

## THE SWIMMING BEHAVIOR OF *TRIBORODON HAKONENSIS* IN STREAM-TYPE FISHWAY WITH THE SLOPE OF 1/10

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### ABSTRACT

The purpose of this study was to research a column arrangement a lot of fish can run up stream type fishway of a steep slope. To complete them, using a stream type fishway with a longitudinal slope of 1/20 in Case1, and 1/10 in Case2. Therefore, the experiments were carried out to measure the hydraulic quantities (flow velocity, water depth) and to observe the movement of real fish. The element of flow resistance used the column, because to increase the water depth. There were two patterns of column arrangement what were zigzag and aligned arrangements. The real fish used in the experiments were Ugui; *Triborodon hakonensis*. The average body length was 8.4 cm (7.4 to 9.3 cm) all of them. The average water temperature was 20.5 degrees (19.8 to 22.6 degrees). The Results showed the Followings; Results show that: 1) The run-up ratio of Case2 was much lower than Case1 in both zigzag and aligned arrangements. Comparing the zigzag and alignment arrangements slope of 1/10 in Case2, the former had a greater number of the fish that run up the fishway. 2) As a whole, the flow velocity  $V$  was faster in Case2 than in Case1, however *Triborodon hakonensis* swam along at the wall side in both Case1 and Case2, the flow velocity of the wall side was the same degree in both cases. Therefore, by devising a column arrangement, it is possible that fish can run up even if the stream type fishway is steep.

*Keywords: stream-type fishway, steep slope, run up ratio, swimming behavior of fish, Triborodon hakonensis*

### 1. INTRODUCTION

There are three sections of fishways in Japan. Fishway sections are classified into pool type, stream type and operation type. This study focused on the stream-type fishway. The stream-type fishway can create various flows and is excellent in terms of landscape. Generally, the recommended longitudinal slope of the Japanese stream-type fishway is 1/20. However, there may be cases where there is not enough fishway length in the field. In that case, the longitudinal slope of the stream-type fishway becomes steep. At this time, water depth is low, and the flow velocity is rapid, making it difficult for fish to run up.

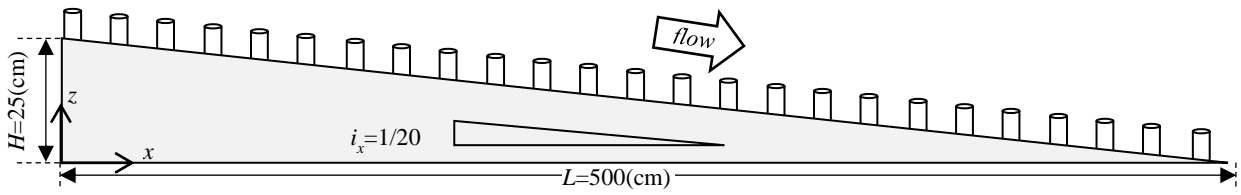
The previous experiments (Case1); Aoki and Funakoshi (2018) was carried out using the different column arrangements (zigzag arrangement and aligned arrangement) in the stream type fishway with the longitudinal slope of 1/20. As the results, although there was no difference between the two column arrangements in the run-up ratio of the fish, there was a difference in the run-up time and distance required for the of the fish.

Therefore, this study aimed at the following two things. The first thing is to compare the flow and swimming behavior of fish with between a longitudinal slope of 1/10 and a longitudinal slope of 1/20 of a stream-type fishway. The second thing is to examine the column arrangements even if the longitudinal slope of the stream-type fishway is steep, fish can run up easily. To complete them, the experiments were carried out to measure the hydraulic quantities (flow velocity, water depth) and to observe the movement of real fish.

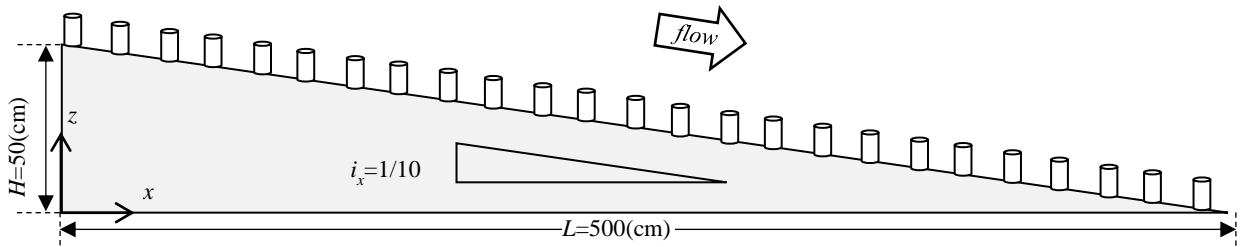
### 2. EXPERIMENTAL METHODS

Figure 1 shows the stream-type fishway used in the experiments. The fishway width  $B$  was 50 (cm), horizontal length  $L$  was 500 (cm), height  $H$  was (cm) and longitudinal slope  $i_x = 1/10$ . The element of flow resistance used the column with a diameter of 4.8 (cm) and a height of 15.0 (cm). The zigzag and alignment arrangements were used for the column arrangements. The fishway in the previous study (Case1); Aoki and Funakoshi (2018) had a

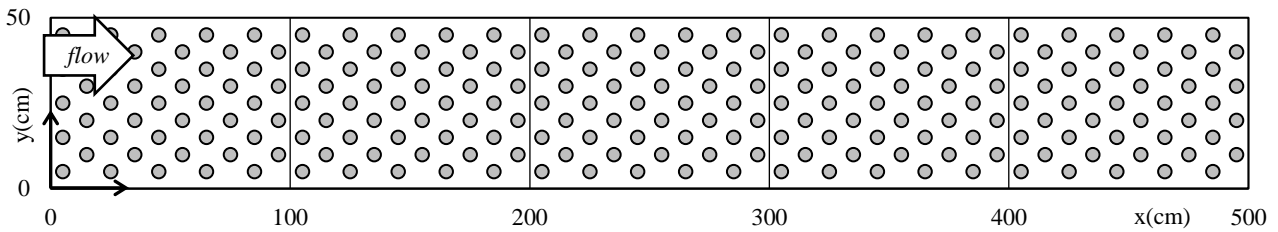
width  $B$  was 50 (cm), horizontal length  $L$  was 500 (cm), height  $H$  was 25 (cm), and longitudinal slope  $i_x = 1/20$ . Table 1 shows the cases considered in the experiments. In addition, Table 1 also shows the stream-type fishway that was a (Case1) with the longitudinal slope of  $1/20$ . The average water temperature was 20.5 degrees (19.8 to 22.6 degrees), illuminance was 200 to 250 (lx) at water surface.



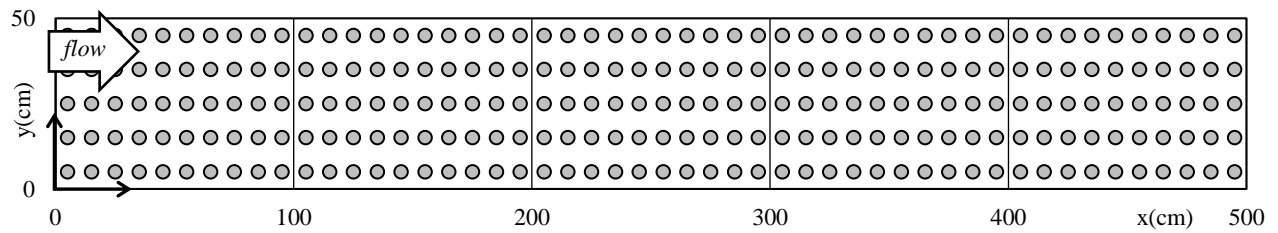
a) Side view of fishway with longitudinal slope of  $1/20$  (Case1)



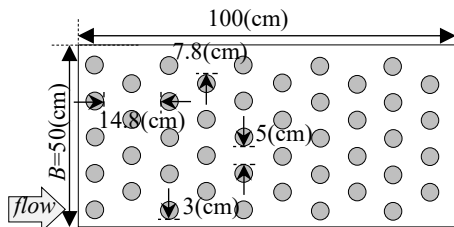
b) Side view of fishway with longitudinal slope of  $1/10$  (Case2)



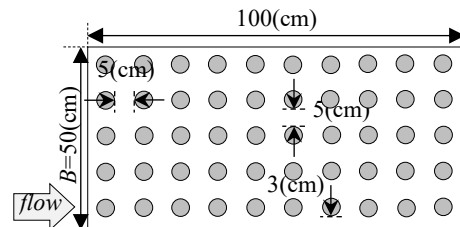
c) Zigzag arrangement



d) Alignment arrangement



e) Zigzag arrangement enlarged view



g) Alignment arrangement enlarged view

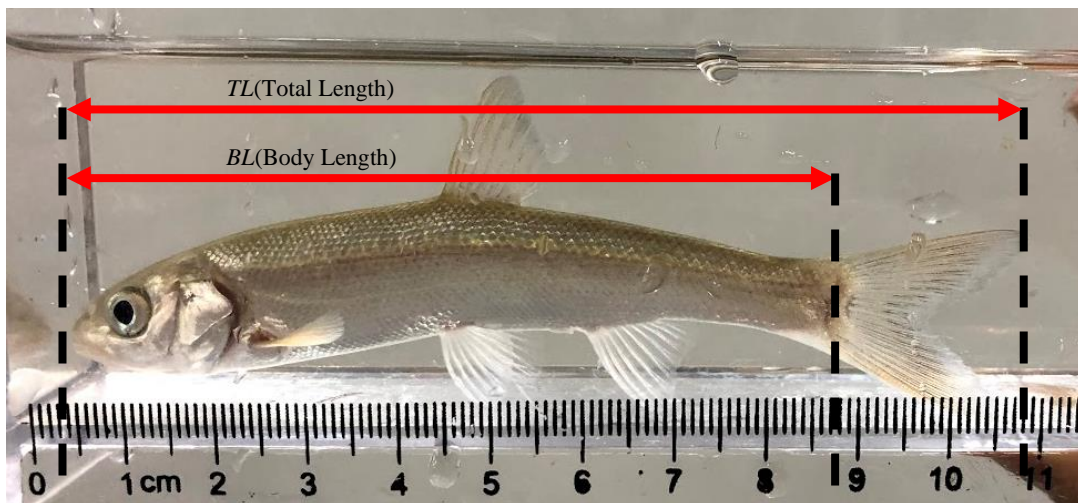
Figure 1. The arrangement of the columns

Table 1. Cases considered in the experiments

Case	Run	column arrangement	Discharge $Q$ (l/s)	longitudinal slope $i_x$	Column density $\lambda_s$
1	1-1	zigzag	20	1/20	0.180
	1-2	alignment			0.162
2	2-1	zigzag	20	1/10	0.180
	2-2	Alignment			0.162

## 2.1 Movement of real fish

The real fish used in the experiments were Ugui; *Triborodon hakonensis* (Picture 1). The average body length ( $\overline{BL}$ ) was 8.4 (cm) ( $BL$  was 7.4 to 9.3 (cm)) all of them. In the experiments, the lower part of the fishway ( $x = 500$  (cm), 550 (cm)) was separated by the nets. In this section, 10 fish were released. After 5 minutes, only the nets ( $x = 500$  (cm)) was opened and the experiment was started. Immediately after the start of the experiment, the movement of real fish was observed and captured for 30 minutes using a camera. This procedure was performed three times for each case. The swimming speed of fish is expressed by body length speed to standardize differences in fish species and size. There are two types of fish swimming speed: the cruising speed and the blast speed. The cruising speed is the swimming speed that can be maintained for a long time. Specifically, it is the speed of 2 to 4 times the body length ( $\overline{BL}$ ) per second. The blast speed is a swimming speed that can be exerted instantaneously. Specifically, it is the speed of 10 times the body length ( $\overline{BL}$ ) per second. In addition, fish has two swimming characteristics. One is the preference along the wall. Two is the characteristic behavior of swimming against the flow.



Picture 1. ugui; *Triborodon hakonensis*

## 2.2 Hydraulic experiments

The water depth was measured using a digital point gauge (KENEK, SDV-60E), and the flow velocity was measured using a two-dimensional electromagnetic current meter (KENEK, VM2001). As for the flow velocity, 512 data were acquired with the sampling frequency set to 20 (Hz) and simply averaged. The flow velocity in the  $x$  direction is  $u$ , the flow velocity in the  $y$  direction is  $v$ , and the simple averaged flow velocity is the time-averaged flow velocity  $\bar{u}$ ,  $\bar{v}$ . The swimming depth of the fish was visually observed and found to be approximately 2 (cm) from the fishway bed. Therefore, in this experiments the flow velocity were measured at 2 cm above the fishway bed.

### 3. RESULTS OF EXPERIMENTS

Figure 2 shows the run-up ratio of Case1 and Case2. Case 2 showed a very low run-up ratio compared to Case 1. First, we focused on the flow velocity  $\bar{V}$  in the fishway (Figure 3). In the case of the zigzag arrangement,  $\bar{V}$  was 3 to  $8\bar{BL}$  (cm/s) in Run1-1, on the other hand  $\bar{V}$  was 3 to  $11\bar{BL}$  (cm/s) in Run2-1. In the case of alignment arrangement, the flow velocity  $\bar{V}$  in the fishway was 2 to  $8\bar{BL}$  (cm/s) in Run1-2, while  $\bar{V}$  was 3 to  $12\bar{BL}$  (cm/s) in Run2-2. Overall, the flow velocity  $\bar{V}$  in the fishway of Case 2 was rapid, and the area where fish could swim was narrow. Therefore, it is considered that the run-up ratio of Case 2 was lower. Second, we focused on the flow velocity  $\bar{V}$  around the wall because the fish has the preference for the wall (Figure 4). The flow velocity  $\bar{V}$  near the wall in Case 2 is 3 to  $10\bar{BL}$  (cm/s). Therefore, if the fish could detect the flow velocity  $\bar{V}$  around the wall, the run-up ratio in these experiments may have improved. Third, focused on the swimming route of the fish in Case1 and Case2 (Figure 5, Figure 6). The swimming route of the fish was different in the case of the zigzag and aligned arrangement. In the case of aligned arrangement, the fish swam around the wall. Finally, we focused on the run-up time and distance of the fish that succeeded for run up in the experiments (Figure7, Figure8). In the zigzag arrangement, the run-up time of the fish that succeeded in running up was shorter in Run2-1 than in Run1-1. In Run2-1, the fish sometimes stayed for approximately 15 seconds. However, the fish generally moved to the route with the flow velocity  $\bar{V}$  that allowed them to run up. As the results, it is expected that the fish can run up even in the stream-type fishway with the longitudinal slope of 1/10.

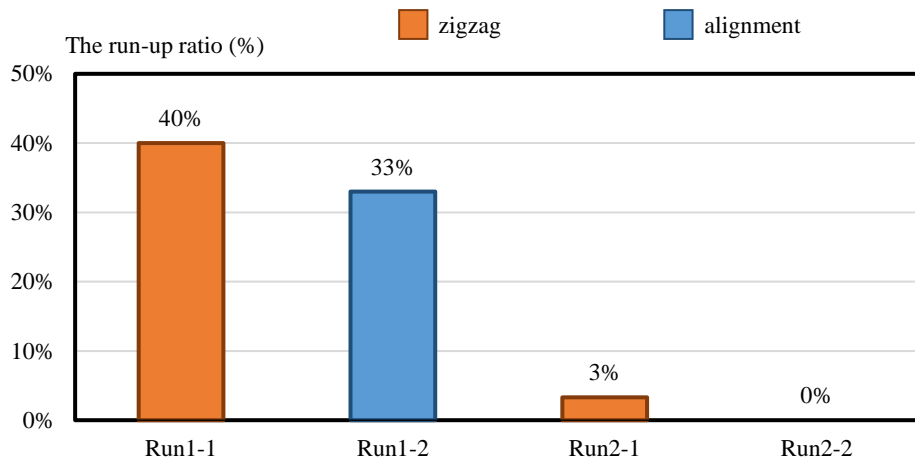


Figure 2. Run-up ratio of each case

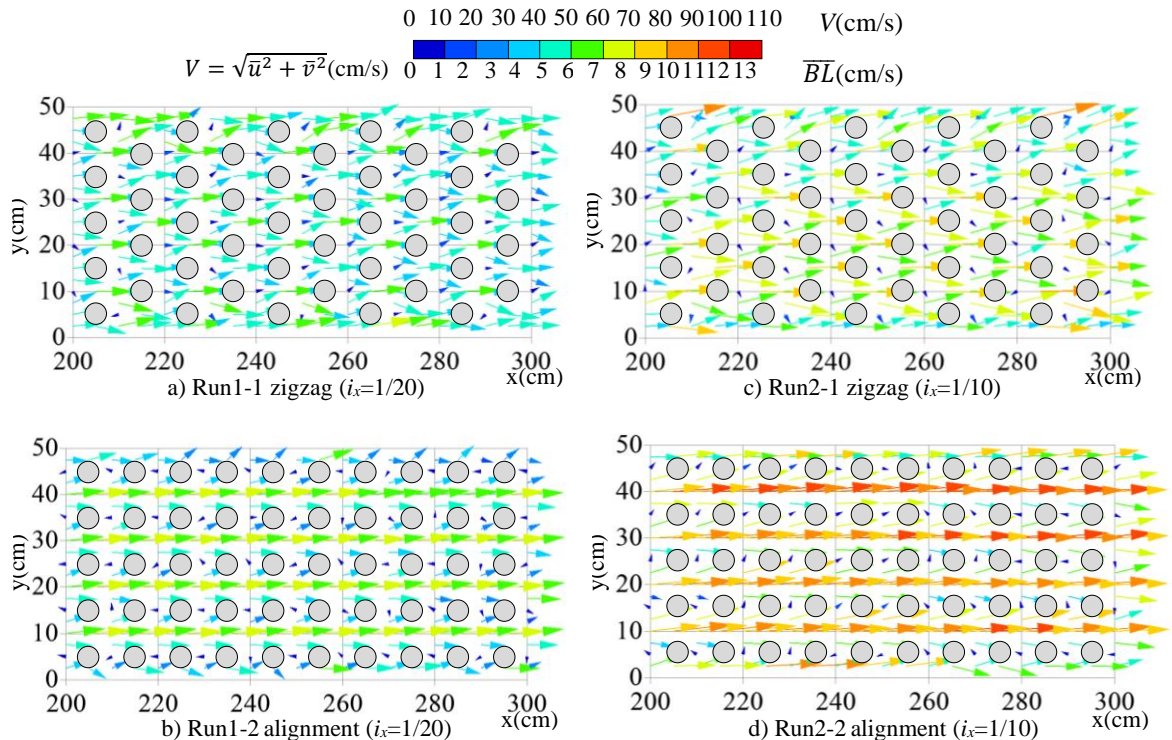


Figure 3. Flow vector diagram of each cases

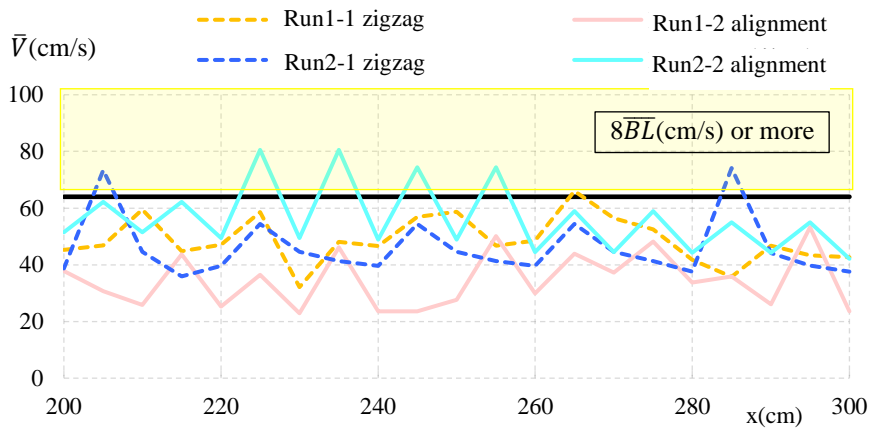
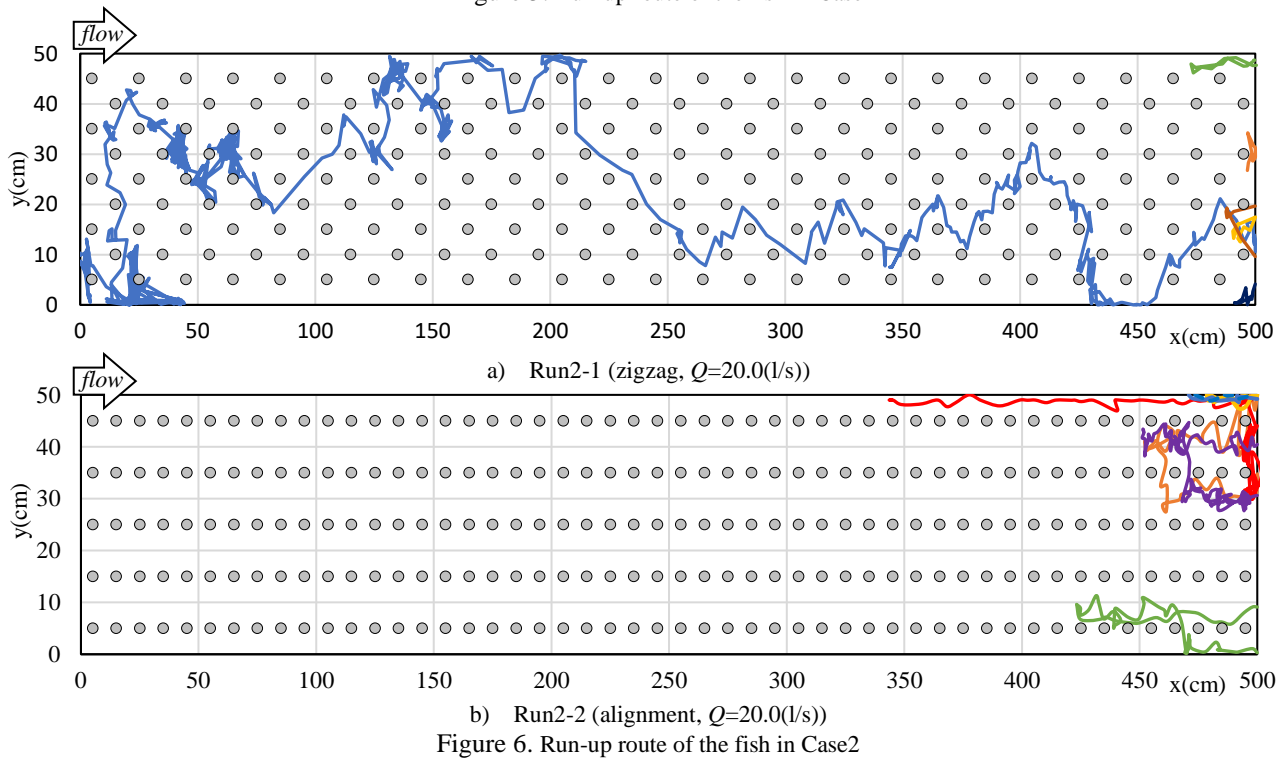
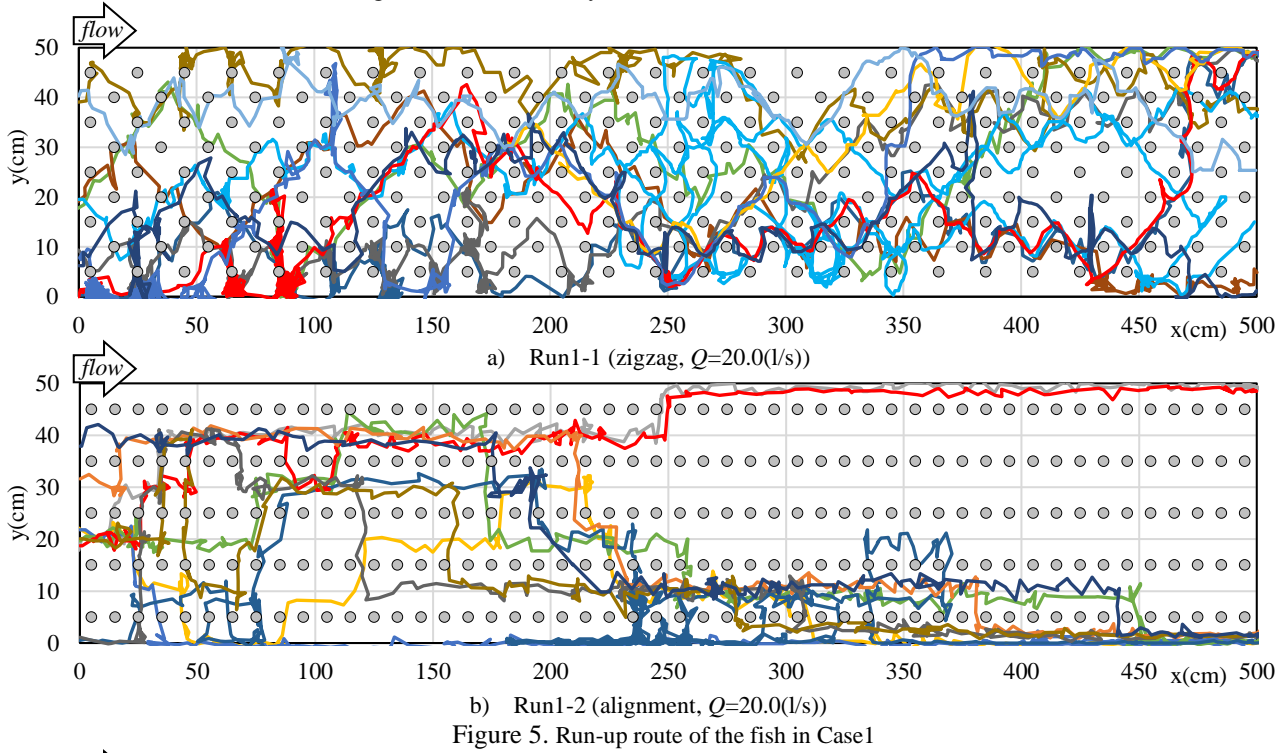


Figure 4. Flow velocity  $\bar{V}$  around the wall of each cases





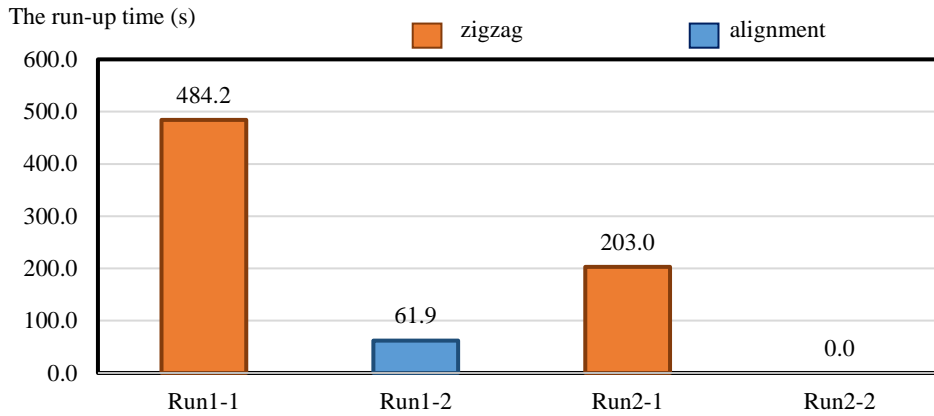


Figure 7. Run-up time of each cases

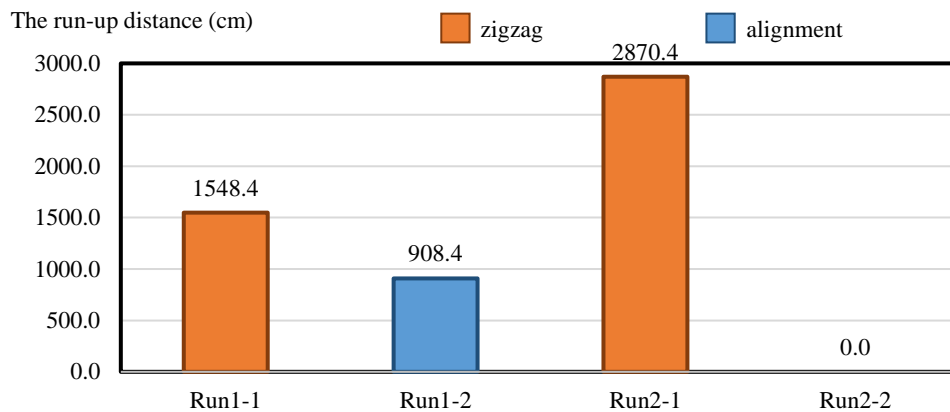


Figure 8. Run-up distance of each cases

#### 4. CONCLUSIONS

The findings obtained in this study are as follows.

- 1) The flow velocity in Case2 was higher than in Case1. Therefore, run-up ratio of the fish in Case2 lower more than Case1. In addition, the flow velocity around the wall was almost similar to the case of zigzag arrangement. Because the flow was dispersed by the column with zigzag arrangement.
- 2) The swimming route of the fish was different in the case of the zigzag and aligned arrangement. In the case of aligned arrangement, the fish swam around the wall.
- 3) The run-up time in Run1-1 was approximately twice in Run2-1. The run-up distance in Run2-1 was approximately twice in Run1-1.

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