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Fluvial transport of nutrients along the river-to-ocean continuum in the Fuji River watershed

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Riverine transports of nitrogen and phosphorus from watersheds can be an important flux that impacts the integrity of downstream and coastal ecosystems. Therefore, numerous nutrient-transport models have been developed to predict the nitrogen and phosphorus flux from lands to the oceans, but these models have paid rather less attention to the nutrient uptake from water column by stream communities. Recent empirical studies have increasingly identified that aquatic communities in river networks uptake and/or mineralize the large amount of river-borne material leaking from terrestrial ecosystems. However, the uptake rates of nitrogen and phosphorus by aquatic communities in the entire area of a river network from headwater streams to downstream rivers to estuary has remained unknown, especially in mountainous watersheds with high relief, such as watersheds in Japan. We developed the nutrient transport models that explicitly incorporate stream ecosystem metabolism in order to understand the roles of stream ecosystem function (i.e., nutrient uptake) in controlling the nitrogen and phosphorus flux to the coastal ecosystems.

We performed a field sampling campaign covering the whole area of the Fuji River watershed, central Japan, during September and October in 2010. In each of 107 study streams/rivers, we measured stream discharge, total nitrogen (TN) and total phosphorus (TP) concentrations, as well as other physico-chemical attributes. We then developed the modified version of spatially referenced process-based model (SPARROW) to predict the observed flux of nitrogen and phosphorus in the entire area of the Fuji river networks. The models describe phosphorus and nitrogen yields from watershed sources, terrestrial processes during their transports from the sources to rivers, and aquatic processes during their fluvial transports from upstream to downstream rivers. In the models, we formulate the aquatic processes as kinetic equations of stream metabolism, which depends on water temperature, photosynthetically active radiation, and/or substrate concentration.

The best predictive models revealed that rice paddies and orchards yielded the largest amount of TN and TP among the various landscape types, with the specific discharges both accounting for 46% and 66% of nitrogen and phosphorus exports from the watershed, respectively. Moreover, landuse affected the nutrient uptake by stream communities; the estimates of areal uptake rates were significantly higher in agricultural and urban streams than forested streams. However, our model also revealed that although stream metabolism was accelerated in highly impacted streams, the estimates of uptake velocity (vf) of nitrogen and phosphorus atoms from the water column were greatly decreased, implying the decrease of nutrient removal efficiency in these stream ecosystems.

The areal uptake rates were summed to calculate the basin metabolism of nitrogen and phosphorus in this river network. Those estimates showed that stream ecosystem can uptake the large amount of nitrogen (25t/d) and phosphorus (0.3 t/d), both contributing the 78% of nitrogen and 44% of phosphorus yields from the watershed sources. These results showed that the Fuji river network controls the nitrogen and phosphorus delivery to the coastal ecosystems. We argue that the management actions that do not consider the maintenance of stream ecosystem function may be insufficient for the controls of nutrient transports along the land–to-river-to-ocean continuum.

Keywords: Drainage networks, spiral metrics, nutrients, basin metabolism