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An Improvement of Migration Rate of Ayu in Pool-and-Wear Fishway with White Lamp

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ABSTRACT

Visual information is one of the factors that fish decide actions, so taking control their behaviors by light can be considered. However, the action control technique with light has not been established well. In this study, the position of an installed white lamp in the pool was changed and the swimming behavior in statistic water was recorded with the aid of two set of digital video cameras. As a results, taking control their behaviors can be expected and it is effective to improve migration rate in pool-and-weir fishway with white lamp.

KEY WORDS: *Plecoglossus altivelis altivelis*, white lamp, statistic water, swimming behavior, pool-and-weir fishway, migration rate

INTRODUCTION

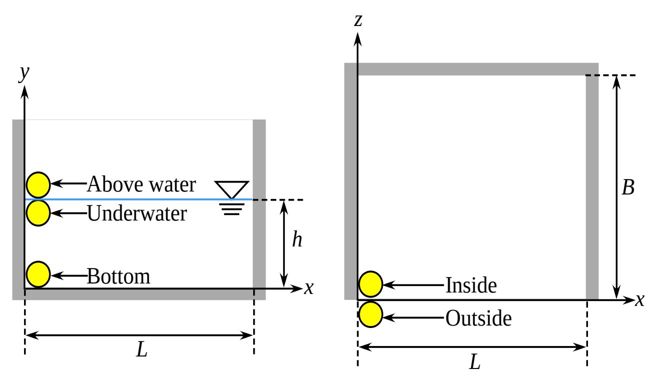
In the existing fishway, it is preferable to improve migration rate by small construction. Fish bear a sense of sight, smell, taste and touch (Arimoto, 1991). In these senses, the relationship between visual information and action properties was focused on.

Reactions against light of fish in habiting the river have been studied. Nemeth and Anderson showed high illuminance has threat effects for *Cyprinus carpio* (Nemeth and Anderson, 1992). Terazono *et al.* observed swimming behavior of *Oncorhynchus masou* with the light of various wavelengths irradiated from the upper part of the experiment channel. As a result, *Oncorhynchus masou* was attracted to the light of all wavelengths and it is found that they bear phototaxis (Terazono *et al.*, 1997). Therefore, it is thought the reactions against light vary according to fish species.

Sekiya *et al.* showed that *Plecoglossus altivelis altivelis* which is worthwhile in the fishery field gets active when it becomes brighter than 60Lx morning (Sekiya *et al.*, 2005). Koyama pointed out that *Plecoglossus altivelis altivelis* bear phototaxis to blue and green light (Koyama, 1978). These knowledge suggests that taking control their behavior by light is possible. However, the action control technique with light has not been established well. In this study, the position of an installed white lamp in static water was changed and an improvement of migration rate of *Plecoglossus altivelis altivelis* in pool-and-weir fisfway was elucidated.

EXPERIMENTAL SET UP AND HYDRAULIC CONDITIONS

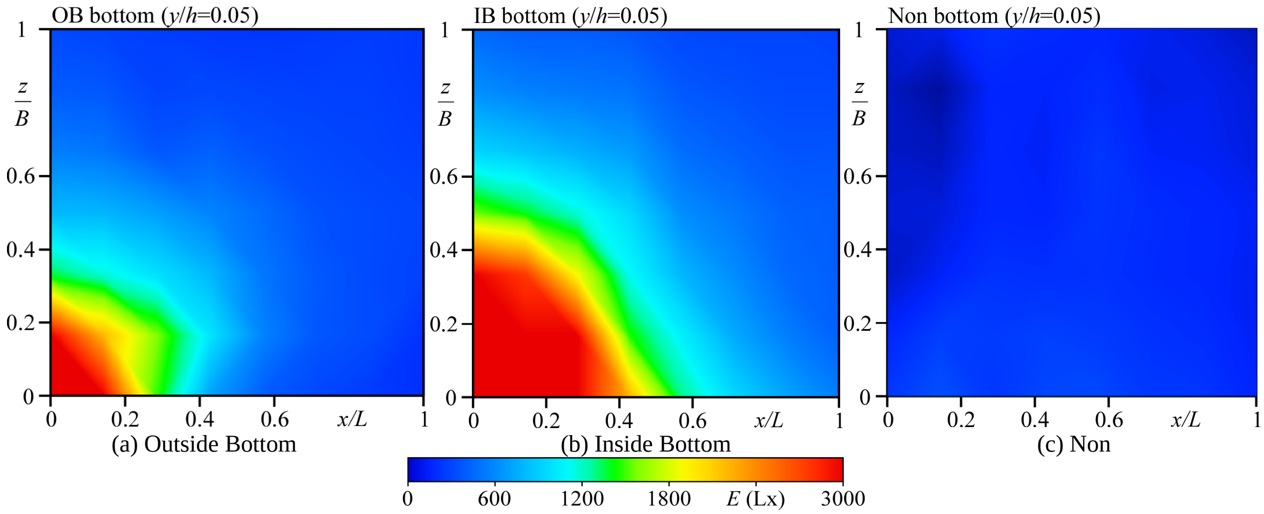
Fig. 1 shows the pool of pool length *L*=0.9m, width *B*=0.8m and water depth *h*=0.3m. *x* axis is taken in the direction of long side of the pool, *y* axis is taken in the upper direction of the vertical and *z* axis is taken in the direction of short side of the pool. The sidewall of *x*-*y* section in *z*=0m is made of an acrylic board and the others are made of wood painted gray. Table 1 shows experimental conditions. In the vertical section (*x*-*y*) as shown in Fig. 1(a), the position of the white lamp was changed three place, Above water, Underwater and Bottom. In addition, in the horizontal section (*x*-*z*) as shown in Fig. 1(b), the position of it was changed two place, Inside and Outside. Experiments were performed 6 cases in total. Each case name was defined based on the positions. The light distribution angle of the white lamp was approximately 300 degrees and total luminous flux of it is 810lm.



(a) Vertical section (b) Horizontal section
Fig. 1 Installed position of the white lamp

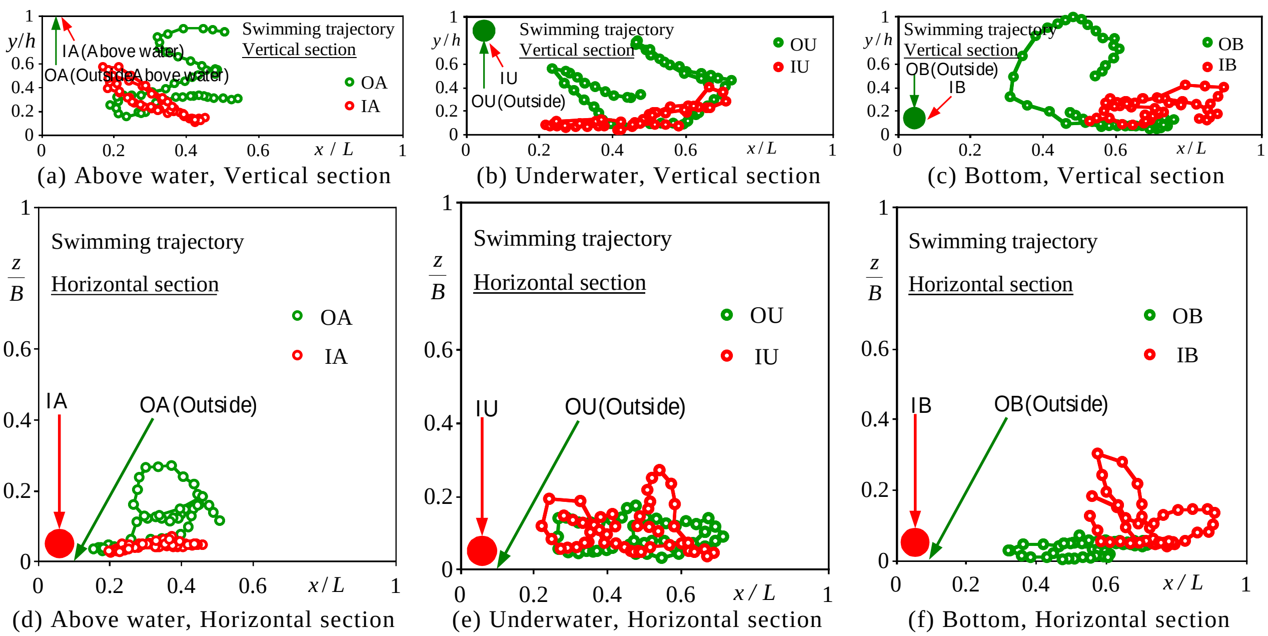
Table 1. Experimental condition

White lamp position		Case name
Outside	Above water	OA
	Underwater	OU
	Bottom	OB
Inside	Above water	IA
	Underwater	IU
	Bottom	IB



(a) Outside Bottom (b) Inside Bottom (c) Non

Fig. 2 Contour of illuminance



(a) Above water, Vertical section (b) Underwater, Vertical section (c) Bottom, Vertical section

(d) Above water, Horizontal section (e) Underwater, Horizontal section (f) Bottom, Horizontal section

Fig. 3 Swimming trajectory

10 tails (*N*) *Plecoglossus altivelis altivelis* that average length ($\overline{B_L}$) was 80mm were put into the pool in each case. Swimming behavior was recoded with two digital video cameras from sidewall and upper part of the pool for 1 minutes after confirming *Plecoglossus altivelis altivelis* steady by watching. Swimming position was investigated after recording. The illuminance of white lamp in the pool were measured at 8×7=56points composed with every 0.1m in *x* axis and *z* axis in *y*/*h*=0.05. When the illuminance in the pool is measured, water is not poured into the pool.

EXPERIMENTAL RESULTS AND ANALYSIS

Illuminance in the pool

Fig. 2 shows the illuminance in the pool in *y*/*h*=0.05 for the cases of OB, IB and that the white lamp was not installed (Non). When the white lamp was installed, the illuminance was more than 3000Lx near it and was approximately 200Lx at the farthest place in the pool. In the other cases, the illuminance was high at the lower part of the white lamp and was more than 200Lx in the whole place in the pool. On the other hand, when the white lamp was not installed (Non), the illuminance was 100~300Lx in *y*/*h*=0.05.

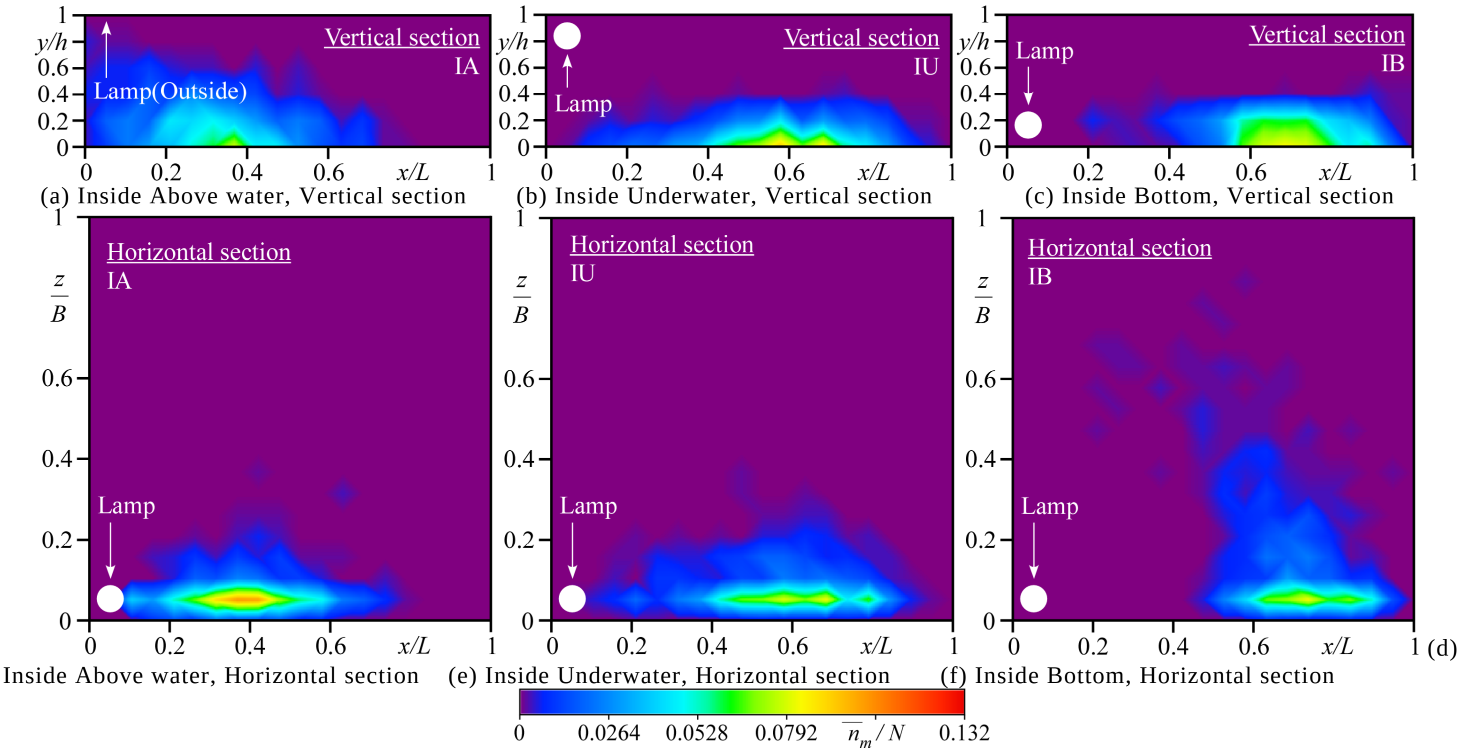


Fig. 4 Contour figure of existing probability

Swimming trajectory

Fig. 3 shows an example of the swimming trajectory of *Plecoglossus altivelis altivelis* for each case. The swimming trajectory was analyzed by locating the swimming position of *Plecoglossus altivelis altivelis* with every 0.2second in 10seconds after 25seconds of starting the experiment for each case.

Fig. 3(a)~(c) show swimming trajectories in vertical section. In the changes of *y* axis for the case of OA and IA as shown in Fig. 3(a), the swimming trajectories of them are neighborhood of water surface and bottom. The case of OU and OB drawn with green as shown in Fig. 3(b) and (c) are neighborhood of water surface and bottom. On the other hand, the case of IU and IB drawn with red as shown in Fig. 3(b) and (c) are neighborhood of bottom. In the changes of *x* axis for the case of Outside (OA, OU, OB) drawn with green, clear differences are not observed among each case. In contrast, the case of Inside (IA, IU, IB) drawn with red get away from the white lamp in order of IA, IU and IB.

Fig. 3(d)~(f) show swimming trajectories in horizontal section. In the case of Outside (OA, OU, OB) drawn with green, clear differences are not observed among each case. In contrast, in the case of Inside (IA, IU, IB) drawn with red, although the swimming trajectory of IA is neighborhood of the acrylic board, the others of IU and IB are neighborhood of the acrylic board in addition to other place far from acrylic board.

Relationship between the position of the white lamp and the swimming position

Fig. 4 shows the contour figure of existing probabilities for each case of Inside (IA, IU, IB) that it was calculated by locating the swimming position of *Plecoglossus altivelis altivelis* with every 1second.

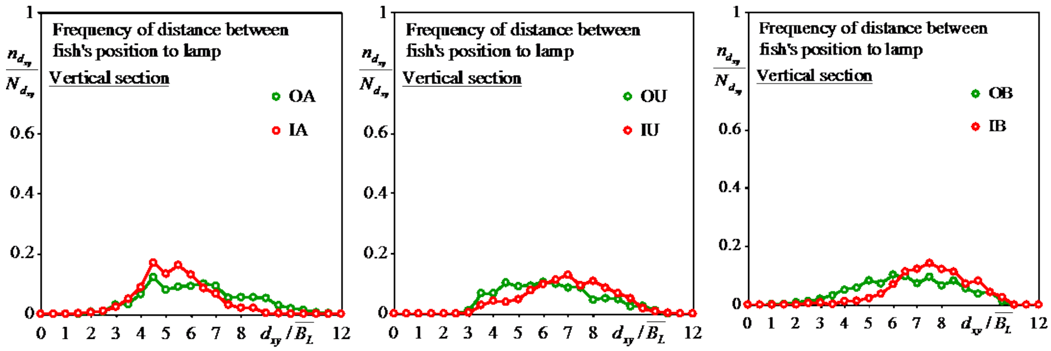
Fig. 4(a)~(c) show contour figures of existing probabilities in vertical section. In the case of IA, each distributed width to *x* axis and *y* axis is large. In the case of IU, the distributed width to *y* axis is smaller than IA and the distributed position to *x* axis is farther from the white lamp than IA. In the case of IB, the distributed width to *y* axis is as small as IU and the distributed position to *x* axis is farthest from the white lamp of three cases.

Fig. 4(d)~(f) show contour figures of existing probabilities in horizontal section. In the case of IA, the distributed width to *z* axis is small. In the case of IU, the distributed width to *z* axis is larger than IA. In the case of IB, the distributed width to *z* axis is even larger.

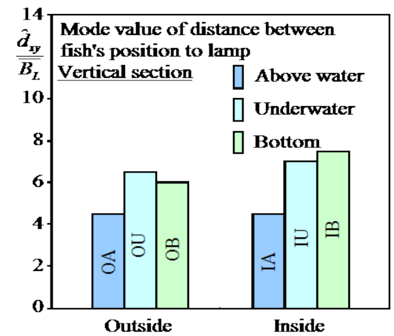
Judging from these result, the swimming position of *Plecoglossus altivelis altivelis* changes depending on the position of the white lamp.

Distance between the white lamp and *Plecoglossus altivelis altivelis*

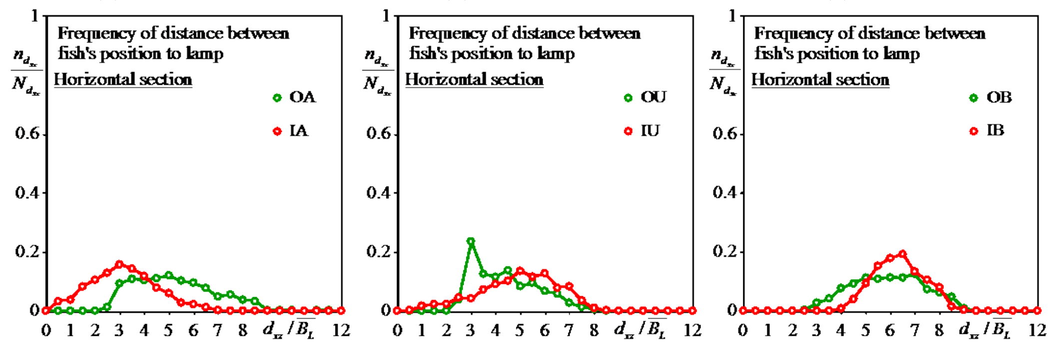
Fig. 5 shows frequency distributions of the value ($d_{xy}/\overline{B_L}$, $d_{xz}/\overline{B_L}$) for each case. Vertical and horizontal distances (d_{xy}, d_{xz}) between the white lamp and each *Plecoglossus altivelis altivelis* are divided by the average length of *Plecoglossus altivelis altivelis* ($\overline{B_L}$).
Fig. 5(a)~(c) show frequency distributions in vertical section. In the



(a) Above water (b) Underwater (c) Bottom

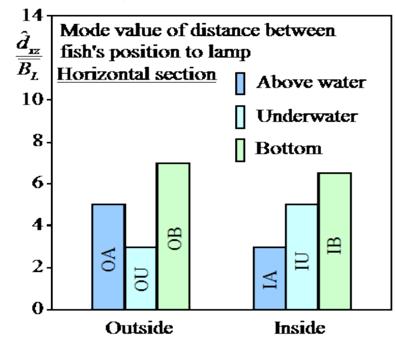


(a) Vertical section



(d) Above water (e) Underwater (f) Bottom

Fig. 5 Frequency distribution of distance between the white lamp and *Plecoglossus altivelis altivelis*



(b) Horizontal section

Fig. 6 Mode value of distance

case of Outside (OA, OU, OB) drawn with green, clear differences of frequency distributions of $d_{xy}/\overline{B_L}$ are not observed among each case. In contrast, in the case of Inside (IA, IU, IB) drawn with red, the frequency distributions of $d_{xy}/\overline{B_L}$ shift to high value of $d_{xy}/\overline{B_L}$ in order of IA, IU and OB.

Fig. 5(d)~(f) show frequency distributions in horizontal section. In the case of Outside (OA, OU, OB) drawn with green, clear differences of frequency distributions of $d_{xz}/\overline{B_L}$ are not observed among each case. In contrast, in the case of Inside (IA, IU, IB) drawn with red, the frequency distributions of $d_{xz}/\overline{B_L}$ shift to high value of $d_{xz}/\overline{B_L}$ in order of IA, IU and OB.

Fig. 6 shows the value ($\hat{d}_{xy}/\overline{B_L}$, $\hat{d}_{xz}/\overline{B_L}$) for each case. Mode values ($\hat{d}_{xy}$, $\hat{d}_{xz}$) in vertical and horizontal distances (d_{xy}, d_{xz}) are divided by the average length of *Plecoglossus altivelis altivelis* ($\overline{B_L}$).

Fig. 6(a) shows mode values in vertical section. In the case of Outside (OA, OU, OB), clear differences of mode values are not observed among each case. In contrast, in the case of Inside (IA, IU, IB), $\hat{d}_{xy}/\overline{B_L}$ demonstrate an upward trend in order of IA, IU and OB.

Fig. 6(b) shows mode values of horizontal section. In the case of Outside (OA, OU, OB), clear differences of mode values are not observed among each case. In contrast, in the case of Inside (IA, IU, IB), $\hat{d}_{xy}/\overline{B_L}$ demonstrate an upward trend in order of IA, IU and OB.

Judging from these result, even if the white lamp is installed outside of the pool, the swimming position of *Plecoglossus altivelis altivelis* is hardly influenced. However, when the white lamp is installed inside of the pool, *Plecoglossus altivelis altivelis* gets away from the white lamp with the white lamp approaching the bottom.

CONCLUSIONS

In this study, the position of an installed white lamp in static water was changed and an improvement of migration rate of *Plecoglossus altivelis altivelis* in pool-and-weir fisfway was elucidated. As a result, the following have been understood.

(1) Even if the white lamp is installed outside of the pool, the swimming position of *Plecoglossus altivelis altivelis* is hardly influenced. However, when the white lamp is installed inside of the pool, *Plecoglossus altivelis altivelis* gets away from the white lamp with the white lamp approaching the bottom.

(2) Taking control of rest position and directing *Plecoglossus altivelis altivelis* to the neighborhood of notch are possible, when the white lamp is installed in bottom of the pool-and-wear fishway. Therefore, the decrease of the distance to migration entrance is anticipated and improving migration rate is expected. It is effective to use the white lamp as the action control technique of *Plecoglossus altivelis altivelis.*

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