Study on long-term change trends of nutrient elements in the Yamato River — based on historical water quality and flow data

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Introduction

Water security and stability are paramount concerns for societal well-being. Significant changes have occurred in riverine environments due to climate change and human activities. Human activities have led to increased nutrient loads, disturbances in major ion compositions, and the degradation of freshwater resources. However, the impact of climate on river environments has yet to be effectively quantified.

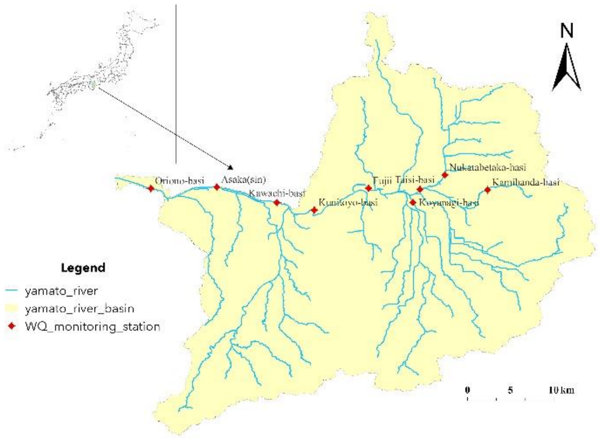

Figure 1. Infographic of the Yamato River basin and water quality monitoring station location map.

This study investigates new characteristics of river water quality (RWQ) changes by analyzing the concentrations and trends of nutrient components in the Yamato River (as shown in Figure 1)[1]. From 1990 to 2023, the concentrations of 6 water quality variables, including nutrients, major ions, and sediments, were analyzed, accompanied by targeted trend analysis.

Methodology

Water quality and river flow data were acquired from national, prefecture, and local sources (the Yamato River Management Office). The obtained data were matched with river discharge records and used to run the Watershed Regressions on Time, Discharge, and Season (WRTDS) model[2]. WRTDS output was used to produce annual flow-normalized concentration for all water quality constituents and to perform trend analysis.

$$E[c]=w(Q,T)$$

Where c is concentration, in mg/L, E[c] is the expected value of concentration, w is a function that depends on two variables, Q is discharge, in m^3/s, and T is time, in decimal years.

the estimates of $E[c]$ are made as follows. A weighted regression model is estimated. It takes the form:

$$ln(c)=\beta_0+\beta_1 q+\beta_2 T+\beta_3 sin(2\pi T)+\beta_4 cos(2\pi T)+\varepsilon$$

Where c is concentration, in mg/L, β is the regression coefficients, q is ln(Q) where Q is daily mean discharge, in m^3/s, T is time, in decimal years, and ε is the error (unexplained variation).

Daily concentration and flux are vital for evaluating a river's water quality history. The outcome can be significantly influenced by the history of flow conditions, so WRTDS must normalize flow.

$$E[c_{fn}(T)]=\int_0^\infty w(Q,T)\cdot f_{T_s}(Q)\mathrm{d}Q$$

$E[c_{fn}(T)]$ is the flow-normalized concentration for time T (a specific day of a specific year). $W(Q, T)$ is the WRTDS estimate of concentration as a function of Q (discharge) and T (time, in years). $f_{T_X}(Q)$ is the probability density function (pdf) of discharge, specific to a particular time of year, designated at T_s.

The WRTDS is implemented using the R programming language packages *EGRET* and *EGRETci*.

Results

We present some of the findings here. The simulation results of Fujii Station are taken as an example to show the changes in the river water environment in the Yamato River basin. From Figure 2, we can obtain the simulation results of the Fujii site through the WRTDS model.

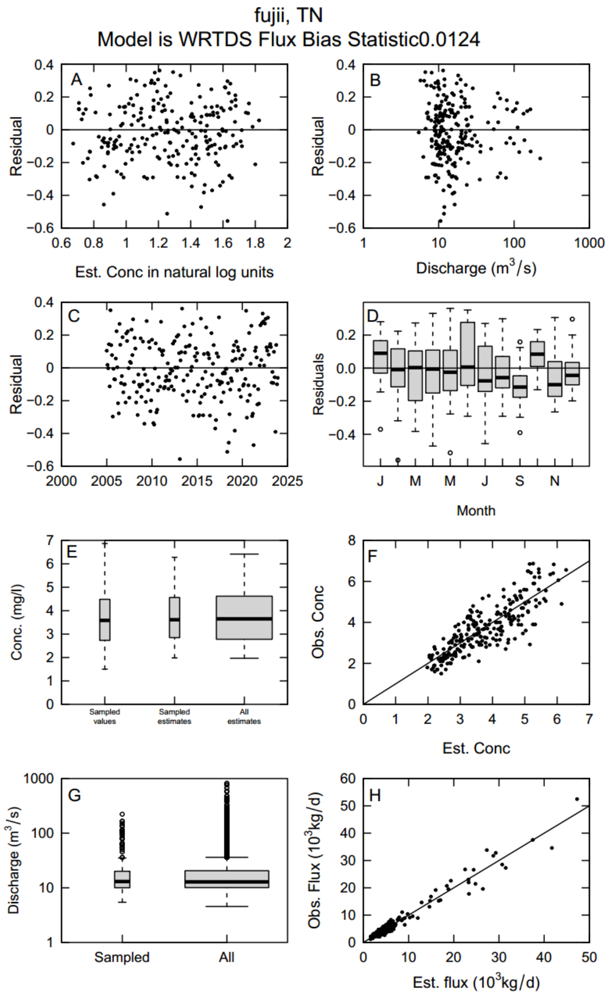

Figure 2. Output of simulation for TN for the Fujii station. (A: graph of the residuals of the WRTDS model as a function of the model estimates. B: graph of the residuals of the WRTDS model as a function of the log of discharge. C: graph of the WRTDS residuals as a function of DecYear. D: graphic of the WRTDS residuals as boxplots by month. E: graph of three boxplots of concentration. F: scatter plot of observed concentration values. G: boxplots of discharge, on a log scale. H: scatter plot showing observed flux values on all sampled days as a function of estimated flux values on all sampled days).

As Fig 3, based on the nature of the heteroscedasticity seen in this data set, the SE becomes substantially smaller as discharges increase above about 8 m^3/s. Late summer and fall have the highest SE values, and spring has the lowest SE values.

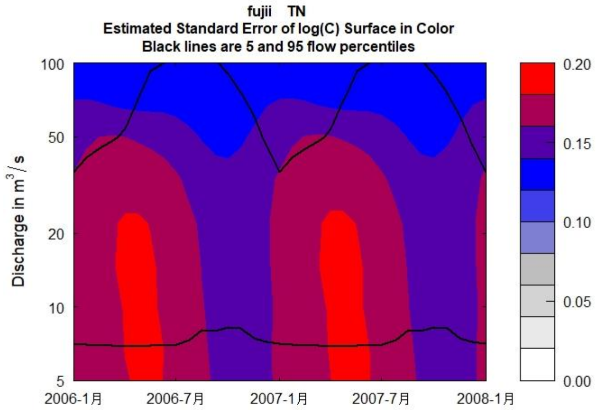

Figure 3. Contour plot output of the seq function for the WRTDS model of TN (in milligrams per liter, as N).

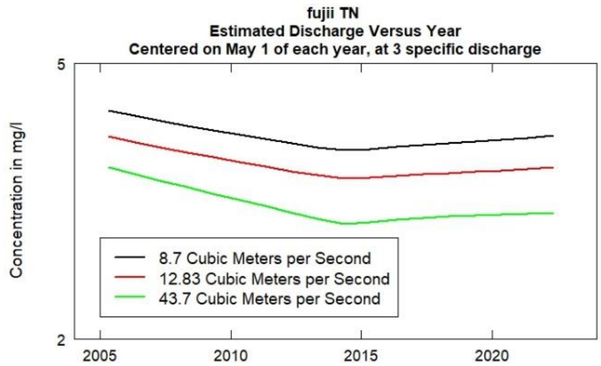

Figure 4. Concentration versus time plots of TN at three discharge values, centered on May 1st each year.

This example is illustrative of just how different the patterns of trend can be across the range of streamflow conditions.

Other research results and discussions will be detailed at the annual meeting of DPRI.

Reference

1. Ministry of Land, Infrastructure, Transport and Tourism, Hydrologic Quality Database. http://www1.river.go.jp/. (2024.10.12).

2. Hirsch, Robert M., Douglas L. Moyer, and Stacey A. Archfield. "Weighted regressions on time, discharge, and season (WRTDS), with an application to Chesapeake Bay River inputs 1." *JAWRA*. 46.5 (2010): 857-880.