

RELATION BETWEEN NUTRIENT AND PHYTOPLANKTON
IN STAGNATION AND CURRENT AREAS OF THE KINOKAWA RIVER IN JAPAN

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<Abstract>

Under both stagnant and flowing water conditions in the Kinokawa River, a number of phytoplankton and their species were analyzed. Under flowing water condition phytoplankton activity was concluded to be small. When water temperature was less than 25 degrees centigrade, both stagnant and flowing water condition, 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 increase of water temperature and decrease of the river flow. The blue-green algae showed sudden increase in stagnated areas of the river whereas the number of diatom and green algae increased slowly when water temperature was high. Under stagnant condition, influence of nutrient on phytoplankton activity was clarified. In particular, diatom number increased from 90 cell/ml to 20000 cell/ml with the increase of total nitrogen from 0.9 mg/l to 2.2 mg/l. However, remarkable species change did not occur with the changes of nutrient.

1. Introduction

The purpose of the study is to clarify the increase of phytoplankton in summer and the relations of the water quality and the number of phytoplankton in the Kinokawa River. Therefore sampling sites were both located at the Funato station for a flowing condition and the upper of the Kinokawa flood gate for a stagnant condition. Furthermore, Sarutani dam with stagnant and low nutrient conditions was also studied in the upstream of the Kinokawa River. Land uses of the Kinokawa River system are forest in the upstream, orchard and rice field in the middle stream and rice field and housing site in the lower stream. Then nutrient along the Kinokawa River increased down the stream. A water environmental problem must be considered by the wider viewpoint, and then a 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 an 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 can change water quality consuming nutrient. Consumption of silica at stagnated areas brings out silica deficiency and as a result, silica deficiency also change sea environments because river water with little silica content flows into the sea (2).

As a lot of dams and weir, aimed for river improvement and water utilization, were built, too many stagnated areas appeared. It is a matter to apply in the Kinokawa River. Phytoplankton is sensitive for water quality and acts as a producer in the ecosystem. Therefore, observation of phytoplankton is important because a change of species composition is thought to affects the whole ecosystem. Therefore, field research in the upper area of the Kinokawa flood gate with stagnation was performed in 2004. Increase of blue-green algae and a diatom in the upper area of the Kinokawa flood gate with little flow can be observed when water temperature increased in July 2004(3). However, it was impossible to grasp phytoplankton species composition change in a short term because observation frequency is low once every two weeks. It has not been clarified how flowing water condition and water chemistry give

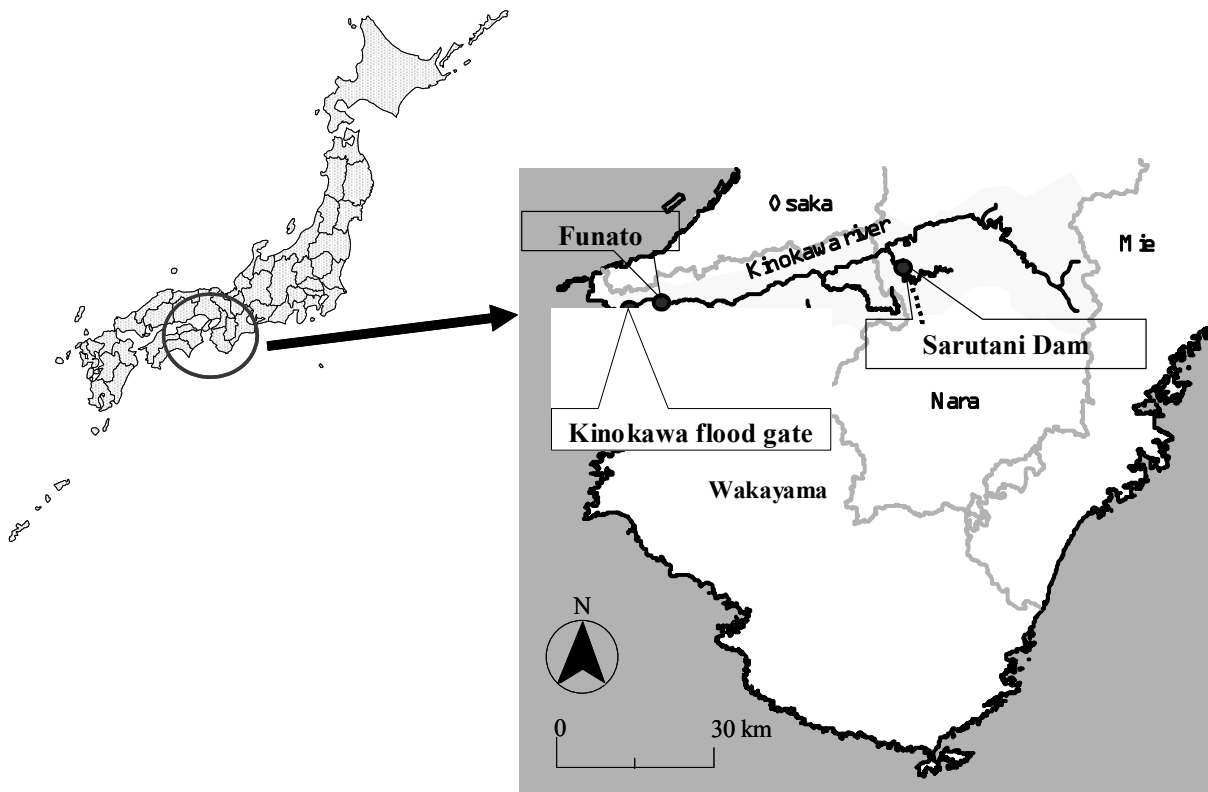


Fig. 1. A map of the Kinokawa down stream part and Sarutani dam

an influence on species composition of phytoplankton. Thereat, water sampling and in-situ measurements were performed every day in the summer season to clarify the species composition of phytoplankton of the summer and relations of the water quality and species composition. Comparison between the Funato site with flowing water condition and the upstream of Kinokawa flood gate, with no flow, was performed also to clarify the influence of flowing water conditions on phytoplankton activity.

2. A summary of an investigation

The field reseach was carried out from March to December, 2005. Two sampling points of the Funato flow area and the upper area of the Kinokawa flood gate (stagnated areas of the water) were performed to clarify a difference of 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 two stations is about 10km. Also, there are no weir and gate in the Funato area. The periodical sampling and measurement were performed once a month from March to July 2005 and the intensive sampling and measurements were performed from 13th to 19th April and 13th to 25th July. The Kinokawa river catchment has an area of 1,750km² and its length is 136km. The Kinokawa flood gate operation started from June, 2003. The total water storing capacity of the Kinokawa flood gate is 5,100,000m³. The Kinokawa flood gate is a movable weir and it has seven gates. The maximum flow rate is more than 40m³/s. About 1m³/s is usually discharged from a fish way with both sides of the gate.

Sarutani dam is located in the upstream of the Kinokawa River and its storing water capacity is 23,300,000m³ (available storage capacity 17,300,000m³). Major land use is forest and it is thought that there is little artificial influence for the water in the dam lake. The field reserch of the Sarutani Dam was carried out in March, June, August and October 2005 with vertical sampling, surface water, middle layer (15m in depth) and bottom layer (35m).

Figure -2 shows AMeDAS precipitation data in the Gojo and Nara cities located in the Kinokawa midstream. It is necessary for this study to avoid the days with strong rain because phytoplankton in the stagnated areas flashes past the gate and gate opening days because quantity of water flows out with water in stagnation area and then the proliferated phytoplankton also flows out.

3. A summary of water analysis

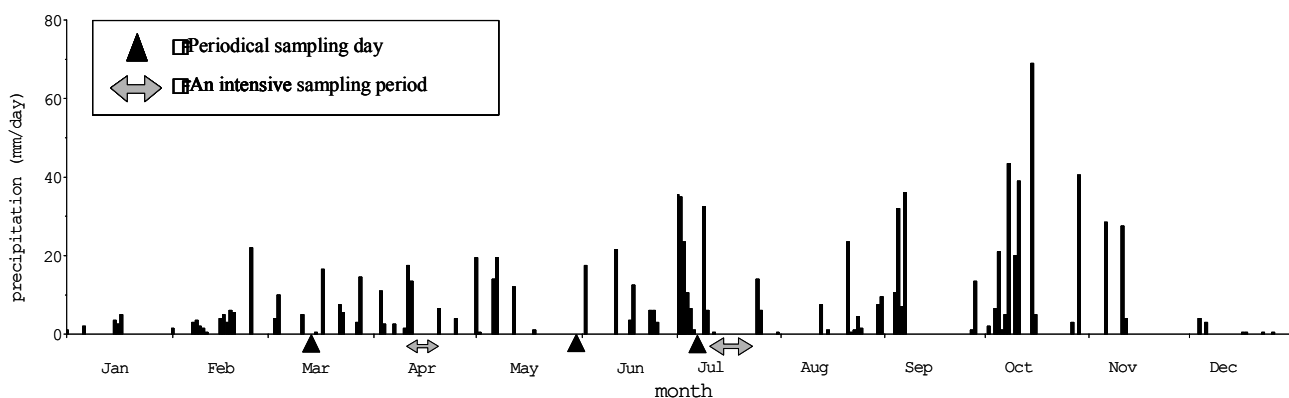


Fig. 2. An AMDAS precipitation change of Gojo, Nara City (From January to December in 2005)

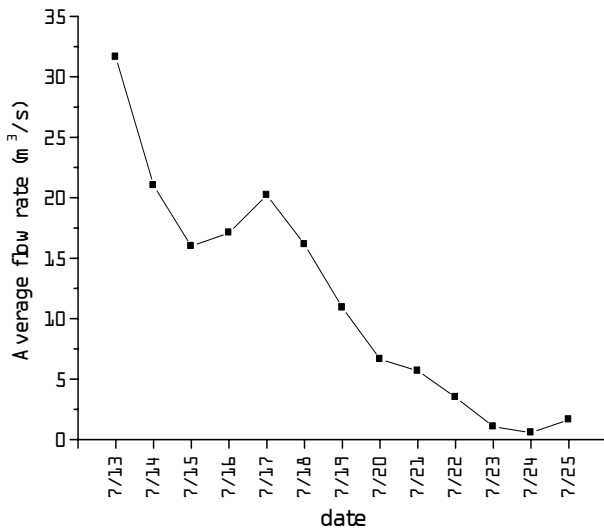


Fig. 3. Flow rate in Funato (From 13 to 25 on July in 2005)

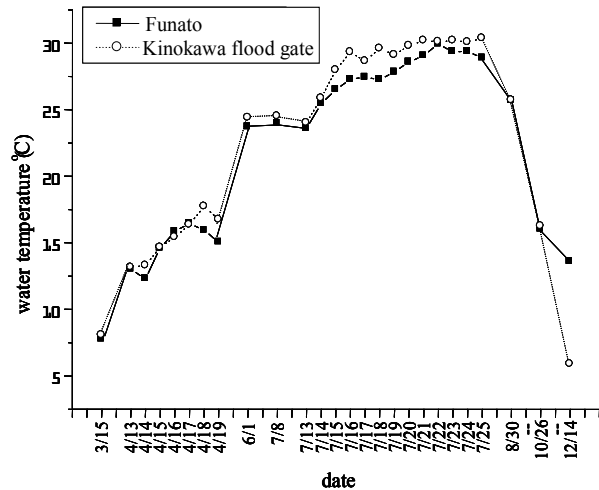


Fig. 4. A water temperature change in Funato and the Kinokawa flood gate

pH, TB, chlorophyll (Chl. a, intensity of fluorescence method), water temperature and dissolved oxygen (DO) along the river were measured by 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 sampling from only the surface layer, in depth less than 0.25m, was performed at the right bank side of the upstream of Kinokawa flood gate and left bank side of the Funato.

The concentrations of Nitrate Nitrogen (NO_3^- -N), Nitrite nitrogen (NO_2^- -N), Ammonia nitrogen (NH_4^+ -N), 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). T-N was measured by the absorptiometer after all the organic nitrogen in sampled water resolved into nitrate. Dissolved nitrogen (DN) of sampled water after filtration with 0.45 μm were measured and then to subtract DN from T-N makes particle organic nitrogen (PON) and to subtract inorganic dissolved nitrogen (NO_3^- -N, NO_2^- -N, NH_4^+ -N) from DN makes dissolved organic nitrogen (DON). Residual substances were filtered by glass fiber filter paper (GF/B, Whatman company and, with pore size 1 μm) were added N, N-dimethylformamide (DMF), and photosynthesis pigment extracted from residual containing phytoplankton. The absorbance of the extract was measured with DR/2500(4)

25cc picric formalin was put 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 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)

4. As a result of water change

Figure 3 shows a change of flow rates at the Funato. Although during July 13th to July 25th it did not rain in the catchment, flow rates in the Funato increased till July 17th. After July 17th the flow rate decreased from 20 m³/s to less than 2 m³/s and the flow rate at the Funato was less than 5 m³/s after 23rd.

Figure 4 shows changes of water temperature at the Funato and the Kinokawa flood gates. Water temperature rose from 13.2 degree centigrade to 17.7 degree centigrade both in the Funato and

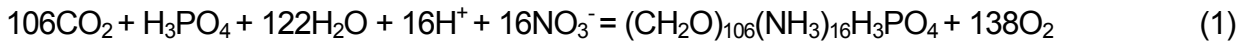
Kinokawa flood gates during April and it rose from 24.0 degree centigrade to 30.4 degree centigrade during July. The difference between both stations was few degrees centigrade and usually downstream was a little high.

Figure 5 shows a vertical water temperature in the Sarutani Dam. The difference of temperature between surface water and bottom water in the Dam reached more than 10 degrees centigrade in June but spring and fall season the difference was small.

Figure 6 shows changes of Chl. a, pH and DO at the Funato and the Kinokawa flood gates and the Sarutani dam. Excluding June from July 14th till autumn, the differences of 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 at the Kinokawa flood gate. Chl. a at the Kinokawa flood gate reached the maximum value, 95µg/l in August 22nd although Chl. a at the Funato reached maximum values, 23µg/l. After July 25th, Chl. a at the Kinokawa flood gate decreased and agreed with those at the Funato.

DO values at the Funato were stable from April to mid July, but after mid July the values decreased to be 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 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 reached to be over 9. 5. The gaps between the Kinokawa flood gate and Funato were 1 and pH values at the Funato were changeable but 8 on the average. After July 25th, both DO and pH values at the Kinokawa gate decreased and then pH values at the Kinokawa flood gate agreed with those at the Funato. Therefore, Chl. a, pH and DO values at the Kinokawa flood gate increased remarkably from July 13th to 16th and then kept high values. After July 25th, both values decreased.

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



From the equation, phytoplankton activity increased with DO and pH values because oxygen produced from phytoplankton makes partially over 21 % oxygen content in air and over 100% in DO and consume of H⁺ increases the pH. As phytoplankton activity becomes high, a lot of organic compounds, which phytoplankton consists of, are produced and then Chl. a in water also increases. Therefore, the increase of Chl. a, pH and DO in June and July was thought to indicate high activity of photosynthesis. Photosynthesis activity depends on temperature, weather and flowing water conditions. The difference of temperature and weather between the Funato and the Kinokawa flood gate was small from Fig. 4 but flowing water conditions were quite different because river water at the Funato flows excluding after July 23rd to 25th from Fig. 3. Therefore, river flow was thought to be in critical condition. After August 30th, a swell of river stream caused by rain created flow at both the Funato and Kinokawa flood gate and was thought to reduce phytoplankton activity. Then, after August 30th, Chl. a, pH and DO values were low and the differences between both stations became small.

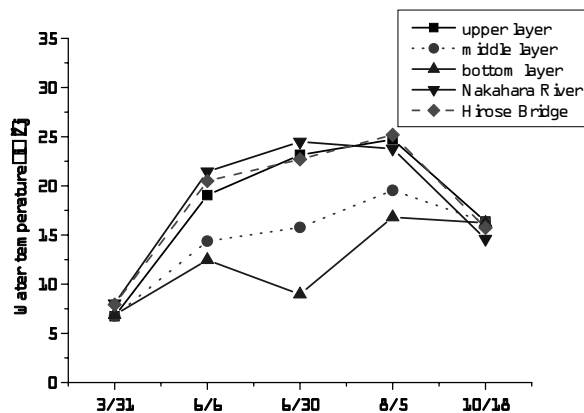


Fig. 5. A water temperature change in the Sarutani dam and Nakahara River and Hirose Bridge

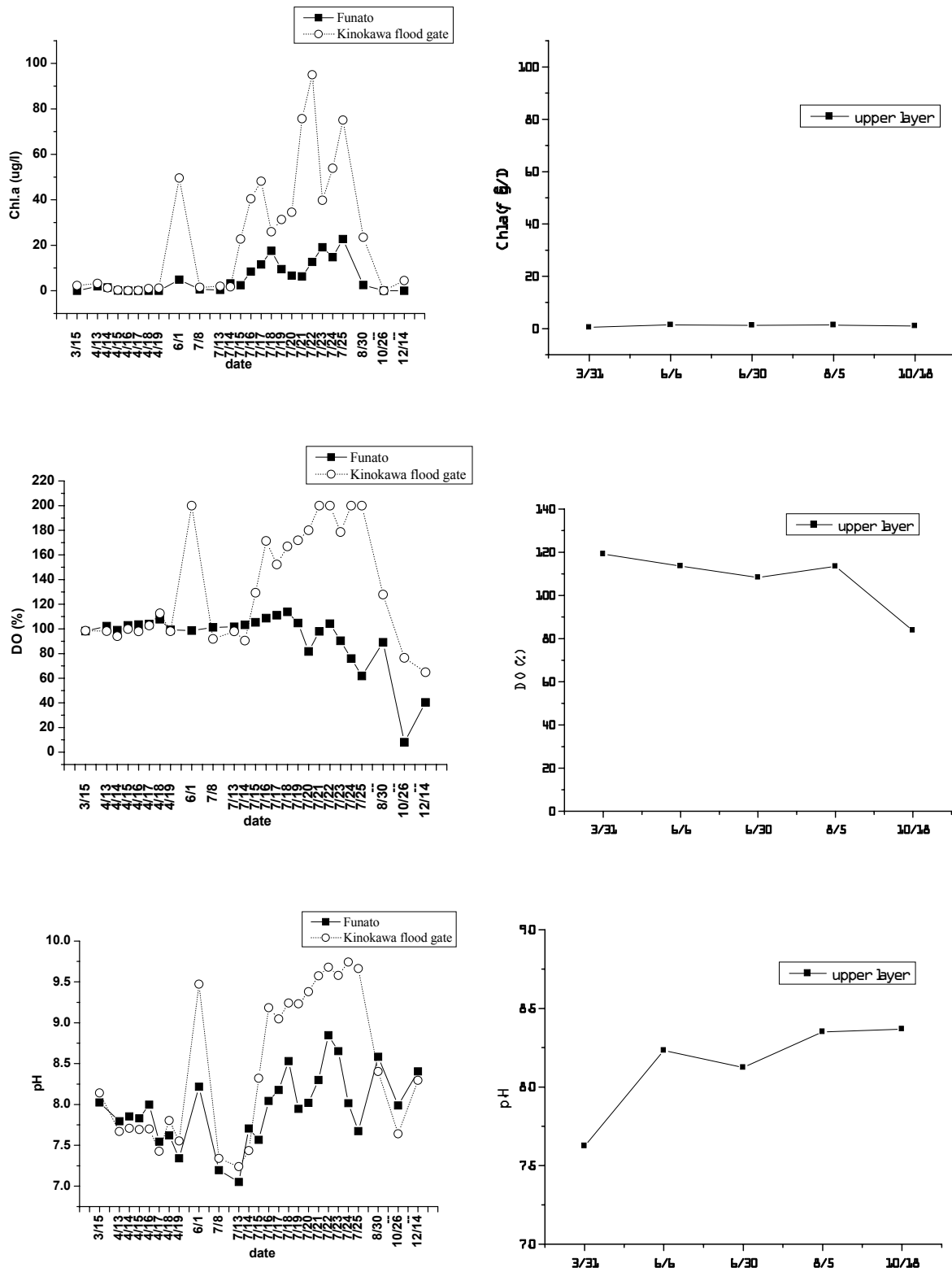


Fig. 6. Time series of Chl. a, DO and pH in sampling water at the Funato and the Kinokawa flood gate and the Sarutani dam

Figure 6 shows changes of Chl.a, DO and pH in the Sarutani Dam from March to October 2005. Chl.a in the surface was relatively high but Chl.a in the Sarutani Dam were extremely smaller than those in the Funato and Kinokawa flood gate, in particular, June and July to August. DO values about 100 % and stable and pH values increased gradually from 7.7 to 8.2. If photosynthesis is active, Chl.a, DO and pH values will increase. However, the increase of them in the Sarutani Dam is extremely small comparing with the sudden increase of June and July to August in the Funato and Kinokawa flood gate.

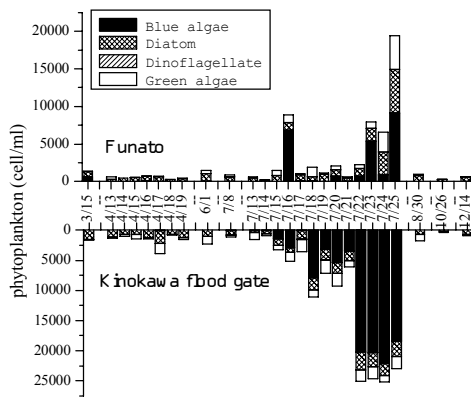


Fig. 7. Species composition of phytoplankton change of in Funato and the Kinokawa flood gate

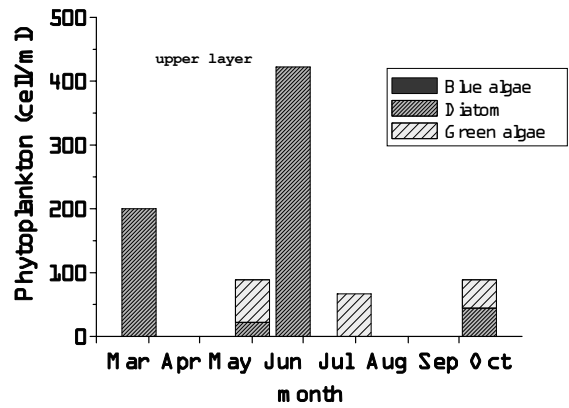


Fig. 8. Species composition of phytoplankton change of in the Sarutani dam

Therefore, photosynthesis in the Sarutani Dam is concluded not to be active.

5. Phytoplankton

Figure 7 shows a species composition of phytoplankton. Before July 14th, total numbers of phytoplankton at both stations were very little 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 m³/s and number of phytoplankton increased as well as the Kinokawa. Therefore, number of phytoplankton was in agreement 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, the number of phytoplankton did not increase.

Usually, blue green algae and dinoflagellate were not observed, but diatom and green algae were the main species. However, when numbers of phytoplankton increased in July, blue green algae was observed and became a main species. In particular, at the Kinokawa flood gate, the increase of total number depended on number of blue green algae. On other hand, dinoflagellate was not observed all season.

A change of species composition of phytoplankton depends on generally water temperature. High water temperature prefers diatom 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, water temperature was higher than 23 degree centigrade but species composition did not change till 2nd July remarkably.

On the other hand, after July 22nd the flow rate at the Funato remained to be few m³/s and the number of blue green algae at the Funato also increased. Therefore, flowing water condition was thought to be important for determining species composition. Figure 8 shows a phytoplankton species composition change in the Sarutani Dam. All phytoplankton number increased in June and reached 400 cell/ml. The numbers were extremely small comparing with those in the Funato and Kinokawa flood gate. The changes of Chl. a, DO and pH were small in the Sarutani Dam and they were in agreement with phytoplankton number and then photosynthesis in the Sarutani Dam is concluded not to be active. The maximum phytoplankton number season in the Sarutani Dam is different from those in the Funato and Kinokawa flood gate. Usually, blue green algae and dinoflagellate were not observed, but diatom and green algae were the main constitutions as well as Funato and Kinokawa flood gate.

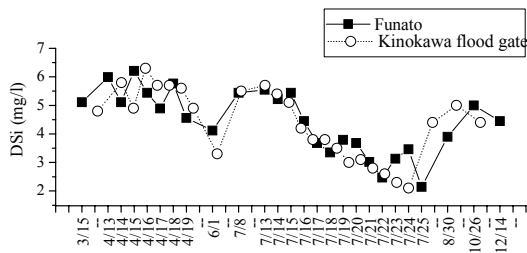


Fig. 9. DSi concentration change in Funato and the upper area of the Kinokawa flood gate

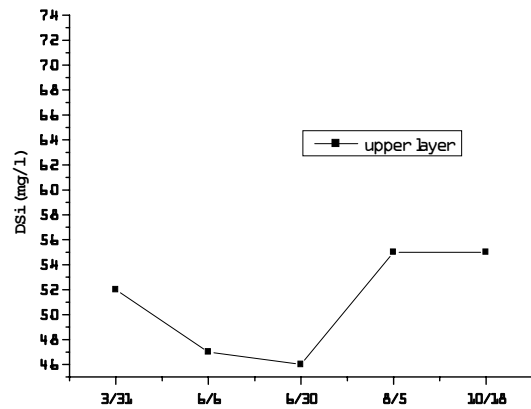


Fig. 10 DSi concentration change in the Sarutani dam

6. Relation between phytoplankton and nutrient

Figure 9 shows DSi concentration change in Funato and the Kinokawa flood gate. As 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. Actual 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 was thought to consume silica in river water.

Figure 10 shows DSi concentration change in Sarutani dam. The DSi was 4.5-6.0mg/l and uniform.

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

Figure 12 shows nutrient concentration changes at the Sarutani dam. The averages of T-N of the Sarutani dam area were about 1.0mg/l and NO_3^- -N were 0.4 mg/l. They indicated oligotrophic condition. They were half of those in the Funato and Kinokawa flood gate. On the other hand, PON increases on June 6 and October 18 of the upper layer. Totally T-N changed with PON in particular in the surface water. Therefore, T-N was thought to depend on number of phytoplankton because phytoplankton number can be represented as PON.

7. 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 condition phytoplankton activity was concluded to be small 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 condition, 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. 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. The number of blue-green algae increased with increase of water temperature and decrease of the river flow. As the river flow rate decreased in summer season, 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 sudden increase in stagnated areas of the river whereas the number of diatom and green algae increased slowly when

Table. 1. This table is summary of the study

			nutrient		flow condition	
			low	high	flowing water	stagnant
Water temperature	less than 25 degrees C	phytoplankton activity	low	low	low	low
		ecologically important species	diatom	diatom	diatom	diatom
	over 25 degrees C	phytoplankton activity	low	high	high	extremely high
		ecologically important species	diatom or green algae	blue green algae	blue green algae	blue green algae

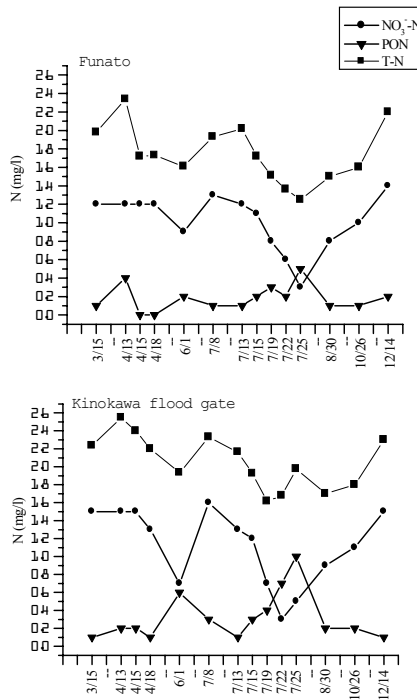


Fig. 11. Nutrient at the Funato and Kinokawa flood gate

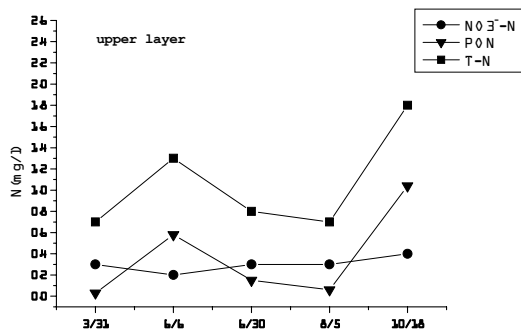


Fig.12 . Nutrient at the Sarutani dam

water temperature was high.

Under stagnant conditions, the Sarutani Dam has low nutrient and the Kinokawa flood gate has high nutrient. Diatom number were 130cell/ml in the Sarutani dam but 1300 cell/ml in the Kinokawa flood gate, although main species in both areas were diatom and green algae.

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In Japanese