Biodiversity and phosphorus cycling in the river ecosystem

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Introduction

Phosphorous (P) is a key element to determine ecosystem processes because its natural abundance is rare in the bio-available form. Because of its scarcity relative to other macronutrients, anthropogenically loaded P often causes cultural eutrophication and biodiversity loss in aquatic ecosystems. The anthropogenic disturbances in the P cycling also result in deterioration of ecosystem services in quality and quantity through the loss of ecosystem functions provided by biodiversity. In spite of such a pivotal role, P dynamics, including biological recycling, have been poorly understood. Considering such social and ecological backgrounds, we applied two advanced technique, nutrient spiral metrics and phosphate oxygen isotope ($\delta^{18}O_p$) analysis, to estimate biological P recycling in the river ecosystem *in situ*. In addition, we examined how epilithic microbial community properties can determine the P recycling function of river ecosystem.

Materials & Methods

We conducted the synoptic research in the whole catchment of Yasu River in the Lake Biwa Watershed, Japan, in 2016. We set 63 monitoring sites at its tributary streams, which vary in catchment size and land use pattern. For these sites, we measured concentration of soluble reactive P (SRP) and physical characteristics. We also collected GIS data in their catchments. For nutrient spiral metrics, we used a modified method of SPARROW (Smith et al. 1997). We estimated P uptake rate, defined as microbial phosphate uptake per unit area of riverbed and per unit time, incorporating the above environmental and GIS data into the model.

At 30 out of 63 monitoring sites, we also collected epilithons from the riverbeds to characterize algal and bacterial community properties for each stream. For each epilithic sample, algal taxa were identified under microscopic observation and then their abundances were counted. For the epilithic bacteria, operation taxonomic units are identified on the basis of 16S rRNA gene using a MiSeq sequencer.
For the $\delta^{18}O_p$ analysis, we collected river water samples from the 30 biological sampling sites. These samples were converted into solid Ag_3PO_4 to determine their $\delta^{18}O_p$ values using a TC/EA-IRMS. Based on an isotope exchange equilibrium value $\delta^{18}O_{p\text{-}IEE}$, we estimated how much dissolved phosphate is biologically recycled in river waters. If the dissolved phosphate is completely turned over, a measured value of $\delta^{18}O_p$ converges to the $\delta^{18}O_{p\text{-}IEE}$.

Results & Discussion

P uptake rate showed great variation among streams within a whole catchment. It was positively associated with green algal abundance and/or taxa richness (Fig. 1a, b), but not with bacterial community properties. As previously reported (Cashman et al. 2013), the green algae are sensitive to nutrient availability, so that they may play an important role in P recycling in the river ecosystem. Our study demonstrated that fluvial microbial diversity has positive effects on ecosystem functioning in nature.

The $\delta^{18}O_p$ analysis revealed that river water $\delta^{18}O_p$ had a wide range of isotopic values across the streams. While these isotopic values might be imprinted partly by source signatures derived from external P loading, they tended to converge to the $\delta^{18}O_{p\text{-IEE}}$ in streams where P uptake rate is higher (Fig. 2), suggesting that both methods can be promising tools to estimate biological P recycling *in situ*.

Keywords: Biodiversity, Biological phosphorous recycling, Ecosystem functioning, Epilithic algae, Nutrient spiral metrics, Phosphate oxygen isotope analysis

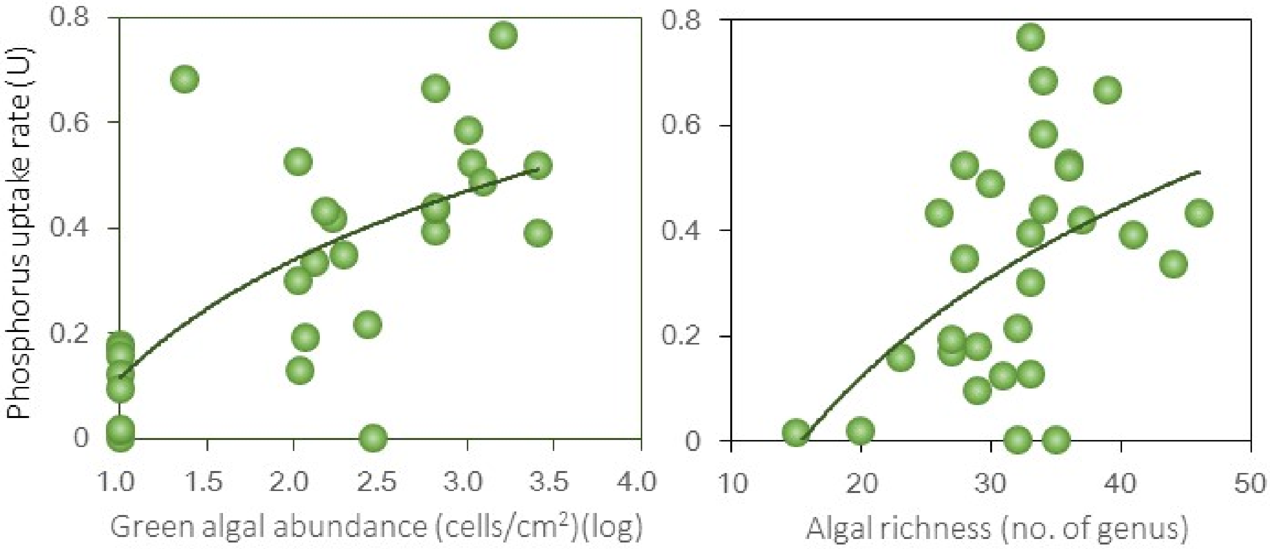

Fig. 1 Biodiversity-ecosystem functioning relationships in Yasu River. P uptake rate (mmol/m^2*day) is positively correlated with green algal abundance (**a**: left) and green algal diversity, expressed as the number of taxa observed for each stream (**b**: right).

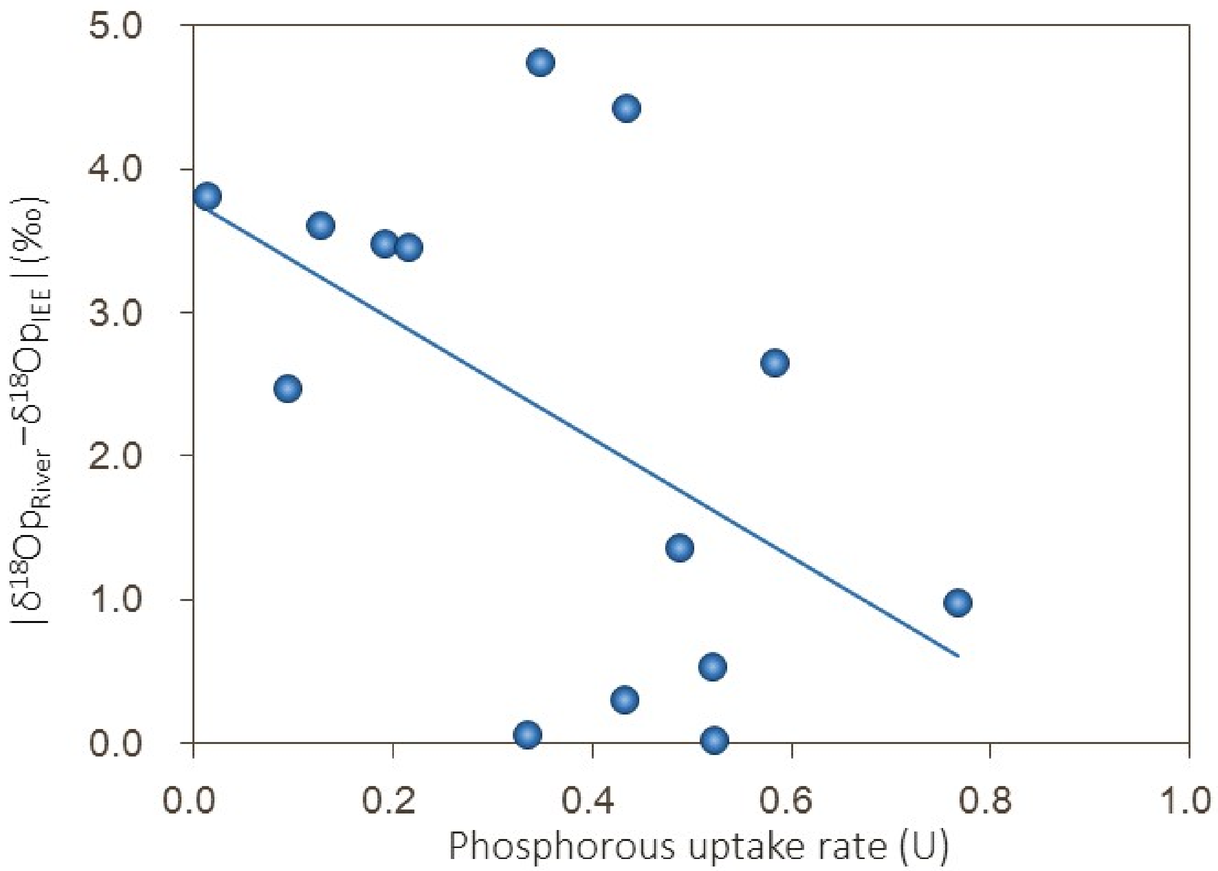

Fig. 2 River water $\delta^{18}Op$ had tendency to converge to $\delta^{18}Op_{\text{-}IEE}$ with increasing P uptake rate, suggesting that the process of P recycling dominated in streams where epilithic microbial activity is high.