An Improvement of Migration Rate with Evasion Color of *Plecoglossus Altivelis Altivelis* in Pool-And-Weir Fishway

Kouki Onitsuka [a], Juichiro Akiyama [a], Akira Shishido [a], Tomoko Arisuda [a] and Shuhei Takamatsu [a]

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

Abstract

Most of the fishway installed in Japanese rivers belongs to the pool-and-weir fishway type. This fishway is usually made by concrete, so that the color of the pool side-wall and bed are gray. On the other hand, it is pointed out that the fish behavior is affected by the wall color. Unfortunately, the effect of wall color in the fishway on the fish behavior has not been investigated. It has been found that Ayu (*Plecoglossus Altivelis Altivelis*) evade red (5R4/14). In this study, the position where painted red were changed to pool side-wall and bottom. It was found that the migration rate increases by painting downstream and left bank sidewall. It's because Ayu evaded painted sidewall and center of fish's school is located nearby upstream notch.

Keywords: pool-and-weir fishway, evasion color, migration rate, center of fish's school, Ayu

1. Introduction

Most of the fishway installed in Japanese rivers belongs to the pool-and-weir fishway type. However, Noonam *et al.* (2012) revealed that, approximately, 30% Salmonidae and 60% non-Salmonidae has failed to migrate at the pool-and-weir fishway. The best way to maintain high migration rate is to provide adequate flow regime to migrate. However, it is hard to upgrade geometric construction an existing fishway, for example in terms of the cost of construction. Therefore, one of the way to control fish behavior without changing geometric construction is using sense of fish such as vision. Most pool-and-weir fishway is usually made by concrete, so that the color of the pool's sidewall and bottom are gray. On the other hand, it is pointed out that Ayu's behavior is affected by the red (Simomura *et al*., 2002). So, by changing fishway's sidewall and bottom color, there is a possibility that the behavior of Ayu changes. In this study, the position where painted red were changed to pool side-wall and bottom, and observed the behavior of Ayu.

2. Materials and Methods

2.1. Experimental device

Fig. 1 shows pool-and-weir fishway that was made of wood. However, left bank sidewall was made of an acrylic board for taking a picture. It was designed following. Pool length (L) was 0.7m and width (B) was 0.6m. The pool was connected in a staircase pattern. Thickness of the partition wall (Δx) was 0.15m, pool drop (Δy) was 0.15m and notch width (Δz) was 0.12m. x axis is taken in the direction of flowing. y axis is taken in the vertical direction from bottom. z axis is taken in the direction of the crossing. Pool number was in ascending order toward downstream to upstream.

Fig. 2 shows location of painted surface. For example, the painted case on the Right bank Sidewall (x/L=0~1.0, y/h=0~0.2, z/B=0) was denominated "RS" (Fig 2 (a)), on the Upstream Bottom (x/L=0~0.5, y/h=0 z/B=0~1.0) was denominated "UB" (Fig 2 (b)).

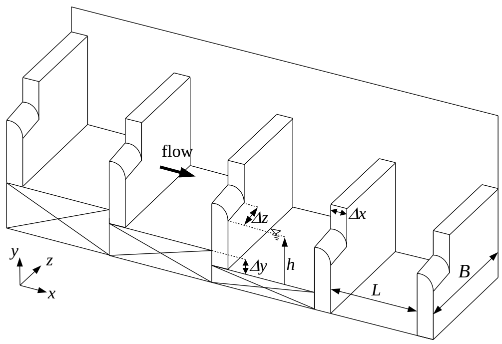
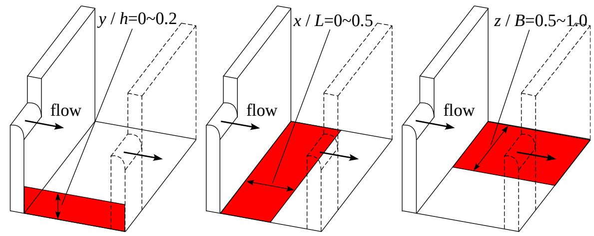


Fig. 1 Pool-and-weir fishway



(a) RS (b) UB (c) LB

Fig. 2 Location of painted surface

Tab. 1 Experimental case

Pool condition			Case name
Standard pool (Non color)			Non
Painted wall	Upstream	Sidewall	US
		Bottom	UB
	Downstream	Sidewall	DS
		Bottom	DB
	Left bank	Sidewall	LS
		Bottom	LB
	Right bank	Sidewall	RS
		Bottom	RB

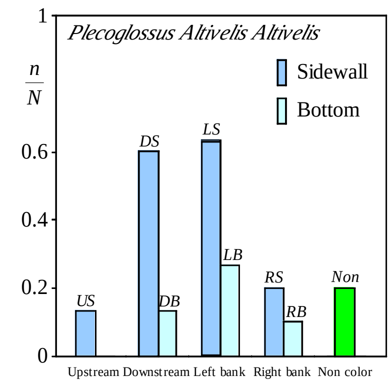


Fig. 3 Migration rate of Ayu

2.2. Experimental methodology

30 tails Ayu (*Plecoglossus Alitvelis Altivelis*) that average length ($\overline{B_L}$) is 80mm were put into the second pool. Discharge was maintained at 5 (l/s). Recording was began with the video camera from the sidewall and the upper part of the fishway for 20 minutes at the same time as net for migration prevention was removed after confirming steady flow by watching. Number of migration, swimming position and fish angle was analyzed after recording. Three components of flow velocity were measured. Average of flow velocity (U, V, W) of each direction axis (x, y, z) and synthetic flow velocity was calculated after measuring. When flow velocity is measured, Ayu is not put in the fishway.

3. Results and Discussion

3.1. Relation between painted position and migration rate

Migration rate was defined as following equation.

$$\text{Migration rate} = \frac{\text{Number of fish that succeeded in migration } n}{\text{Number of fish that used to experiment } N(=30)} \qquad (1)$$

Fig. 3 shows migration rate (n/N) of Ayu for each case. Compared Sidewall and Bottom, former's migration rate was high in any case. Especially, DS and LS gained high migration rate. Therefore, by changing painted position, migration rate was changed.

3.2. The velocity in the pool and the point of swimming position of Ayu

Fig. 4 shows contour figure of three components of flow velocity V_V in vertical section at y/h=0.15, 0.35 for each case. Although the velocity near the right bank (z/B=0~0.2) is around 0.5 m/s, the other region has less approximately 0.3 m/s.

Fig. 5 (a), (b) shows instantaneous position of swimming for each case. In horizontal section "Bottom", center of fish's school is located on the relatively left bank side, the difference

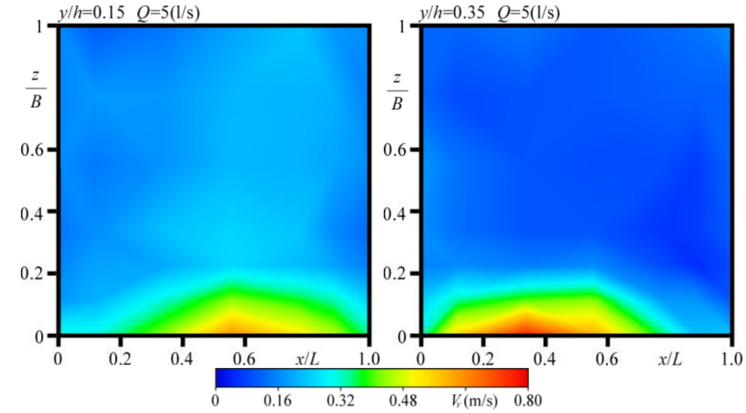
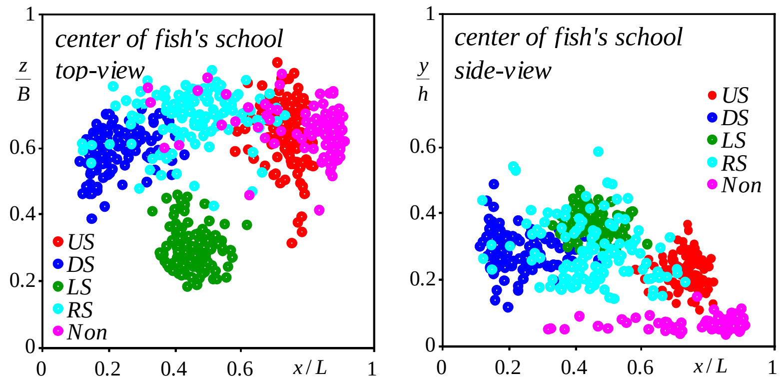
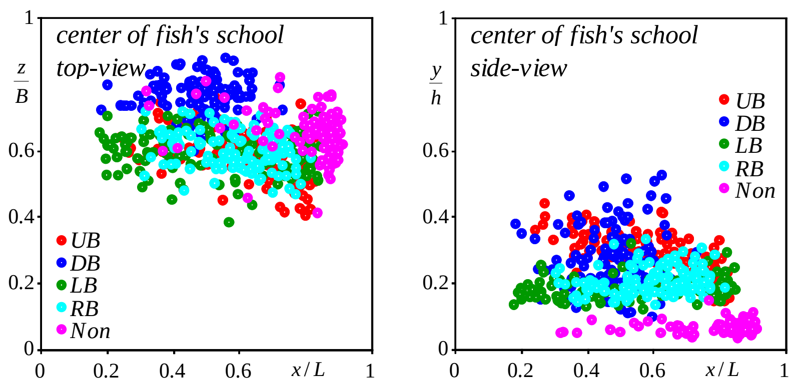


Fig. 4 Contour of flow velocity in vertical section



(a) Sidewall



(b) Bottom

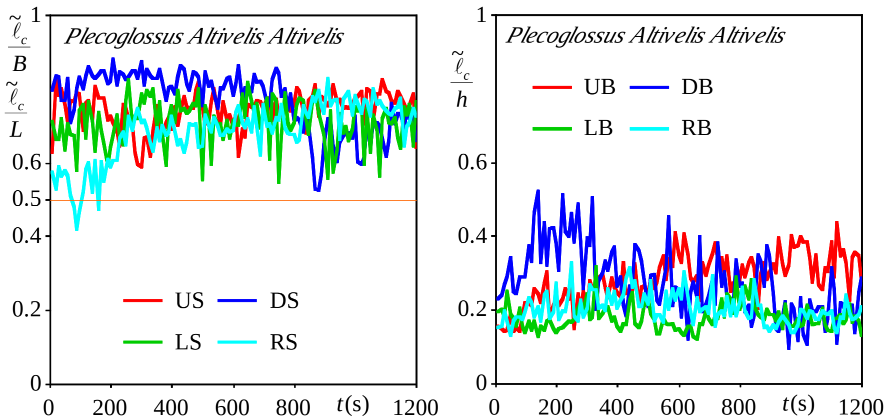
Fig. 5 Instantaneous position of center of fish's school

between the cases are not significant. However, in "Sidewall", the position is varied by the case. Particularly, "LS" is located on the right bank side significantly than other cases.

On the other hand, focusing on both the vertical cross section, there were no clear difference by the case.

3.3. The distance between the center of fish's school and painted wall of Ayu

Fig. 6 (a), (b) show the instantaneous distance ($\tilde{\ell}_c/L$, $\tilde{\ell}_c/B$, $\tilde{\ell}_c/h$) between the center of fish's school and painted wall of Ayu for each case. Focusing Fig 6 (a), center of fish's school was



(a) Sidewall (b) Bottom

Fig. 6 The distance between the center of fish's school and painted wall of Ayu

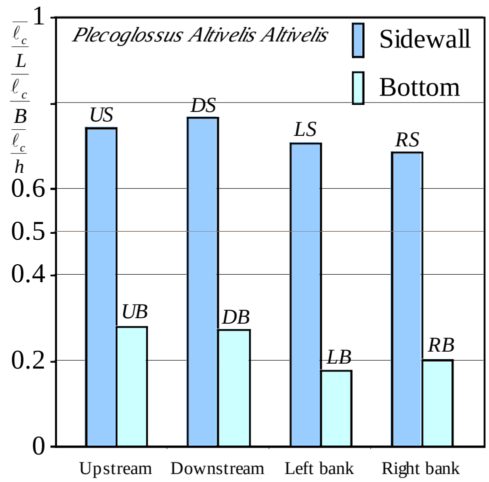


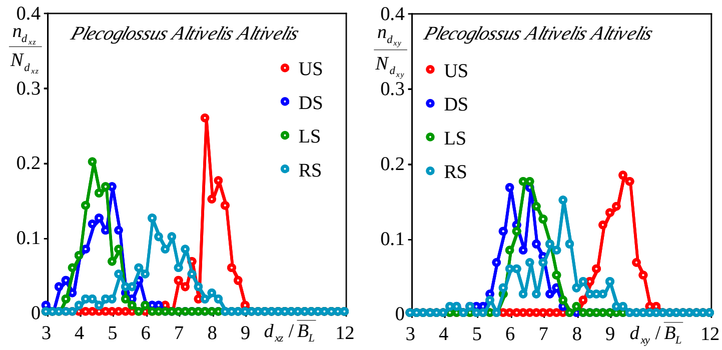
Fig. 7 The average of distance between the center of fish's school and painted wall of Ayu

moving away more than half of the pool length and width from painted wall in all case. This is estimated that Ayu evaded painted wall. On the other hand, focusing Fig 6 (b), center of fish's school was always below a half depth, there were no clear difference for each case. Therefore, in Fig 5 (a) for center of fish's school are difference, in Fig 5 (b), there are similar in all cases.

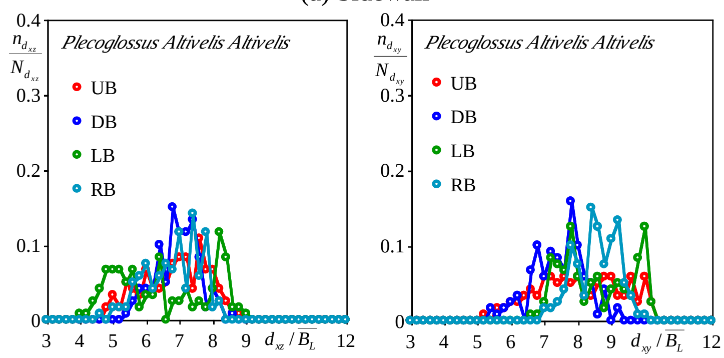
Fig 7 shows the average of the distance between the center of fish's school and painted wall of Ayu ($\overline{\ell_c}/L$, $\overline{\ell_c}/B$, $\overline{\ell_c}/h$) for each case. In Sidewall, in all cases, $\overline{\ell_c}/L$ and $\overline{\ell_c}/B$ are larger than 0.5. Thus, this is estimated that Ayu evaded painted wall clearly too. By the way, Onitsuka *et al.* (2009) was carried out Ayu induction experiments by installing a mirror on the sidewall and bottom of the open channel. As a result, though there was no change Ayu's behavior to be installed mirror on the bottom, Ayu be mistaken for a fellow the figure of himself in the mirror and to change the swimming behavior by installing mirror on the sidewall. This shows Ayu is influenced by the visual information got from the horizontal direction than vertical direction. In this study, similar results were obtained.

3.4. The distance between the center of fish's school and upstream side notch

Fig. 8 (a), (b) show the frequency distribution of distance ($d_{xz}/\overline{B_L}$, $d_{xy}/\overline{B_L}$) between the center of fish's school and upstream side notch for each case (d_{xz} = horizontal distance between

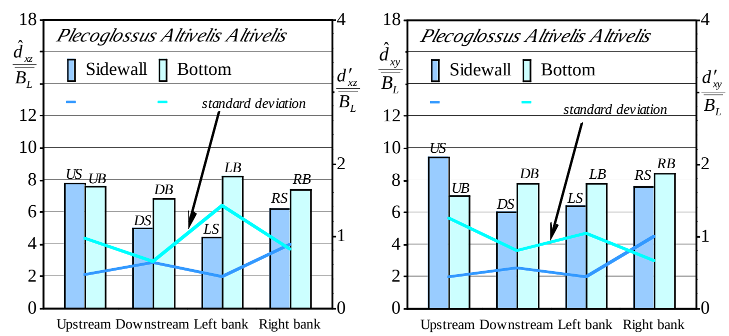


(a) Sidewall



(b) Bottom

Fig. 8 The frequency distribution of distance between the center of fish's school and upstream notch



(a) Horizontal section (b) Vertical section

Fig. 9 The standard deviation of distance between the center of fish's school and upstream notch

center of fish's school d_{xy} = vertical direction between center of fish's school). In Sidewall, distribution range of the distance is different for each case. This shows that the distance were changed by changing painted wall. On the other hand, in Bottom there were no difference by the case.

Fig 9 (a), (b) show the mode ($\hat{d}_{xz} / \overline{B_L}$, $\hat{d}_{xy} / \overline{B_L}$) and standard deviation ($d'_{xz} / \overline{B_L}$, $d'_{xy} / \overline{B_L}$) of distance for each case. Focusing Fig 9 (a), $\hat{d}_{xz} / \overline{B_L}$ was comparatively lower in DS and LS (These got high migration rate.). This shows Ayu evaded painted wall and moves away from there, as a result, it's estimated that center of fish's school was close to the upstream side notch in DS and LS. On the other hand, it's no difference in the mode of Bottom. In the standard deviation, Sidewall was below the Bottom in many cases. So, it's estimated that the Sidewall's movement of the center of fish's school is less than Bottom's.

3.5. The distance of migration and the direction of Ayu

Fig. 10 shows the average of migration distance ($\overline{S_m} / \overline{B_L}$) for each cases. Migration distance of DS and LS are shorter than the other cases. As observed Fig 5 (a), center of fish's school of DS and LS has been crowded left bank. Most of individual start to migrate from center of fish's school. Thus, migration distance is shorter both DS and LS cases due to move to nearby upstream notch by painted wall. As a result, fatigue accumulation of Ayu is suppressed, migration rate increases.

Fig 11 shows the definition of the direction of Ayu. Fig 12 (a), (b) show the frequency distribution of the direction of Ayu (n_θ / N_θ). Fig 12 (a) shows that they were swimming in parallel to the bottom surface in US and RS. On the other hand, DS and LS show a peak value at 60°~80°. This corresponds to direction of upstream notch. Since it becomes easier to recognize the flow, it estimates that migration rate increased.

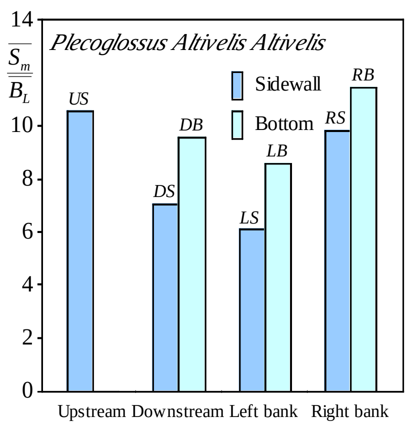


Fig. 10 Migration distance of Ayu

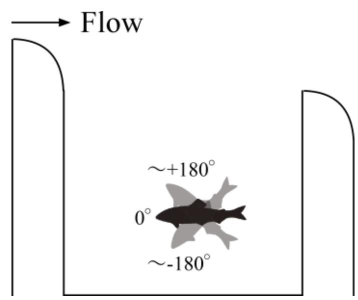
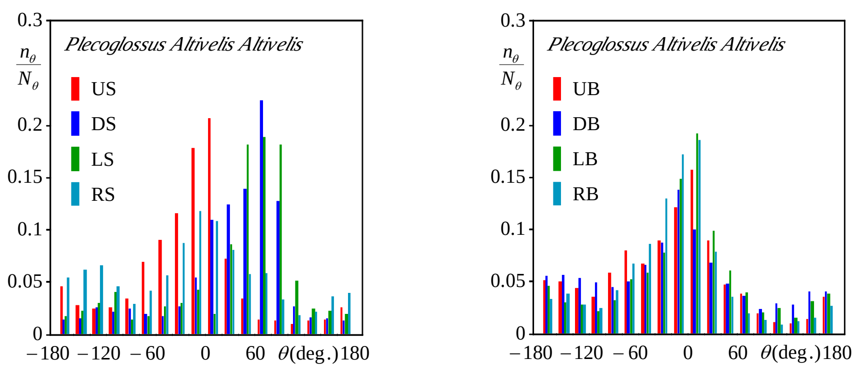


Fig 11 Definition of the direction of Ayu



(a) Sidewall

(b) Bottom

Fig 12 Frequency distribution of the direction of Ayu

4. Conclusion

In this study, the position where painted red were changed to pool side-wall and bed, and experiments of migration with Ayu. As a result, it was found that following.

(1) It was found that it's a little effect for Ayu to paint pool bottom, however, by painting sidewall, we are able to control Ayu's swimming position.

(2) It was found that the migration rate increases by painting downstream and left bank sidewall.

Acknowledgements

This study was received assistance from Grants-in-aid for Scientific Research when the study conduct.

References

Onitsuka K, Akiyama J, Yamamoto A and Ikeno M. Guidance control of school of Ayu using a mirror. Annual Journal of Hydraulic Engineering. JSCE. 2009. Vol. 53. 1231-36.

Noonan M, Grant J W A, Jackson C D. A quantitative assessment of fish passage efficiency. Fish and Fisheries 2002, Vol.13: 450-64.

Simomura M, Shirakawa H, Fukui Y, Sekiya A. Methods for preventing Ayu from straying analysis of the behavior of fishes by random walk method. Kasengijyutsuronbunnsyuu 2002, Vol.8: 337-42.