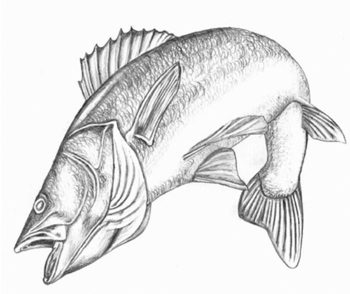

ISU FISHERIES EXTENSION

Managing Iowa Fisheries

Intensive Aquaculture Systems

Background

As aquaculture (fish farming) has expanded into regions of the United States beyond the trout and salmon cultures in the Northwest and the catfish cultures in the Southeast, interest has increased in this form of agriculture as a way to diversify farm operations. In the Midwest interest has emerged (in addition to the interest in pond culture) in converting abandoned agricultural buildings into intensive (recirculating) aquaculture systems. This bulletin provides potential aquaculturists with information to help them objectively study the feasibility of incorporating intensive aquaculture into their farming enterprises.

The advantages of intensive recirculating systems are:

- less water required than for flow-through systems,
- less land required than for ponds,
- water quality control,
- water temperature control, and
- lower harvest costs than for ponds.

The disadvantages of intensive recirculating systems are:

- capital intensive-high costs for development and backup electrical generators,
- heating costs,
- electrical costs for pumping,
- labor costs associated with maintenance,
- construction costs,
- variable design criteria,
- lack of established profitable operations,
- high production and overhead costs, and
- complex technology, which requires a high level of management skill.

History of Intensive Aquaculture

Intensive aquaculture has been tried and abandoned several times since the late 1960s. The Marine Protein Corporation facility at Mammoth Spring, Arkansas (an integrated trout operation using silos) operated from 1973 to 1976. By the time this company sold out, it had invested $3 million. This operation did not use recirculation; instead, water passed (once) through the system. The major limitation to this system was the high nitrogen levels (110% to 138% saturation) in the water supply that caused stress-related diseases such as Columnaris, a bacterial infection.

One of the early completely closed systems was King James Shrimp, Inc. of Park Forest South, Illinois. This company operated from 1980 to 1983. The company's researchers felt that energy cost did not limit them; instead they were limited by the disposal of organics resulting from the system, e.g., feed and fecal wastes.

Companies fail in intensive aquaculture systems for several reasons. Such companies may lack the following attributes:

- an adequate knowledge of intensive aquaculture,
- an understanding of the basic sales operating costs dynamics needed to make a profit,
- established sound market plans, and
- realistic expectations of product profits.

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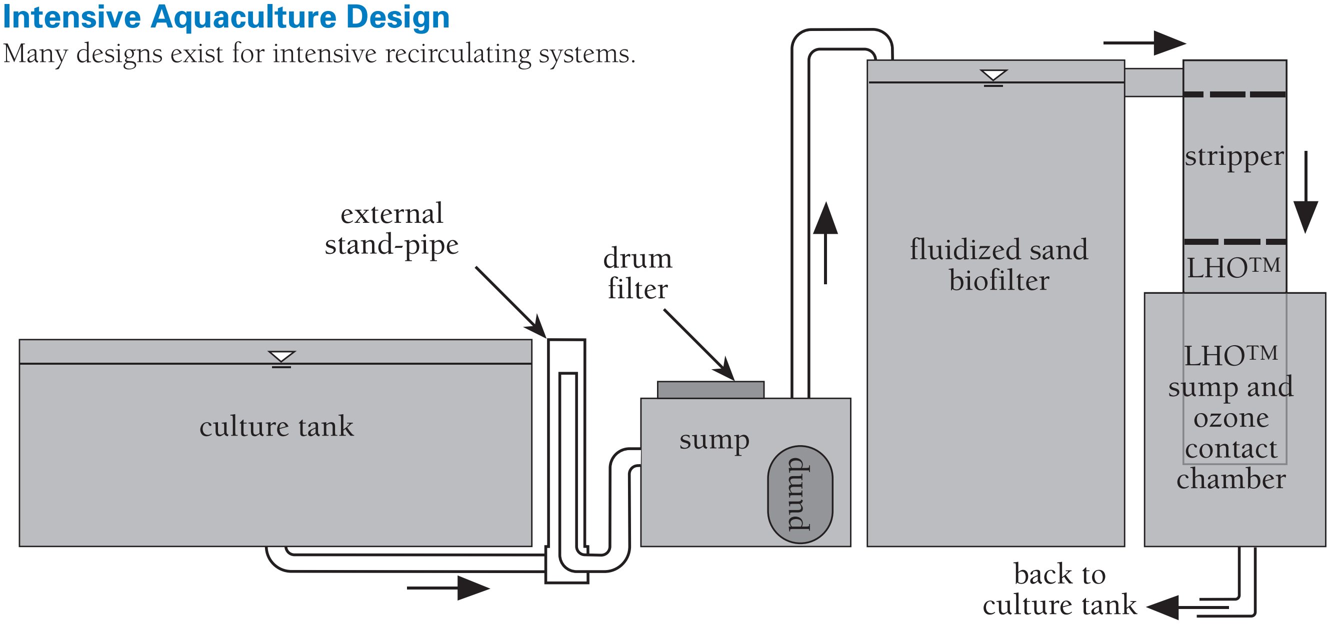
Intensive Aquaculture Design

Many designs exist for intensive recirculating systems.



Regardless of design, recirculating systems must include tanks, clarifiers, biological filtration, aeration, adequate recirculation efficiency, and temperature control. Designs range from simple systems using an aquarium filter to larger systems using integrated components. As intensive systems have evolved, designs often have changed, but the principles remain the same.

Tanks

Tanks may be concrete, painted plywood, or fiberglass; and their shape may be square or round. Concrete tanks are relatively cheap but immobile, and therefore inflexible to modification and design. In contrast, fiberglass tanks are easily moved but may be more expensive. Square tanks are space efficient but water moves through in a "plug flow" fashion. Round tanks are not space efficient and are harder to harvest, but they can be self-cleaning. Regardless of construction or shape, producers should consider ease of cleaning, smooth walls, access, and costs.

Clarifiers

Clarifiers need to be designed to eliminate solid wastes (typically fish feces and uneaten food) often called particulate wastes. These wastes may account for up to 70% of the nitrogen load in the system. If these wastes enter the biofilters, they may clog the biofilter, decreasing water flow or the dissolved oxygen levels; or they may allow the growth of heterotrophic bacteria, which produce ammonia while breaking down the wastes. (Heterotrophic bacteria require complex compounds of nitrogen and carbon for their metabolism.) The design of clarifiers should allow daily removal of solid wastes, which decreases both the input of nitrogenous compounds to the biofilter and reduces the possibility that the oxygen level in the biofilter will be exhausted.

There are many ways to remove solid wastes. To date, no single design efficiently removes and concentrates the wastes while using a minimal amount of energy. Early methods used settling basins or sand filters. But settling basins need to be large to be effective/ and sand filters are costly to purchase and operate. Recent developments in clarifiers involve new settling basin and filter designs.

Biofilters

Biofilters often are considered the heart of the intensive system. This component first oxidizes the potentially dangerous ammonia in the system (NH3-ammonia) to nitrites (NO2-nitrite) and then to nitrates (NO3-nitrate) using chemotrophic bacteria. Nitrates are relatively safe forms of nitrogenous compounds. These bacteria {Nitrosomonas arid Nitrobacter) require adequate oxygen, temperature, and pH levels.

Nitrosomonas Nitrobacter NH_3-->NO_2 ->NO_3

If Nitrobacter are not present [due to pH, dissolved oxygen (DO), or temperature extremes] nitrites may accumulate. As a result, "Brown Blood" disease may appear, in which the fish's blood hemoglobin does not efficiently transport oxygen to the tissues. The result of this disease may be stress-related diseases or death.

The biofilter must not clog with waste. So, frequent backwashing is essential for efficient operations. The biofilter's effectiveness depends upon water-flow rate, waste load, surface area, void space, DO, and temperature. Filter and operational costs (amount of temperature maintenance) are associated costs. Biofilters should be developed specifically for aquaculture. (The biofilters designed for municipal sewage treatment are not designed to reduce ammonia levels to the lower concentrations required by aquaculture.)

The size of the biofilter depends upon the amount of ammonia added to the system. Ammonia production is closely related to the feeding rate and the animal's efficiency of food usage. Food usage, then, depends upon fish size, food quality, temperature, fish activity level, and feeding rate. In general terms, 100 lb. of feed will produce 1 to 3 lb. of ammonia. One thousand pounds of fish, fed 30 lb. (3% of body weight fed daily), would yield 0.3 to 0.9 lb. of ammonia daily.

The quantity of bacteria available to oxidize ammonia is limited by the biofilter medium (stones, carbon, disks, etc.). Conversion efficiency depends upon the mixing action to bring water in contact with bacteria, dissolved oxygen level, pH, and temperature. In warm-water fish culture systems, nitrification will occur at a rate of 0.00037 to 0.00074 lb. / sq. yd. / day (200 to 400 mg. of ammonia per square meter of biofilter surface per day). Thus, to oxidize 0.90 lb. of ammonia, a biofilter with 2,450 sq. yd. of surface area would be required (1.52 acres). So it is important to get the most surface area per volume. However, the smaller the particles (high surface area per volume ratio), the greater the chance for filter clogging. From an engineering viewpoint, the dilemma is to find a suitable small-sized medium that still allows for adequate water flow.

Aeration

This component may encompass mechanical aerators in simple systems or oxygen injection devices (pure oxygen being placed into the tanks) in complex systems. The amount of aeration needed is determined by the size, density, and loading rates of fish in the systems; operational temperatures (higher temperatures result in lower dissolved oxygen levels); and feeding rates (increased feeding rates require increased DO levels). If the systems are designed for high levels of fish production (approximately 0.7 lb./gal.) the need for oxygen injection systems becomes evident. Costs of oxygen injection can add as much as 25 cents per pound of fillet.

Recirculation Efficiency

Recirculation efficiency is the percentage of total system water volume that must be added daily as makeup water. New water is needed to compensate for evaporation, backwashing the filters (biofilter, clarifiers, etc.), and splash. No design operates at complete efficiency. Most designs will operate in the 90 to 95% efficiency range. The amount of water used in the makeup is not as important as is the cost of heating the make-up water and the loss of the heat in the exchanged water.

It is imperative that water quality parameters such as pH, alkalinity, and carbon dioxide be maintained at optimal levels for fish survival and growth. Fish grown in intensive systems require the same levels of water quality as do pond-raised fish. For further information regarding water quality, consult Iowa State University Extension publication PM 1352A, Managing Iowa Fisheries – Water Quality.

Additional Considerations

Other points to consider are:

- the type of pumping systems,
- foam (highly efficient recirculating systems often have high levels of foam),
- feeding system,
- lighting sequence,
- holding vats for fish destined for market,
- reservoirs of water suitable for aquaculture (suitable water is not always available),
- emergency backup electrical systems,
- waste management,
- harvest and transport capabilities,
- processing and marketing,
- fingerling availability, and
- technology of the system itself.

Last, but certainly not least, is the need for true economic modeling before large financial investments. No single design for a recirculating system may be used in all situations. Each system must be designed with the individual site in mind. Consultants are available (for a fee) to design such systems.

Conclusions

The purpose of this fact sheet is not to discourage interest in recirculating systems. Many people are excited about the future of these systems. As with any agriculture venture, intensive aquaculture should not be undertaken without much forethought. For the best chance of success, consider a variety of designs and advice before making the investment. In addition, it is best to work with a fish of high market value and an unmet demand. There is no single sure plan that individuals can obtain to convert an abandoned agricultural building to a profitable fish farming operation.

Keep in mind that many of the intensive aquaculture systems are based on experimental concepts. It is hard to make a profit while doing research. Researchers hope to provide more information that addresses many of the basic questions about this form of aquaculture.

Acknowledgments

Some of the preceding information was obtained from Tetzlaff and Heidinger, 1990, *Basic Principles of Biofiltration and System Design*, Southern Illinois University Cooperative (SlUC) Fisheries Bulletin No. 9.

Figure from Summerfelt, S.T. "Engineering design of a water reuse system," in *Walleye Culture Manual,* ed. R. C. Summerfelt (North Central Regional Aquaculture Center Publications Office, Iowa State University, Ames, 1996), NCRAC Culture Series 101, 277-309.

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