Evasion characteristics of Plecoglossus altivelis altivelis in fish school against air bubbles in open-channel flows

Evasion characteristics of *PLECOGLOSSUS ALTIVELIS ALTIVELIS* in fish school against air bubbles in open-channel flows

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ABSTRACT

1. INTRODUCTION

Fish sometimes enter into an intake gate of weirs and dams, so that a lot of released larval *Plecoglossus Altivelis Altivelis* and salmon are lost. Some techniques with air bubbles, electricity and transmitted light have been developed to deter fish from coming near an intake gate and an outlet gate. [1, 2, 3, 4, 5] At first, a study was done on the influence of the air bubbles on the behavior of the fish that live in sea. In his experiment, Smith [6] cut off the course of the school of *Clupea pallasii* using air bubbles film. Arimoto *et al.* [7] succeeded in collecting the fish in the fixed shore net using air bubbles film. On the other hand, there are few studies on the influence of the air bubbles on the movement behavior of fish that live in river. Onitsuka *et al.* [8] observed the influence that air bubbles gives to the behavior characteristics of *Zacco platypus* and *Nipponocypris temminckii*. As a result, they pointed out that air bubbles hardly exert any behavioral change of *Zacco platypus* and *Nipponocypris temminckii*.From the above, it is believed that the fish behavior characteristics in the presence of air bubbles depend on fish species. There are few studies that examined the behavior characteristics with air bubbles about fish that live in the river. In this study, the air bubbles are injected from the bottom of channel with changing the flow velocity, and trajectories of fish are recorded.

2. MATERIALS AND METHODS

Fig. 1 shows the open-channel used for experiment. The pool length L_x, width L_z and height are 2.0m, 0.8m and 0.3m, respectively. x, y and z are the coordinates of the streamwise, vertical and spanwise directions, respectively. Interception wall was settled in upper reach (z/L_z =0.5). Thickness of interception wall was 0.02m. For the wall, range of $0< z <0.39$m and $0.41< z <0.8$m are defined bubble area and non-bubble area. The other area is defined normal area. Table 1 shows hydraulic conditions. Water depth was set to 0.04m. Flow velocity divided by averaged body length of *Plecoglossus altivelis altivelis* was set to three patterns within the range from 2 to 8. The quantity of air bubbles mixture is 25.0(l/(m^2・s)). *Plecoglossus altivelis altivelis* was used for the experiments. The number of used *Plecoglossus altivelis altivelis* was 6 in one recording. The recording has been carried out 60 cases in each speed. Averaged body length $\overline{B_L}$ was about 70mm. Further, trajectory of *Plecoglossus altivelis altivelis* was recorded with a digital video camera set up the upside of the open-channel. Recording speed of video camera is 30 frames per second and the number of pixels is 1440×1080. This study is performed 60 times in each case, and 180 times in total. Three components of flow velocities in the open-channel were measured with a 3-D electromagnetic current meter after removing the fish.

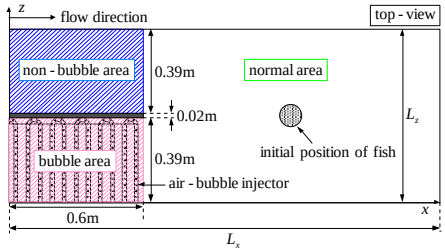

Fig. 1 Open-channel

Tab. 1 Experimental case

case name		
$U_m / \overline{B}_P$ (1/s)		
2	4	8
V2	V4	V8

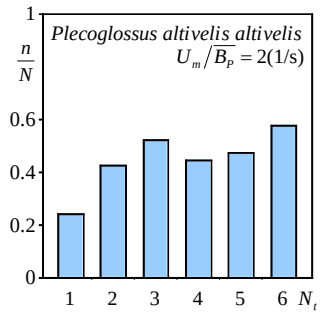

Fig. 2 Rate of approach to bubble area

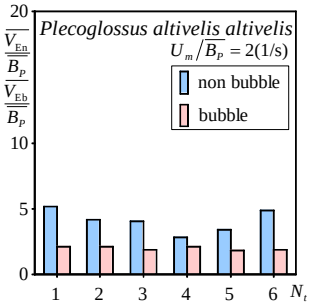

Fig. 3 ground speed

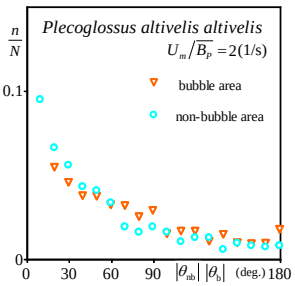

Fig. 4 Turning angle

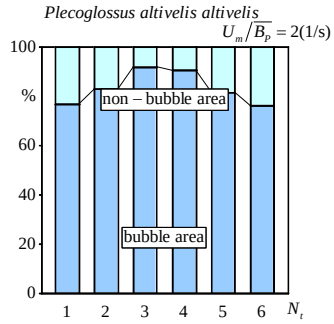

Fig. 5 staying time

3. RESULT AND DISCUSSION

Fig. 2 shows the relationship between the rate of approach to bubble area and number of fish. In the case of migration, *Plecoglossus altivelis altivelis* evade the area with air bubble. This tendency is prominently when one fish swim alone. However this tendency become lax with the number of fish school in each school of fish increase. Fig. 3 shows the relationship between the average of the approach speed from normal area to bubble area or non-bubble area $\overline{V_{\mathrm{En}}}$ or $\overline{V_{\mathrm{Eb}}}$ divided by average length of *Plecoglossus altivelis altivelis* $\overline{B_p}$ and the number of fish school in each school of fish. The approach speed at approaching to air bubble area decreased. The swimming speed also decrease in air bubble area. This tendency is hardly influenced the number of fish school in each school of fish. Fig. 4 shows frequently distribution of turning angle of *Plecoglossus altivelis altivelis* $|\theta_{\mathrm{nb}}|$ and $|\theta_{\mathrm{b}}|$. In both of bubble area and non-bubble area, the turning angle of *Plecoglossus altivelis altivelis* hardly change. Distribution profiles in bubble-area and non-bubble area are similar and there are no remarkable difference. It is thought that, the turning angle of *Plecoglossus altivelis altivelis* is not affected by air bubble. Finally, average staying time of *Plecoglossus altivelis altivelis* in bubble area and non-bubble area was calculated each. Fig. 5 shows the relationship the time ratio and the number of fish school in each school of fish. It is found that average staying time ratio in bubble area is higher than average staying time ratio in non-bubble area. It is thought that staying tendency in bubble area was shown because air bubble let migration promotion of *Plecoglossus altivelis altivelis* decline.

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