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Simplified Numerical Computation of Flow in Rearing Tank of Marine Fish Larvae

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Summary

This paper deals with estimation of flow in the rearing tank of marine fish larvae. The larvae are seven band grouper larvae *Epinephelus Septemfasciatus,* of which the survival rate is very low in the initial stage after hatching of eggs. The estimation of environment of flow in a rearing tank is very important, as the flow seems to depend on mass mortality of seven band grouper larvae by experiments of rearing of larvae. The numerical computational method was simplified by two dimensional flow based on experimental results. Based on the results, it was confirmed that the simulation of vertical circulating flow observed in experiments was possible by this method and the stationary flow in the rearing tank was provided in good agreement with experimental results qualitatively and quantitatively.

Introduction

Recently, the culture of marine fish has been developed and growth of many kinds of fish larvae has succeeded by improvements of culture technique. However, marine fish are fragile; physical stress such as unfavorable flow, light, water temperature etc, may result in mass mortality of larvae. Among fish species, grouper larvae are highly sensitive to physical stress and mass mortality is caused by floatation in the rearing tank after hatching of eggs [1]. It was thought that the flow in the rearing tank gave the most effective impact to grouper larvae with small size.

In general, the flow in the rearing tank was generated by aerators, which were commonly used to provide oxygen as well as aid in the even distribution of live food. However, few studies have been conducted on the flow field in the rearing tank [2]. Authors reported the systematic experiments of flow measurement and rearing seven band grouper *Epinephelus Septemfasciatus* using 1m^3 polyethylene rearing tank [3].

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The estimation of flow in the rearing tank using a flow meter is very important against the examinations of larvae growth and mass mortality caused by floatation. However, as the comfortable circumstance of flow in the rearing tank is different for each kind of larvae, the measurement of flow each time is not effective for time and economy.

This paper deals with estimation of flow in the rearing tank of marine fish larvae by a numerical computation method. The results from such studies may be very useful for the purpose of flow estimation in the rearing tank and in the design of larval rearing tanks. However, few studies have been conducted to evaluate the flow field in rearing tanks.

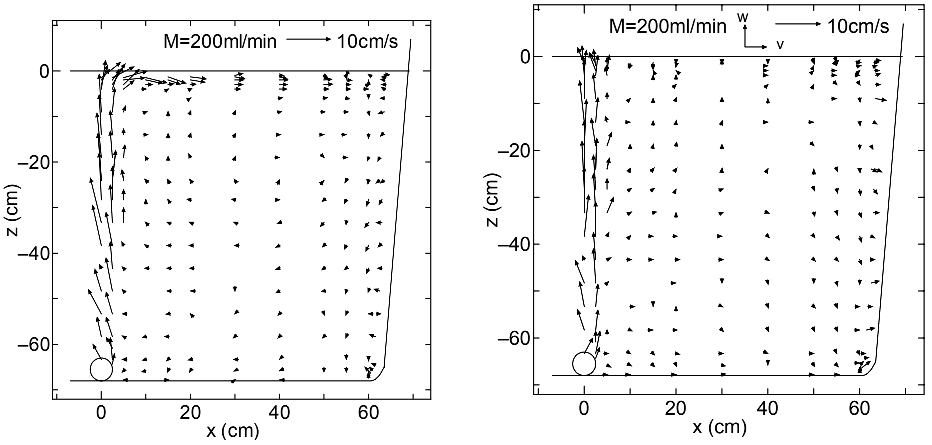
Experiment of Rearing Grouper

In a previous paper, authors presented the systematic measurement of flow in the rearing tank and experiments of rearing for grouper larvae to depend on flow [3]. The measurements of flow generated by a usual spherical aeration having a diameter of 5cm in the rearing tank were carried out by using a 1m^3 polyethylene tank as shown in Fig.1. The rearing water tank was cylindrical, with a 154cm upper diameter, 132cm bottom diameter, and a height of 82cm and a curved bottom.

The larval rearing experiments with grouper larvae *Epinephelus Septemfaciatus* were carried out in four aerating conditions, and the survival rates of rearing under each condition were compared. At the same time, the measurements of flow generated by aerating in the rearing tank at the same conditions were made. The measurement of flow in the rearing tank was carried out in the half vertical section through the center of water tank.

Fig.1 Rearing tank and aerator

Aerating rate at 200ml/min in four kinds of proposed conditions resulted in the highest survival and growth of grouper larvae. Fig.2 shows flow velocity distribution under this aerating condition for rearing larvae. The figure on the left shows u-w velocity distribution on the measured vertical section (x, z) and the figure on the right shows v-w velocity distribution. In the u-w velocity distribution, remarkable vertical circulation was observed, however in the v-w velocity distribution the flow was not regular and the v velocity component was very small. This means that the horizontal circulating flow was not generated in the rearing tank. Therefore, it was concluded that the flow profile in the rearing tank was two dimensional on the vertical section.



(u-w distribution) (v-w distribution)

Fig.2 Experimental distribution of stream velocity

Basic Equation

For the purpose of estimating flow in the rearing tank, numerical computation of flow in the rearing tank was carried out. The governing equations were the two dimensional incompressible Navier-Stokes equations and the continuity equation as follows:

$$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+w\frac{\partial u}{\partial z}=-\frac{1}{\rho}\frac{\partial p}{\partial x}+\nu\left(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial z^2}\right) \quad (1)$$

$$\frac{\partial w}{\partial t}+u\frac{\partial w}{\partial x}+w\frac{\partial w}{\partial z}=-\frac{1}{\rho}\frac{\partial p}{\partial y}+\nu\left(\frac{\partial^2 w}{\partial x^2}+\frac{\partial^2 w}{\partial z^2}\right) \quad (2)$$

$$\frac{\partial u}{\partial x}+\frac{\partial w}{\partial z}=0 \quad (3)$$

where the origin in the Cartesian coordinates system was placed at the center on a free surface of rearing water tank and (*x, z*) represented the axis in radial and upward

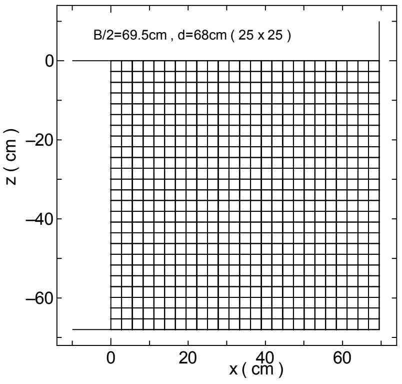


Fig.3 Grid topology

directions respectively. The velocity components were (u,w), p was the pressure in the water, ρ was the water density and ν was the kinematic eddy viscosity.

The calculation of flow in the rearing water tank was made by the finite differential method using MAC scheme. The time differentials in Eqn. (1) and (2) were expressed by the first order forward difference, namely the Euler explicit scheme. The second order central differences were used for the spatial differentials in Eqn. (1), (2) and (3). Keeping the numerical computation stables, the convection terms were evaluated by the third order upstream difference. The Poisson equation for obtaining the pressure term was solved by the SOR method.

Fig.3 shows the grid topology of the calculated region in the rearing water. The number of grid points was 25×25 in the (x, z) directions and the grid spacing was regular. The staggered mesh was used. The minimum spacing of the grid near water wall was relatively large, because the main objective of the computation was to simulate stationary flow in the rearing tank, and the more detailed flow in the boundary layer near the wall was not necessary. On the free surface condition, it was assumed that the free surface elevation was fixed and the velocity component of w was zero, because the weak aerating rate was not almost caused the variation of the free surface.

Comparison of Experimental and Calculated Results

Fig. 4 shows the calculated flow velocity distribution in the rearing tank. The remarkable vertical circulation is observed as the same as that shown in Fig.2. The center of circulation in the experimental result means to be located at the position of about x=45cm and z=-25cm, though there were few measured data points and the position was not clear. On the other hand, the position in the calculated results was x=48cm and z=-23cm. On the whole, the experimental results were very similar to the calculated results.

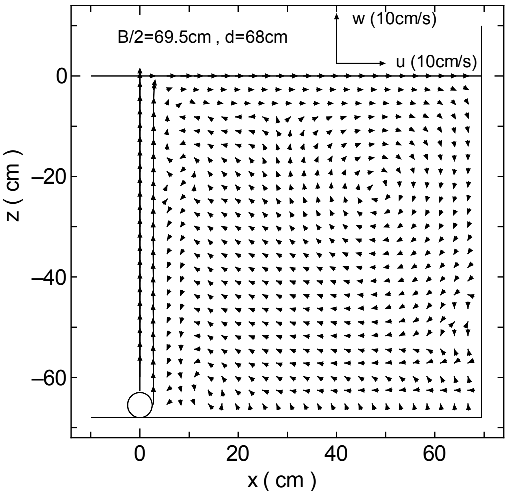
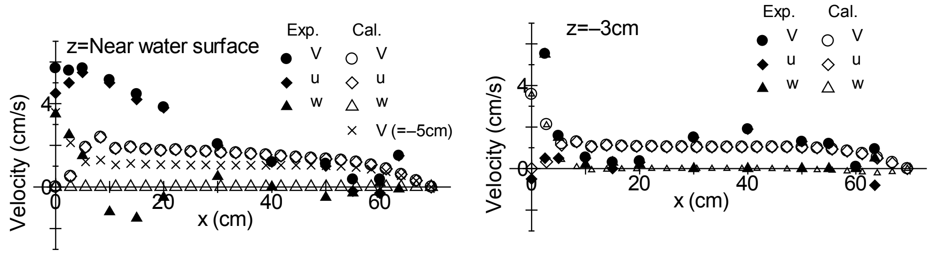


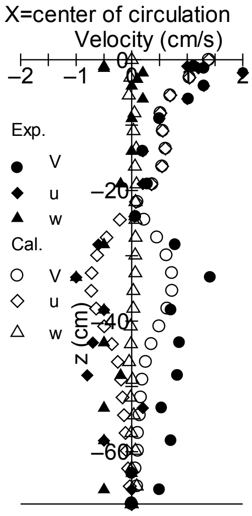
Fig.4 Calculated distribution of flow

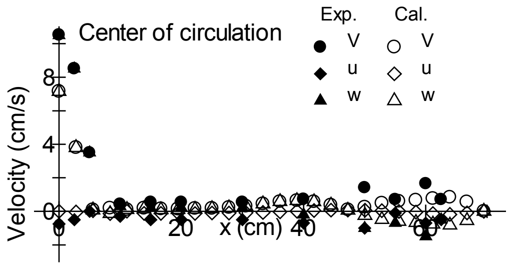
Fig.5 shows a comparison of calculated and experimental velocity distributions near a free surface. The left figure shows flow under free surface of about z=-1.0cm and the right figure shows under z=-3.0cm. In the left figure, the experimental u velocity component near the center of the rearing tank was relatively strong compared with the calculated one. The weak w velocity component near the center depended on the fixed free surface condition. In the right figure, both velocities were very similar.



(z=-1cm) (z=-3cm)

Fig.5 Comparison of calculated and experimental velocity distributions near a free surface





(Vertical velocity distribution)

Fig.6 Comparison of calculated and experimental velocity distributions on the vertical and the horizontal lines through the center of vertical circulation in the rearing tank

(Vertical velocity distribution)

The calculated flow was partially compared with the experimental one in detail. Fig.6 shows a comparison of calculated and experimental velocity distributions on the vertical and the horizontal lines through the center of vertical circulation in the rearing tank. The black marks show the experimental data and

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the white marks show the calculated data. The mark V shows the strength of flow velocity $\sqrt{u^2+w^2}$. In the figure, on the vertical line, both Vs approach zero near z=-25cm and both flow directions of u velocity components changed. This point z is the center of the vertical circulating flow. Both profiles of V were very similar. On the horizontal line, the strong upward flow of w velocity component near the center of the rearing tank depends on aerating, and the flow of the other position was very weak.

Conclusion

From the measured results of flow velocity distribution generated by aeration in the rearing tank, it was confirmed that the remarkable vertical circulating flow was created, however the horizontal circulating flow was not observed. This fact means that two dimensional calculations can be used to estimate the flow in the vertical section of the rearing tank, including the center of the tank. Comparing the experimental and calculated results, the stationary vertical circulating flow was satisfactorily represented by the simplified numerical computation method proposed in present paper. The velocity distributions on vertical and horizontal lines, including the center of the circulating flow, are in good agreement. Also, both locations of the center of the vertical circulating flow were very similar.

However, the improvement of free surface boundary condition is demanded for obtaining flow near free surface with higher accuracy.

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