Effects of Transverse Width Pattern of Interception Constructed in Open-channel on Swimming Characteristic of Ayu, *Plecglossus Altivelis Altivelis*

Kouki Onitsuka [a], Juichiro Akiyama [a] and Keisuke Kasugai [a]

[a] *Department of Civil Engineering, Kyushu Institute of Technology, Kitakyushu, 804-8550, Japan*

Abstract

It is important to secure the rest area for fish. Fish has the ordinary and dark muscle. When fish uses ordinary muscle, fish got tired. In such a situation, fish needs a rest. In this study, rest characteristic of Ayu (*Plecglossus altivelis altivelis*) with changing the width and the number of interception was researched. The migration rates of Ayu were obtained with the aid of a digital video camera. It was found that the swimming speed increased with an increase of flow velocity, because Ayu swims in keeping with flow velocity for preventing to be drift towards downstream. The total time of the rest increased with an increase of flow velocity.

Keywords: rest area; ordinary and dark muscle; flow velocity; migration speed

1. Introduction

Ecosystem conservation is necessary for river maintenance business. It is necessary to protect the river resources. Ayu is protected as edible fish in Japan. Ayu migrates from the sea to the river in spring. Ayu has to migrate in a river for spawning. There are rest areas for fish in the river which is not artificial. It is important to secure the rest area for Ayu. However artificial structure made in river like fishway may not has appropriate rest area. Most of fishways constructed beside of weirs and dams in Japan. It is important to install the rest area in fishway. When fishway is made, it is necessary to investigate rest characteristic of Ayu to protect them. Likewise it is important to understand the relationship between fish behavior and flow characteristics against interception. Some researchers investigated on such relationships. However, the detailed parameters such as instantaneous swimming direction and instantaneous swimming speed have not been investigated. In this study, rest characteristic of Ayu with changing the width and the number of interception was researched.

2. Materials and Methods

2.1. Experimental device

Fig. 1 shows the open-channel. Pool length (L) was 4.0m and width (B) was 0.6m. x, y and z were the coordinates of the streamwise the vertical and the spanwise directions, respectively. Thickness of interception wall (Δx) was 0.015m. Fig. 1 shows location of interception walls. Interception walls were installed at even intervals.

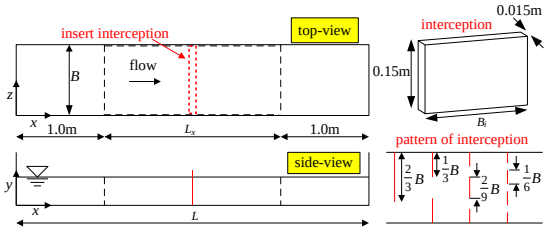


Fig. 1 Open-channel

Tab. 1 Experimental case

Number of interception	B_i	$U_m / \overline{B_L}$(1/s)			
		2	4	7	10
1	(2/3)B	C1-02	C1-04	C1-07	C1-10
2	(1/3)B	C2-02	C2-04	C2-07	C2-10
3	(2/9)B	C3-02	C3-04	C3-07	C3-10
4	(1/6)B	C4-02	C4-04	C4-07	C4-10

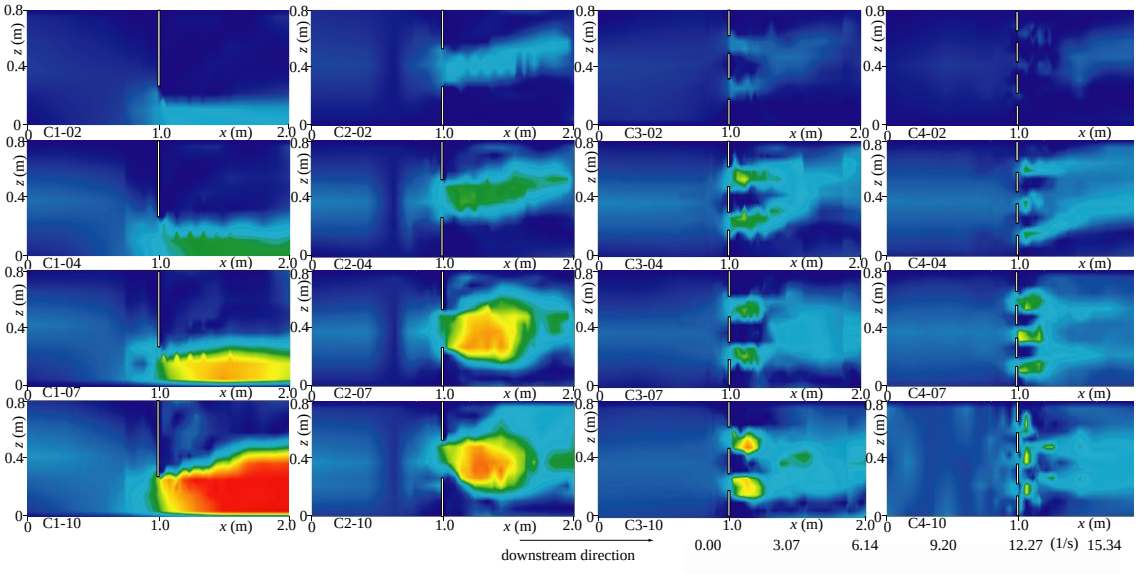


Fig. 2 The contour figure of flow velocity for each case

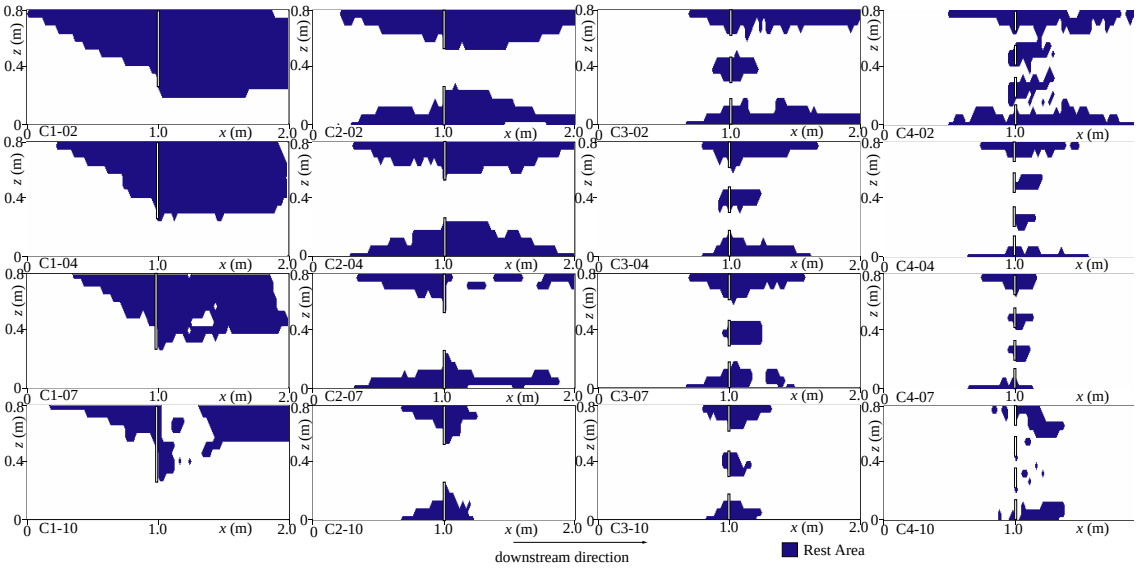


Fig. 3 The distribution of rest area for each case

2.2. Experimental methodology

Tab. 1 shows experimental conditions. Flow velocity divided by averaged body length of Ayu was set to four patterns within the range from 2 to 10. Number of interception was set to four patterns within the range from 1 to 4. Ayu was used for the experiments. The number of used fish was 1 in one recording. The recording has been carried out for 50 conditions in each case and 800 conditions in total. 800 of Ayu were used for the experiments. Averaged body length was about 60mm. A circular wire net of 0.25m in diameter was set up 2m downstream from upstream edge and a quintet of Ayu is inserted. After it is confirmed that the Ayu settled down, the circular wire net is taken up. Further, trajectory of Ayu was recorded with a digital video camera set up the upside of the open-channel. The number of pixel of the digital video camera is 1440×1080, and recording speed is 30fps. The migration rates of Ayu and the rest rates were obtained with the aid of the digital video camera.

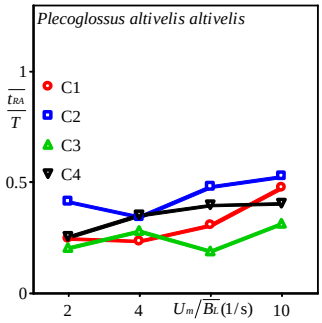


Fig. 4 The ratio of rest time divided by test duration

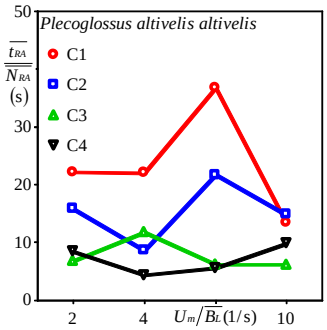


Fig. 5 One stay time in rest area

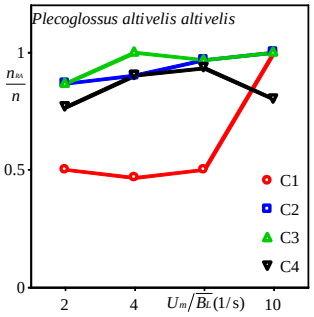


Fig. 6 The relation of frequency of use and flow velocity

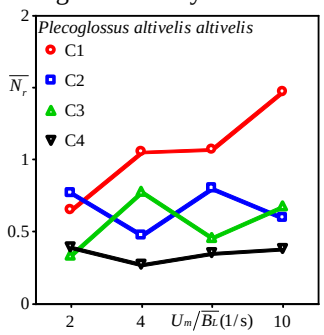


Fig. 7 One rest number of times

3. Results and Discussion

3.1. Definition of the rest

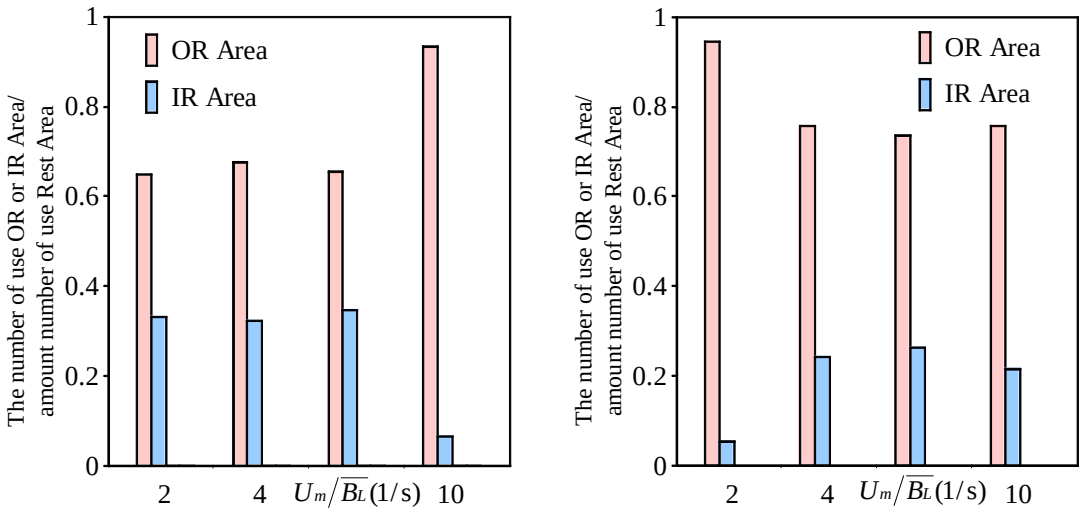
Fig. 2 shows contour figure of three components of flow velocity for each condition. Fast flow velocity is observed in just below gap of interception walls. Slow velocity flow is observed in just below interception walls. In addition, when the number of interception wall increases, flow velocity becomes slow. Fish has the ordinary and dark muscle. Fish gets more and more tired when fish uses ordinary muscle. In such a situation, fish needs a rest. It is thought that the fish takes a rest in the state that is lower than cruising speed without the accumulation of fatigue when using the dark muscle. Generally, the cruising speed V_{fC} is defined as follows:

$$V_{fC}/B_L = 2\sim4 \quad (1)$$

Ayu has a characteristic that swimming to a course of upstream when there is flow to the downstream. The "rest area" is defined as the area where the flow velocity divided by the body length is less than 2. Rest time was defined as the time when Ayu swims at swimming speed (V_f) 2 1/s which is divided by the averaged body length ($\overline{B_L}$) and less in rest area. Coloring area in Fig. 3 shows the demarcation that Ayu can take a rest. It is understood that when the number of interception wall increases, fast velocity flow area increases.

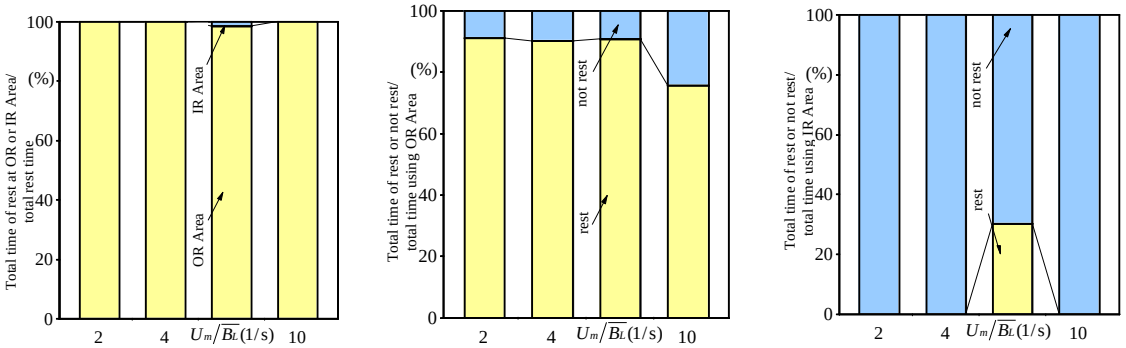
3.2. Characteristic of Ayu to take a rest

Fig. 4 shows ratio of rest time ($\overline{t_{RA}}$) divided by test duration (T). The increase of number of interception wall is not influential on the ratio. Fig. 5 shows relation of rest time ($\overline{t_{RA}}$) divided by entering number of times to rest area ($\overline{N_{RA}}$) and flow velocity ($U_m/\overline{B_L}$). When the flow velocity and the number of interception wall increases, stay time of one rest area decreases. It is understood that when the number of interception wall increases, entering number of times to rest area increases. This is because that Ayu went from rest area to fast velocity flow area and came back. Frequency



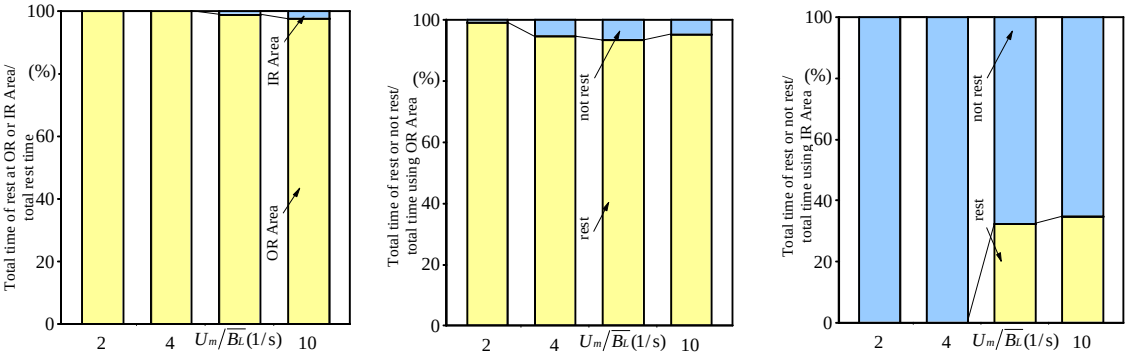
(a) C3 (b) C4

Fig. 8 The ratio of the entering number of times divided by the total number of times of entering rest area



(a) The ratio of rest time in OR Area or IR Area divided by the total rest time (b) Rest vs non-rest time in OR (c) Rest vs non-rest time in IR

Fig. 9 The relation of rest area and rest time in C3



(a) The ratio of rest time in OR Area or IR Area divided by the total rest time (b) Rest vs non-rest time in OR (c) Rest vs non-rest time in IR

Fig. 10 The relation of rest area and rest time in C4

of use for rest area is defined as follows:

$$\text{Frequency of use} = \frac{\text{The number of the experiments using rest area}(n_{RA})}{\text{Number of run}(n = 50)} \tag{2}$$

Fig. 6 shows relation of frequency of use and flow velocity ($U_m/\overline{B_L}$). In C1, frequency of use is about 50%, when flow velocity ($U_m/\overline{B_L}$) is 2～7. C1 is the case that each side of the interception wall contacts with a sidewall alone. Because there was much Ayu which swam along a sidewall, Ayu went up without entering in the rest area. In other cases, more than 70% of the number of the experiments using rest area. Fig. 7 shows relation of the rest number of times ($\overline{N_r}$) and flow velocity ($U_m/\overline{B_L}$). The increase for numbers of interception walls is not influential on the rest number of times.

3.3. Comparison of the use by the position of rest area

In this study the rest area below interception wall which contacted with a sidewall is defined as "Outside Rest Area (OR Area)". Rest area existing in the central part is defined as "Inside Rest Area" (IR Area). Fig. 8(a), (b) shows ratio of the entering number of times to OR Area and IR Area divided by the total number of times of entering rest area in C3 and C4. A ratio of approach number of times to OR Area rises. Fig. 9(a) shows ratio of rest time in OR Area or IR Area divided by the total rest time in C3. Fig. 9(b), (c) show ratio of rest time divided by the total stay time in OR Area and IR Area. A stay in OR Area occupied 90% or more. Fig. 10(a) shows ratio of rest time in OR Area or IR Area divided by the total rest time in C4. Fig. 10(b), (c) show ratio of rest time divided by the total stay time in OR Area and IR Area. A stay in OR Area occupied 90% or more. OR Area is used in a rest purpose, and IR Area is used for the purpose of evading fast velocity flow area or the movement to the crossing direction.

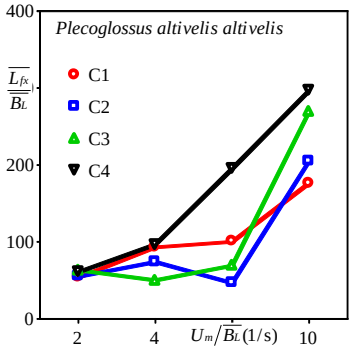


Fig. 11 The relation of swimming distance and flow velocity of the x-axis direction

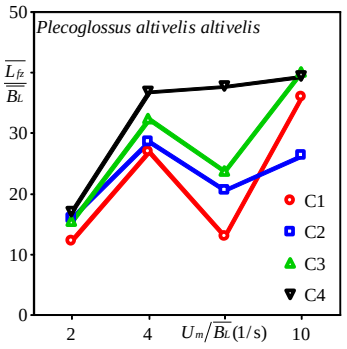


Fig. 12 The relation of swimming distance and flow velocity of the z-axis direction

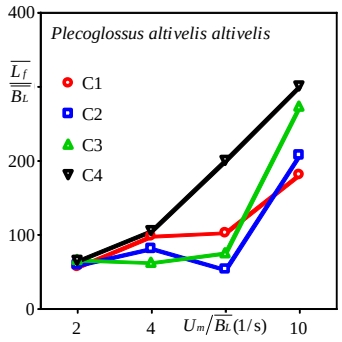


Fig. 13 The relation of swimming distance and flow velocity

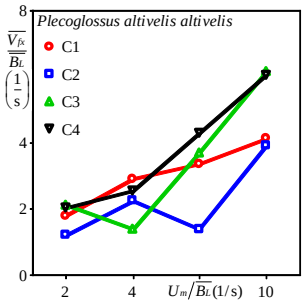


Fig. 14 The relation of swimming speed and flow velocity of the x-axis direction

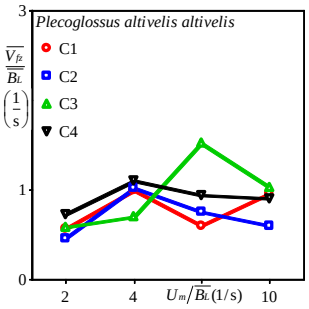


Fig. 15 The relation of swimming speed and flow velocity of the z-axis direction

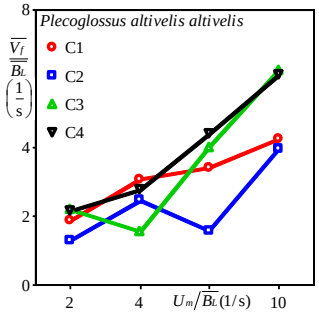


Fig. 16 The relation of swimming speed and flow velocity

3.4. Characteristic of swimming distance and swimming speed of Ayu

Fig. 11, 12 and 13 show relation of swimming distance ($\overline{L_{fx}}$, $\overline{L_{fz}}$ and $\overline{L_f}$) divided by the averaged body length ($\overline{B_L}$) and flow velocity ($U_m / \overline{B_L}$).When flow velocity ($U_m / \overline{B_L}$) and the number of interception wall increase, swimming distance becomes increase. This is because that the number of interception wall and the number of times of entering rest area increase. Fig. 14, 15 and 16 show relation of swimming speed ($\overline{V_{fx}}$, $\overline{V_{fz}}$ and $\overline{V_f}$) divided by the averaged body length ($\overline{B_L}$) and flow velocity ($U_m / \overline{B_L}$).When flow velocity ($U_m / \overline{B_L}$) and the number of interception wall increase, swimming speed becomes($\overline{V_{fx}}$) increase. This is because that Ayu swims for purpose of evading the fast flow velocity in the rest area.

4. Conclusion

The rest characteristic of Ayu was found with changing the width and the number of interception wall. When the flow velocity and the number of interception wall increases, swimming distance becomes increases and swimming speed becomes increase. This is because that Ayu swims for preventing to be drift towards downstream when Ayu swim out of rest area.

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