Examination of Control of Suitable Area of Oikawa, *Zacco Platypus*, in Pool-and-Weir Fishway with Partition

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Abstract

It is important to keep suitable area for fish in pool-and-weir fishway to make migration rate high (Hyashida et al, 2000). In this study, control of suitable area was tried by installing of partition with various positions in pool-and-weir fishway. Migration rate of Oikawa (*Zacco Platypus*) was obtained with the aid of two sets of digital video cameras. It was found that migration rate of Oikawa takes high value by installation of partition to an area between upstream side notch and downstream one. This is because suitable area of Oikawa was moved to upstream side of partition from middle part of pool, and migration from slow flow area was induced.

Keywords: *Zacco Platypus*, partition, pool-and-weir fishway, migration rate, suitable area

1. Introduction

Dam is constructed for the purpose of water control and water utilization. However, the construction blocks fish's migration that seeks to upstream. This is problem for migratory fishes in river. Therefore, fishway is constructed in their rivers in order to comfort migration of fishes. The most of fishway in Japan is pool-and-weir fishway (Nakamura, 1995). It is necessary to understand the most suitable geometric condition and flow condition in pool-and-weir fishway. In the past study, fish's migration rate takes high value when flow velocity is low (Takahashi & Nakamura, 1984). However, it is very difficult to make condition that flow velocity is low in pool-and-weir fishway that was set up at actual river. It is necessary to investigate position of suitable area in the pool. And also making suitable area in easy way is important. In this study, suitable area was made by installing wooden partition with various positions in pool-and-weir fishway, and fish's behavior was observed.

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 partition (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.

Partition was installed in a variety of positions in second pool. The partition that height is 0.8m and width is 0.25m was fixed in position of x/L=0.5 and changed only crossing position as shown in Fig. 2 (a). A green arrowed line in Fig. 2 (b) shows installed range of partition. Experiments were performed 5 cases in total. They were 4 cases as shown in Fig. 2 (b) and not installed partition (standard pool). The region that was projected notch section to direction of flowing was defined as notch area, and other regions were defined as pool area. Case name was defined as shown in Tab. 1.

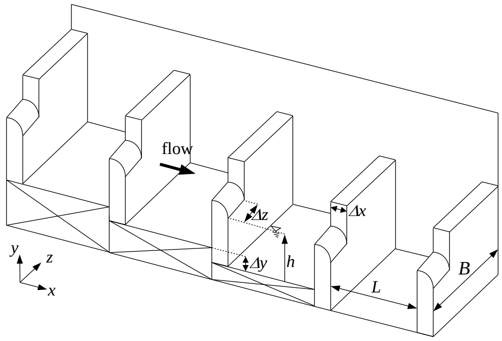
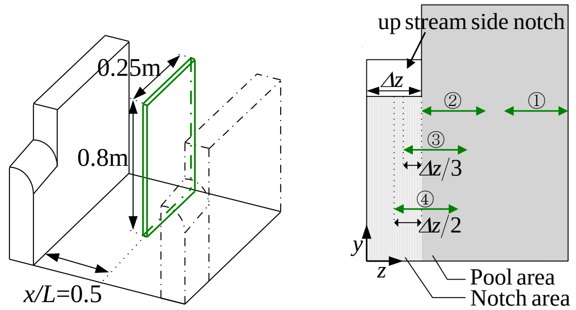


Fig. 1 Pool-and-weir fishway



(a) Longitudinal position (b) Crossing position

Fig. 2 Installed position of partition

Tab. 1 Experimental case

Pool status		Case name
Standard pool		Sp
Installation position of partition	① Pool left	Pl
	② Pool right	Pr
	③ Notch third	Nt
	④ Notch half	Nh

2.2. Experimental methodology

30 tails Oikawa (*Zacco Platypus*) that average length ($\overline{B_L}$) is 80mm were put into the second pool. Discharge was maintained at 3 (l/s). Recording was began with the video camera from sidewall and upper part of the fishway for 30 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, Oikawa is not put into the fishway.

3. Results and Discussion

3.1. Relation between installed position of partition and migration rate

Migration rate was defined as following equation.

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

Fig. 3 shows migration rate (n/N) of Oikawa for each case. Migration rate indicated just same value in the case that partition was not installed (Sp) and the case that partition was installed in left bank side of pool area (Pl). Therefore, existence or non-existence of partition in left bank side of pool has a no impact on migration rate. However, migration rate of the case that partition was installed in right bank side of pool area (Pr) was lower than Case (Sp). In addition, migration rate of the case that partition was installed in notch area (Nt), (Nh) were higher than Case (Sp). From the above results, migration rate of Oikawa was changed by changing position of partition in Case (Pr), (Nt) and (Nh).

3.2. Suitable area of Oikawa in pool

Fig. 4 (a) shows center of fish's school in vertical section (x-y) and Fig. 4 (b) shows center of fish's school in horizontal section (x-z) that were given for each 10 seconds. h is water depth. Fish's center moved with time in all cases in vertical and horizontal section. However, moving region is narrow. Therefore, this is estimated that Oikawa recesses at nearly this region. Focusing on vertical section in Fig. 4 (a), suitable area of Oikawa is half water depth or less in all cases. There were no differences between the case that partition was not installed (Sp) and others.

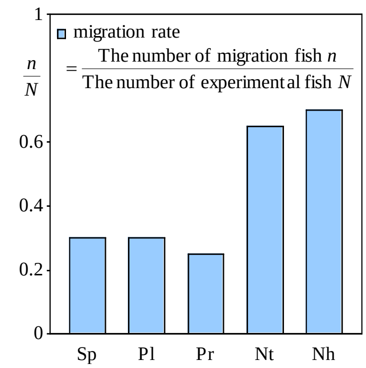
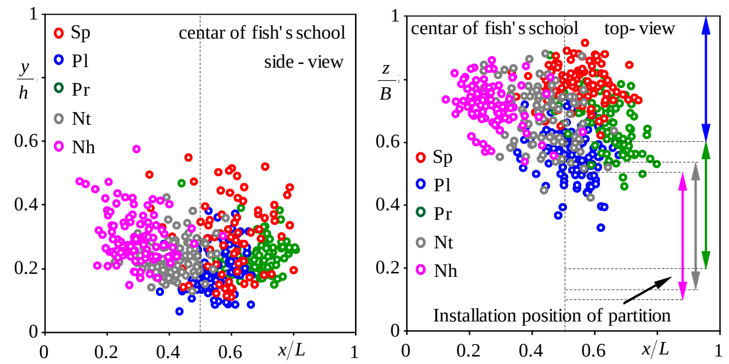
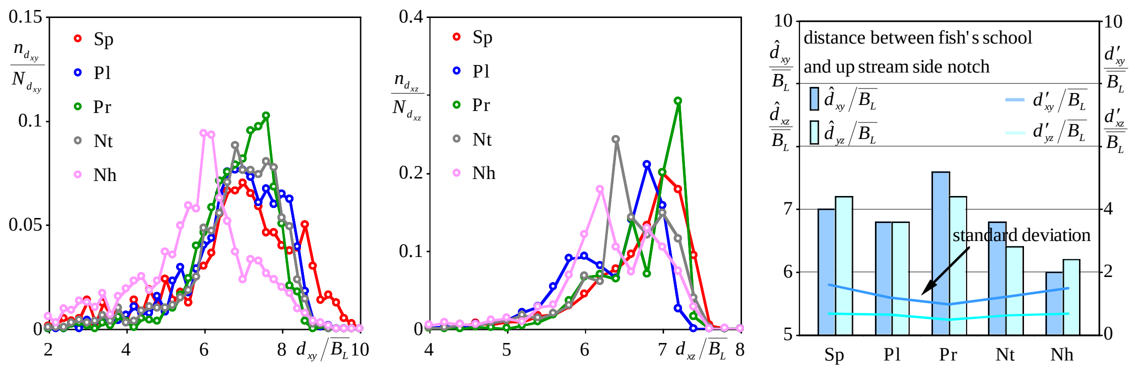


Fig. 3 Migration rate of Oikawa



(a) Vertical section
(b) Horizontal section

Fig. 4 Moving condition of center of fish's school



(a) Vertical section
(b) Horizontal section
(c) Mode value and standard deviation

Fig. 5 Instantaneous position of swimming and distance between fish's school and upstream side notch

On the other hand, focusing on horizontal section in Fig. 4 (b), Oikawa recesses at nearly left bank sidewall in Case (Sp). In Case (Pl), Oikawa recesses at nearly right bank side more than Case (Sp). In Case (Pr), Oikawa recesses at downstream side of partition. Furthermore, suitable area concentrates at $0.2<x/L<0.5$ in Case (Nt) and (Nh) that migration rate is high. This means that Oikawa recesses at nearly upstream side of partition. This is considered that suitable area of Oikawa was controlled by installing partition.

3.3. Instantaneous position of swimming and distance between fish's school and upstream side notch

Fig. 5 (a), (b) shows instantaneous position of swimming and frequency distribution of the value ($d_{xy}/\overline{B_L}$) and ($d_{xz}/\overline{B_L}$) in vertical section (*x-y*) and horizontal section (*x-z*) for each case. Vertical and horizontal distance between fish's school and upstream side notch (d_{xy}), (d_{xz}) were divided by average length of Oikawa ($\overline{B_L}$). Distribution configuration and range are differed in each case and section. This means that instantaneous position of swimming and distance between fish's school and upstream side notch were changed by installing partition.

Mode value of (d_{xy}) and (d_{xz}) are ($\hat{d}_{xy}$) and ($\hat{d}_{xz}$). They were divided by ($\overline{B_L}$). Bar chart in Fig. 5 (c) shows mode value ($\hat{d}_{xy}/\overline{B_L}$) and ($\hat{d}_{xz}/\overline{B_L}$) for each case. Furthermore, standard deviation of (d_{xy}) and (d_{xz}) are (d'_{xy}) and (d'_{xz}). They were divided by ($\overline{B_L}$). Polygonal line in Fig. 5 (c) shows value of standard deviation ($d'_{xy}/\overline{B_L}$) and ($d'_{xz}/\overline{B_L}$) for each case. The mode of Case (Nh) that indicated the highest value of migration rate indicated the lowest value. In contrast, the mode of Case (Pr) that indicated the lowest value of migration rate indicated the highest value. This is estimated that migration is induced when distance between instantaneous position of swimming and upstream side notch is near. On the other hand, differences among the case are not as noticeable as

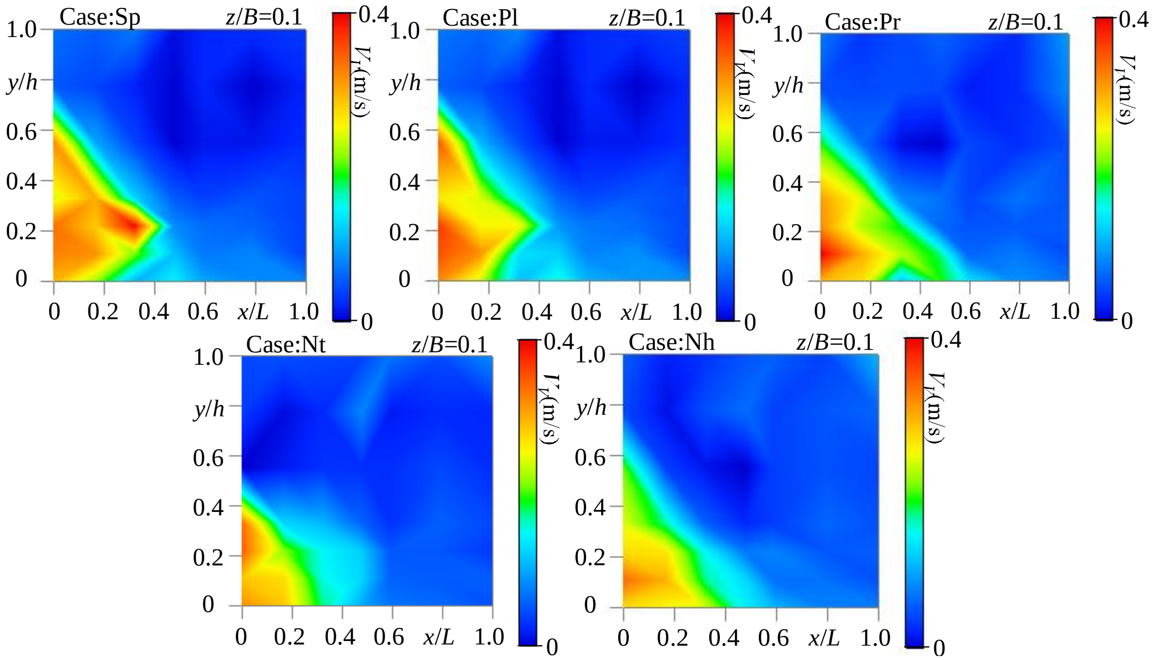


Fig. 6 Contour of flow velocity at z/B=0.1 in vertical section

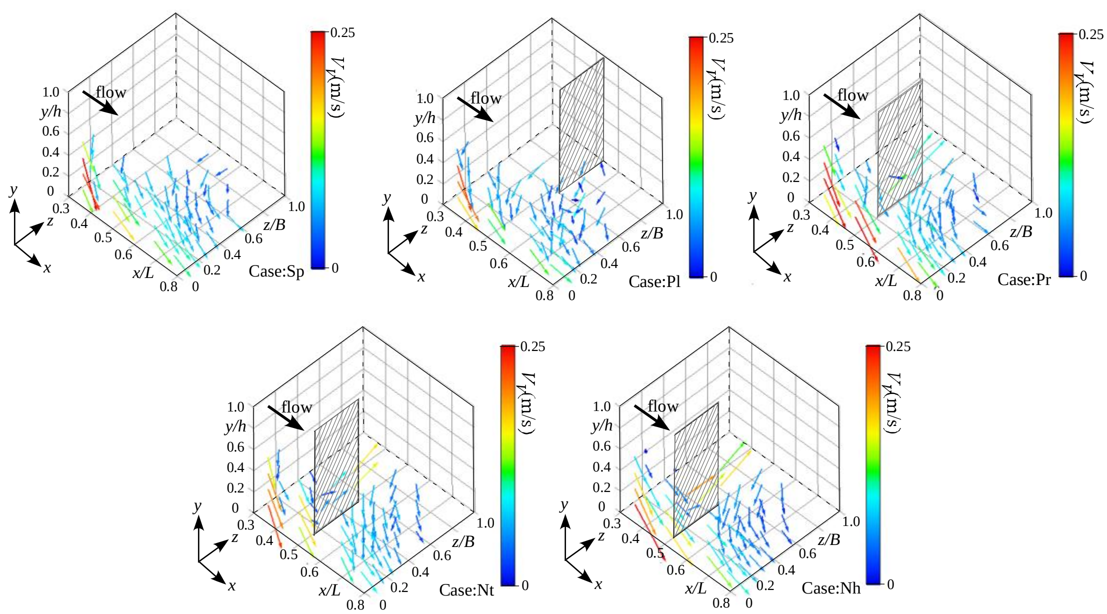


Fig. 7 Vector of flow velocity at nearly partition

mode value in regard to standard deviation. This is considered that changing position of partition has no impact on dispersion of distance between instantaneous position of swimming and upstream side notch.

3.4. Comparing flow condition in each pool

Fig. 6 shows contour figure of three components of flow velocity V_V in vertical section for each case. Fast velocity flow is present in just below upstream side notch. This is water fall that flows into the pool. There are no differences between flow velocity of Case (Sp), (Pl) and (Pr). However, flow velocity of water fall in Case (Nt) and (Nh) are little slow compared with

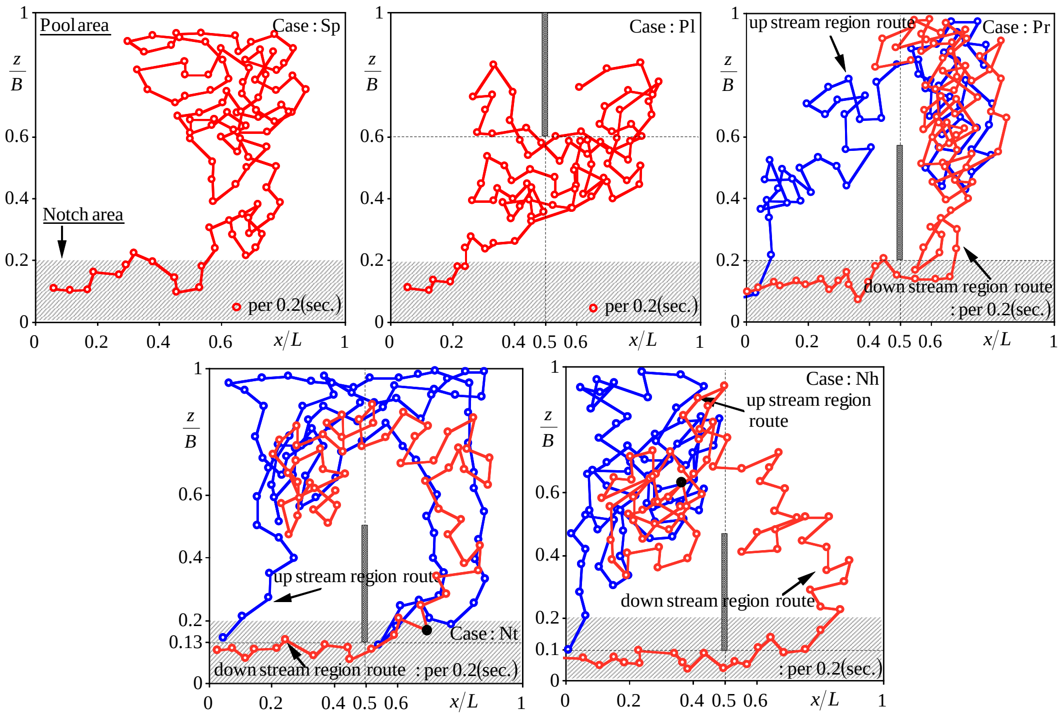


Fig. 8 Swimming trajectory of Oikawa

other cases. In Case (Nt) and (Nh) that were installed partition between upstream side notch and down one. Therefore, water fall conflicts with partition and it is reduced.

Fig. 7 shows three components of flow velocity V_V that is picked out of around the partition discretionally and shows contour color and vector for each case. Observing flow direction for each case, fast flow is present toward downstream side notch from upstream side notch in Case (Sp). In other region, flow velocity is slow comparatively. In Case (Pl), a stream around the partition is irregular. However, there is not so different from Case (Sp). In Case (Pr), (Nt) and (Nh), after water fall conflicts with partition, a stream is divided into upstream side and downstream side of partition. Furthermore, the case changes as (Pr) to (Nt) to (Nh), flow velocity of upstream side of partition is fast with an increase in the rate of installed into the notch area. In Fig. 4 (b), Oikawa recesses at upstream side of partition in Case (Nt) and (Nh). Therefore, this is considered that Oikawa finds a stream that flow in water fall to upstream side of partition simply. However, flow velocity in upstream side of partition is faster than flow velocity of water fall.

3.5. Relation between installed position and migration behavior of Oikawa

3.5.1. Swimming trajectory of Oikawa

Fig. 8 shows swimming trajectory that Oikawa migrates before 20 seconds in horizontal section for each case. This is an example figure of swimming trajectory is plotted per 0.2 seconds. Furthermore, migration route of Case (Pr), (Nt) and (Nh) were present 2 patterns. One, the route that migrate from upstream side of partition. The other one, the route that migrate from downstream side of partition. The former was defined up stream region route and the latter was defined down stream region route, and showed blue and red. Observing swimming trajectory for each case. In Case (Sp), Oikawa migrates and passes notch area. Considering Fig. 6 and Fig. 7, this is estimated that Oikawa migrates the region that flow velocity is fast comparatively. In Case (Pl), Oikawa deviates from notch area slightly. However, they migrate the region that flow velocity is fast comparatively. In Case (Pr), (Nt) and (Nh), Oikawa migrates and passes notch area along with Case (Sp) and (Pl) in down stream region route. In contrast, Oikawa migrates the region that flow velocity is slow comparatively without passes notch area.

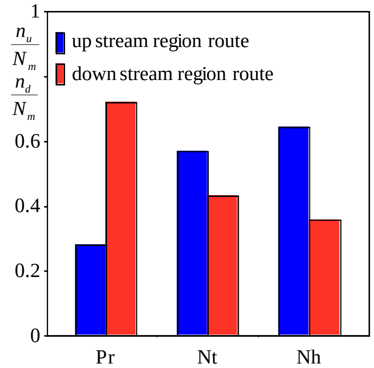


Fig. 9 The selection rate of each migration route in Case (Pr), (Nt) and (Nh)

3.5.2. Relation between the selection rate of migration route and migration rate of Oikawa

Fig. 9 shows the selection rate of up stream region route and down stream region route (n_u/N_m) in Case (Pr), (Nt) and (Nh) for each case. The selection rate of up stream region route is increased with an increase in the rate of installed into the notch area. In Fig. 7, the rate of water fall flows into upstream side of partition is increased with an increase in the rate of installed into the notch area. As a result, this is considered that migration of Oikawa was induced from upstream side of partition. Furthermore, compared with Fig. 3, migration rate takes a high value with an increase in the case that the selection rate of up stream region route is high. This means that Oikawa does not pass notch area that flow velocity is fast comparatively in up stream region route. As a result, fatigue of Oikawa is difficult to accumulate compared with down stream region route and increased individual that succeed in migration.

4. Conclusion

In this study, suitable area was made by installing wooden partition with various positions in pool-and-weir fishway, and the fish's behavior was observed. As a result, it was found that following.

(1) It was proved that suitable area is enabled to control by installing partition in pool-and-weir fishway.

(2) It was proved that migration rate is increased when distance between instantaneous position of swimming and upstream side notch is more nearer.

(3) Water fall is divided in half by installing partition wall between region of upstream side notch and downstream side notch. Therefore, migration of Oikawa is induced from upstream side of partition that flow velocity is slow comparatively and fatigue of Oikawa is not accumulated. As a result, it was proved that individual that succeed in migration is increase.

Acknowledgements

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

References

Hayashida K, Honda T, Kayaba Y, Shimatani, Y. The Flow Pattern of the Pool-And-Weir-Fishway in the Pool and the Swimming Behavior of Leuciscus Hakonensis. J Hydraulic Engineering, JSCE 2000, 44: 1196-1191

Nkamura S. gyodounohanashi. sankaidou 1995.

Takahashi N, Nakamura S. Experimental Study on the Behavior of Ayu in Fishladder. J Hydraulic Engineering, JSCE 1984, 28: 358-353