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Research paper

Short-term river response and restoration of biological diversity following slit construction

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Abstract

This study examined short-term temporal river restoration following slit construction using yearly surveys conducted from 2009 to 2011. The temporal changes caused by river restoration were monitored with regards to the river response, velocity diversity, channel geomorphic unit diversity and species diversity.

The temporal change indicated a rapid increase in the hydraulic and channel geomorphic unit diversity by the river response, whereas the species diversity decreases by the rapid river response with the debris flow. The channel pattern changes were explained by an excess of shear stress, which eroded the bank toe. Bank scour or sediment failures then occurred during normal discharge. This process was the main mechanism of river widening in the Wasada stream.

We suggested methods to assess the velocity and geomorphic diversity based on the Shannon diversity index for river conditions. The velocity and channel geomorphic unit diversity increased after the slit construction, with 1.31 in 2009, 1.68 in 2010, and 1.93 in 2011 for the velocity diversity and 1.05, 1.45, and 1.66 for the channel geomorphic unit diversity. Both diversities responded immediately to the slit construction, after which the response slowed. However, the species diversity remained lower than the pre-condition levels after the physical environment recovered. The reasons for the diversity decrease were the species evenness and the decrease in taxa richness. In the results, the species diversity varied as 2.33 (2009) to 2.38 (2010), and 2.12 (2011), while the species evenness decreased continuously: 0.79 (2009) to 0.74 (2010), and 0.73 (2011). The latter trend was caused by a rapid river response by debris flow that disturbed both the species population and species diversity. Species density and diversity decrease when the river response is very active in the early stage of river restoration.

Keywords: Slit-check dam; River response; Biological diversity; Excess shear stress; Bank erosion

1. Introduction

Permeable check dams, designed to block and trap debris, have many different styles and shapes, e.g., slit dams, dams with a rectangular slit, grid dams, and dams with bottom infiltration screens (Lien, 2003). The efficiency of the permeable check dams in preventing landslides or debris flow is usually investigated by experimental and field researchers (Bovolin and Mizuno, 2000; Armanini et al., 2006; Shrestha et al., 2008). The criteria for the design of permeable check dams are also being studied (Johnson and McCuen, 1989; Lien, 2003). However, little is known about how the installation of slit-check dams affects ecosystems. Two causes of this research gap are the lack of data on the pre-dam conditions for comparison and the difficulties in data collection caused by the mountainous streams in which slit-check dams are constructed. The conversion of a monitored check dam, a gravity dam with vertical concrete, into a slit-check dam with two paths in August 2010 provided a good opportunity to monitor the river response and the biological diversity by river

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restoration following slit-check dam construction. The existing data on the pre-construction conditions allow a temporal comparison.

River response is an adjustment process of hydraulic, geomorphic and sediment characteristics to special events, such as the removal of an artificial structure. Water flow velocity is directly and indirectly important because it influences the riverbed composition and the amount of silt deposition (Popoola and Otalekor, 2011). Biological diversity can be considered using concepts of ecosystem diversity and species diversity. Rivers as aquatic systems are composed of various habitats, each of which influences the lives and interactions of aquatic organisms. In addition, the geomorphic parameter is now recognized as fundamental to assessments of river health (Reid et al., 2008). The non-biotical factors affect the distribution of benthic organisms. Therefore, both river response and biological diversity are indicators of river restoration.

Doyle et al. (2005) suggested a conceptual framework for ecosystem recovery with two variations, full recovery and partial recovery, following the removal of a small dam. Each fluvial parameter returns to pre-dam conditions within a few years, decades or centuries. River restoration using a slit construction is expected to have a recovery trend similar to that of dam removal. If the recovery trend can be calculated numerically, we can assess the river restoration. The purpose of this paper is to verify the river response and changes in biological diversity indicative of river restoration soon after the construction of the slit dam. Channel patterns and cross-section changes caused by sediment erosion are important factors in explaining the river response. In addition, we apply suggested methods for measuring hydrological and channel geomorphic unit diversity. Finally, we suggest a scenario for river restoration based on our results for the Wasada stream.

2. Study area

The check dam was modified into a slit-check dam in August 2010 (Fig. 1). The dam is in the Wasada stream, which is located at N 38°35′19.68″, S 139°51′16.3″, Japan. The Wasada stream is a second-order stream with a 25.59 km^2 catchment area and a stream length of approximately 8 km up to the confluence with the main river. The headwater starts at an elevation of approximately 500 m. The sinuosity is 1.3, and the slope of the stream bottom is 0.034 m/m. The Wasada stream has two check dams. The downstream dam is located approximately 1.2 km from the conflux with the main river, and the upper dam is approximately 1.1 km from the first dam. The upper dam was constructed in 1994, and the lower dam was constructed in 1980 and modified with two path-slit in 2010 (Fig. 1(a)). The mean daily discharge averaged 24.89 m^3/s over the 5 years recorded, with a minimum of 6.83 m^3/s and a maximum of 94.07 m^3/s recorded by Mikuriya station (38°35′23″N, 139°51′06″E). The peak discharge, observed in May, is due to melting snow. The least discharge was observed from August to October, at a rate of approximately 6–9 m^3/s.

A reference reach can be useful as a standard to compare and assess certain parameters. We selected a reference reach located 1 km upstream from the second check dam in the same catchment.

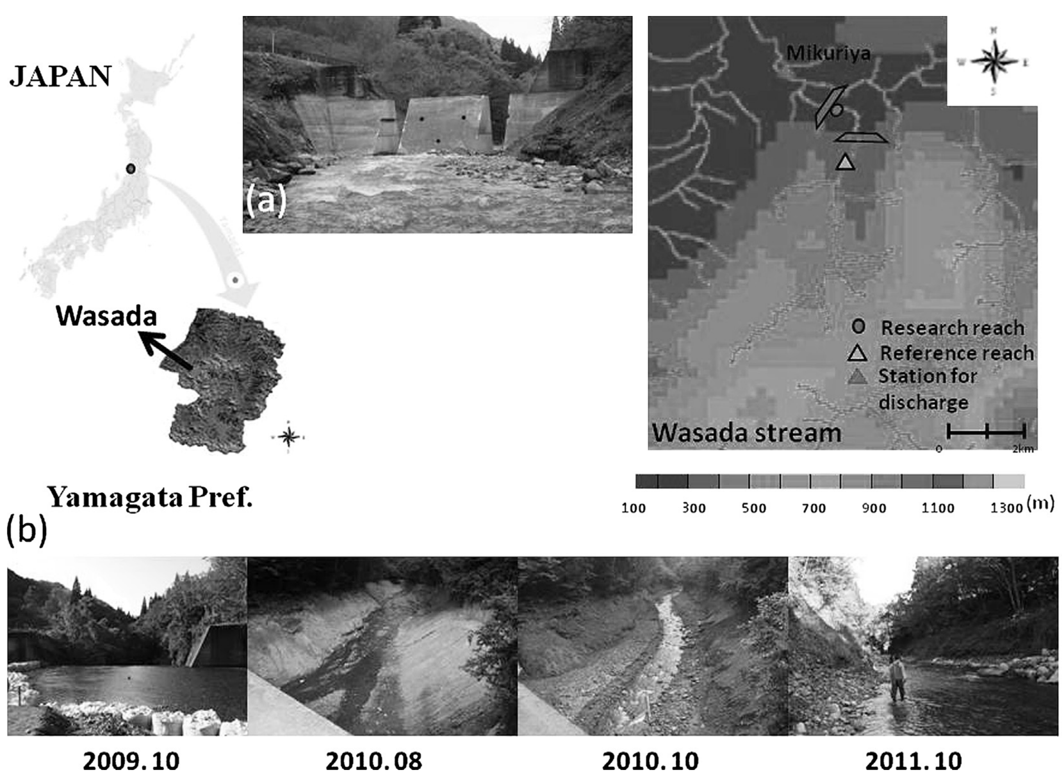

Fig. 1. Study area and channel pattern changes. Photo (a) shows the shape of dam after slit construction, and photo (b) is channel pattern changes.