MODELLING FISH MOVEMENT IN A VERTICAL SLOT FISHWAY

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Fishways are constructed for the safe passage of fish through obstructions like dams or weirs. Though swimming is inborn property of fish, it is not possible for all fish to swim through fishways. Hence a better understanding of fish behaviour in fishways is requisite to design better fishways. The behaviour of fish in a fishway is quite different from that in rivers or sea. Since the sole purpose of fish to ascend fishways is to pass the barriers to reach the spawning ground or feeding ground, the velocity field in the fishway is the dominant governing factor which decides the behaviour of fish in fishways.

This paper presents the numerical modelling of fish movement through a vertical slot type fishway based on Newton's 2nd law of motion with random variable which is introduced to express uncertainty of biological aspects.

There are two forces acting while fish are ascending fishways. The thrust force applied by the fish and the drag force opposing the fish. When thrust force used by the fish is more than the drag experienced by it, fish can ascend the fishway.

The drag force D acting on a fish is expressed as

$$D=\frac{1}{2}\rho A C_d U^2 \tag{1}$$

where ρ is the water density, A the projected area of the fish on a plane normal to flow direction, C_d the drag coefficient (=0.6) and U the relative velocity.

In this experiment, speed associated with fish is classified as cruise speed and burst speed. The cruise speed U_{cru}, which fish can sustain for a long time, is set as 4 times the body length per second (U_{cru} = 4 BL/s) and the burst speed $U_{\max}$ set as 15 times ($U_{\max}$ = 15 BL/s). The thrust requisites by fish for cruise and burst are given by;

$$T_{cru}=\frac{1}{2}\rho A C_d U_{cru}{}^2 \tag{2}$$

$$T_{\max}=\frac{1}{2}\rho A C_d U_{\max}{}^2 \tag{3}$$

Fish swim in burst speed to swim against the rapid flow. This numerical model allows the fish to ascend the fishway using their burst speed when the water velocity (WV) exceeds 0.8 times the cruise speed of the fish. The time limit to which the fish can ascend using the burst speed is set as 2 seconds in maximum in this work.

To express the uncertainty of biological aspects while choosing the direction of ascending, stochastic concept is introduced with normal random variable R.

$$\theta = \theta_0 \pm \sigma R \tag{4}$$

where, θ is the direction to which the fish will move, θ_0 the opposite direction of the flow and σ the standard deviation.

For WV less or equal to 6 BL/s and greater than 6 BL/s, σ is set as $\pi/6$ and $\pi/18$ respectively. This concept will introduce more freedom for fish to align their way other than just opposite the flow direction when flow speed is relatively low and induce less liberty for fish to change their direction when water current is high.

The numerical model of fish movement was performed in a computed steady state flow of a vertical slot type fishway, obtained by using Godunov type numerical method of solving two dimensional shallow water equations. The length and width of fishway was set 25 m and 2 m with five pools of 2.2 m length, slope 1/25 and slot opening of 0.2m. The maximum velocity was over 1.5 m/s and was found around the slots.

At the downstream end of fishway 50 fish with size 0.2 m, 0.3 m and 0.4 m respectively were released. The simulation was performed to find out the ascending route and percentage of each type of fish that could ascend the fishway. The simulation was done for 10 minutes time period.

Results show that the fish takes rest in the wake regions at the time of ascending. The wake regions at the both sides of the pool are found to have taken as resting place by ascending fish.

In the case of fish with body length 0.2 m, the trajectories of fish movement were seen complicated in the main stream as the fish need to pass through very high velocity compared to their cruise speed. In those areas the fish were hence found to have diverted away in the stagnation region. But in the case of fish with body length 0.4 m, the cruise speed of fish was 1.6 m/s. Fish did not need to travel in burst speed in most of those region hence the trajectories were simpler than the previous case. In this case also fish are found to have taken rest in wake regions.

Like wise, the simulation results show that the number of fish ascending to the upstream level is increased with the increment in the size of fish.

Hence the results obtained showed that the model is found to have interpreted the trajectories and ascending behaviour similar to the pattern which ascending fish shows.

Fig. 1: Trajectories of fish movement in a vertical slot fishway. (BL=0.3 m)