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Fish behaviour in circular tanks: a video documentation on fish distribution and water quality

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Abstract

The film presents behaviour patterns of fish under a variety of operational conditions in circular tanks. At high stocking densities fish interact with their artificial environment (the circular tank) in complex, unexpected ways, and these interactions - amplified by the artificially crowded conditions - have often severe negative impacts on total culture system performance. Various flow rates, turbulences and inlet-outlet arrangements have drastic effects on fish distribution, mechanical contact between fish (skin damage), and on water exchange, water mixing characteristics and water quality. Means to minimize crowding stress and their negative side effects on water quality are presented.

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Introduction

The trend in modern aquaculture has been towards higher stocking densities and one consequence has been numerous water quality problems (Rosenthal & Murray, 1986). Very few studies have studied the hydrodynamics in circular fish tanks in relation to tank size, inlet and outlet arrangements and flow rates. Burrows and Chenoweth (1955, 1970) described the performance of a rectangular circluating pond, for which Piper et al. (1982) identified the advantages of ease of flushing and fish handling. However, circular tanks have increasingly become in use and in order to make the most efficient use of a given volume of fluid for fish rearing purposes it is necessary to understand that fluid dead volumes, bypass flows and local recirculation need to be avoided. Recent studies concentrated on the description of the hydrodynamics of such tanks operatin with different inlet arrangements and water depth (Klapsis & Burley, 1984; Burley & Klapsis, 1985). However, these studies were undertaken without fish. The film demonstrates how fish behaviour can influence the distribution and exchange of water bodies in small and medium sized circular tanks.

Material and Methods

The video recordings were performed in experimental and commercial units, using trout and Atlantic salmon as principle species. Tank diameter varied between 1 m and 3.5 m using water depth between 0.5 m and 1.3 m. Tanks were mainly installed indoors, receiving dailight at various levels of intensity. Fish size ranged from 10 to 12 cm (pre-smolts) for Atlantic salmon, and 8-12 cm to 15-17 cm for rainbow trout. Since most of the video recording were performed at commercial units, the stocking densities could not be controlled and varied drastically between tanks according to the operational situation at the farm. Video pictures were not primarily taken for the purpose of this demonstration film but mainly undertaken to study quantitatively the changes in fish distribution and fish behaviour over a 24 hour cycle and under a given set of environmental circumstances. Therefore, no special arrangements were made (e.g. no additional illumination, no movement of the camera the day prior to and during the recordings) to optimize filming conditions. Fish behaviour was usually recorded in 15 minutes intervall for a period of 15 to 30 seconds. Because of the limited height of the buildings in which tanks were installed, and the limited focal distance of the camera, a restricted tank area could be selected (usually oposite to the inflow) for regular behaviour recordings in larger tanks.

Film demonstrations

The film makes extensive use of graphic presentations to visualize the underlying mixing characteristics and water quality variations exerted by the action of fish and the various design criteria of the tanks in use. The documentations of the interactions between fish behaviour and operational conditions focus on three major aspects: (1) Routine daily occurrences, (2) tank hydrodynamics, and (3) special handling procedures.

Interaction between water flow rates and water quality at high stocking densities

Most circular tank systems operate at a constant rate of water exchange, usually set to meet the oxygen demand of the fish at peak consumption periods. If this demand cannot be met, a commonly held belief is that raising the water flow rate will accomplish this; but the higher flow rate can create a stronger current so that fish must swim harder and consume more oxygen, at least partly canceling any benefit.

Farmers often respond by directing the inflow slightly against the tank wall, reducing the current. It is shown that this also lowers the uniform exchange of water. At the center of the tank, where exchange is normally poorest, a vortex low in oxygen grows larger. Fish tend to crowd to the outside, creating a localized stocking density far higher than calculated for the tank, and just after feeding, when oxygen demand outstrips the supply, the fish may be temporarily in difficulty.

The introduction of pure oxygen to raise the oxygen concentration in the inflow will deliviate this problem and will allow to reduce the flow rate and support better fish distribution in the tank. However, a back-up system must be installed since a breakdown of the main system will quickly lead to the loss of all fish. Reduced flow rates lower also the water exchange and there will be a buildup of metabolic end products excreted by the fish, limiting the utility of this method. The effects of additional aeration to minimize carbon dioxide builtup and to cope with gas supersaturation and with the accumulation of suspended solids and metabolites are also demonstrated. The application of new technologies must consider how they interact with the fish,if negative side effects should be avoided. At high stocking densities, even small individual changes in metabolic activity will collectively have a large impact.

Operational conditions influencing fish behaviour and water quality

Routine daily occurences

The film describes three routine daily occurences that influence tank performance: (1) The day and night cycle, (2) feeding and excretory activity, and (3) random external disturbances. It is shown how these events affect fish behaviour, metabolism, and water quality. The extent of changes in daily oxygen consumption and metabolite excretion is demonstrated over a 24 h period, showing the elevated behavioural activity when tanks are illuminated at night. Further, the different amplitudes and frequencies for oxygen and metabolite concentration are demonstrated, requiring frequent adjustments in water exchange at high stocking density. Disturbances around the tank also effect fish behaviour, metabolism and water quality. Even small movements of personell or vibrations will trigger panic or elevated swimming activity, raising oxagen consumption and stress levels. Examples are shown for small and medium sized tanks.

Tank hydrodynamics

In this section of the film tank hydrodynamics are described as additional sources of potential water quality problems in intensive fish culture using circular tanks. The effects of the following factors are demonstrated: (1) Current speed, (2) Inflow and drain design, and (3) water flow rates.

Different current speeds in different sections of the tank have drastic effects on fish distribution, swimming activity and hyrarchic structure of the school. At very high current speeds, fish may drift backwards at certain time of the day, not being able (or willing) to maintain there position within a school by forced swimming. The examples show that regulating water flow patterns must be done with great care to prevent the added stress and wasted energy caused by abrupt shifts in schooling formation.

Many problems with current speed, water exchange and flow rates are influenced by the design of the inflow and the drain. Examples are shown for "point source"-inflow (the most common used inflow arrangement for circular fish tanks) and "spray-bar" water supply. The point source inlet produces a single jet that disperses as a sharply defined tongue, stimulating the fish to crowd together in a zone of preferred current speed. This behaviour has further adverse effects on circulation because the swimming activity also generates turbulence which reduces mixing, and channels already depleted water back to the fish. Replacing the point source inflow with a spray bar is a possible way to control problems related to current speed and water exchange, dispersing the inflow more uniformely over a larger surface area. A properly designed central drain pipe will also help direct the flow and improve circulation and fish distribution. The film provides examples how the rate of flow also influences the distribution of fish and the mixing and exchange of water masses.

Special handling procedures

Special handling procedures, which are not required on a daily basis can be considered as another variable that influence water quality over quite some time during the culture period. Examples provided look specifically on the late transfer of growing fish to larger tanks and on the altered behaviour of fish during the adaptation to higher salinity.

Growing fish often remain in a small tank for too long because larger ones are still in use. Usually, feeding is cut back to lower metabolic activity and satisfy waster quality requirements. After transfer to a larger tank, the temptation is to resume normal feeding right away to make up for lost growth as soon as possible, but this is often a mistake. A majority of the fish will still be so habituated ti their previous confinement that they continue to form a tight schooling pattern which reflects the dimensions of the former tank. The localized stocking density will be in excess of what the tank can handle - especially after feeding. Even days after the fish seem to have adapted to their larger tank, feeding can retrigger the previous behaviour pattern for hours.

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