C104

Comprehensive Assessment of Sediment Replenishment in Naka River: Hydrological, Morphological and Ecological Perspectives

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Due to the construction of hydraulic infrastructures, such as dams, considerable sediment is trapped in the upstream reaches, which reduce reservoir storage capacity and increase the flood risks of nearby residents. Simultaneously, the problem of sediment deficit will occur at downstream reach, which will lead to a significant morphological change, such as riverbed incision, riverbank instability, as well as armouring bed. Moreover, reduction of shallow geomorphic units, such as riffles, pools, and sandy bars, that adversely impacts on downstream fish spawning and food web system. To mitigate it, sediment replenishment (SR) is a common restoration measures implemented in Japanese rivers, which aims to recover the degraded river's morphology and aquatic ecosystem caused by sediment deficit. In our research, we developed an integral assessment approach to evaluate the effectiveness of SR strategy on flow regime, river bed, and ecological changes along the downstream reaches.

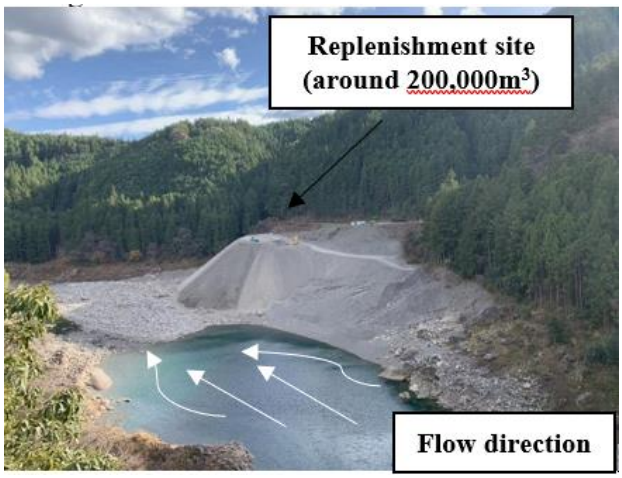

Fig. 1 Photo of replenishment site at Kohama

The study area is in the Naka River Basin, which is located in the Tokushima Prefecture. The total area of the Naka River Basin is 874 km^2, and the total length of flow channels is around 125.0 km. Since 2011, Naka river started implementing the replenishment works at Kohama, which is located at 1.0 km below the Nagayasuguchi dam (Fig. 1).

The flow chart of the developed comprehensive approach is depicted in Fig. 2. Indicators were selected that had a direct linkage with the characteristics of the SR and monitored data that indicated the sensitivity to SR. The assessment approach commenced by analyzing basic and simple SR information about sediment quality and quantity, and flushing discharge.

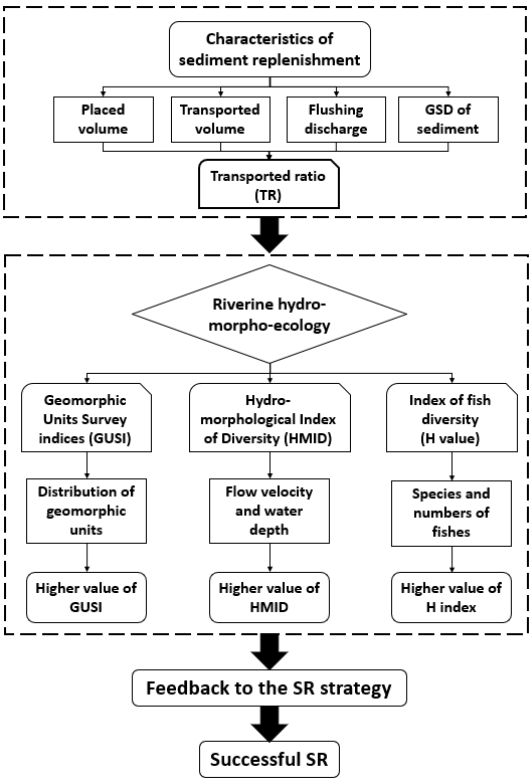

Fig. 2 Flow chart of the integral assessment

After the assessment of replenishment works, the hydro-morpho-ecological assessment of riverine system will be implemented. Specifically, the geomorphic units, such as sand bars, riffles, pools, and puddles, are the basic linkages between riverine morphology and habitat. Hence, in the beginning, we will conduct the GUS (Geomorphic Unit Survey) in order to investigate the distribution of geomorphic units. Two typical indices can be calculated simply based on the survey, which are GUS Richness index (GUSI-R) and GUS Density index (GUSI-D). These indicators and indices can be calculated separately with an interval of 1.0 km reach. The results of GUSI-R and GUSI-D are shown in Fig. 3.

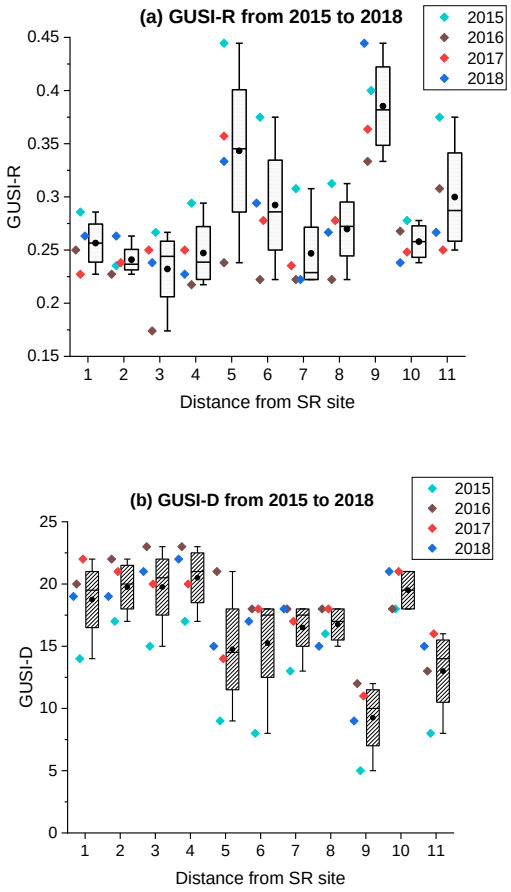

Fig. 3 Indices of GUS from 2015 to 2018 with the distance from SR site.

Then, the HMID was calculated which aims to access the heterogeneity of habitat structures according to the coefficient of variation of the hydraulic variables water depth and flow velocity. The results of HMID in 2015 and 2016 was shown in Fig. 4.

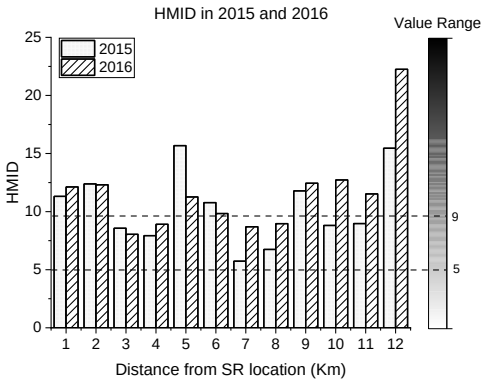

Fig. 4 HMID values in 2015 and 2016

Finally, for assessment of riverine habitat, we applied a simple index to investigate the diversity of the fish species (H value). Its variation can be utilized to establish the connection to morphology, such as formation of geomorphic units and changes of bed level and bed material, should be mainly concerned. An example of H value variation at 1km downstream of the SR site was shown in Fig. 5.

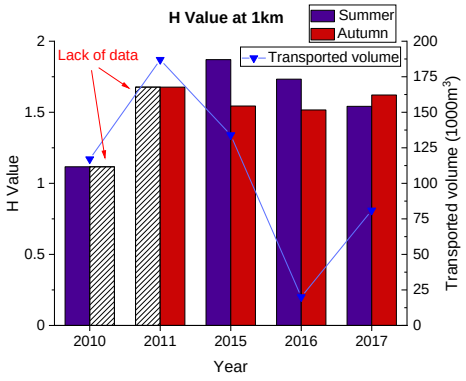

Fig. 5 H value at 1.0 downstream of SR

In summary, an integrated assessment approach was developed and implemented in Naka River to investigate the hydro-morpho-ecological responses caused by SR. the numbers of geomorphic units, such as runs, rapids, and pools were increased around 15% annually, and a tendency of average distribution of each unit can be founded as well. While habitat quality for fish spawning was promoted partly due to the alteration of the morphological and hydrological characteristics (riverbed material, riverbed level, water depth, and flow velocity) at different sites.