Effects of Particle Diameter Over River Bed on Swimming Behavior of *Nipponocypris Temminckii*

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Abstract

Fish has the ordinary and dark muscle. When fish uses ordinary muscle, fish gets tired. In such a situation, fish needs a rest (Nakamura, 1995). In this study, particle diameter over river bed and flow velocity are changed. The trajectories of Kawamutsu (*Nipponocypris temminckii*) were observed. It was found that Kawamutsu attaches underpart at river bed to decrease fatigue in the rest time. The total rest time of Kawamutsu increases with increase of particle diameter and also velocity. The migration speed decreases with an increase of velocity. Kawamutsu turns to the upstream in the rest time.

Keywords: rest time; ordinary muscle; dark muscle; particle diameter; *Nipponocypris temminckii*

1. Introduction

River development in consideration of river environment is desired. Therefore, preservation and control of river environment are necessary. It is important to investigate and understand river ecosystem to maintain and manage river environment. Further, it is necessary to understand habitat and the swimming behavior of fish to maintain the livable river environment of the fish. Therefore, the relations of river environment and the habitat of fish were investigated. Nogami et al (2002) performed field experiment about the habitat environment of demersal fish in the *Makomanai River*. They pointed out that it is necessary to increase velocity and make particle size large for improvement in habitat environment where the population density of Hanakajika (*Cottus nozawae*) is small. However, the study was not analyzed in detail on relations of the particle size and swimming behavior of fish yet. This study elucidated swimming properties of Kawamutsu when particle diameter over river bed and flow velocity are changed.

2. Materials and Methods

2.1. Experimental device

Fig. 1 shows the open-channel that was used for experiment. It was designed following. The length L, width B and height H are 4.0m, 0.8m and 0.2m, respectively. x y and z are the coordinates of the streamwise, vertical and crosswise directions, respectively.

2.2. Experimental methodology

Averaged body length of Kawamutsu $\overline{B_L}$ is 60mm. Tab. 1 shows experimental case. Water depth was set to 0.04m. Particle diameter over river bed was set to 1.2mm, 2.5mm, 5mm, 10mm. The flow velocity divided by averaged body length of Kawamutsu $U_m / \overline{B_L}$ was set to 2, 4, 6, 10. Experiment was conducted 16 cases in total. A circular wire net of 0.25m in diameter is set up 2m downstream from upstream edge and isolated Kawamutsu is inserted. After it is confirmed that the Kawamutsu settled down, the circular wire net is taken up. Further, trajectory of Kawamutsu 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. Experiments were performed 50 times in each case, and 800 times in total. Number of swimming position was analyzed after recording. Furthermore, ground distance, ground speed, swimming speed and swimming distance were calculated from swimming position. Meanwhile, Fig. 2 shows turning angle in swimming.

3. Results and Discussion

3.1. Swimming trajectory in each particle diameter

Fig. 3 shows arbitrary swimming trajectory of Kawamustu in each particle diameter when velocity divided by averaged body length is 4. The points in Fig. 3 show swimming position for each 0.4 seconds. From Fig. 3, it is shown swimming range decreases and distance of between points approach with grow of particle diameter. As particle size increases, Kawamutsu tends to stay.

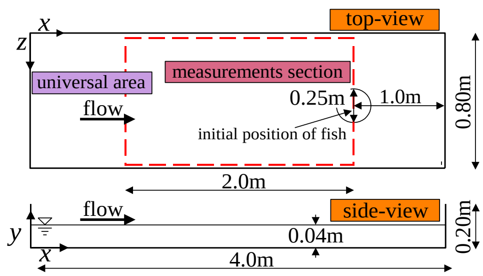


Fig. 1. Experimental setup.

Tab. 1 Experimental case

case name	Particle size(mm)	$\overline{B_L}$ (mm)	h (m)	U_m/B_L (1/s)
P012-02	1.2	60	0.04	2
P012-04				4
P012-06				6
P012-10				10
P025-02	2.5			2
P025-04				4
P025-06				6
P025-10				10
P050-02	5			2
P050-04				4
P050-06				6
P050-10				10
P100-02	10			2
P100-04				4
P100-06				6
P100-10				10

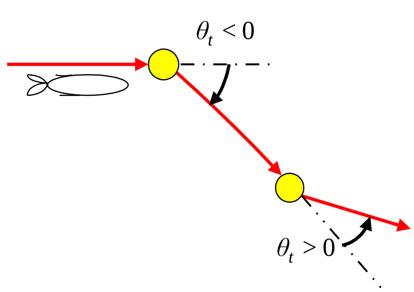
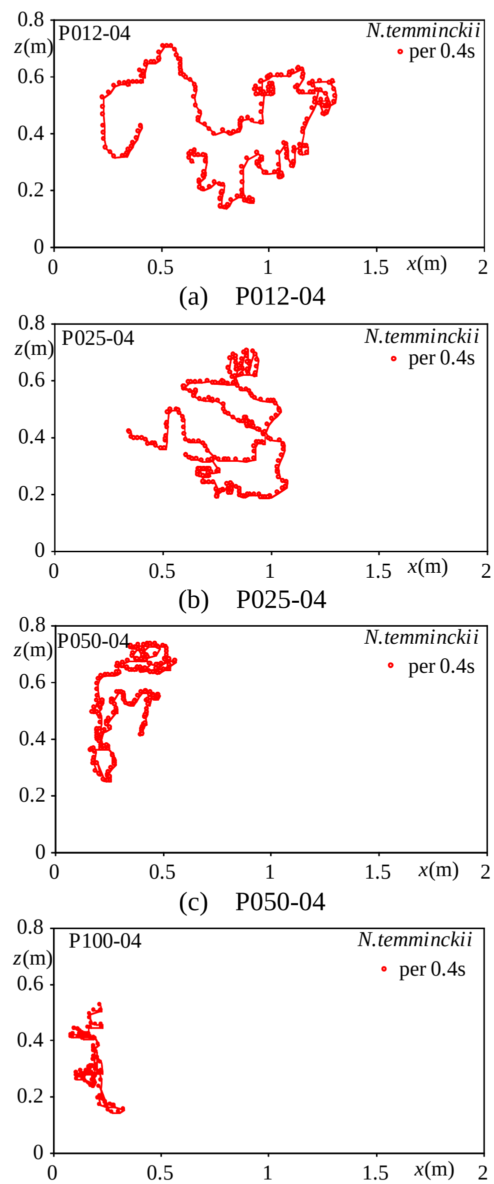


Fig. 3. Diagram of turning angle



(a) P012-04

(b) P025-04

(c) P050-04

(d) P100-04

Fig. 3. Arbitrary swimming trajectory of Kawamustu when velocity divided by averaged body length is 4

Fig. 4. Kawamutsu in rest time

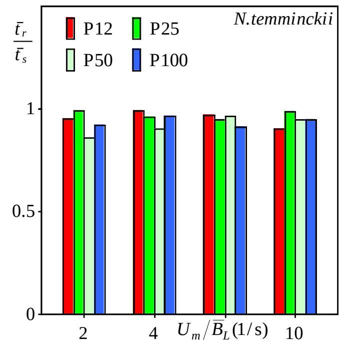


Fig. 5. Rest time divided by stay time in each case.

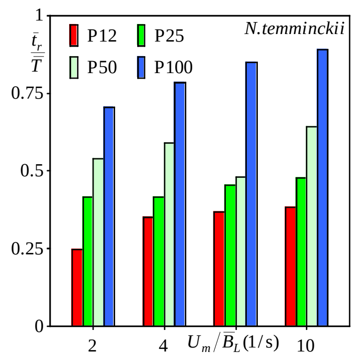


Fig. 6. Total rest time in each case.

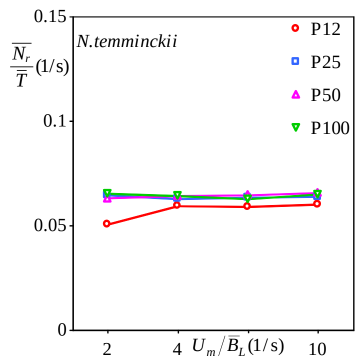


Fig. 7. Averaged the number of rest in each case.

3.2. Swimming behavior of Kawanutsu in rest

3.2.1. Definition of the rest

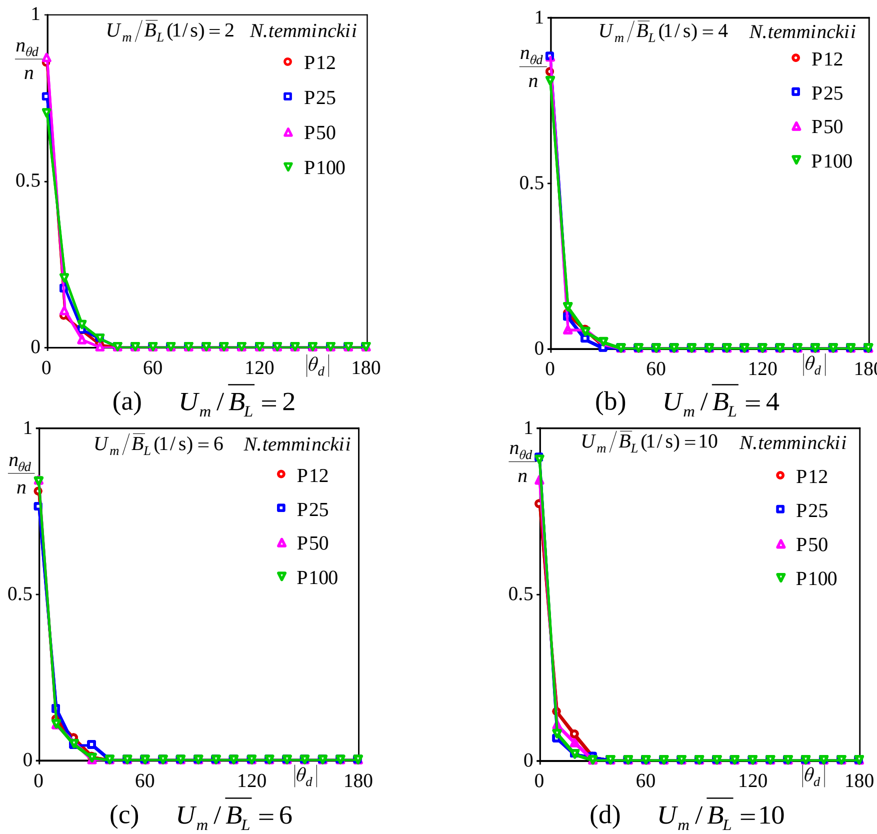
Fig. 4 shows Kawamutsu in rest time. From Fig. 4, it is shown that Kawamustu attaches underpart at river bed. It is probable that Kawamutsu attaches underpart at river bed for decrease fatigue in rest time. Therefore in this study, "rest time" is defined when Kawamutsu attaches underpart in river bed and swimming speed is less than the speed divided by the body of fish is 0.5.

3.2.2. Relation between rest time and swimming behavior of Kawamutsu

Fig. 5 shows rest time divided by stay time in each case. From Fig. 5, it is shown Kawamutsu takes rest when Kawamutsu stays in flow.

Fig. 6 shows rest time per unit time of in each case. From Fig. 6, it is shown rest time increases with grow of particle diameter. This results are assumed that rest is facilitated by increase of irregularity of river bed. Furthermore, From Fig. 6, it is shown rest time increases with increase of velocity. This results are assumed that fatigue is accumulated with increase of velocity.

Fig. 7 shows averaged the number of rest by divided total experiment time. From Fig. 7, it is shown the number of rest does not change when particle diameter grows. This results are assumed that rest time increases in of the once.



(a) $U_m/\overline{B_L}=2$ (b) $U_m/\overline{B_L}=4$

(c) $U_m/\overline{B_L}=6$ (d) $U_m/\overline{B_L}=10$

Fig. 8. Fish direction in rest time.

3.3. Fish direction in rest time

In this study, "fish direction" is defined angle formed by line connecting head and tail with x-axis $|\theta_d|$. Furthermore, fish direction $|\theta_d|=0°$ when fish turns to downstream and fish direction $|\theta_d|=180°$ when fish turns to upstream. Fig. 8 shows the frequency distribution of absolute value of fish direction in each case. From Fig. 8, it is shown distribution of $|\theta_d|=0\sim20°$ shows high-frequency in all case. Therefore, Kawamutsu turns to upstream to decrease fatigue in rest time.

3.4. Ground distance and speed in rest time

Fig. 9 shows averaged ground distance in x-direction $\overline{L_{Gx}}$ divided by averaged body length in each case. In case of P12 and P25, ground distance in x-direction decreases remarkably when flow velocity divided by averaged body length of Kawamutsu increases from 6 to 10. This is because rest time increases by increase of velocity. Meanwhile, in case of P100, ground distance in x-direction does not change when flow velocity divided by averaged body length of Kawamutsu increases from 6 to 10. This is because rest time is long in all velocity.

Fig. 10 shows averaged ground distance in z-direction $\overline{L_{Gz}}$ divided by averaged body length of Kawamutsu in each case. When velocity increases, ground distance in z-direction changes. However, change amount of ground distance in z-direction is small compared with change amount of ground distance in x-direction. This is because swimming range in z-direction decreases with increase of velocity.

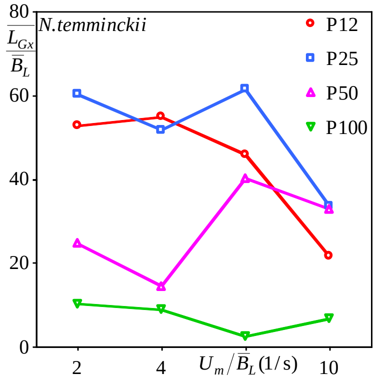


Fig. 9. Ground distance in x-direction

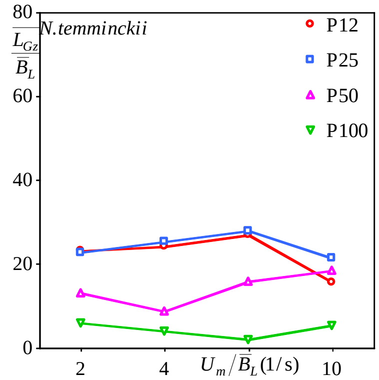


Fig. 10. Ground distance in z-direction.

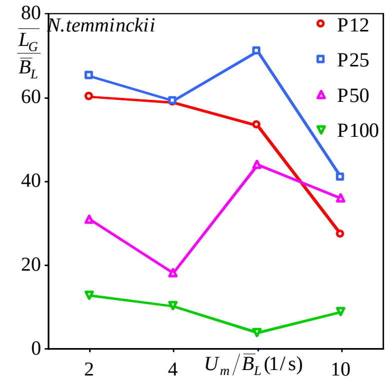


Fig. 11. Ground distance

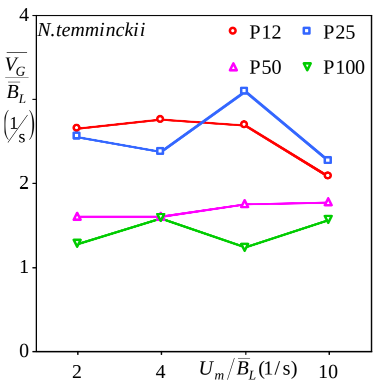


Fig. 12. Ground speed

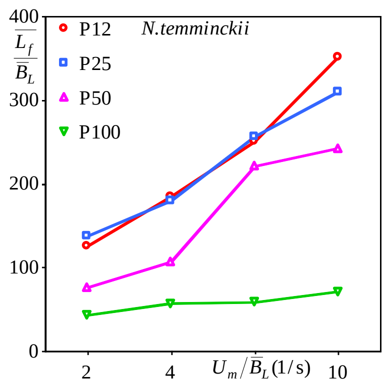


Fig. 13. Swimming distance

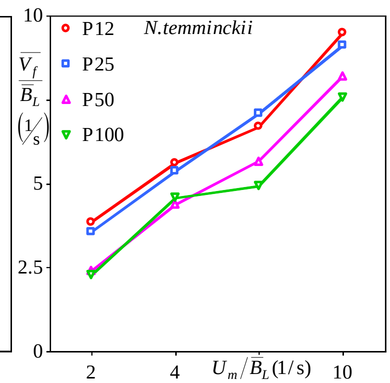


Fig. 14. Swimming speed

Fig. 11 shows averaged ground distance $\overline{L_G}$ divided by averaged body length of Kawamutsu in each case. From Fig. 11, it is shown ground distance decreases with grow of particle diameter. This is because rest time increases with grow of particle diameter.

Fig. 12 shows averaged ground speed $\overline{V_G}$ divided by averaged body length of Kawamutsu in each case. From Fig. 12, it is shown ground speed does not change when velocity increases in all particle diameter. This is because rest time increases with grow of particle diameter. However, ground speed decreases with grow of particle diameter in all velocity. This is because rest is facilitated by increase of irregularity of river bed.

3.4. Swimming distance and speed

Fig. 13 shows averaged swimming distance $\overline{L_f}$ divided by averaged body length of Kawamutsu in each case. From Fig. 13, it is shown swimming distance increases with increase of velocity. Meanwhile, swimming distance decreases with grow of particle diameter. Furthermore, increase rate of swimming distance decreases with grow of particle diameter. This is because rest time increases with grow of particle diameter.

Fig. 14 shows averaged swimming speed $\overline{V_f}$ divided by averaged body length of Kawamutsu in each case. From Fig. 14, it is shown swimming speed increases with increase of velocity. Meanwhile, swimming speed decreases with grow of particle diameter. This is because rest time increases with grow of particle diameter and increase of velocity.

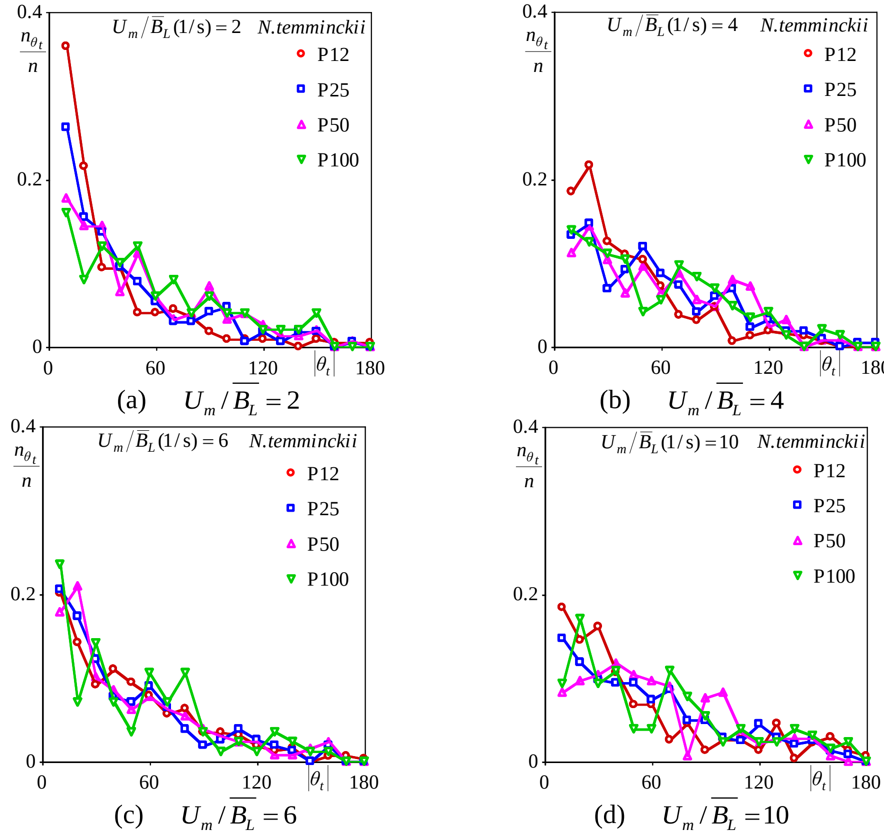


Fig. 15. Tuning angle in each velocity.

3.4 Turning angle in each velocity divided by averaged body length

Fig. 8 shows the frequency distribution of absolute value of turning angle $|\theta_t|$ in velocity divided by averaged body length. In distribution of $|\theta_d| = 0 \sim 20°$, case of P12 and P25 shows high-frequency than case of P5 and P10 when velocity divided by averaged body length is 2. Furthermore, in distribution of $|\theta_d| = 0 \sim 20°$, case of P12 shows high-frequency than other case when velocity divided by averaged body length is 4. However, distribution of each particle diameter does not show difference when velocity divided by averaged body length are 6 and 10. This results are assumed that turning angle is small when velocity and particle diameter are small. However, turning angle does not change basically when particle diameter increases.

4. Conclusion

In this study, particle diameter over river bed and flow velocity are changed, and the fish's behavior was analyzed. As a result, the following have been understood.

(1) Kawamutsu attaches underpart at river bed for decrease fatigue in rest time.
(2) Because rest is facilitated by increase of irregularity of river bed, rest time of Kawamutsu increases with grow of particle diameter.
(3) Because fatigue is accumulated with increase of velocity, rest time of Kawamutsu increases with increase of velocity.
(4) Swimming distance of Kawamutsu increases with increase of velocity, but decreases with grow of particle diameter.
(5) Kawamutsu turns to upstream to decrease fatigue in rest time.
(6) Turning angle of Kawamutsu does not change basically when particle diameter increases.

It was found that Furthermore, it was found that rest time of Kawamutsu increases with grow of particle diameter and increase of flow velocity.

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References

Nakamura S. gyodounohanashi. sankaidou 1995.

Nogami T, Watanabe Y, Kobayashi M, Hasegawa K. Research on Classification of Fish Habitat in Mountain Rivers. Proceedings of JSCE 2002.