Study on Fish Migration through Stones Embedded Fishway Using Suitability Index

Graduate school of Science and Engineering, Yamaguchi University
Rina Febrina, Tsuneyuki Tsukada, Masahiko Sekine, Ariyo Kanno, Koichi Yamamoto

1. Introduction

In recent years, there is increasing concern that fisheries and the associated livelihoods are being threatened as a consequence of dam construction. Because of that fishways have been established in order to reduce the impact on the ecosystem. One of the most popular constructions of fishway in Japan is Stones Embedded Fishway (SEF) because it looks natural. SEF is a kind of fishway that can reduce velocity by adding stones on the slope. However, efficiency of SEF has not been evaluated well and the design of SEF condition is not clear. Therefore, it is demanded to evaluate and analyze efficiency of SEF for fishes.

Field survey has been done at Fushino River`s SEF in Yamaguchi (Katsube, 2011), and the SEF was revealed to be a network of small pools and channels. In this paper we attempt to evaluate whether Ayu can swim through the Fushino River's SEF or not by using Suitability Index obtained through laboratory experiments.

2. Research Method

2.1 Experimental Apparatus

We attempt to create the condition of SEF at Fushino River based on laboratory experiment. The experimental apparatus consists of a pool and a channel (Figure 1). The structure of experimental apparatus is shown in Figure 2.

2.2 Experimental Method

In this experiment, we measure velocity, turbulence and bubble. The experimental condition based on field survey is shown in Table 1, where DoC (depth of channel), SoC (slope of channel), LoC (Length of channel), SoP (size of pool), and DoP (depth of pool). Before measurement, we set the depth of channel, depth

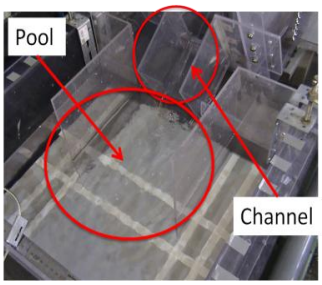


Figure1. Pool and channel

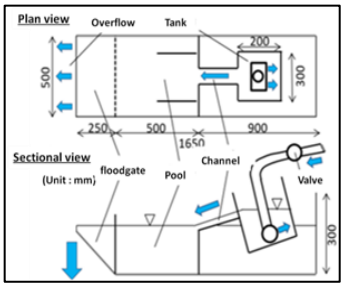
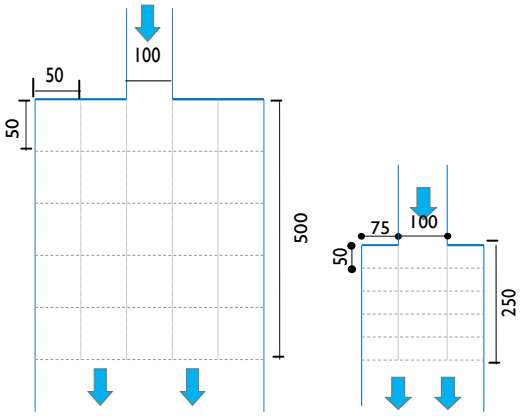


Figure 2. Structure of device

of pool and slope of channel base on the experimental condition. We divide pool to be 25 areas (Figure 3a) for pool with size 50 x50 and 15 area (Figure 3b) for pool 25 x25. Velocity is measured by using current meter (KENEK VR-201), turbulence is measured by using 3D current meter (KENEK VP-3000), and air bubble mixing rate is measured by using syringe with a steel tube of 30 cm to the tip (Figure 4). We calculate air bubble mixing rate (BM) by equation: BM = A/58x100%, where A is the amount of cell contamination.

Table 1. Experimental condition

SoP	DoC (cm)	LoC (cm)	SoC	DoP (cm)
25x25 50x50	1, 4, 10	5, 15, 30	0.1, 0.5, 1	2, 9, 18



a. 50 x 50 b. 25 x 25

Figure 3. Size of Pool

2.3. Suitability calculation method

We converted velocity to velocity SI (VSI) by using HSI shown in Figure 5. For turbulence, the strength of turbulence is measured by turbulence energy K:

$$K = (x'+y'+z') / 2$$

Where x', y' and z' are variance of velocity in the direction of x, y, z respectively. Turbulence SI (TSI) is obtained by using HSI shown in Figure 6.

For bubble SI (BSI), we use the equation:

BSI = Bubble Condition Index x Bubble Mixing rate SI + (1-Bubble Condition).

Where for bubbles condition: if there is no air bubble in the pool, Bubble Condition Index (BCI) is 0, air bubble on surface, BCI is 0.1, air bubble in the middle of pool, BCI is 0.5 and then if air bubble reaches to the bottom, BCI is 1. For bubble mixing rate Case 1. (BM ≤5%：SI=1), Case 2. (5 %< BM≤10: SI=0.75), Case 3. (10 %< BM≤20% : SI=0.5), Case 4. (BM>20% : SI=0.25). To calculate Combined Suitability Index (CSI), we use the formula: CSI=VSI×TSI×BSI. CSI=0 means fish dislikes the condition, and CSI=1 means fish prefers that condition.

2.4. Threshold evaluation

To evaluate if "Ayu can rest and pass through the channel or not", we define a set of parameter values as threshold for Ayu of Body Length (BL) 6cm and BL 11cm based on Nakamura (1995).

a. Threshold of evaluation if "Ayu can rest in the pool"

For BL 6cm, thresholds are; V: 0.33cm/s or less. T: 1.2 $(m/s)^2$ or less. BM: 20 % or less. BCI: for DoP 2cm 0.1 or less, for DoP 9cm and DoP18 cm 0.5 or less. Where: V is velocity and T is turbulence. For BL 11cm, thresholds are; V : 0.605 (cm/s) or less. T : 1.2 $(m/s)^2$ or less. BM: 20% or less. BCI: for DoP 9cm and 18cm 0.5 or less. In addition, Ayu with BL 11cm cannot rest under the condition of DoP of 2 cm because the body height of Ayu with BL 11 cm is 2.3 cm.

b. Threshold of evaluation if "Ayu can pass through the channel"

We calculate the time Ayu spends to pass through the channel by equation: (Length of channel/ (Dash speed – V)). Dash speed of Ayu is BL×15. When it is over 4 seconds, Ayu cannot pass through the channel.

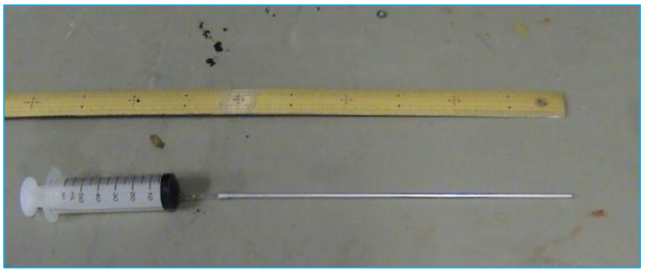


Figure 4. Syringe with a steel tube of 30 cm to the tip for air bubble mixing rate measurement

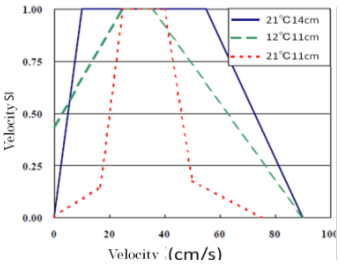


Figure 5. HSI for velocity

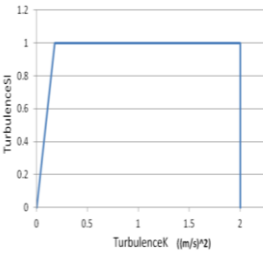


Figure 6. HSI for turbulence

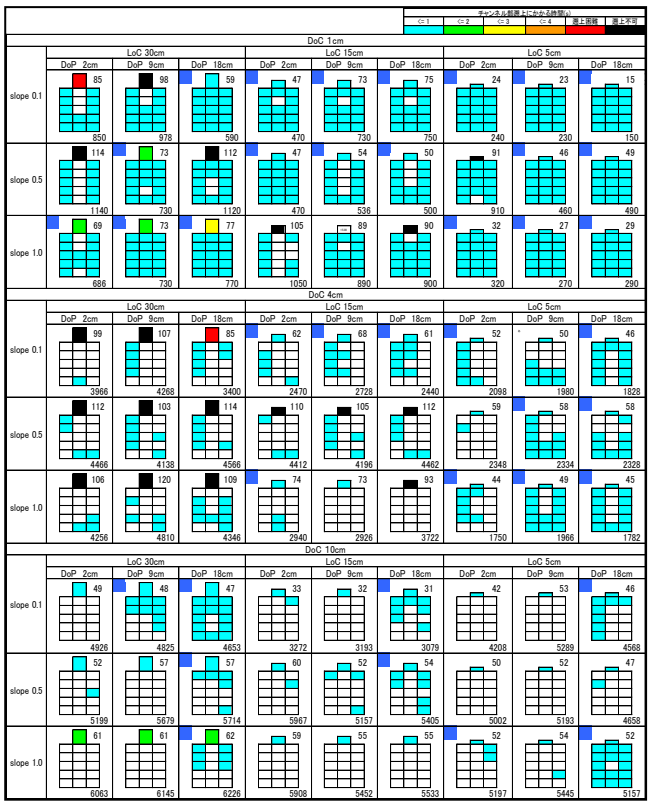


Figure.7 Threshold evaluation of Ayu of BL6 at 25×25 Pool

3. Result and Discussion

The result for CSI show Ayu dislike most of the condition of pool. It means SEF not suitable for habitation of Ayu. And Figure 7 shown the result of threshold based on the evaluation of 25×25 pool. This figure explains in some condition of Ayu with BL 6cm cannot through the channel but Ayu with BL 11cm can through the channel in all condition except DoP 2 cm. For pool 50x50, Ayu with BL 11 cm can through the channel for DoP 9cm and 18cm. For DoP 2 cm, Ayu cannot through the channel because of body height of fish 2.3 cm. The main cause Ayu can not through the channel because of velocity. Turbulence becomes worst when DoP is 9cm. When flow rate 4.6 (l/s) or less, Ayu can rest in the pool under the most of situation.

4. Conclusion

Firstly, based on the CSI calculation, Ayu dislike most of the condition of pool. That mean, Fushino River`s SEF is not suitable for habitation of Ayu. Flow rate is a main factor which divides whether Ayu can rest and pass through the channel or not. Secondly, Ayu with body length of 11cm can through the channel in all condition of pool 50×50 and 25x25 where depth of pool was 9cm or 18cm. But, Ayu with BL 11cm need depth of pool deeper than 2.3cm to rest in the pool. Third, in some condition of Ayu with BL 6 cm cannot through the channel. Fourth, turbulence becomes strong where depth of pool is 9cm. Border value of flow rate which influence “Ayu can rest or not” is 4.6 (l/s).

5. Reference

1. Katsube, Shinichi et al., Proc. JSCE Chugoku annual conference, II-27 (CD-ROM), 2011.

2. Nakamura, Shunroku. GYODOU NO HANASHI, Sankai-do, pp.225, 1995.