Analysis of the Metabolism of Water in the Reservoirs

1. Introduction

Global warming has led to an increase in water-related natural disasters around the world. So, reducing CO_2 emissions has become an urgent issue. Nellemann et al. (2023) pointed out that in coastal shallow waters with high biodiversity, the photosynthetic effects of aquatic organisms enable blue carbon to absorb large amounts of carbon dioxide, prompting increasingly active global efforts to promote blue carbon. Recently, attention has also been focused on the CO_2 absorption capacity of freshwater areas such as lakes and marshes, known as "freshwater carbon". CO_2 absorption through the activity of aquatic plants and phytoplankton has been pointed out. Still, the factors are not limited to active photosynthesis, and there is little research on this topic worldwide, so the quantitative evaluations of this process have not yet been sufficiently advanced. Lake metabolism is evaluated using methods that estimate photosynthetic rate (EP) and ecosystem respiration (ER) from hourly changes of dissolved oxygen (DO), with the influence of pH being considered important.

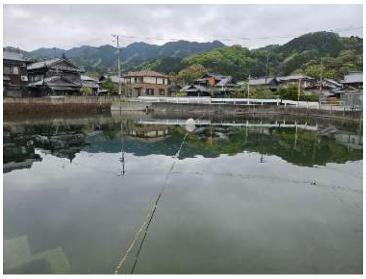
In this study, we observed water temperature, pH, and DO from spring to autumn at Yamanokami Reservoir and Shiode Reservoir in Saijo City, Ehime Prefecture, and analyzed the relationship between EP, ER, and pH. Additionally, we conducted concentrated observations in April when aquatic plant activity increases and investigated the relationship with CO_2 partial pressure.

2. Methods

2.1. Study site

Yamanokami Reservoir and Shiode Reservoir are located in Saijo City, Ehime Prefecture (Fig.1). There are no aquatic plants in Yamanokami Reservoir which is representative of low biological activity. And Shiode Reservoir where the aquatic plants growing is a more biologically active water body.

To investigate changes in ER and EP over the long term, water temperature loggers were installed at 20 cm intervals below the water surface in Yamanokami Reservoir and Shiode Reservoir, and measurements were taken at 10-minute intervals from March 24 to October 13, 2024. Additionally, to measure DO and pH, dissolved oxygen loggers and pH loggers were installed at a depth of 50 cm below the water surface. Measurements were conducted over the same period as the water temperature chain. The measurement intervals were set to 10 minutes for DO and 15 minutes for pH.



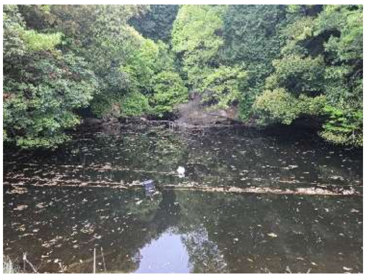


Fig.1 Yamanokami Reservoir and Shiode Reservoir in Ehime Prefecture

2.2 Methods for estimating ER and EP

ER and EP are methods proposed by Odum (1956) for evaluating lake metabolism, and are obtained using DO measured at hourly intervals. First, based on sunrise and sunset times, the day is divided into nighttime, when ER predominates, and daytime, when EP and ER coexist. Using the rate of change in DO during nighttime and calculating its average value, ER (mg·L-1·h-1) can be obtained as follows.

$$\mathrm{ER} = \frac{1}{T_N}\int \frac{\partial DO}{\partial t}dt \tag{1}$$

where T_N is the continuous duration during the night (h).

For EP, using the known ER value, it can be obtained using the following formula.

$$\mathrm{EP} = \frac{1}{T_D}\int \frac{\partial DO}{\partial t} dt - ER \qquad (2)$$

where T_D is the continuous duration during the day (h) .

The ER for respiration is negative, while the EP for photosynthesis, must be positive. However, in reality, estimating ER and EP using equation shown here can sometimes be difficult due to DO inflow, outflow and consumption by bottom sediments. Therefore, this study only used the data where ER is negative and EP is positive to explore their relationship with pH.

3. Result

In Yamanokami Reservoir, stratification developed significantly between April and July. DO was close to saturation in April, but gradually declined thereafter, reaching unsaturated levels by summer. There was little change in pH. Due to the lack of aquatic plants in the water body, no correlation was observed between phytoplankton photosynthesis and pH. On the other hand, Shioide Reservoir exhibited vertical mixing in early spring, and a surface water layer developed by summer, when aquatic plants flourished. DO was above saturation in early spring, fluctuating greatly and increasing to the maximum, and then slowly decreased. In response, the pH value exceeded 9.0 in early spring and rose to the maximum, then remained at around 7.0 to 8.0.

Depending on the observation result, it indicated that when the pH increases due to photosynthesis in aquatic plants, DO also increases. Therefore, we did a correlation analysis between pH and DO. The results showed that Yamanokami Reservoir did not exhibit a clear relationship due to inactive photosynthesis, while Shiode Reservoir yielded the expected result. The rate at which DO increases as the pH value rises can be divided into three stages.

The calculated metabolism showed the absolute value of ER in the Shiode Reservoir is larger than that in the Yamanokami Reservoir. In Shiode Reservoir, in addition to the decomposition of organic matter, the respiratory activity of aquatic plants results in a greater consumption of DO. Similar to ER, the EP in Shiode Reservoir is also larger than that in the Yamanokami Reservoir. This due to the aquatic plants and phytoplankton present in the Shiode Reservoir, more DO is produced through photosynthesis.

Then we analysis the relationship between pH and ER, EP. The results showed that the effect of pH on EP was negligible. On the other hand, although EP in Shiode Reservoir fluctuated significantly, it generally increased with rising pH. This phenomenon supported the hypothesis of this study, namely that the increase of pH leads to the increase of EP, indicating active growth of aquatic plants and phytoplankton. Yamanokami Reservoir with low biological activity showing the lack of correlation, further corroborated this view.

4. Conclusion

We found that DO is strongly related to pH, and the relationship between the two can be classified into three stages. Also, It was suggested that photosynthetic activity may increase with rising pH.

References

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