July 23rd under stagnant condition. When water temperature was less than 25 degrees centigrade, both stagnant and flowing water conditions, phytoplankton activity was low. However, when water temperature was over 25 degrees centigrade, phytoplankton activity became high from the results of species composition at the Kinokawa flood gate under stagnant condition. In particular, after July 23rd water supply into the Kinokawa flood gate was small from the results of flow rate at the Funato and then phytoplankton activity under stagnant condition remarkably became high.

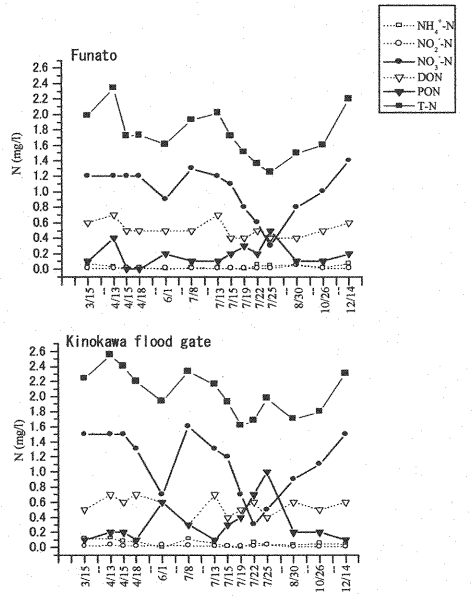

Fig. 11 Nutrient at the Funato and Kinokawa flood gate

The number of blue green algae increased with each increase in water temperature and a decrease in the river flow rate. Since the river flow rate decreased in summer, the ratios of Merismopedia sp. in blue-green algae, Nitzschia sp. in diatom, and Scenedesmus sp. in green algae increased. The blue green algae showed a sudden increase under stagnant condition whereas the number of diatom and green algae increased slowly when water temperature was high.

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Table 1 The relation between phytoplankton activity and water temperature on flowing water conditions

		flow condition	
		flowing water	stagnant
Water temperature	less than 25 degrees C	phytoplankton activity low	phytoplankton activity low
	over 25 degrees C	phytoplankton activity high	phytoplankton activity extrmely high

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