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Structure of Thermal Convection Development in a Closed Water Body with Aquatic Plants

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ABSTRACT: A field observation was conducted in order to consider the effects of the abundance of aquatic plants on the water quality and water flow of a small water body, such as an agricultural pond. The results of measuring the luminance showed that solar radiation was blocked significantly under the abundance of vegetation. This effect increased with the increase of the vegetation abundance density. In addition, the result of measuring the water temperature showed that fluid exchange was performed by a thermal convection between the area with and without an abundance of vegetation at nighttime. Moreover, the results of the measuring of water qualities showed that, although the nutrients decreased due to the absorption and adsorption from vegetation during the flowering period in the summer, these nutrients conversely increased due to the elution from the bottom of the water body after vegetation decayed in the winter.

Keywords: Aquatic plant, DO, Underwater luminance, Thermal convection, Water quality, Nutrients, Vegetation abundant density, Rate of vegetation abundance

1 INTRODUCTION

In some closed water bodies, the fluid flow tends to stagnate because of insufficient inflow and outflow. Hence, hydraulic characteristics are different from those of river or irrigation canals. When the water is undisturbed in a closed water body, the fluid is stratified based on vertical density distribution. In these bodies, the main fluid movement of the environmental substances in the water is caused by the convective flow based on thermal disturbance.

On the other hand, water quality purification by use of an aquatic plant is proposed in a closed water body. The method is to purify the water quality by moving the nutritive salt out of the water body after being absorbed into aquatic plants in a closed water body. To make use of the method in a water body with floating aquatic plants, we have to transport the nutritive salt, which accumulates at the bottom of the water body, from the bottom to the surface of the water. When we apply aquatic plants for water quality purification in a closed water body, firstly, it is important for us to comprehend what the aquatic plants influence in the water body.

In this study, we particularly focused on the change of the water environment due to the abundance of aquatic plants by a field observation. First, we conducted a field observation and evaluated the effect of aquatic plants on the underwater luminance. Being the most important factors in water quality, the change of water temperature and dissolved oxygen were measured. Also, we evaluated the effect of aquatic plants on the convection and the variation of water quality in a closed water body.

2 MATERIALS AND METHODS

2.1 *Observed objects and Measurement Methods*

The observed object was Hokusui Pond located on the Iwate University campus (Figure. 1). The water surface area was 962m^2, and the active storage capacity was 450m^3. The influent water was groundwater and its quantity was 33m2/day, so that the water was replaced in about 14 days. Water lilies, which were flourishing in the pond, acted as the aquatic plants, as shown in Figure 1. Each observation point is shown in Figure 1. The meteorological terms (solar radiation, air temperature, rainfall, humidity, wind velocity, and wind direction) were observed by the HOBO weather station (onset) at hourly intervals. Dissolved oxygen (DO) and water temperature were observed by the miniDOT (Precision Measurement Engineering) at 5 different points below the surface of the water at 10 minutes intervals. The total organic carbon (TOC), total nitrogen (TN) and total phosphorus (TP) were analyzed by sampling the water at the same points as DO at weekly intervals. The status of vegetation abundance was taken from three cameras at hourly intervals. Luminance was measured by T-10MA (KONICA MINOLTA) in two places just below the water surface and the vegetation at 2-minute intervals. Measurements were carried out from June 1st to December 25th, 2013. It should be noted that the luminance was measured from October 28th to November 17th 2013.

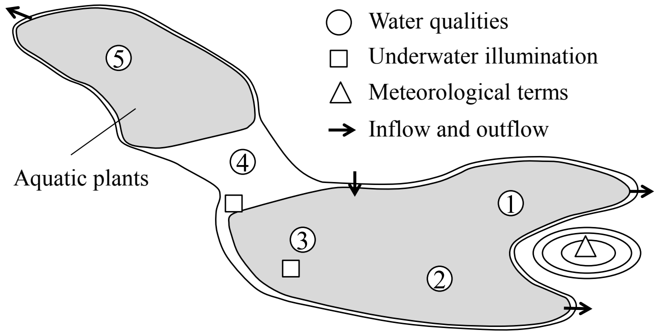

Figure 1. The observed objects and Measurement Methods.

3 RESULTS

3.1 *Changes in the status of vegetation abundance*

Changes in the status of vegetation abundance during the observation period have been determined from photographs taken by three cameras. Photo 1 shows the change of the status of vegetation abundance. The status of vegetation abundance was 66% in June, which was the start of measurement. During the flowering period, it increased up to 100% or more by the end of August. After this, it started to decline, reducing to 42% in December.

Photo 1. The change of the status of vegetation abundance.

3.2 *Changes in the water temperature and DO*

Figure 2 shows the changes in the amount of solar radiation and the changes of water temperature and DO at Point 3 (with an abundance of vegetation) and Point 4 (without an abundance of vegetation) from the 24th of August to the 31st of August. It is understood that there is no little difference for water temperature between with and without an abundance of vegetation. On the other hand, although DO increased with the increase of the solar radiation at Point 4 without an abundance of vegetation, there was no significant change at Point 3 with an abundance of vegetation. The measuring of the luminance showed that about 98% of the solar radiation was blocked under the abundance of vegetation; hence, the abundance of vegetation has a large impact on the variation of the DO. Also, the DO value was almost the same at night with radiation cooling, revealing that the fluid exchange was performed by thermal convection between the area with and without an abundance of vegetation.

From the above result, it can be understood that the status of vegetation abundance affects the DO; therefore, the relationship between the daily accumulation of solar radiation and the incremental amount of DO was plotted in each vegetation abundant density in Figure 3. The incremental amount of DO to the daily accumulation of solar radiation decreased with the increase of the vegetation abundant density. That is why the water body is likely to be in a non-oxygenated state during the flowering period.

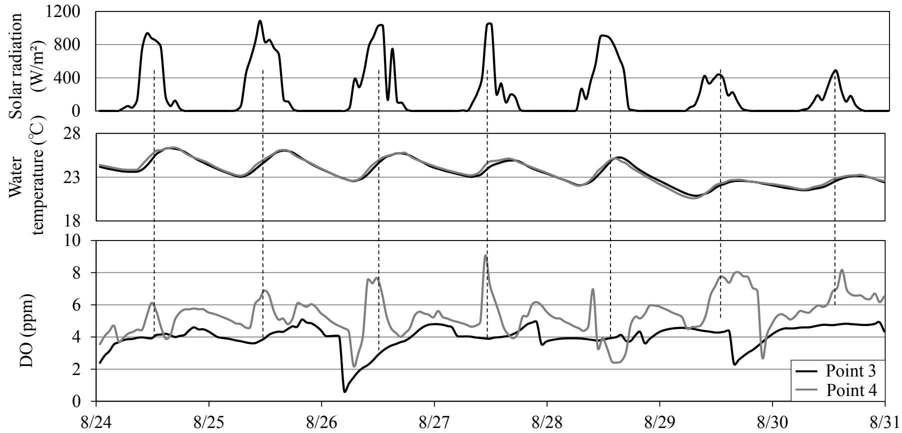

Figure 2. The changes in the amount of solar radiation and the changes of water temperature and DO.

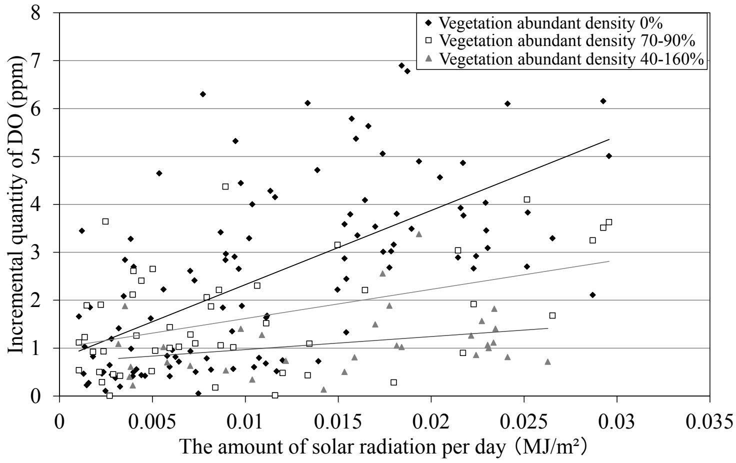

Figure 3. The relationship between the daily accumulation of solar radiation and the incremental amount of DO.

3.3 *Changes in nutrients*

Figure 4 shows the changes of TOC, TN and TP for each week at points 1, 2, 3 and 4. This figure shows that there is an increasing trend in each point in the winter period after October. However, there was not a significant difference between Point 4 with an abundance of vegetation and any other measuring points. Therefore, the rate of vegetation abundance was calculated as the status of vegetation abundance for the entire water body during each month. Figure 5 shows the relationship between the rate of vegetation abundance and each water quality. From the figure, it can be seen that there is a negative correlation between nutrients and the rate of vegetation abundance. That is because although the nutrients decreased due to the absorption and adsorption from the vegetation during the flowering period in the summer, these nutrients increased in reversal due to the elution from the bottom of the water body after the vegetation decayed in the winter. It is important that the vegetation should be reaped after flowering in the eutrophied water body.

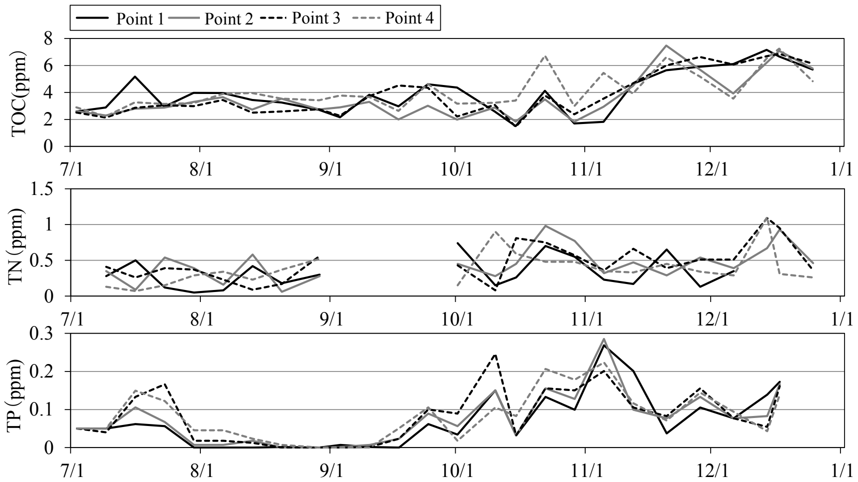

Figure 4. The changes of TOC, TN and TP.

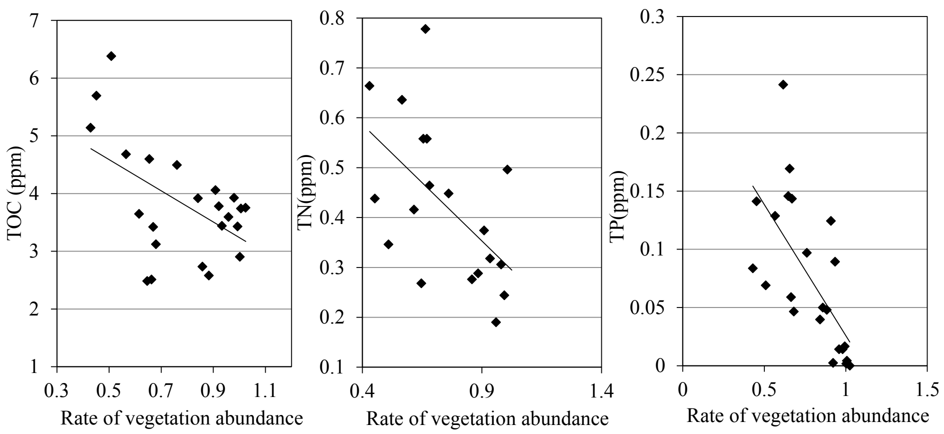

Figure 5. The relationship between the rate of vegetation abundance and each water quality.

4 CONCLUSION

A field observation was conducted in order to consider the effects of the abundance of aquatic plants on the water quality and water flow in a small water body, such as an agricultural pond. The following results were obtained:

(1)The measuring of the luminance showed that solar radiation was blocked significantly due to the abundance of vegetation. This effect increased with the increase of the vegetation abundant density.

(2)The fluid exchange was performed by thermal convection between the area with and without an abundance of vegetation at nighttime.

(3)Though the nutrients decreased due to the absorption and adsorption from the vegetation during the flowering period in the summer, these nutrients increased in reversal due to the elution from the bottom of water body after the vegetation decayed in the winter.

From the above results, it can be concluded that aquatic plants should be adequately controlled to exert its effect sufficiently on the eutrophied water body.

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