Analysis Of Annual Characteristics Of Phytoplankton And Nutrient Concentrations In Japanese Dams Over The Past 30 Years Using Observational Data And Prediction of Future Reservoir Environments Using A Vertical One-Dimensional Reservoir Model

Kazuma Aoki (Electric Power Development Co.,Ltd., Tokyo, Japan, nikonikoaokazu02@gmail.com) Tomohito J. Yamada (Guraduate School of Hokkaido, Sapporo, Japan)

1.Introduction

- Dam reservoirs have the function of flood control during rainfall and providing a stable supply of water. In contrast, artificially impounding a river can cause river water to stagnate for long time, and various problems become apparent in the reservoir and its downstream areas.
- One of these problems is the overgrowth of phytoplankton, which often causes problems such as landscape disturbance and foul odors in the water supply. The growth of phytoplankton is mainly influenced by nutrient concentrations, water temperature, and sunlight.
- Since long-term observation data are available for dams all over Japan, analysis of the relationship between past changes in phytoplankton concentrations over years and water quality based on dam observation results could provide insight for future reservoir management.
- In addition, there is concern that climate change will increase water temperature in reservoirs and phytoplankton concentrations in the future. Quantitative predictions are needed for future reservoir management.

2. Annual trend of water quality in dams in Japan

2.1.Method

- We analyzed annual characteristics of nitrogen concentration, phosphorus concentration, and chlorophyll-a concentration which represents indicator of phytoplankton concentration, at 81 dams which managed by the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) and the Japan Water Agency, using observation data over a period of 30 years published by MLIT.
- We determined a regression line for the average annual concentrations of chlorophyll-a, nitrogen, and phosphorus at each dam over the past 30 years. We then performed a t-test on the slope of the regression line and selected dams that met the 5 percent significance level.

2.2.Result

Table.1. Annual trend of nitrogen concentration, phosphorus concentration, and chlorophyll-a concentration For all water indicators, water quality has been improving in many dams over the past 30 years.

[mg/m^3]	Number of Dams on Increasing trend	Number of Dams on Decreasing trend
Chlorophyll-a	4 / 81	26 / 81
Nitrogen	8 / 81	33 / 81
Phosphorus	13 / 81	42 / 81

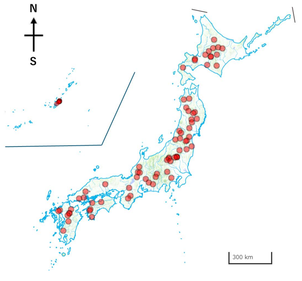

Fig.1. Location of Dams we analyzed

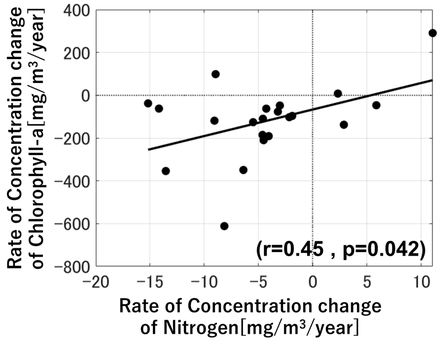

Fig.2. Positive correlation between rate of concentration change over the past 30 years of Nitrogen and rate of concentration change over the past 30 years of Chlorophyll-a

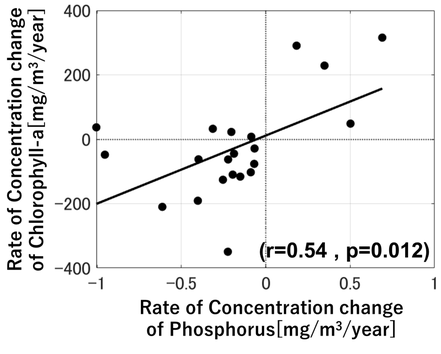

Fig.3. Positive correlation between rate of concentration change over the past 30 years of Phosphorus and rate of concentration change over the past 30 years of Chlorophyll-a

These results suggest that nutrient reduction is important for reducing eutrophication in dams in the long term.

3. Prediction of Future Reservoir Environments

3.1.Method

- To investigate changes in dam reservoir environment in a future Japanese climate, we constructed a reservoir model, which consists of a reservoir water thermodynamics and a lower trophic ecosystem(Fig.4, Fig.5).

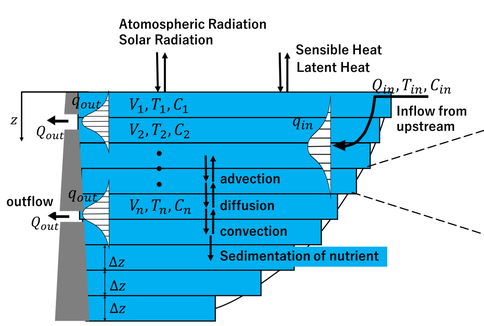

Fig.4. A Schematic illustration of modeling of a dam reservoir water thermodynamics
This vertical one-dimensional thermodynamic model is based on the advection-diffusion equation, with the energy balance equation on the water surface and inflow from the river and outflow from the dam as input terms.

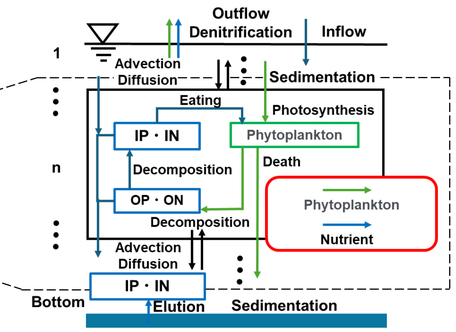

Fig.5. A Schematic illustration of the flows between five state variables, inorganic phosphorus (IP), organic phosphorus (OP), inorganic nitrogen (IN), organic nitrogen (ON) and Phytoplankton. Each layer of the thermodynamic model incorporates this lower trophic ecosystem model.

3.2.Result

- To analyze the impact of rising temperatures on phytoplankton concentration in the reservoirs, we calculated 14 dams in Japan, stretching the temperature data for the past 28 years by 4 degrees Celsius.
- Annual average chlorophyll-a concentration increased in 12 of the 14 dams by an average of about 1.1 times. Seasonal comparisons show that chlorophyll-a concentrations increase the most in spring(March, April, May). (Fig.7)
- The increase in chlorophyll-a concentration tends to be larger for dams with higher phosphorus inflow loadings and longer turnover times.(Fig.8)

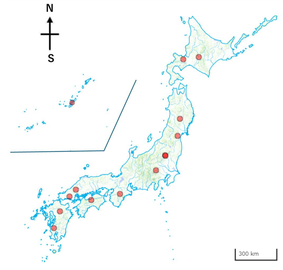

Fig.6. Location of Dams we analyzed

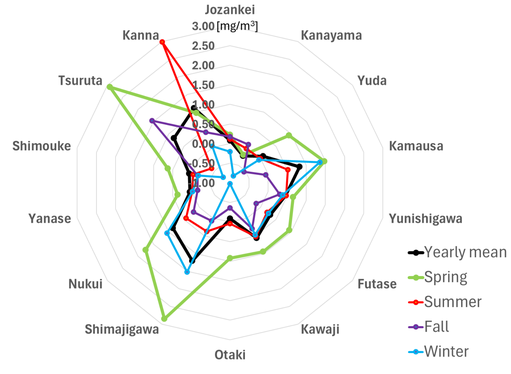

Fig.7. Amount of change in chlorophyll-a concentration at each dam by stretching temperature by 4 degrees Celsius.

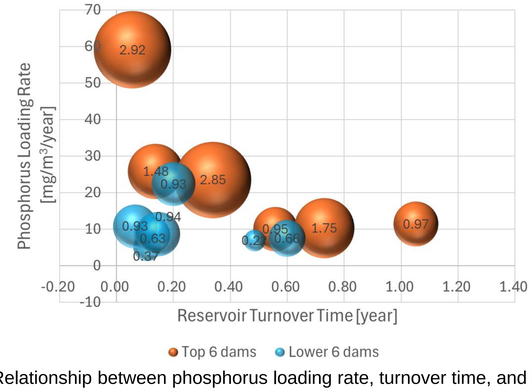

Fig.8. Relationship between phosphorus loading rate, turnover time, and increase in chlorophyll-a concentration. The size of the bubble chart and the numbers on the bubbles indicate the amount of increase in chlorophyll concentration[mg/m^3].

4. Conclusion

- Past observations indicate that nutrient inflows at many dams have remained the same or have been decreasing for many years, and chlorophyll-a concentrations have been decreasing accordingly.
- The calculations of this model suggest an earlier onset of spring bloom and an increase in average annual chlorophyll-a concentration.
- Since dams with shorter turnover times tend to have smaller increases in chlorophyll-a concentration, the effects of future changes in water inflow to the dam should be considered in future work.