THE IMPACT ASSESSMENT OF RIVERBED EXCAVATION WITH A RIVER ECOSYSTEM MODEL

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ABSTRACT

In recent years, a riverbed excavation project is planned and implemented for safety against frequent floods in many rivers of Japan. It is necessary to predict the impacts on the growth and habitat of aquatic organisms because riverbed would be largely altered by the excavation. In this study, we developed an ecosystem model, which can do the effects assessment of a project. Then, we examined the effects of the riverbed excavation project on the riverine ecosystem in the Takatsu River with the model. As a result, the ecosystem model has sufficient reproducibility for physical environmental variables and the biomass of aquatic organisms. Moreover, the ecosystem model estimated that the distribution of water depth and velocity changed due to the riverbed excavation and the longitudinal distribution of water temperature also changed. In addition, the biomass distribution of aquatic organisms changed in response to the differences in the physical environment. When total biomass in the calculated interval was examined, the attached algae and benthic invertebrates were maximally up 12.7% and 26.3%, respectively. In contrast, the biomass of fishes did not significantly change (~2% increase/decrease) in the total biomass.

Keywords: ecological model, riverbed excavation, Takatsu River, impact assessment

1. INTRODUCTION

Today, river management that balances flood control and environment conservation is being desired. The maintenance and management of rivers need to be done based on the quantitative evaluation to sustain the integrity of riverine environment, as well as safety level of flood control. The integrity of riverine environment is currently evaluated and maintained based on ecological monitoring, with a particular focus on aquatic organisms in Japan. Moreover, it is vital to quantitatively predict the response of river organisms using models, in order to understand the impact of flood control projects such as riverbed excavation on the riverine environment in advance (Chen et al., 2013). The ultimate goal in such modeling is to estimate the biomass of riverine organisms. Because the biomass of river organisms changes greatly over time and space (John and Christopher, 1994; Mizuno and Gose, 1993), it is necessary to consider the traits of the spatiotemporal distribution in order to estimate biomass with sufficient accuracy. In this study, we focused on a river ecosystem model as a biomass predicting tool. There are several river ecosystem models that can evaluate temporal variation of biomass in Japan. However, they have not been developed based on sufficient field observations, and there are no models that can predict the spatial distribution of biomass. In this study, we developed a hybrid river ecosystem model that can predict a spatiotemporal distribution of biomass based on sufficient field observations in the Takatsu River. Finally, we attempted to analyze the effects of a riverbed excavation project on the ecosystem in the Takatsu River with the developed model.

2. DEVELOPMENT OF THE RIVER ECOSYSTEM MODEL

2.1 The basic outlines of the model

We developed a hybrid river ecosystem model which can predict spatiotemporal distribution of biomass. Figure 1 shows schematic diagram of the model. The model consists of five sub models: unsteady flow model, heat balance model, material transport models, distribution prediction models, and growth models for attached algae, benthic invertebrates, and fishes. The term "hybrid" has two meanings: physical model and statistical model, one-dimensional calculation and planar two-dimensional calculation. Spatiotemporal distribution of biomass can be predicted by estimating biomass distribution with a statistical model and solving temporal variation of

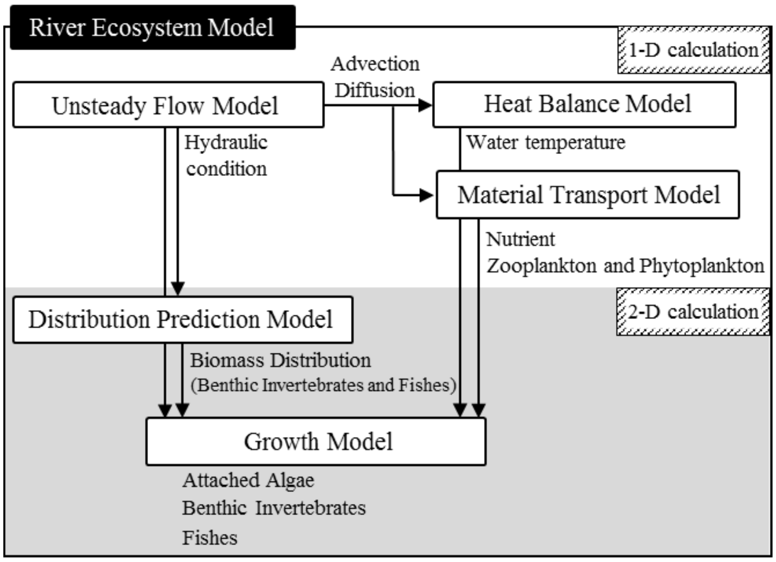

Figure 1. Schematic diagram of the model.

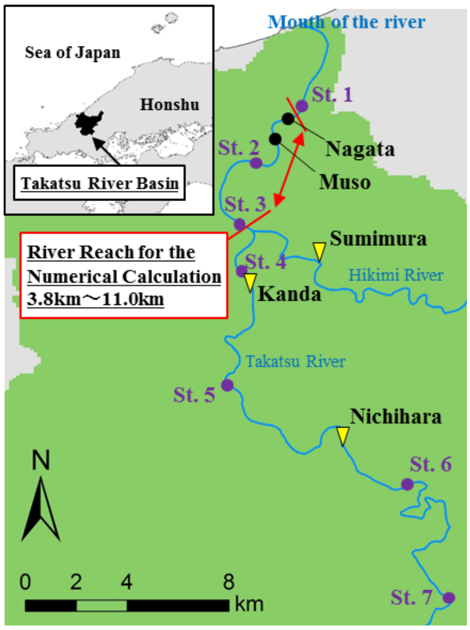

Figure 2. Plan view of the study area and observed points.

physical environment and material circulation with an ecosystem model. Physical environmental variables such as hydraulic quantity, water temperature, and water quality were calculated by one-dimensional calculation, whereas the biomass distribution was calculated by two-dimensional calculation, in order to reduce the computational time. For benthic invertebrates and fishes, spatiotemporal distribution of biomass was reproduced by modeling each dominant taxonomic group separately, incorporating temporal variations of biomass due to life history events such as emergence and spawning for each group.

2.2 Overview of investigation and calculation condition

The target river is the Takatsu River located in the west part of Shimane Prefecture, west Japan. Field observations of water level, water temperature, dissolved oxygen, solar radiation, and biomass have been carried out since April 2015. Figure 2 shows plan view of the study area and observed points. Water discharge was observed at Kanda and Sumimura by Ministry of Land, Infrastructure and Transport. Observational instruments for water level, water temperature, dissolved oxygen, and solar radiation, have been placed for monitoring at St. 1-7, Nagata, Muso, Nichihara, and Kanda since April 2015. The biomass observations of attached algae, benthic invertebrates, and fishes with quadrat method have been conducted at Nagata and Muso once a month since April 2018. For organism samples, dry weights of benthic invertebrates and ignition loss of attached algae were measured.

The river reach for the numerical calculation was 3.8-11.0 km from the mouth of the river. The target period was between 1st May 2018 and 1st December 2018. The total discharge of Kanda and Sumimura was given as the upstream condition, and the steady flow depth was employed as the downstream condition. Upstream condition of water temperature was given from observed data at St. 3. Dissolved oxygen and insolation were given from observed data at Nichihara and Kanda. The initial biomass distribution was given by the distribution prediction model of April.

2.3 Examination the accuracy of the model

The reproducibility of the model was examined by comparing predicted values with measured values. Unsteady flow model had sufficient reproducibility, since the calculated water level agreed with the observed data. The reproducibility of the water temperature and water quality was also sufficient. The biological model had a certain level of reproducibility because seasonal variations in biomass could be reproduced with the model.

3. THE IMPACT ASSESSMENT OF RIVERBED EXCAVATION

3.1 Overview of calculation condition

We analyzed the effects of riverbed excavation on the ecosystem in the Takatsu River with the developed model. The analysis compared two cases of simulation: the current channel conditions prior to riverbed excavation (Case 1) and the channel conditions after the riverbed excavation (Case 2).

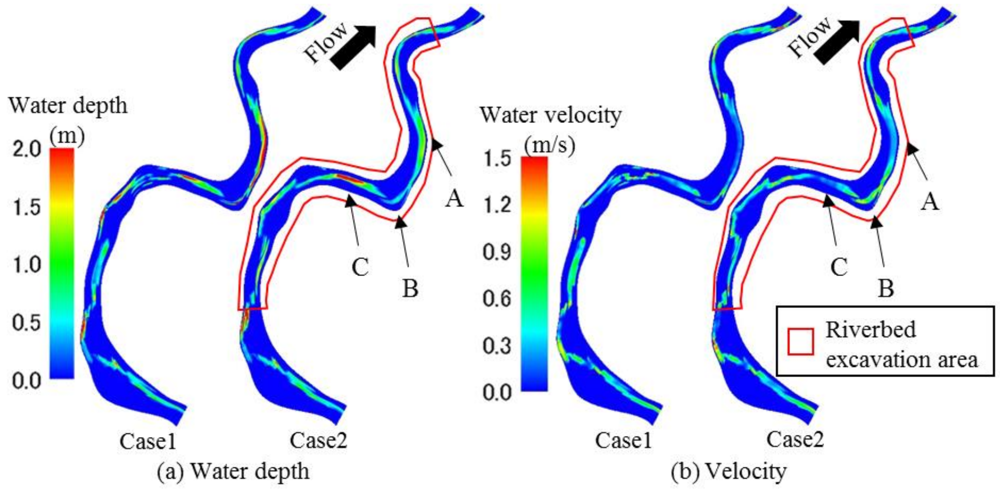

Figure 3. (a) Water depth, (b) Velocity distribution of 2 cases on 3rd August. Case 1 means the current channel conditions prior to riverbed excavation and case 2 means channel conditions after the riverbed excavation. A, B, and C are areas that had a characteristic tendency.

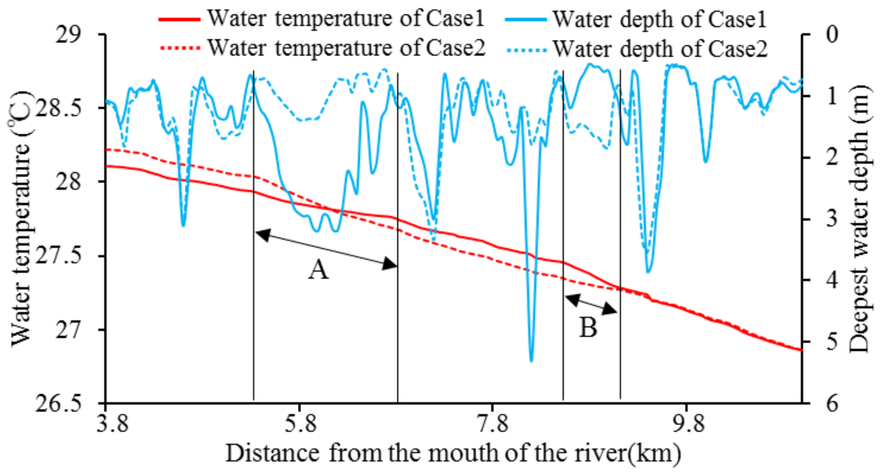

Figure 4. The longitudinal distributions of water temperature and deepest water depth in the cross-sections. Case 1 means the current channel conditions prior to riverbed excavation and Case 2 means channel conditions after the riverbed excavation. A and B are areas that had a characteristic tendency.

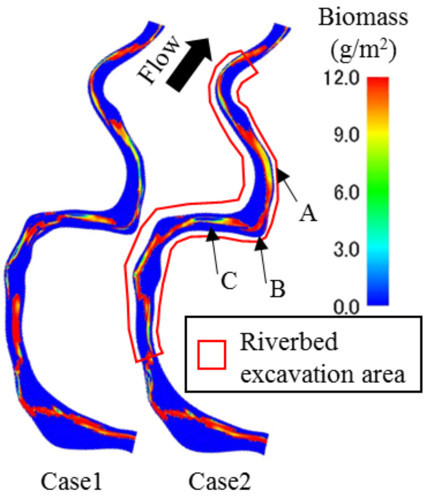

Figure 5. Biomass distribution of attached algae on 3rd August. Case 1 means the current channel conditions prior to riverbed excavation and Case 2 means channel conditions after the riverbed excavation. A, B, and C are areas that had a characteristic tendency.

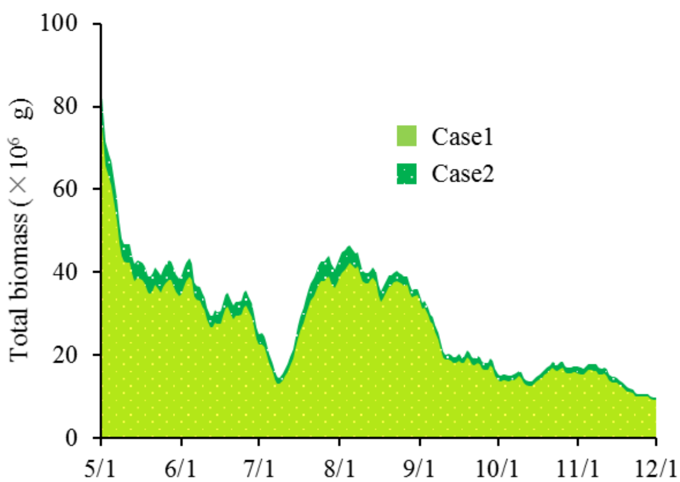

Figure 6. Total biomass of attached algae in the calculated time period. Case 1 means the current channel conditions prior to riverbed excavation and Case 2 means channel conditions after the riverbed excavation.

3.2 The impact assessment of river excavation

The ecosystem model estimated that the distributions of water depth and velocity changed due to the riverbed excavation and the longitudinal distribution of water temperature also changed. Figure 3 shows (a) water depth

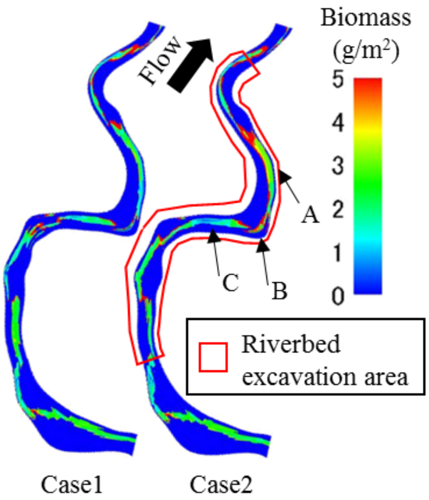

Figure 7. Biomass distribution of benthic invertebrates on 3rd August. Case 1 means the current channel conditions prior to riverbed excavation and case 2 means channel conditions after the riverbed excavation. A, B, and C are areas that had a characteristic tendency.

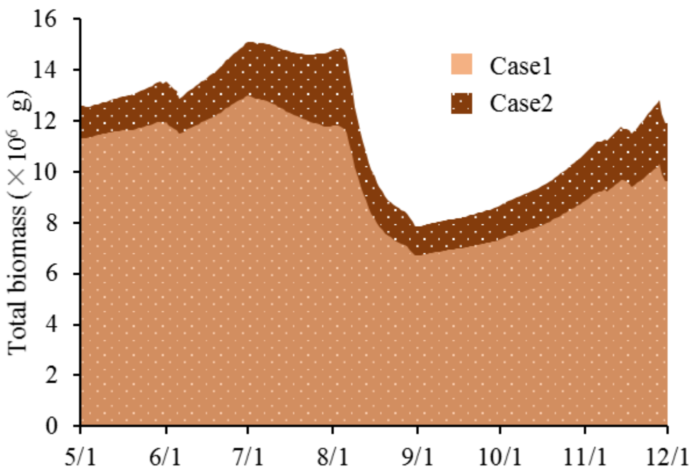

Figure 8. Total biomass of benthic invertebrates in the calculated time period. Case 1 means the current channel conditions prior to riverbed excavation and Case 2 means channel conditions after the riverbed excavation.

and (b) velocity distributions of the 2 cases on 3rd August. These distributions of water depth and velocity of case 2 particularly changed at A, B, and C compared with case 1. Figure 4 shows the longitudinal distributions of water temperature and deepest water depth in the cross-sections. The water temperature of case 2 changed at A and B with the change of water depth compared with case 1. In addition, the biomass distribution of aquatic organisms changed in response to the differences in the physical environment. Figure 5 shows the biomass distribution of attached algae on 3rd August. The biomass of case 2 increased at A and B and decreased at C compared with case 1. Figure 6 shows the total biomass of attached algae in the calculated time period. The biomass of attached algae increased by a maximum of 12.7%. Figure 7 shows the biomass distribution of benthic invertebrates on 3rd August. The biomass of case 2 increased at A and B and decreased at C compared with case 1. Figure 8 shows the total biomass of benthic invertebrates in the calculated time period. The biomass of the benthic invertebrates increased by a maximum of 26.3%. In terms of fishes, *Rhinogobius nagoyae* and *Tridentiger brevispinis* decreased, whereas other fishes such as *Plecoglossus altivelis altivelis* increased. The overall biomass did not change significantly (an increase or decrease rate was about 2%).

4. CONCLUSIONS

In this study, we developed a hybrid river ecosystem model that can predict a spatiotemporal distribution of biomass based on sufficient field observations in the Takatsu River. We attempted to analyze the effects of a riverbed excavation project on the ecosystem in the Takatsu River with the developed model. As a result, the hybrid ecosystem model was effective for grasping the effects of artificial modifications of a river and changes in external forces by climate change.

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