Study on the tank shape and aeration for small-scale larviculture of marine fishes

小型飼育水槽の形状と流場が海産仔魚の飼育成績に与える影響

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Many larviculture trials of marine fishes have been conducted in large-scale (m^3), and little attention has been paid to the small-scale (<50-l) larviculture. Large rearing tanks are known to be preferable for marine fish larvae due to the stable flow field and stabilized water quality, and a lesser chance of damage from the contacting the tank walls for larvae. Small tanks are easily manipulated, however, survival rates are usually low comparing to the large tanks due to the difficulty of maintaining stable flow field. Tank shapes and sizes can differ the flow field in larval rearing tanks. Therefore, to seek for optimal flow field in small-scale larviculture, I conducted rearing experiments using 50-l small tanks in different shapes, cylindrical (CT) and rectangular tank (RT), with different aerators and compared rearing results and flow field.

First, I chose red seabream (RSB) *Pagrus major* as experimental fish and compared survival, growth and swim-bladder inflation between CT (1.7×10^3 cm^2 water surface area, 30 cm depth) and RT (1.8×10^3 cm^2 water surface area, 28 cm depth, Chapter 2). This species is an important cultured marine fish in Japan and aquaculture technique has been established. However, little attention has been paid to the small-scale larviculture experiments for this species. One air stone with 100 ml/min aeration rate was set at the bottom center of CT and RT (RT1AS), and two air stones with 50 ml/min aeration rate were set at the bottom center of half of RT (RT2AS). Then fish were reared until 14 days post hatch (dph). Two-phase bubbly flow simulations were performed in the experimental tanks using a dispersed flow model. Survival rate in CT (54.7±11.0%) and RT1AS (55.3±6.0%) at 14 dph were significantly higher than that in RT2AS (29.6±9.3%; n=3, $p<0.05$). Growth of larvae was not significantly different between tank shapes and aerators. Swimbladder inflation rates were not significantly different between tank shapes and aerations, however, CT (58.9±28.3%) showed lower trends in swimbladder inflation than RTs (80-100%). The low-flow areas in tanks were defined as the area where the water velocity is slower than the swimming speed of RSB larvae (4.6 mm/s) at 14 dph (4.8±0.2 mm in total length). At the water surface in tanks, the low flow areas were observed along the sidewalls in CT and RT1AS, and along the sidewalls and in the middle in RT2AS. These areas at tank bottom varied by tank shape, occurring at the edge of the tank wall on the bottom in the CT, from the air stone to the tank wall in RT1AS, and at the center (between air stones) and from the air stones to the tank wall in RT2AS. Further, high rotifer distribution at tank bottom coincided with the stagnate areas where the water velocity is lower than the swimming velocity of rotifers (1.3 mm/s). Hence, more complicated flow field was observed in the RT2AS. Velocity of water surface in CT

(24.6 mm/s) was higher than those in RTs (19.3-22.1 mm/s). High water velocity at water surface was assumed to prevent the larvae from accessing water surface for swim bladder inflation. These results revealed that small-scale (50-l) experiments can be conducted for RSB larviculture using either a CT or RT1AS with present aeration system.

Second, larviculture of Pacific bluefin tuna (PBT) *Thunnus orientalis* larvae was performed using CT and RT (Chapter 3). One air stone with 100 ml/min aeration rate was set at the bottom center of three CT and RT. Since high mortality of PBT larvae due to sinking syndrome during the first 10 days is known to be obstacle, continuous illumination at 2000 lx was set to reduce the sinking syndrome. Survival of larvae in the CT (52.7±5.1%) at 8 dph was about 60-folds higher than that in the RT1AS (0.8±0.7%, $p<0.01$). Larval growth was not significantly different between tank shapes either in body length (CT: 4.23±0.26 mm, RT1AS: 4.09±0.20 mm) or dry weights (CT: 95.1±17.6 μg, RT1AS: 67.7±10.9 μg). The swimbladder inflation rates were not different significantly between tank shapes but similar trend as RSB was observed (CT: 16.5±14.5%, RT1AS: 56.9±3.5%). Low flow areas in RT, where the water velocity is lower than the swimming speed of PBT larvae (8.8 mm/s) at 8 dph (4.2±0.1 mm in total length), were larger than those in CT. High rotifer distribution was observed in the areas where the water velocity is slower than the swimming speed of rotifers (1.3 mm/s). Therefore, these low flow areas in RT1AS may be a cause of sinking syndrome of PBT larvae. These results indicated that small-scale (50-l) PBT larviculture experiments can be conducted using a CT with the present aeration system, but RT requires improvement in aeration.

To improve the aeration system in RTs for PBT larviculture, I tested several different aerators (Chapter 4). One spherical air stone (5 cm in diameter) was set at the bottom center of RT as control. Then, long bar-shaped aerators were set at three patterns; two long aerators (30 cm) with 50 ml/min were set at the both narrow sides of bottom, one long aerator (60 cm) was set at the long side of bottom adjusting 400-500 ml/min aeration rates, and 4 baculiform aerators (15 cm) were set at the edge of the bottom walls with 100 ml/min aeration rates. Survival, growth and swimbladder inflation of PBT larvae were similar or lower in these 3 different aeration systems than control.

The flow field in different larval rearing tank shapes affected the survival of RSB and PBT larvae. Sinking syndrome occurred in PBT larvae but not in RSB. The CT and RT1AS with a single-pair vortex system were more suitable for survival of RSB larvae than RT2AS with two single-pair vortex systems. Only the CT was feasible for survival of PBT larvae due to the stagnate areas at the bottom of the tank, which may cause the sinking syndrome. On the other hand, larger stagnate areas at the water surface of RTs may support fish larvae to access the air through the water surface for the swimbladder inflation. However, RTs are generally easier to handle and clean than CTs. Therefore, the improvement of aeration beyond a single air stone or different aerator types were required to get the optimal flow velocity in RTs. Measuring the rotifer density at the various points of a rearing tank is proposed for estimating the flow field in the tank, especially for the stagnate areas with higher rotifer densities than the average density.