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Environmental Impact and Improvement Effect of Sediment Replenishment on River Dam Downstream

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ABSTRACT:
For Yahagi Dam in Central Japan, sediment bypass (a facility to discharge sediment from the reservoir) is planned due to the progress of sedimentation in the reservoir, and sediment discharge may affect the downstream river environment. This study conducted sediment augmentation and sand-covering experiments based on BACI design (Before, After, Control: Setting of points with no impact, Impact: Setting of points with impact) as field monitoring survey to investigate the effects of sediment augmentation on river biota including attached algae, benthic fauna, and fishes, and examined, analyzed, and evaluated changes in physical environment including bed material resulting from sediment discharge from dams and consequent impact on biota.

Keywords: sediment augmentation experiment, sand covering experiment, sediment bypass, impact / response, BACI

1. INTRODUCTION

Yahagi Dam is a multipurpose dam constructed about 40 years ago at the upstream of Yahagi River, a class A river, which faces the border between Aichi and Gifu Prefecutures and is about 80km away from the estuary of Yahagi River. Yahagi River is one of Japan's major rivers transporting sediment and is closely associated with the life of local residents in urban areas through which the upstream and downstream flow, such as Toyota City and Okazaki City, respectively. (Basin population of about 1,400,000)

About 300,000 m^3 sediment flows into Yahagi Dam every year. Particularly, in the 2000 Keinan Heavy Rain, about 2.8 million m^3 of sediment accumulated in the dam reservoir. It is therefore expected to implement measures against sediment in the reservoir to maintain the soundness of dam functions. As one of such measures, sediment bypass, a facility to discharge sediment from the reservoir, is planned.

Meanwhile, river-crossing structures such as hydroelectric dams and agricultural diversion weirs are located in succession in the Yahagi Dam downstream, which control the flow of sediment from the river basin into the further downstream. It is therefore feared in recent years that the granulation of bed material and decrease in gravel might affect the ecosystem. Hence, sediment discharge from the dam is expected to improve the river environment.

In this study, as a survey to examine the effect of sediment discharge from the dam on the river environment, we conducted on the site (i) "sediment augmentation experiment," in which sediment is temporarily set in the river channel to examine comprehensively the effect of sediment discharge on the river environment by reproducing the same effect as sediment discharge at the time of flood, and (ii) "sand-covering experiment," in which sediment is artificially accumulated on the river bed of the basin area to examine minutely the effect of sediment accumulation and flow on bed material, benthic fauna, etc. We will predict the effects of sediment discharge on the river environment by combining the results of these field experiments with changes in bed height, distinction of rapids and pools, bed material, etc., changes in hydraulic variables such as flow velocity and depth, etc.

This paper reports some findings obtained from these field experiments

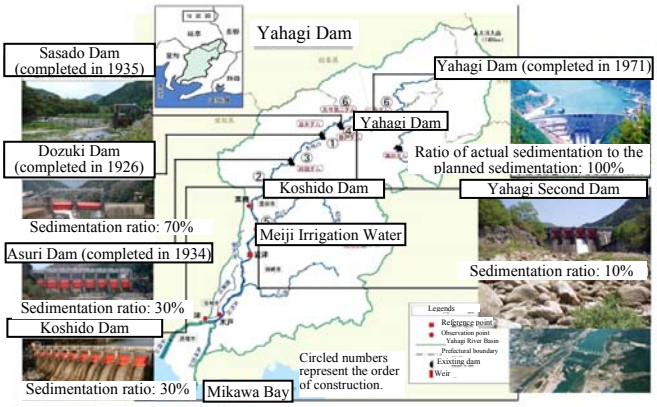

Figure 1. Yahagi River Basin and Main River-Crossing Structures

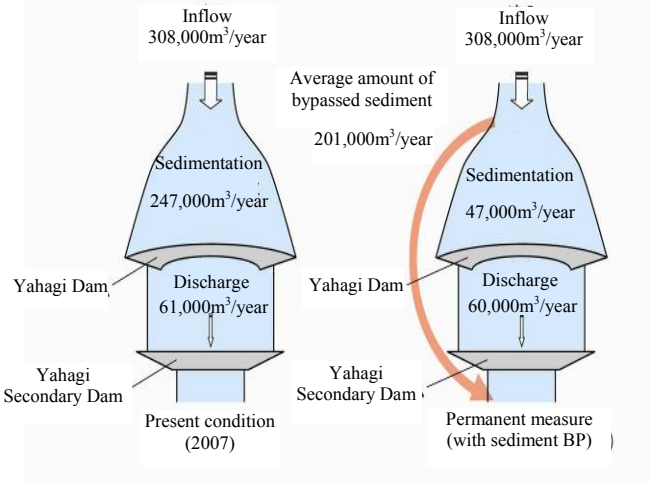

Figure 2. Sediment Inflow to Yahagi Dam and Sediment Balance After BP Development

2. EFFECT OF SEDIMENT FLOW ON RIVER ENVIRONMENT

The effect of sediment discharge from a dam on the downstream river environment is generally assumed from the findings to have a relationship of Impact and Response (IR) as shown in Fig.3.

For reference, Table 1 shows the surveys so far conducted. Although the degree of impact on the rivers varies depending on the relationship between replenished sediment and river size, etc., each survey has examined and analyzed the relationship between sediment replenishment and river environment through monitoring survey. However, few reports show quantitative data on specific changes in habitat due to changes in bed height, distinction of rapids and pools, bed material, etc.

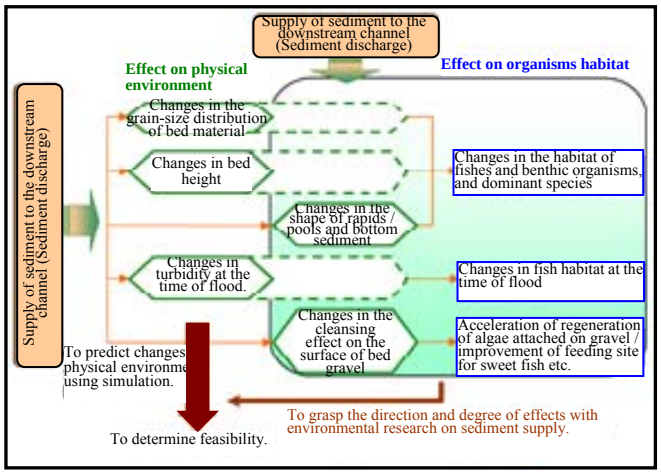

Figure 3. Impact-Response (IR) Relationship Assumed from Sediment Flow

Table 1. Sediment Replenishment Experiments (Water Resources Environment Technology Center, 2008)

Dams	River systems Rivers	Location Construction year	Year of experiment	Purpose *	Replenished sediment (1000m^3/ time)
Nibutani	Saru R. Saru R.	Hokkaido 1997	2002-2006	ii) (Granulation) iii) (Smelt)	1-10
Miharu	Abukuma R. Ohtakine R.	Fukushima 1998	2000-2006	ii) iii) iv)	0.55-2
Futase	Ara R. Ara R.	Saitama 1961	2001-2006	ii)iii) (Cottid) iv) (Sedimentation measures)	3-13.3
Kawamata	Tone R. Kinu R.	Tochigi 1966	2005, 2006	ii) (Granulation) iii)iv) (Sedimentation measures)	0.2-1.6
Aimata	Tone R. Akatani R.	Gunma 1959	2004, 2005	ii) (Granulation) iii)	0.2-1
Nagashima	Oi R. Oi R.	Shizuoka 2001	2000, 2001	iv) (Impact evaluation of sediment discharge)	20-25.3
Yahagi	Yahagi R. Yahagi R.	Aichi, Gifu 1971	2006	iv) (Impact evaluation of sediment discharge)	4
Managawa	Kuzuryu R. Mana R.	Fukui 1979	2004-2006	i)v) (Flexible management)	0.2-0.22
Hachisu	Kushida R. Hachisu R.	Mie 1991	2002-2006	ii)iii) (Sweet fish)	0.1-2
Nagayasuguchi	Naka R. Naka R.	Tokushima 1956	2004-2006	iii)	12-24
Urayama	Ara R. Urayama R.	Saitama 1998	2000-2005	ii)iii) (Leuciscinae) iv) (Sedimentation measures)	0.6-20.7
Shimokubo	Tone R. Kanna R.	Gunma 1968	2003-2006	iv) (Sedimentation measures) v) (Landscape)	1-6.6
Agigawa	Kiso R. Agi R.	Gifu 1990	2004, 2005	ii) (Granulation) iv) (Check dam)	0.6-1.2
Nunome	Yodo R. Nunome R.	Nara 1991	2004, 2005	i)iv) (Check dam)	0.19-0.54
Muroo	Yodo R. Uda R.	Nara 1973	2006	i)	0.06-0.09
Hitokura	Yodo R. Ina R.	Hyogo 1983	2002-2006	ii) (Granulation) iii) (Sweet fish)	0.3-1
Akiba	Tenryu R. Tenryu R.	Shizuoka 1958	2000, 2001, 2005	iv) (Sedimentation measures) v) (Degradation, beach erosion)	18-20

*: Purposes of experiments are classified according to i) Improvement in the downstream river environment (ii) and/or iii)), ii) Improvement in physical environment, iii) Improvement in biological environment, iv) Countermeasures for sediment, and v) Other.

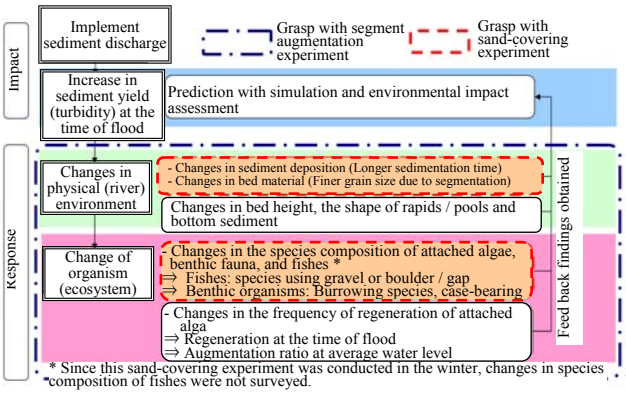

Figure 4. Method of Grasping IR and Effects concerning Sediment Supply in Yahagi Dam

We studied past surveys as follows.

2.1. Purpose of Surveys

The past surveys studied are classified into (i) those that discharge sediment mainly for the life extension of the reservoir and like Yahagi Dam (ii) those mainly for environmental improvement of the dam downstream river.

2.2 Monitoring Items

Monitoring items are roughly classified into (i) those for physical environment survey and (ii) those for biological survey. Most of the items of (i) physical environment survey were relevant to changes in bed height, grain size distribution of bed material, turbidity, etc. and most of the items of (ii) biological survey were observed and studied over time at fixed points about the habitat of attached algae, benthic fauna, fishes, etc.

3. SEDIMENT AUGMENTATION EXPERIMENT AND SAND-COVERING EXPERIMENT IN YAHAGI DAM

Consequences of sediment discharge from the sediment bypass (BP) of Yahagi Dam would include increase in turbidity and resultant effects on the river biota, acceleration of the detachment / regeneration (cleansing effect) of attached algae by sediment, and grain refining of bed material and incidental changes to the interaction between living organisms.

As a method of predicting the effects of sediment discharge, we assumed a scenario comprising sediment discharge, predictive calculation of river bed evolution (simulation), changes in rapids and pools of the river, and ecosystem response, and conducted "sediment augmentation experiment" and "sand-covering experiment" for Yahagi Dam based on the concept of the flow in Fig.4 as field experiments to grasp "habitat changes" and "ecosystem response to the changes" under the scenario.

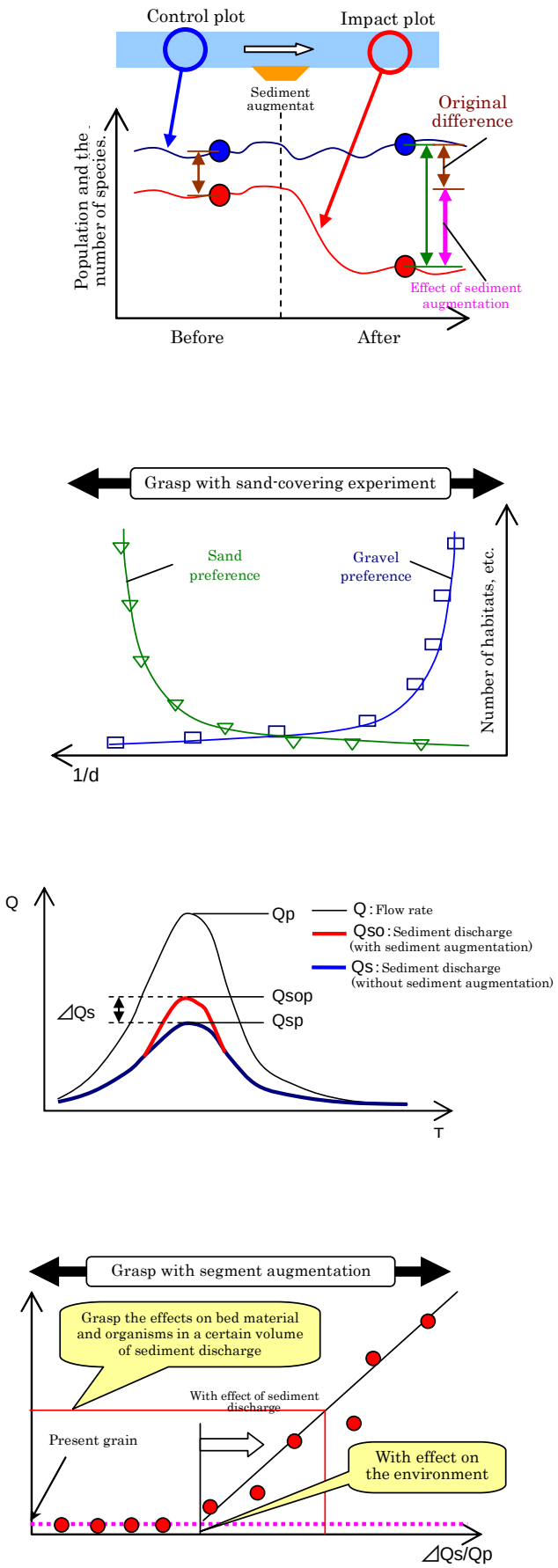

Figure 5. BACI Design of Yahagi Dam

3.1. Sediment Augmentation Experiment

For the sediment augmentation experiment in Yahagi Dam, with the aim to "examine overall impact on the downstream river environment (physical system / eco-system) by creating a situation similar to sediment discharge and acquire social acceptance of dam sediment discharge," we conducted a monitoring survey to study the effects on the downstream by discharging the augmented sediment into the channel at the time of a flush that does not affect turbidity.

We have been conducting the sediment augmentation experiment since 2006, and compiled and analyzed age-dependent changes in the results of the fixed-point survey based on the predicted impact-response relationship using BACI Design (Before, After, Control: Setting of points with no impact, Impact: Setting of points with impact) (Fig. 5)

Figure 6. Augmented Sediment (Odo)

Figure 7. Augmented Sediment (Ikezima)

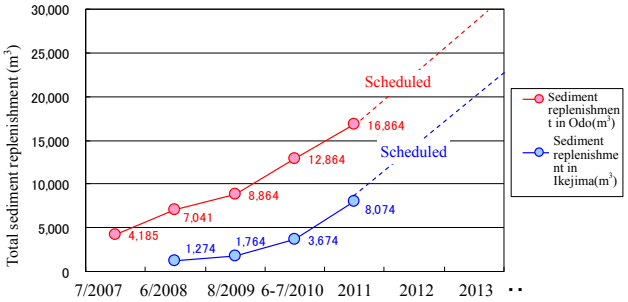

Figure 8. Discharge of Augmented Sediment

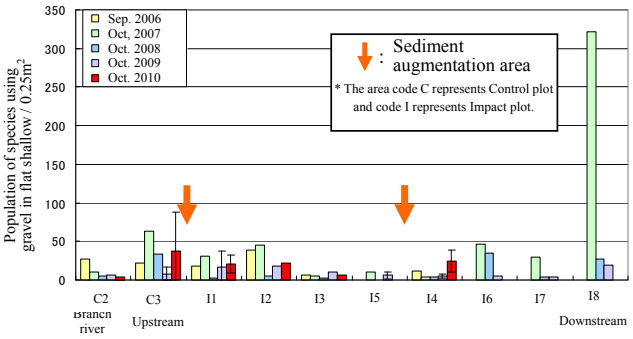

Figure 9. Secular Changes in Population of Benthic Fauna in Sediment Augmentation Experiment

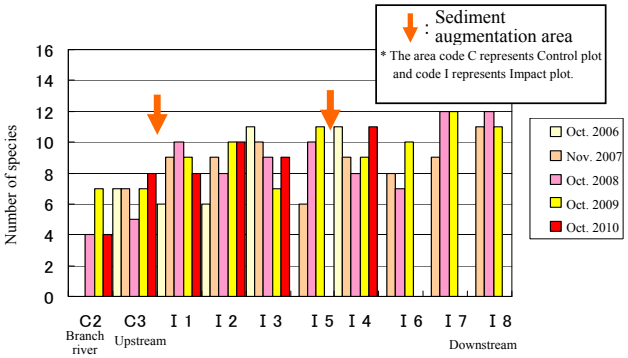

Figure 10. Secular Changes in Number of Fish Species in Autumn (in Flat Shallow)

We conducted sediment augmentation at two points: One in Odo (downstream of Sasado Dam) since 2006 and the other in Ikejima (downstream of Dozuki Dam), and no clear effects of sediment augmentation on the river environment have been measured from the results of the survey. The absence of clear effects would be attributable to the small scale of sediment replenishment by augmentation as compared with the river size, since only about 1.5% (about 3,000 m^3 annually) is replenished every year from the total sediment of about 300,000 m^3 flowing into Yahagi Dam due to the restraints from the downstream river users. (See Figs. 8,9, and 10)

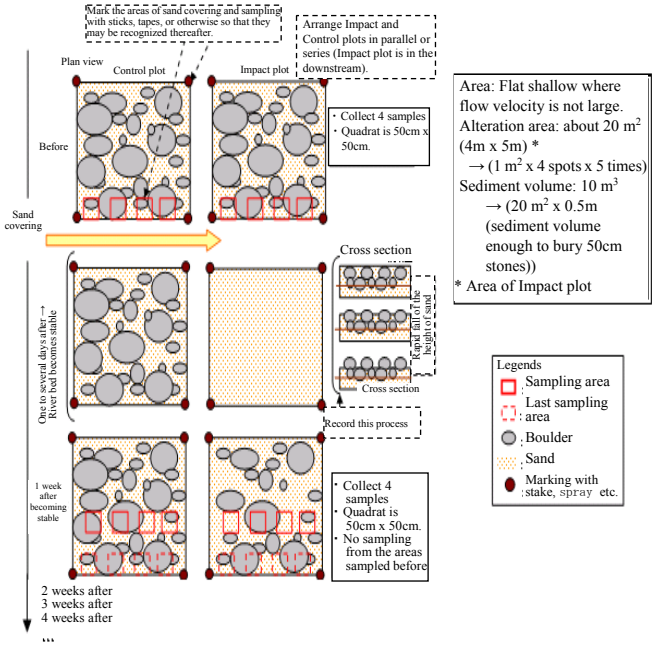

Figure 11. Image of Sand-Covering Experiment

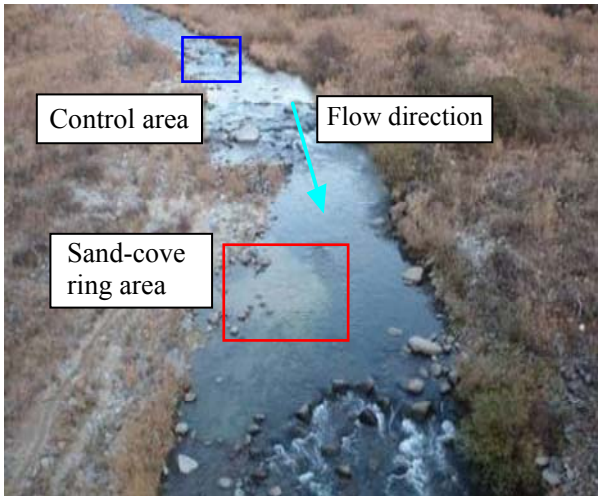

Figure 12. Sand-covering Experiment in the distant view

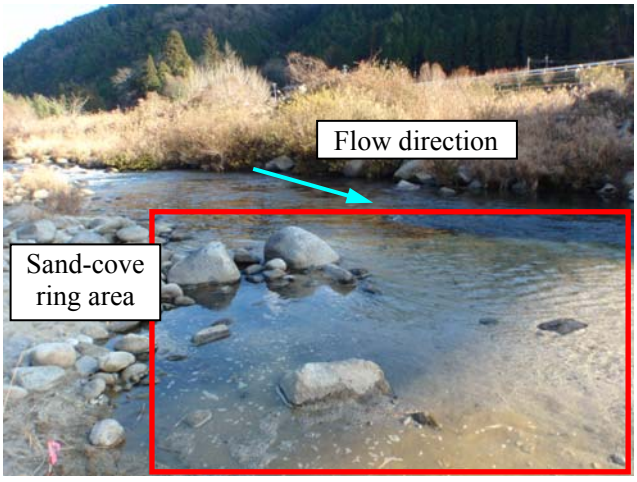

Figure 13. Sand-covering Experiment in the foreground

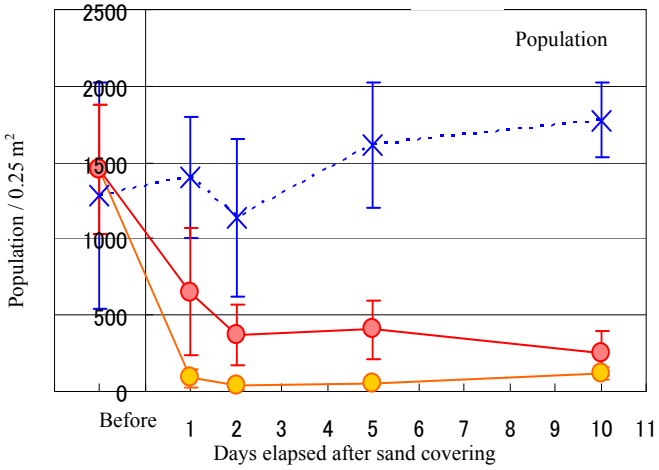

Figure 14. Temporal Changes in the Population of Benthic Fauna Caused by Sand Covering

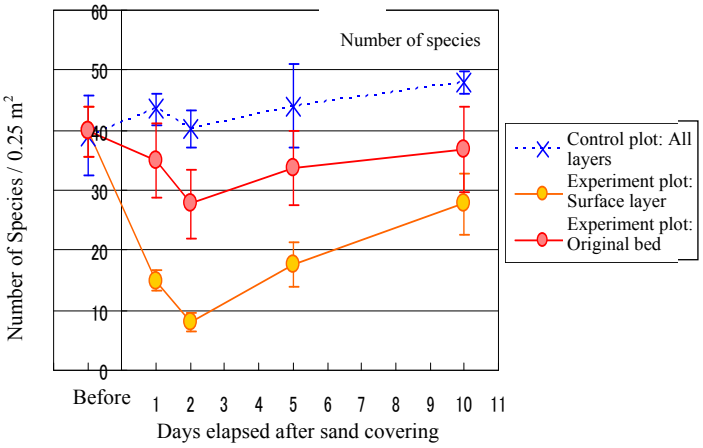

Figure 15. Temporal Changes in the Number of Species of Benthic Fauna Caused by Sand Covering

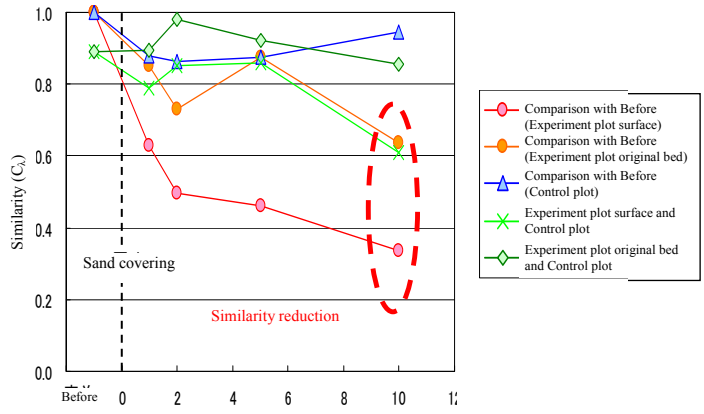

Figure 16. Temporal Changes in Similarity Index (C_λ (Morisita 1959))

3.2 Sand-covering Experiment

We conducted the sand-covering experiment by placing sediment artificially on the river bed to examine the effects of sedimentation on living organisms, grasp changes of effects on them according to sedimentation time, and thereby improve the accuracy of prediction. Figure 11 shows the image of sand-covering experiment.

Reviewing the experimental results, we focused on increase in the ratio of gravels due to sand covering and changes in benthic fauna expected to be affected by reduced water depth. As a result, the population and the number of species decreased immediately after sand covering but turned to increase from 5 days after sand covering. Species composition began to change from 10 days after sand covering, i.e., species that prefer fast flowing shallow streams have become dominant, including Rhithrogena tetrapunctigera (mayfly) and Capniidae.spp (stonefly). (See Figs. 14, 15, and 16).

These results show that accumulation of gravels will reduce both population and the number of species and then species composition will change according to the new environment.

4. CONCLUSION AND ISSUES TO BE ADDRESSED

This study provides the results of analysis and evaluation on the data obtained from the sediment replenishment experiment (sediment augmentation and sand covering experiments) we have conducted in Yahagi Dam since 2006. The findings of the study are as follows.

(1) The data of sediment augmentation experiment was analyzed and evaluated based on the assumed impact-response relationship. As a result, no outstanding effect was acknowledged with benthic organisms, fishes, etc. This would be attributable to the small amount of sediment replenishment as compared with the river size and flush volume. In the future, it will be necessary to continue monitoring with increased sediment replenishment including addition of sediment augmentation areas.

(2) In the sand-covering experiment, we observed temporal changes in the bed material and benthic organisms at the old and present beds on the covering sand. As a result, both population and the number of species decreased soon after sand covering, but turned to increase from 5 days after sand covering, and species composition changed after 10 days. These experiments were conducted in December, which is not the flood season, in a condition where sediment gradually flows after sedimentation. In the future, it would be necessary to conduct a sand-covering experiment in the flood season when organisms are active to study changes in population, number and composition of species, etc.

ACKNOWLEDGEMENT

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