

Exercise Training for Salmonid Aquaculture

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INTRODUCTION

Water current velocity in an aquaculture rearing unit has a dramatic effect on growth rate, disease resistance, behaviour and welfare of farmed salmonids. Exposing fish to continuous moderate aerobic exercise is an effective strategy to improve robustness in farmed salmonids. Robustness gives better growth, survival and fish welfare, which leads to greater productivity and ethical food production.^[1]

Salmonids are migratory fish that have a natural capacity for sustained aerobic swimming.^[2] Whether motivated by foraging, predator avoidance or reproductive migrations, wild salmonids swim on average at a speed of 1.0 body lengths per second.^[3] In aquaculture, the intensity of exercise is controlled primarily by water velocity in the rearing unit. Increasing water velocity stimulates fish to swim with greater resistance against a current, providing more exercise training, leading to healthy, robust salmonids.

Achieving optimal water velocity in the rearing unit is critical for the success of exercise training. When water velocity is too low, salmonids are more aggressive toward each other, have elevated levels of stress hormones and show increased dominance hierarchies.^{[4],[5]} When water velocity is too high, salmonids experience a decreased growth rate and may suffer from exhaustive exercise stress, which, in severe instances, can cause death.^{[6],[7]}

OPTIMAL WATER VELOCITY

Water velocity is calculated by measuring the distance water travels within a unit of time. For fish, intensity of exercise training is defined as water velocity relative to average body length (BL) and expressed as the number of body lengths water travels per second (e.g., 1.25 BL/s).^[8] Research indicates that exercise training intensity for farmed salmonids is optimized for growth and animal welfare at approximately 1.0 BL/s.^{[1],[5],[8],[9],[10]} Exercise training is most effective when performed continuously rather than intermittently.^[6]

Calculating Exercise Training Intensity

1. Calculate the average water velocity in the rearing unit in cm/s.
2. Calculate the average total fish length in cm.
3. Sample formula:
Exercise training intensity
= water velocity (cm/s) ÷ fish length (cm)
= 21.2 cm/s ÷ 20 cm
= 1.06 BL/s

Fish size and species affect optimal water velocity for exercise training. As fish length increases, the optimal water velocity relative to body length decreases. Smaller fish are better able to handle higher water velocity relative to body length when compared to larger fish.^{[6],[11],[12]} This is because, at a lower relative swim speed, larger fish experience anaerobic metabolism in the muscle.^[12]

GROWTH RATE

Exercise training can be used to improve growth in farmed salmonids, which enables fish to reach harvest size faster.^{[5],[6],[9]} Continuous and prolonged moderate exercise training has been proven to enhance growth at all life stages in salmonid species, including rainbow trout, brook trout, brown trout, Atlantic salmon and Arctic char.^{[7],[12]} During exercise training, appetite is stimulated by an increase in energy demand and/or lower stress levels.^{[4],[6],[11]} Behavioural changes in fish exposed to optimal water velocity allow for a more even distribution of feed intake and collectively better growth within the rearing unit.^[12] Research on the effect of exercise training on feed conversion ratio (FCR) has mixed results. Some findings indicate improved FCR at moderate exercise intensity, while other research indicates that FCR is unaffected by exercise training.^{[1],[4],[6],[7],[9],[12]} Exercise training is a valuable management tool that can improve operational efficiency of aquaculture by accelerating growth and reducing time to harvest.

BEHAVIOUR, HEALTH AND WELFARE

Water velocity and exercise training can affect the behaviour, health and welfare of farmed salmonids. Negative effects occur when water velocity is either too low or too high. Positive outcomes occur when water velocity is optimized for moderate exercise training at approximately 1.0 BL/s. The impacts of water velocity are outlined below in more detail.

Low Water Velocity

When water velocity is low, fish display an unorganized distribution in the rearing unit, display spontaneous activities and are prone to territorial behaviour leading to aggressive interactions.^{[4],[11]} Aggressive interactions increase the prevalence of fin erosion, open wounds and susceptibility to pathogen infections.^{[5],[6]} Spontaneous and aggressive behaviour requires energy output, which is often equal to or greater than the energy required to swim against the water current in moderate exercise training.^[6] The cumulative effects of low water velocity (< 0.5 BL/s) have been shown to increase levels of stress hormones and decrease overall growth in salmonids.^{[5],[6]}

Moderate (Optimal) Water Velocity

Moderate, or optimal, exercise training promotes even fish distribution in the rearing unit (Figure 1).^[8] This allows for better feed and water quality distribution, promoting a reduction in dominance hierarchies.^[1] Improved group dynamics result in less aggressive behaviour, leading to fewer injuries and infections.^{[5],[12]}

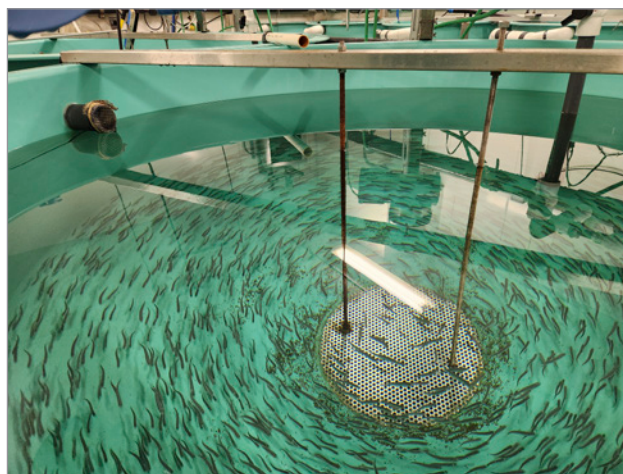


Figure 1. Juvenile salmonids in a circular tank.

Exercised salmonids have a more uniform body size and lower variable growth rate compared to unexercised fish.^[12] There are advantages to uniform fish size where feeding hierarchies are diminished and size grading frequency is reduced.^[6] Exercise training provides many health and welfare benefits, including:

- lower levels of stress hormone ^{[4],[6]}
- increased aerobic capacity ^[12]
- enhanced swimming efficiency ^[12]
- improved oxygen carrying and extraction capacity ^{[8],[12]}
- greater skeletal integrity ^{[5],[8]}
- accelerated recovery from stressors (e.g., handling, transportation, wounds) ^{[6],[9],[11]}

High Water Velocity

Excessive water velocity can have serious health and welfare implications. The most obvious is exhaustive exercise stress. Severe exercise can lead to exhaustive stress and death by intracellular acidosis — even after exercise is discontinued.^[7] Excessive exercise training decreases the thickness of the epidermis, the fish's outermost skin layer, which

weakens the epidermis's ability to defend against pathogens; mucosal health is negatively correlated with high water velocity. When water velocity exceeds 1.8 BL/s, the prevalence of inflamed muscle fibres, fin damage and gill lesions increases.^[8]

MEASURING WATER VELOCITY

Optimizing exercise training requires an accurate measure of water velocity. Regularly check the water velocity in the rearing unit to ensure fish are swimming at a moderate exercise intensity of approximately 1.0 BL/s.^{[1],[5],[8],[9],[10]} There are several options to measure water velocity: velocimeter, visual behaviour cues and the floating method.

Velocimeter

The most accurate and efficient way to monitor water velocity in the rearing unit is by using instrumentation such as an impeller-based velocimeter or an acoustic Doppler velocimeter. Always measure water velocity when fish are in the rearing unit, as fish biomass decreases water velocity.^[10] Avoid measuring water velocity in an empty tank. Water velocity varies within the rearing unit. Measure water velocity at multiple depths and locations to determine the average velocity. Water velocity is highest at the surface and closest to the tank wall in circular tanks.^[7]

Visual Behaviour Cues

Visual behaviour cues help producers determine appropriate water velocity. Incorporate these cues into daily husbandry practices even when using a velocimeter.

Salmonids should be able to hold position in the water current, swim actively against the current and orient themselves into the current (excluding *Coregonus*).^{[11],[12]} If fish are unable to hold position in the water current and are frequently swept downstream, water velocity is too high. When fish swim aimlessly in the rearing unit, with no structured orientation and perceived effort of swimming against a current, water velocity is too low.^[12]

Float Method

When a velocimeter is unavailable, water velocity can be determined by recording the time it takes for a neutrally buoyant object to travel a known distance. The float method has medium accuracy due to human error and environmental effects. It is best performed when wind and surface water are calm. The float method is most effective when used in land-based raceways.

CONTROLLING WATER VELOCITY

Water velocity in a rearing unit can be controlled more effectively in land-based aquaculture than in open-water net pen aquaculture. In land-based aquaculture, water velocity is controlled by altering the inflow rate, water level or directional flow of water in a circular tank or raceway. Land-based aquaculture producers can increase water velocity in a rearing unit by increasing the inflow rate, decreasing the water level and/or accelerating the rotational flow of water. Fish should be acclimatized gradually to increasing water velocity and monitored for negative effects.^[3] Water velocity can be increased slightly in subsequent weeks if fish demonstrate no negative or adverse effects of a water velocity increase in week one. Monitor behaviour and fish health until reaching the desired water velocity.

In open-water net pen aquaculture, water velocity is primarily controlled by natural water currents. This makes the location of net pen aquaculture sites important because water velocity is constrained by natural water movement. Aeration within a net pen can promote water movement, although exercise training is rarely the primary intention. Clear nets of biofouling to promote increased water velocity within a net pen. As biofouling organisms colonize nets, the mesh size decreases, constricting the flow of water and water velocity through the net pen.^{[13],[14]} Routinely cleaning nets of biofouling enhances water exchange, oxygen supply and water velocity within the net pen. Configuration and positioning of net pens also effects water velocity. Increasing the surface area of nets exposed to incoming water current promotes water exchange and greater water velocity. Grouping net pens together reduces surface area exposure and decreases water velocity in the net pen. When

net pens are grouped together, increasing the space between net pens can improve water flow.^[15]

CONCLUSION

Despite the documented benefits of exercise training, water velocity in a rearing unit is often set based on the requirements for oxygen demand and tank self-cleaning.^[1] This approach ignores important biological reasons for optimizing water velocity, which includes improved growth, behaviour, disease resistance and welfare of farmed salmonids. The effects of exercise training on fish welfare and productivity are variable, based on the intensity of exercise training. Exercise training at low water velocity (< 0.5 BL/s) produces elevated levels of stress hormone, aggressive behaviour and reduced growth.^{[5],[6]} Exercise training intensity that exceeds 1.8 BL/s has been shown to produce negative health and welfare implications.^[8] Salmonid exercise training intensity is optimized at approximately 1.0 BL/s, which is the level where the true biological and behavioural benefits of exercise training are achieved.^{[1],[5],[8],[9],[10]} Continuous exercise training at moderate intensity is a valuable production practice that can improve productivity, efficiency and animal welfare.

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Published by the Ministry of Agriculture,
Food and Agribusiness
© King's Printer for Ontario, 2025
ISSN 1198-712X
Également disponible en français (Fiche technique 25-028)

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