Evaluation of Ecosystem Health Based on Bed Armouring and Caddisfly Abundance in Uji River

○Sohei KOBAYASHI, Boyuan CAI, Sameh KANTOUSH

Introduction

Sediment shortage and channel degradation due to upstream dam construction and downstream sand mining cause various issues in rivers. In Uji River, Kyoto, riverbed was armoured (increased grain size) after the construction of Amagase Dam in 1964, which lead to bed stabilization and resulted in high production of caddisflies that annoy local people and tourists. Caddisfly abundance may be able to control if we properly replenish sediment and mitigate the armouring in the downstream river channel.

We analyzed river cross-sections and flow discharge data and conducted field surveys to obtain data of spatial distribution of caddisflies. Our objectives were to 1) understand historical changes in flow, channel morphology, and bed stability of Uji River, 2) examine relationships between hydraulic, riverbed properties, stability, and caddisflies abundance, and 3) evaluate sediment replenishment options to effectively regulate caddisfly abundance in Uji River.

Study sites and methods

The target was Uji River, a total of 16–17 km reach, from Amagase Dam in the upstream to the confluence point, where Yodo River starts in the downstream. Due to water storage of the upstream Lake Biwa, flow of Uji River is naturally relatively stable with baseflow of 50–100 m^3/s and flood flow of 50–1000 m^3/s.

Data of daily discharge at Uji gauge station and daily water level at the Uji-sansen station during 2002–2023, and cross-sections of Uji River (37.2–53.2 k.p., 200-m interval) from 2000 to 2022, were obtained from Yodo River Office. Bed grain size (d_{60}) of different years was determined using figures of past reports from the river office. HEC-RAS was used to calculate 1-D flow patterns including shear stress during large floods (500 m^3/s, 1000 m^3/s, 1500 m^3/s). Riverbed grain size of the past years was determined based on figures in the reports of the river office using Plot Digitizer.

Field surveys were conducted at 3 sites (Uji bridge, Keiji Bridge, Ingen bridge), where gravel-bars and pool-riffle structures were developed, in mid-October 2024 when flow was low and stable. At each site, 3 typical river habitats (riffle, run, pool) were defined. At each of 10 sampling locations (4 from riffle, 4 from run, 2 from pool), water depth and flow velocity (bottom, middle, surface) were measured. After taking 5 pictures of bed for grain size analysis, invertebrates in a 900 cm^2 quadrat were collected by washing stones inside the quadrat and placing D-framed net (0.5 mm mesh) on the downstream side.

ImageJ was used for image analysis to obtain randomly selected 125 particles from the bed images. Caddisflies were sorted and classified into different species using books of keys for species identification and numbers are counted for each species.

Results

Discharge, channel shape and hydraulics

There was a week tendency of increasing maximum and high (95 day) flows and of decreasing baseflow (185 day) and low (245 day) flows during 2002–2023 in Uji River. A decreasing trend of minimum water level was evident at the downstream station.

Progress of channel incision was visible in cross-section of all 3 sites; the lowest bottom level gradually

decreased, and channel became narrower with years.

Flow during floods by HEC-RAS calculation suggested that flow with given discharge becomes deeper, narrower, faster, and greater shear stress with years. However, as riverbed grain size increased with years, Shield's parameter (dimensionless) decreased with years, suggesting an increase of bed stability.

Spatial distribution of caddisflies

Typically, flow velocity was higher in riffles and lower in pools, and depth was higher in pools and runs and lower in riffles at each site without obvious difference among sites. Riverbed grain size tended to be greater in riffles and was higher in the upstream site (Uji) than downstream site (Ingen). Consequently, although shear stress did not change so much, Shield's parameter was higher in the downstream site than the upstream site.

Three caddisflies (*Macrostemum*, *Hydropsyche*. *Cheumatopsyche*, corresponding to the big, middle, and small caddisfly), which are causing annoying issues, occurred, though their abundance was not at a maximum level. These caddisflies were more in riffles than runs and pools, especially for the middle caddisflies, across sites, and were more in the upstream than the downstream sites (Fig. 1). Correlations between physical parameters and caddisflies were evident; caddisfly abundance was positively correlated with flow velocity and grain size, while was negatively correlated with Shield's parameter.

Discussion

Channel degradation in Uji River

Channel degradation has been progressing continuously even after 2000. Bed became lower, flow became deeper and faster, and riverbed became coarser and more stable (Fig. 2). Due to sediment shortage after the construction of Amagase Dam, erosion is still a dominant process, which wash away finer particles and also expose clay. Channel incision still progresses also from the downstream Yodo River, which was suggested from the decreasing trend of minimum water level.

Control of caddisflies by sediment replenishment

As expected, the caddisfly abundance was correlated with bed stability (i.e., correlated negatively to Shield's parameter). To reduce bed stability, sediment replenishment with a certain quantity and proper grain size are recommended. Various sizes including sand, gravel and small cobbles are required to build desirable bed contribution for ecosystem, while too much silt and sand may fill and stuck riverbed interstices and also be beneficial to caddisflies as their nest materials.

The Yodogawa River Office plans to conduct sediment replenishment in future, and they estimated that bed grain size at Uji changes from 9 to 6–7.5 cm by 15,000 m^3/year sediment, and to 3 cm by 50,000 m^3/year sediment. In the latter case, Sheild's parameter is close to 0.06, which is sufficient to promote sediment mobility, bed disturbance, and reduction of caddisflies

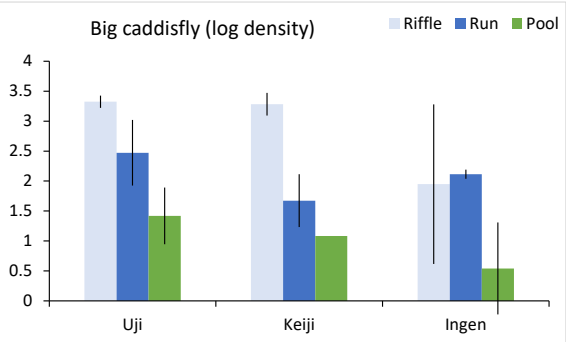

Fig. 1 Spatial distribution of large caddisfly species

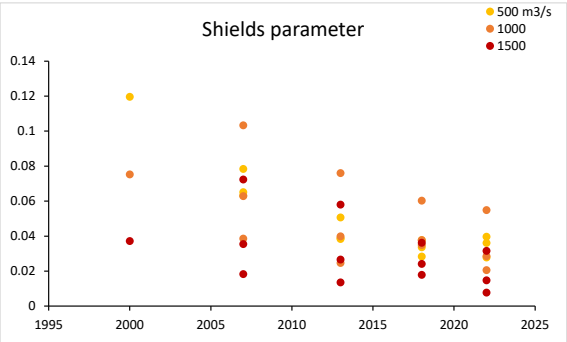

Fig. 2 Changes in bed mobility with years at Keiji.