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Influence of Turbidity on Fish School Behavior of Plecoglossus Altivelis Altivelis in Static Water

Influence of Turbidity on Fish School Behavior of *Plecoglossus Altivelis Altivelis* in Static Water

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ABSTRACT

Most fish use eyes and lateral line during swimming so that the turbidity may affect the swimming behavior of fish school. However, no study has been made on the relations between turbidity and swimming behavior of fish school. In this study, the swimming behaviors of fish school of *Plecoglossus altivelis altivelis*, by changing the turbidity and the number of fish in static water, were recorded. It was found that the fish school is divided into some fish school with an increase of turbidity. This is because *Plecoglossus altivelis altivelis* cannot find the other individuals by view due to turbidity.

KEY WORDS: turbidity, fish behavior, *Plecoglossus altivelis altivelis*, fish school, static water

INTRODUCTION

The water includes turbidity during and after the flood. It is required for an aquatic organism to be able to live also in various quality of water. Therefore, it is necessary to investigate the influence of turbidity on swimming behavior of fish.

At first the elucidation of the feeding behavior of fish in the turbid water was tried. Gregory and Northcote pointed out that an eating action of small fish of the salmon was controlled with turbidity increase (Gregory and Northcote, 1993). Hazelton and Grossman showed a similar conclusion with rosyside dance (Hazelton and Grossman, 2009). Utne-Palm nominates a lowering the visibility in the water by turbidity increase for the reason why a feeding behavior is controlled (Utne-Palm, 2002). On the other hand, Andersen showed that *Salvelinus fontinails* move more active in high turbidity (Andersen *et al*., 2008), and Prchalová showed that activity pattern of *Rutilus rutilus* and *Perca fluviatilis* were equally in static water and muddy water that transparency is 0.35m (Prchalová, 2010). Mayama changed quantity of the clay to issue in an open channel flow which velocity is 0.2m/s, and having observed feeding behavior of *Oncorhynchus masou*. As a result, feeding behavior became more active in muddy water, but feeding behavior is controlled when density exceed a fixed value (Mayama, 1998).

Then elucidation of survival rate of fish of muddy water and evasion action for the muddy water were studied. Muraoka inserted the muddy water which was eight kinds of high density as the figure of the adult fish of *Plecoglossus altivelis altivelis* can not be confirmed by viewing in a water tank of 610 410 315mm and lived and confirmed it (Muraoka *et al*., 2011). As a result, it was elucidated that gills died from suffocation because a particle in the range of 1.2-36μm attach to gills. Newcombe & MacDonald showed that survival of fish depend on not only density but also duration (Newcombe & MacDonald, 1991). Honda poured clear water into one waterway and inserted clay, diatom and kaolin which changed density with each cases and counted the number of migration of *Plecoglossus altivelis altivelis* which are released downstream than a junction in the device that two waterways join. As a result, Honda showed that evasion behavior was not observed when all injection materials are less than 15ppm. (Homda, 1983).

From above studies, it is estimated that fish do not evade low concentrated turbid water, and evasion behavior become remarkable depending on increase in density. Moreover, the elucidation of swimming behavior in turbid water was studied. Inoue *et al*. observed rheotropism of *Tribolodon hakonensis* in rotary tank. Transparency was changed to 28, 17, 13cm. As a result positive rheotropism increase with turbidity increase is elucidated (Inoue *et al*., 1982). Berg & Northcote made clear that order characteristics in the fish school of the *salmonidae* collapse in highly concentrated floating sand (Berg and Northcote, 1985). Onitsuka *et al*. changed turbidity and observed the behavior of one *Plecoglossus altivelis altivelis* (Onitsuka *et al*., 2013). As a result, the swimming speed of the *Plecoglossus altivelis altivelis* decreased with turbidity increase was elucidated. However, the behavior is known to be different from the case fish school consist of three or more in the case fish school consist of one or two (Partridge and Pitcher, 1980), (Onitsuka *et al*., 2014). Therefore, this result (Onitsuka *et al*., 2013) is not necessarily applicable for the fish swimming in the fish school in a river. This study elucidated influence of turbidity on fish school behavior of *Plecoglossus altivelis altivelis* in static water.

EXPERIMENTAL SET UP AND HYDRAULIC CONDITIONS

A blue circular tank that the radius r was 0.9m was used. The depth of the water h was 0.04m. Turbidity was changed five patterns with turbid water. Table-1 shows experimental conditions. Measurement of turbidity was performed as follows. Muddy water was put into the transparent container and irradiated by the light of 120W light source. The illumination was measured with the illuminometer. The case name shows the initial of “Turbidity” and the illumination ratio. 3-7tails of

Plecoglossus altivelis altivelis put into the cylinder wire net in the center of circular tank. Averaged body length of *Plecoglossus altivelis altivelis* $\overline{B_L}$ is 70mm. Fig.1 shows five examples of the swimming trajectory of *Plecoglossus altivelis altivelis* in each illumination. The number of pixel of the digital video camera is 1440×1080, and recording speed is 30fps. Exposure time is 1min with each cases. After the experiment, the picture of swimming behavior of *Plecoglossus altivelis altivelis* when *Plecoglossus altivelis altivelis* start the swimming until reach the side wall was captured at 1s interval. Swimming distance, swimming speed, and the degree of angle of refraction were calculated with the statistic picture and coordinated plot software.

EXPERIMENTAL RESULTS AND ANALYSIS

The swimming trajectory

Fig. 1 shows the swimming trajectory of *Plecoglossus altivelis altivelis* in each turbidity every one second in any 30 seconds with each turbidity. The plots were shown with a different color every 5seconds in this figure. The swimming positions were shown with different color every five seconds. When turbidity is low, *Plecoglossus altivelis altivelis* is often distributed over the region where the same colors concentrate. The matter shows that ratio of individual acting in the fish school is high. On the other hand, standard deviation of the plots of the same color spread with turbidity increase. Therefore, proportion that the fish school separates and a fish swim alone is large.

Distance between the individual in all individuals

Fig. 2 (a), (b) shows the average of the distance between an individual in all individuals $\overline{D}$ and standard deviation D' divided by the average length $\overline{B_L}$ in each turbidity, and approximation line. Considering fig. 2 (a), it is understood that the distance between the individual increases in all cases. Considering fig. 2 (b), it is understood that standard deviation of the distance between the individual increase with turbidity increase in all cases. It is judged that the distance between the individual of the *Plecoglossus altivelis altivelis* increases with turbidity increase, and the degree spread. Therefore, it is suggested there is a tendency that it becomes difficult to confirm the individual which is adjacent when turbidity increase, and school of fish swim independent or separation.

Probability of the number of fish school in each school of fish

In this study, the situation that fish swim alone apart from a fish school and fish school was divided into plural number was observed. However the distance between the individuals depend on the fish class when fish school is formed, the distance between an average individual is 1 time of the length. A group of separated fish which the distance between the individual leaves to some extent than 1 time of the length is not regarded as fish school. In this study, it is defined that the group of the fish which it was far more than 3 times of the mean length of the *Plecoglossus altivelis altivelis*, and was formed as a different school of fish. Because it was confirmed that it was rare that the *Plecoglossus altivelis altivelis* came close again when the distance between the individuals more than 3 times of the length in each turbidity.

Table. 1 experimental conditions

Case name				
		N (tails)		
E_n (lx)	$(E_1-E_n)/E_1\times100$	3	5	7
E_1=1490	0	C00-3	C00-5	C00-7
E_2=1192	20	C20-3	C20-5	C20-7
E_3= 894	40	C40-3	C40-5	C40-7
E_4= 596	60	C60-3	C60-5	C60-7
E_5= 298	80	C80-3	C80-5	C80-7

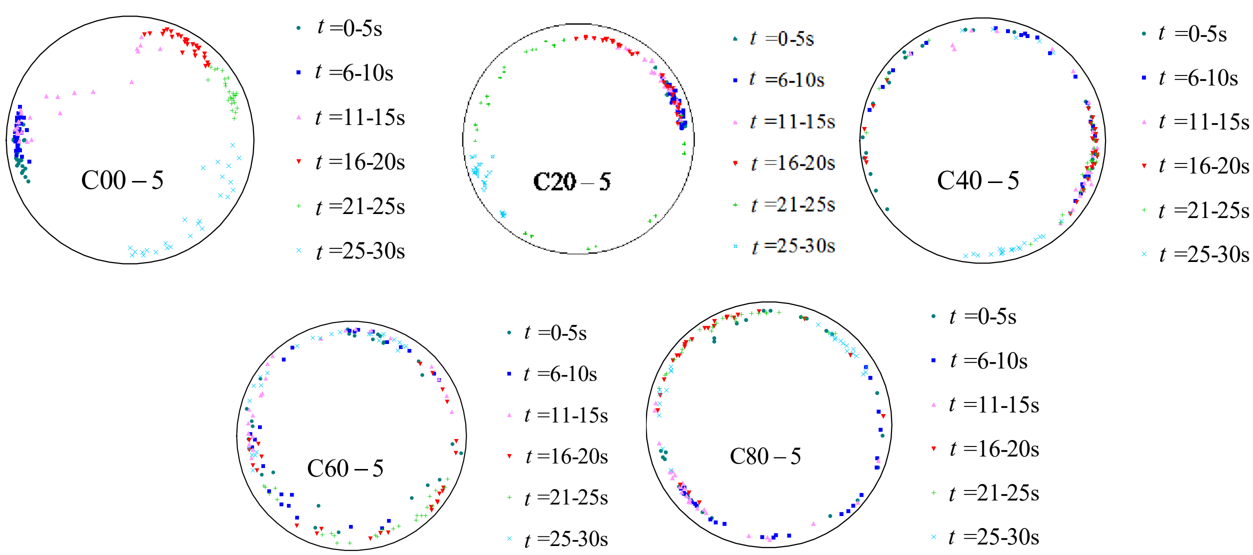
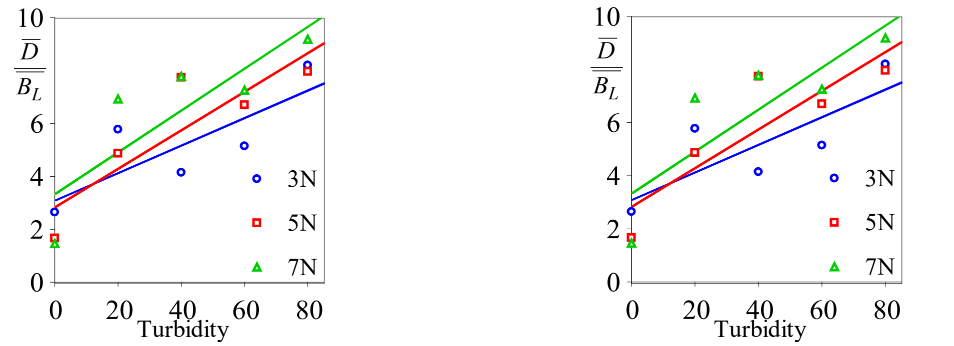
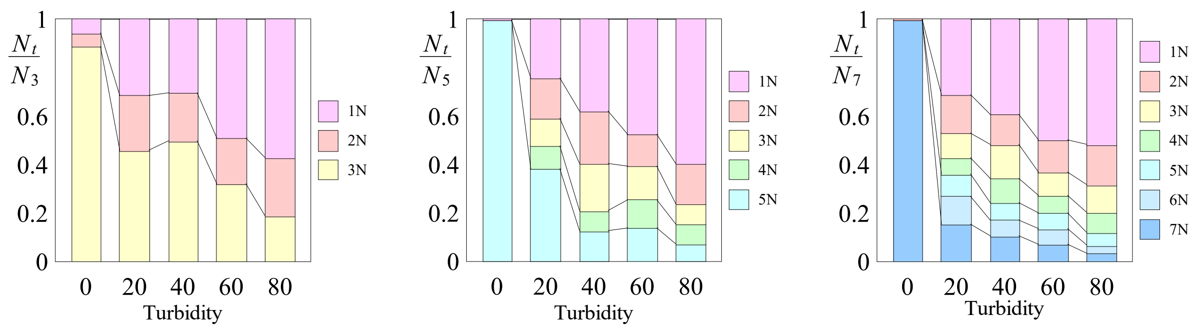


Fig. 1 The swimming trajectory



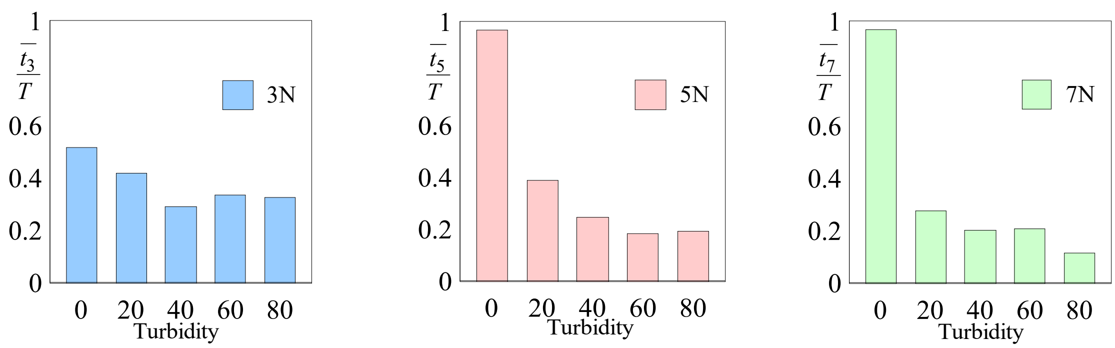
(a) The average of distance between the individuals and all individuals
(b) Standard deviation of distance between the individuals and all individuals

Fig. 2 Distance between the individual in all individuals



(a) 3tails (b) 5tails (c) 7tails

Fig. 3 Probability of number of school fish in each school of fish



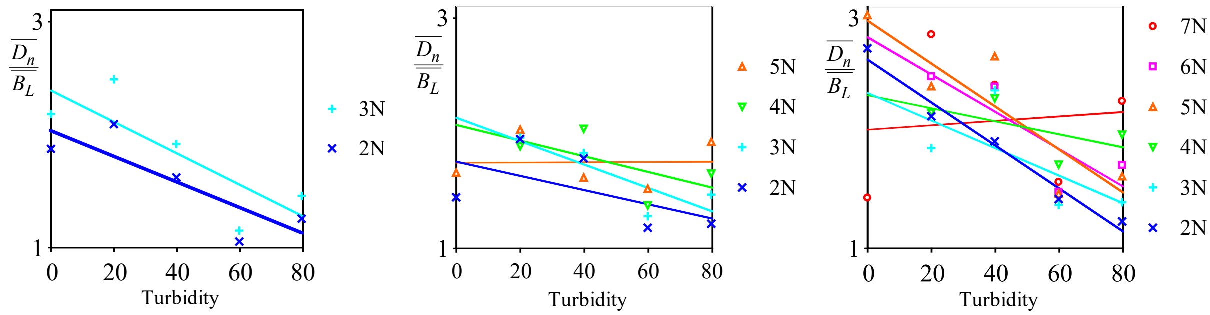
(a) 3tails (b) 5tails (c) 7tails

Fig. 4 Duration of fish school formation

Fig. 3 (a), (b), (c) shows the value which the number of the tails in the fish school in each school of fish N_t divided by the number of the tails inserted N_n in each turbidity. The number of the tails in the fish school decreases than the number of the tails inserted in each case. In addition, it is thought that *Plecoglossus altivelis altivelis* do not form fish school with individuals at a distance even if turbidity is low, because this tendency is remarkable when turbidity varied from 0 to 20.

Duration of fish school formation

In this study, a situation that *Plecoglossus altivelis altivelis* did not necessarily form one fish school was observed. However, a situation that *Plecoglossus altivelis altivelis* form plural fish schools was observed. Plural fish schools were not necessarily kept all in the experiment. Furthermore, some fish schools are divided. Therefore, Fig. 4 (a), (b), (c) shows the value which formation duration $\bar{t}_n$ of fish school including the maximum number of fish during each experiment divided by total experiment time T in each turbidity. The duration of fish school decrease with the turbidity increase in all three cases. It is thought that because of deterioration of visibility by turbidity, it became difficult to go back to an original fish school. In addition, this tendency is remarkable when turbidity varied from 0 to 20. Therefore, when water is approximately clear, a tendency to keep the fish school is strong. In contrast, even if it is low concentration, a tendency that fish school divide in muddy water is strong.



(a) 3tails (b) 5tails (c) 7tails

Fig. 5 Distance between the individual in all each fish school

Distance between the individual in all each school of fish

Fig. 5 (a), (b), (c) shows average $\overline{D_n}$ of the distance between the individual divided by the average length $\overline{B_L}$ of *Plecoglossus altivelis altivelis* in each turbidity, and approximation line. Although there are some exceptions, the distance between the individual almost decreases with turbidity increase. It is thought that it occurred because recognizable distance that can recognize individual decreases with turbidity increase.

CONCLUSIONS

In this study, the influence of turbidity and number of fish on swimming behavior of fish school of *Plecoglossus altivelis altivelis* in statistic water was analyzed. As a result, the following have been understood.

(1) In comparison with clear water, the tendency that fish school divide into in muddy water towards higher. This tendency becomes remarkable with the turbidity increase.
(2) In comparison with clear water, the distance between the individual in the school of fish decrease in muddy water. This tendency becomes remarkable with the turbidity increase. It is thought that such a result was shown because visibility is worse with turbidity increase. Therefore, distance that can recognize individuals nearby in muddy water shorten.

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