North Central Regional Aquaculture Center

Fact Sheet Series

Conversion of Confined Animal Production Facilities and Other Unused Agriculture Buildings for Fish Culture

Introduction

Tank culture offers an alternative to traditional pond aquaculture and can be used in indoor facilities such as unused barns or other buildings. Tank culture systems are examples of recirculating aquaculture systems (RAS). For example, equipment or structures already in place in a former hog operation can be converted for use as a RAS. By retrofitting equipment and reusing water, a RAS can be developed to produce fish in a cost-effective manner. The conversion can require a significant investment, however, so before beginning it is important to gather as much research-based information as possible and to learn about fish culture, water quality, marketing, and other aspects of aquaculture.

Next, develop plans for the enterprise and identify potential markets for the product. Many factors affect the ability to produce fish cost-effectively, including component capital costs, operating costs, and efficient management of the fish culture system, so doing research will help the producer make informed decisions.

Several fish species can be produced in the Midwest using a RAS. Potential warm water fish include sunfish, sunfish hybrids, hybrid striped bass, largemouth bass, and channel catfish. Trout can be raised in cold water where abundant spring water or cold well water is available.

This guide provides basic information on RAS technology and important considerations for converting an unused facility into an aquaculture enterprise (Figure 1). Brief descriptions of the technical aspects of tank culture, component design, and system performance are provided, as well as water quality considerations. The set-up costs may be expensive, so thorough planning of the conversion and operation is critical for successful, profitable production.

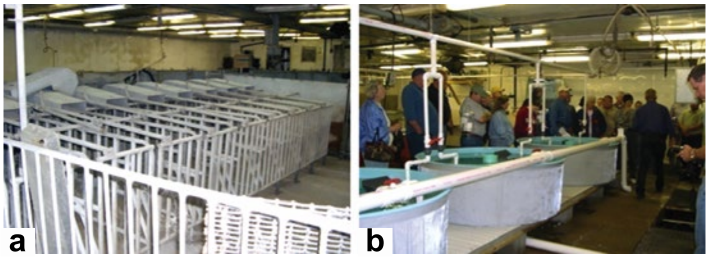

Figure 1. This unused swine barn (a) was converted into an active aquaculture facility (b).

Recirculating aquaculture systems (RAS)

Recirculating system technology enables fish farmers to raise a uniform product while greatly reducing the amount of water used by treating and reusing water. A recirculation system also allows fish to be concentrated in a small space, greatly reducing the labor for handling, harvesting, and processing. Recirculating systems that use tanks for production are ideal for indoor facilities. Like an aquarium, a RAS circulates water to the tank with a pump, and then filters the water and recirculates it back to the tank. A minimal amount of water is replaced during the circulation process, and this amount is controlled by the water input setting. Most of the water is recirculated several times before being discharged.

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A RAS consists of containers to hold the fish (tanks), aerators or air blowers to oxygenate the water, devices to remove solids, biological filters (biofilters) to remove debris and fish wastes, pumps to move the water, and miscellaneous plumbing equipment. Each of these components is described in more detail in the sections below.

Equipment and design features of the unused production facility can be converted into RAS components. For example, the flush tank in a swine facility can be used as the biofilter, the rack structures and tender foot material can be used to support the fish tanks, and the waste pit can be used to remove sediment, which can be flushed through the pit into the existing lagoon that was used for waste in the animal operation. New components to be added include tanks, valves and piping, a pump and a blower, or aeration devices. Other types of unused buildings may also have features that could allow for conversion to fish production. More detailed descriptions of the various components within a RAS are provided in a later section of this guide.

Introduction to fish production

In addition to learning about the components of a RAS, the producer will need to understand other facets of fish production such as:

- Aquaculture and fish culture basics
- Managing water quality and feeding
- Maintaining healthy fish
- Selecting potential fish species
- Assessing the facility, equipment, and water supply
- Establishing a product market
- Creating a budget

These facets of aquaculture production are briefly described below and discussed in more depth in the literature found in the Resources section.

Aquaculture and fish culture basics

To succeed in aquaculture production, a producer must thoroughly understand water chemistry and the biology of the aquatic species being considered. Proper water chemistry and biology interact to create an aquaculture system in which healthy fish will grow in a time interval that will ensure a profit. Fish culture systems are dynamic – a change in one component, such as a water quality parameter, will cause changes in another – and understanding these dynamics is essential for successful fish farming.

Water quality and supply

Water demands in a RAS are not as great as in a flow-through system; however, the source of the water is important. Most farm facilities that have been used for concentrated animal production have a dedicated water system. Many have a well for the water supply and wells are considered one of the best water sources for aquaculture. Regardless of the source, a complete analysis of the water supply should be conducted by a reliable laboratory.

The amount of water needed depends on the size of the system. In any size RAS, a 2-5% daily exchange of new water is expected. The water supply must also be large enough to fill fish transportation tanks within a reasonable time

A producer with a RAS must be an effective water quality manager and have a thorough understanding of water chemistry. Maintaining good water quality is essential because poor water quality can reduce growth rates, cause disease, stress the fish, and force the filter system and other RAS components to be inefficient.

Any water used for a RAS should be thoroughly checked for quality and suitability for producing all potential species of fish planned for the system. Table 1 provides a list of water quality parameters and the general range for their desired concentrations for optimal fish production.

Two water quality parameters to be mindful of are total alkalinity and the presence of chlorine, chloramine, or other substances used to remove organisms for potable water. Alkalinity is an important parameter and should always be above 20 parts per million (ppm) or milligrams per liter (mg/l). Alkalinity is defined as the sum total of titratable bases, but in more common terms alkalinity is important for stabilizing pH and is extremely important to the well-being of fish. Levels in the range of 100-200 mg/l are not uncommon for water supplies originating in limestone or dolomitic rock formations. Alkalinities in the higher range are actually a benefit to the production of fish in RAS conditions.

Different species of fish have different water requirements. Therefore, it is important to know the specific water requirements for the species being considered. Fish species have tolerances for varying levels of these water quality parameters (Table 1):

- Dissolved oxygen
- Ammonia
- Nitrite
- Nitrate
- pH (degree of acidity)
- Alkalinity (a measure of calcium and magnesium carbonate content)
- Hardness

In addition, water velocity (flow rate), fish loading (the weight of fish per rate of water flow – pounds per gallon per minute), density (the weight of fish per volume of water), feeding rate, and turnover directly influence water quality. All of these parameters should be monitored and recorded regularly.

In a RAS, the filtering system removes suspended solids when recycling the water. Solids that settle on the bottom are removed by siphoning. A rotating drum filter or other type of filter system may be used to remove suspended solids (Figure 2). Dissolved solids are diluted with the addition of fresh water and are biochemically broken down into harmless products by a biofilter (Figure 3).

As with other livestock operations, the management of waste products is a significant cost. With fish, both solid and soluble wastes must be considered. Uneaten feed will eventually decompose within the system and produce additional ammonia, which can be toxic to fish.

Table 1. Table of water quality parameters (Boyd 1998).

Element	Form in Water	Desired concentration
Oxygen	Molecular Oxygen (O_2)	5 - 15 mg/l
Hydrogen	H^* [-log(H^*) = pH]	pH 7 - 9
Nitrogen	Molecular Nitrogen (N_2) Ammonium (NH_4^*) Ammonia (NH_3) Nitrate (NO_3^*) Nitrite (NO_2^*)	Saturation or less 0.2 - 2 mg/l < 0.1 mg/l 0.2 - 10 mg/l < 0.3 mg/l
Sulfur	Hydrogen Sulfide (H_2S) - Rotten egg gas Sulfate (NO_4^*)	Not detecable 5 - 100 mg/l
Carbon	Carbon Dioxide (CO_2)	1 - 10 mg/l
Calcium	Calcium Ion (Ca^{2*})	5 - 100 mg/l
Magnesium	Magnesium Ion (Mg^{2*})	5 - 100 mg/l
Sodium	Sodium Ion (Na^*)	2 - 100 mg/l
Potassium	Potassium Ion (K^*)	1 - 10 mg/l
Bicarbonate	Bicarbonate Ion (HCO_3^*)	50 - 300 mg/l

Figure 2. Photo of a Drum filter in a RAS.

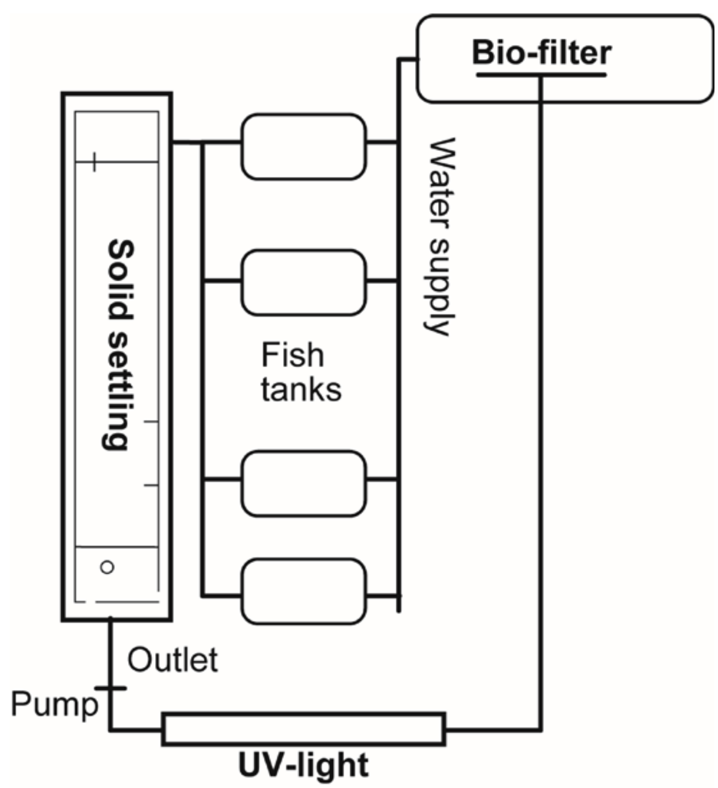


Figure 3. Sketch of a proposed layout that describes the equipment and components that will be needed. The biofilter is the center of a RAS and removes dissolved toxic ammonia from the system.

Cost-effective water treatment components are available that efficiently remove waste solids, oxidize ammonia and nitrite-nitrogen, remove carbon dioxide, and oxygenate the water before returning it for reuse. Success or failure of these systems is directly related to water management strategies. Investing in a water quality sampling kit is highly recommended. These kits are easy to use and produce reliable results. Record each parameter daily and watch for changes, which is the first sign that the water needs to be adjusted

Feed

Feed is often the biggest cost in producing fish. Therefore, to realize a profit, a producer should feed only the amount necessary for the species to achieve maximum growth as quickly as possible for the market being considered. Fish can be fed by hand or with automatic feeders adjusted to provide the appropriate rate of feed on a timely basis.

Knowing the size and weight of fish in the system allows the producer to calculate the amount of feed needed at any given time during production. This ratio has been determined for most commercial species of fish and is typically a feeding rate of 3% of body weight. The producer can calculate the amount to feed in four steps:

1. Weigh and measure a representative sample of fish.
2. Average their weights (sum of weights divided by total number of fish weighed).
3. Multiply the average weight by the number of fish in the system.
4. Multiply the result by 0.03.

Feed must be fresh and stored in a dry place to prevent mold. Fish growth depends not only on the water quality parameters discussed in the previous section, but also on a high-quality diet provided at the appropriate rate that prevents waste. Over-feeding can result in poor water quality, stressed fish, disease, and increased mortality.

Fish health

Monitoring the health of the fish is critical to prevent a disease outbreak. Many pathogens are frequently found with fish and do not cause problems – unless the fish are stressed. Know your fish. Fish behaving differently or going off feed is a warning. Record any mortality daily.

Losing a few fish daily is a sign of a chronic problem; losing a greatly increasing number daily is a sign of higher mortalities and an uncontrollable loss of fish. Disease can be prevented by having a biosecurity plan that helps the producer take corrective action to reduce the cause of mortality and identify the steps to take to maintain a healthy environment for the fish. Refer to United States Department of Agriculture (USDA) Southern Regional Aquaculture Center (SRAC) and North Central Regional Aquatic Center (NCRAC) Biosecurity in Aquaculture fact sheets for information on developing a biosecurity plan (SRAC 4708 and NCRAC FS115). Also, having a working relationship with a trained fish health specialist or veterinarian that has experience in aquaculture is extremely important because very few medicines have been approved to treat fish diseases.

Selecting potential fish species

Several species of fish have the potential to be produced in a RAS. Fish species that are commonly produced in these systems include sunfish, including crappie and bluegill; largemouth bass; hybrid striped bass; yellow perch; and tilapia. Many states within the Midwest may have restrictions on the types of fish that are allowed to be commercially produced. For instance, sunfish and black bass are native to Missouri and are included on the Missouri Department of Conservation's approved aquatic species list (sos.mo.gov/adrules/csr/current/3csr/3c10-9.pdf). However, raising tilapia or other non-native species requires special permission from the Conservation Department. To ensure regulatory compliance, refer to the Wildlife Code of Missouri (sos.mo.gov/adrules/csr/current/3csr/3csr.asp). Other states may have similar requirements so it is extremely important to check with the appropriate fish and wildlife agency that develops and oversees regulations for fish production.

In Missouri and in the Midwest, bluegill and hybrid striped bass are excellent species for production in a RAS. These species grow well at water temperatures that can be normally maintained without heating the water, depending on the facility design. These species have the growth potential and consumer demand to be marketed as a food fish or they can be sold at smaller sizes for pond stocking and for other products. Both species will grow well in water maintained at 70-78°F. Crappie, although more difficult to feed-train, can be grown at lower temperatures of 60-65°F.

Assessing the facility

Below is a list of the minimum requirements for retrofitting an unused swine facility or other potential building for aquaculture production. When reviewing the list, determine what existing equipment in the facility can be used or easily adapted for use.

• Reliable supply of high-quality water. Well water is preferred. If district water is used, residual chlorine must be removed by using a charcoal filter or sodium bisulfate drip.

• Large sediment pit that empties into a lagoon. The sediment pit is used for the removal of solids, fish, excess feed, or other suitable suspended solids.

• Flush tanks. Flush tanks can be used as biofilters (Figure 4a).

• Rack systems. The racks can be used to support the fish-rearing tanks (Figure 4b).

• Reliable electrical supply and backup generator that can be operated from a tractor power takeoff. An LP or natural gas-powered generator with an automatic switching system is the most reliable.

• Telephone alarm system. An alarm system for notifying the operator of pump, blower, or other electrical supply problem is desirable.

Establishing a product market

Identifying potential markets should be the first step taken prior to making a substantial investment in the RAS. It is very important to determine who will buy the fish and in what form they want their product. The final product could be live fish of various sizes, dressed fish, filleted fish, or fish steaks (Figure 5).

Producers selling fish for food markets and human consumption must comply with local and federal food safety and processing regulations. The Food and Drug Administration's (FDA) Fish and Fishery Products Hazards and Controls Guidance provides information about the regulatory requirements for processing seafood for human consumption.

The FDA also requires the development and implementation of a hazard analysis and critical control point (HACCP) plan. A HACCP guide and training can be found online at seafoodhaccp.cornell.edu/the-seafood-haccp-alliance-internet-training-program/. The guide provides information that can help in the development of a HACCP plan and provides additional guidance on complying with FDA regulations. Producers are strongly encouraged to review relevant documents and take HACCP training.

Producers can also sell products directly to restaurants, at farmers markets, or to seafood distributors. Determine where the fish will be sold, and check the local health department regulations. Then, determine how many fish will be sold on each date and ensure that demand is met.

The producer must also determine how the product will get to market. Live fish need to be hauled in aerated water, and processed fish need to be kept cold at the proper temperature.

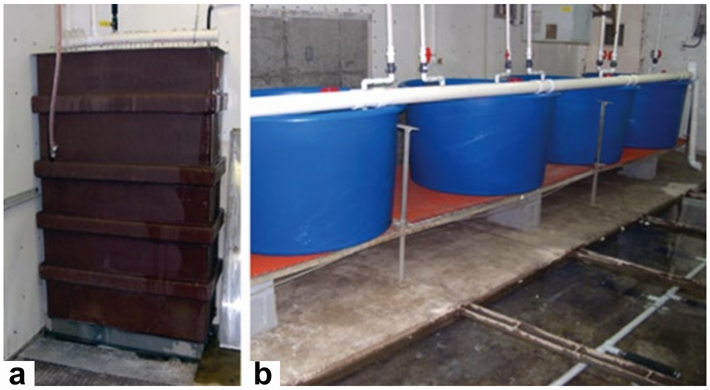


Figure 4. Existing equipment may be retrofitted for aquaculture production: (a) Flush tanks can be converted to biofilters, and (b) racks can be used to support fish-rearing tanks.

Figure 5. Before investing in the conversion of your unused barn, establish a market for your product — identify who will buy your fish and in what form, whether live, filleted, dressed or as steaks.

Creating a budget

Creating a budget will help determine if a proposed aquaculture enterprise is likely to be profitable and to estimate the market value of the proposed product. By skipping this step, the producer risks producing an unmarketable product.

Sketch a proposed layout to help determine what equipment is needed for the conversion (Figure 3). Then list the current prices for the equipment and for the fish, utilities, labor, and other costs. Use realistic numbers when creating a budget.

The example budget in Table 2 is for a system producing 40,000 to 80,000 pounds of fish annually (80,000 gallon system). Smaller systems would have a higher initial capital cost per pound of production. The building cost/lb is provided in terms of the cost of a new building. This value would be less if the building were older with initial building cost "retired." A major advantage of retrofitting an older building is the reduction in initial capital investment. Costs are given in terms of fish cultured at lower density and fed a higher protein feed (such as bass) as opposed to a fish cultured at higher density and fed a lower protein feed (such as tilapia). In both cases, the food conversion ratio is assumed as 1.5/1, and fish survival is assumed at 85% of stocked number.

Table 2: Sample Budget; Medium/High Density System Cost ($/lb).

Density	Medium	High
Fixed Costs		
Building	0.23	0.12
Climate Control	0.11	0.06
Tanks	0.18	0.09
Aeration	0.08	0.08
Biofilter	0.07	0.07
Solid Filters	0.06	0.06
Generator	0.04	0.04
Pumps	0.01	0.01
Total Fixed Costs	**0.78**	**0.53**
Variable cost		
Fish	0.78	0.78
Feed	1.50	0.96
Energy	0.50	0.36
Labor	0.64	0.64
Total Variable Cost	**3.42**	**2.74**
Total Cost	**4.20**	**3.27**

The costs in this sample budget are illustrative only. Enter current costs when creating a budget for your operation.

Components of a RAS

A RAS consists of several components that are crucial for successful production of fish. The following is a general description of these components and how they function.

Biofilter

The biofilter is a container that holds the media (described in more detail in the next section) in which beneficial nitrifying bacteria live and through which water flows. The biofilter supports nitrification, the process through which ammonia is converted to nitrates. Ammonia is produced as waste from fish metabolism and is the primary dissolved waste in a recirculating system. Ammonia is very toxic to fish and must be removed from the water, which is essentially what the nitrifying bacteria do.

There are two types of nitrifying bacteria: *Nitrosomonas* and *Nitrobacter*. Together, they remove ammonia from the water by converting it to a harmless substance. First, *Nitrosomonas* oxidizes the ammonia to nitrite, and then *Nitrobacter* converts the harmful nitrites to harmless nitrates. Nitrates at normal levels are nontoxic to fish.

The biofilter must be designed to hold enough biomass of bacteria to eliminate the production of ammonia. The capacity of the biofilter is determined by the surface area of media necessary to support the number of bacteria needed to remove ammonia from the water. The general assumption is that about 2.5% of feed becomes total ammonia nitrogen (TAN). Note, however, that pH and temperature affect the TAN. Basically, 1 cubic foot of media provides enough surface area to support the bacteria needed to convert ammonia from 1.0-1.4 pounds of feed per day per cubic foot of medium. Several types of media can be used in the biofilter. Most suppliers have technicians who can help determine the proper type and amount of media to use. In addition to commercially made products, sand, rock, and shells can be used as biofilter media.

The capacity of the biofilter limits the fish load (size and number of fish to put into a RAS), feeding rates and water flow rate. Once any of these three factors becomes more than the biofilter can handle, the system becomes overloaded and unhealthy for the fish. At this point, the water needs to be treated, diluted, siphoned or otherwise managed to maintain good water quality. Although not its primary function, the biofilter also degasses water and can aerate water if the filter is elevated and provides a drop for the outgoing water.

Biofilter media

The biofilter media is critical to the effectiveness of the biofilter and influences setup costs. Most media are rated by square feet of surface area per cubic foot of media. Material prices vary, and although their initial costs may be higher, materials with a high surface area per cubic foot will provide the best efficiency.

For example, flush tanks from a swine operation can be converted to a biofilter. The converted flush tank biofilters can contain a substrate called BioFill™ that is rated to have 250 square feet of surface per cubic foot of media, which is generally enough. The media is relatively inexpensive but has some properties that are not as beneficial as other material. In general, the higher the surface area the better, but materials become more expensive and may not be cost-effective to use.

When starting a new biofilter, allow time for the bacteria to build up to a sufficient quantity to handle a full load of fish. Stock only a few fish in the tank while starting the biofilter, then gradually increase fish stocking as bacteria mass and capability increases. Most systems take 45-60 days to become fully operational. Often a biofilter can be made ready to handle a full fish load more quickly with the addition of a specially prepared bacteria culture, which is available from most aquaculture supply companies.

Biofilter capacity design and fish loading

A Fish loading, or the amount of fish produced, depends on the biofilter capacity, as well as water flow, tank size, and feeding rate. The ideal capacity or size of the biofilter is determined by the amount of feed fed daily. For example, assume a tank can support no more than half a pound of near-market-size fish per gallon and that the fish are receiving about 2% of their body weight in feed per day. The maximum load of a 100-gallon tank would be 50 pounds of fish fed 1 pound of feed per day producing about 0.225 pounds of TAN, requiring 1 cubic foot of media (50 pounds × 0.02 = 1 pound). The design criterion has shown the capacity of feed in the tank is one pound per day, so the amount of media needed is 1 cubic foot. Assuming that smaller fish in the tank are fed at twice the rate of the larger fish, the capacity is reduced by half (25 pounds of 4-inch fish fed measured at 4% of their body weight daily would require 1 pound of feed: 25 pounds × 0.04 = 1 pound).

Aeration

Because fish and decomposing organic materials both use oxygen, the water in the system must be aerated. An aeration system consists of blowers, which produce the air, and aeration devices, which diffuse the air into the water and determine the efficiency of the oxygen transfer. The aerators also create water movement, or flow, to allow removal of suspended solids.

Highly efficient regenerative blowers can provide the oxygen needed for aeration. These high-volume, low-pressure blowers provide dissolved oxygen for fish survival and metabolism, and provide oxygen to the biofilters for the nitrification process. Regenerative blowers come in many sizes, so be sure to choose the appropriate size for each system.

The tanks are aerated by simple manifold aerators (Figure 6). A manifold aerator releases dissolved oxygen on one side so that it is deflected into the water to create a directional flow. The circular flow deposits most of the waste matter in the center where it can more easily be removed. Some of the wastes will go out the central drain. Solids should be removed quickly to prevent an adverse effect on water quality. When solid wastes accumulate, the organic matter begins to decompose, which uses dissolved oxygen.

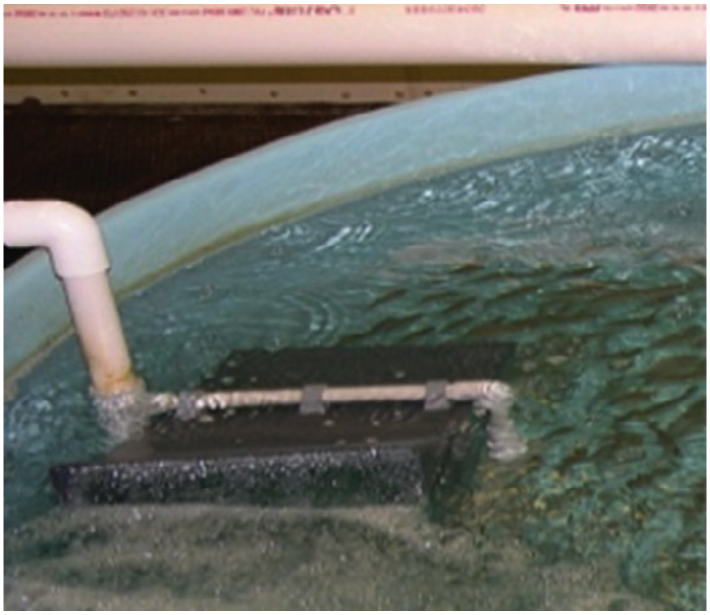


Figure 6. Manifold aerators not only provide oxygen but also create a circular flow that aids in waste removal.

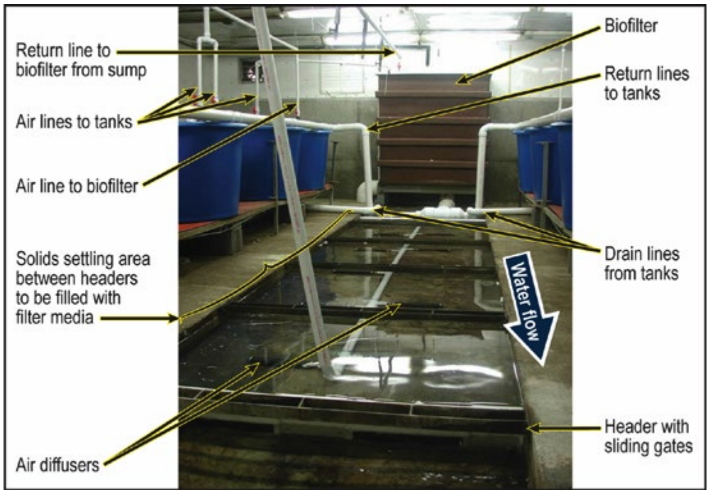


Figure 7. This typical conversion shows select components and water and air flow.

Figure 8. A valve (orange-colored) leads to the water inlet pipe that is submerged in each tank.

Water Flow

The water flow rate directly influences water quality. The flow rate depends on the total volume of water in the tanks, the replacement water coming in, and the capacity of the pumps to move the water. Think of the water as a fluid conveyor bringing in dissolved oxygen and removing harmful wastes. The conveyor must move fast enough to supply enough dissolved oxygen for fish survival and growth and to remove dissolved and solid wastes.

Water flow rate can be measured by collecting the water coming into the tank in six seconds, multiplying the number of gallons collected by 10 to find the gallons per minute, and dividing the tank volume (gallons) by the gallons per minute. The result is the number of minutes it will take to replace the water in the tank. water flow rate = tank volume ÷ (gallons in 6 seconds × 10)

The best management practice is to replace the total water volume every 30 minutes. This replacement is referred to as the water turnover

Plumbing

The fish tank water flows from the biofilter through PVC pipe that is supported by the fish tanks (Figure 7). Because this pipe has no drop, it must have a diameter large enough to prevent any reduction in water flow. Each tank has a corresponding valve (orange colored) and a vertical inlet pipe that is submerged in the tank. Holes are drilled on one side of the inlet pipe and are distributed in the same direction as the shield on the aerator (Figure 8).

The direction of the flow enhances water movement and waste removal. The outlet pipe (PVC) from each tank is normally as large as the main supply line. If multiple tanks are drained into a common exit pipe, the pipe must be large enough to receive the total volume of the tanks when the drain is pulled. Pulling the drain is an easy way to remove wastes that have accumulated in the center of the tanks.

Waste Pit

A waste pit is used primarily for the settling and removal of solids (Figures 9 and 10). Water must be held in the pit for at least 20 minutes to settle most solids out of the system. Holding the water longer will enhance removal of solids to the point that the tanks will require less frequent flushing for cleaning.

A blocking device in the waste pit causes the water to pool and can increase the time water is held in the pit. Slats on the bottom of the blocking device direct most of the flow along the bottom of the pit. The slats need to be easy to remove for when the waste pit needs cleaning.

Air stones or other air-supply devices can enhance removal of settled waste material by re-suspending wastes before the slats are pulled. Air stones prevent further consumption of dissolved oxygen due to decomposition of organic material.

Finally, the best setup is to have a drain at the end of the waste pit that leads to a lagoon. To remove solids, simply pull the standpipe to the lagoon exit. To clean the pit, remove the slats and brush accumulated debris toward the standpipe. Then, pull the standpipe and the wastes will be transported out to the lagoon. Rotating drum filters or air-operated solids filters are often substituted for solids removal with existing waste pits.

Figures 9 and 10. This waste pit and solids settling configuration shows select components and the water and air flow. The waste pit allows solids to settle and be removed to the lagoon through a drain at the end of the pit.

Managing water quality in a RAS

As discussed in previous sections, water quality management is key to raising fish, especially in a RAS. Successfully raising fish in a RAS depends on understanding water chemistry and maintaining various water quality parameters at or above required minimum levels.

Although other water quality parameters are operating in a recycle system, the water quality parameters identified below are the most important and should be monitored and recorded daily. An inexpensive oxygen meter and a water quality test kit that measures these basic parameters are required tools for serious fish farmers. Knowing how to test the water with these tools and interpret the results is a must for aquaculture success. These meters and test kits are available from most aquaculture suppliers.

Oxygen - Fish require dissolved oxygen to live. Low oxygen stresses fish and limits their growth. The bacteria that convert soluble wastes to nontoxic forms also require oxygen. Oxygen levels below 5.0 ppm can stress fish and cause them to eat less and metabolize their food more slowly.

pH - pH is a measure of how acidic or basic water is. It is related to the balance of positive hydrogen ($H+$) and negative hydroxide ($OH-$) ions in the water. pH is especially important in recycling systems, where water tends to become more acidic. Fish use oxygen and give off carbon dioxide (CO_2) when they breathe. The CO_2 mixes with water to form a weak acid. In addition, the conversion of ammonia (NH_4^+) to nitrite (NO_2) and nitrate (NO_3) together with water forms acids. Over time recycle systems become more acidic, especially in waters that are not buffered well. Buffering protects the water from pH changes and has to do with the levels of calcium carbonate ($CaCO_3$) in the water, or the water's alkalinity. High alkalinity indicates a good buffering system. pH does not fluctuate widely in buffered waters. pH values between 7 and 8 are adequate in a RAS.

Alkalinity **-** As mentioned above, alkalinity is a measure of the calcium carbonate concentration in water. Water with alkalinity of 100 mg/l or above has good buffering capacity. Water from wells or other sources in limestone areas, such as Missouri, tend to have high alkalinity.

Ammonia **-** Two types of ammonia exist in an aquaculture system: ionized ammonium (NH_4^+) and un-ionized ammonia (NH_3). The un-ionized form is toxic and occurs in higher concentrations at higher pH. Fish species have varying tolerances to ammonia; however, in general, maintaining un-ionized ammonia levels below 0.03 ppm is best. Conversion tables are available from a variety of sources, including the SRAC water quality fact sheet Ammonia in Fish Ponds, that can give the un-ionized ammonia level if the producer knows the water's temperature and pH.

Additional facility requirements

Fish species have various water temperature requirements in which optimal growth occurs. Thus, the facility must have the capability to maintain the desired temperature for growth. In the Midwest, most facilities must have adequate insulation to prevent wide temperature fluctuations. In addition, facilities should be designed to provide the proper space required for the components that make up the RAS and for the efficient management of the facility. Condensation control is especially problematic in converted agriculture buildings in that moisture reaching into wall and ceiling spaces can erode structural components and limit effectiveness of the insulation. Although ventilation impacts heat loss it does help to control excessive humidity levels. For additional information please see NCRAC fact sheet 128, Buildings for Aquaculture Operations (https://store.extension.iastate.edu/product/15807).

Head space considerations

One issue that should be considered when attempting to adapt existing animal production facilities for aquaculture use is the available head space in the building. Many facilities typically offer limited head space, on the order of 8-10 ft. maximum. To insure maximum efficiency, aquaculture facilities typically require higher head space for operations such as:

1. Automated feed delivery
2. Mechanized fish or shrimp handling and harvesting
3. CO_2 degassing in packed columns
4. Submerged or trickle-flow biofilters

Each of these processes could be operated using once-pumped gravity-flow water if sufficient head space is available. If head space is not an option, the alternative is manual handling of feed and fish, and repetitive pumping of water to lower-profile treatment units.

For example, a 20,000 lb. per year fish culture operation would typically contain a minimum water volume of 30,000 gallons, and this water would need about 10 exchange cycles per day through water treatment operations, amounting to a pump rate of 208 gallons per minute (gpm). If this water flow is delivered to a head tank 18 ft. in elevation, the entire flow could be moved using a single 208 gpm centrifugal pump. Alternatively, if head space is unavailable, three pumps could be provided to independently deliver water to biofilters, solids separation tanks, and CO_2 stripping columns, requiring 624 gpm. At a total head loss of approximately 35 ft (lift + friction), pumping energy requirement would be 1.7 vs 5.1 kW requiring 14,892 vs 44,676 kWh per year. At 11 cents per kWh this amounts to $1,638 vs $4,914 per year in pumping energy costs or, $0.08 lb. per fish vs $ 0.25 lb. per fish. While the additional energy cost of re-pumping in a lower profile building is not necessarily cost prohibitive, the larger issue will likely be increased manual labor for feeding and harvesting of fish production in a lower head space building. This is not likely to be a major issue for smaller operations (10-20,000 lb. per year), but could become increasingly important in larger production facilities.

Openings and equipment considerations

Facilities must also provide large enough openings to allow access by vehicle or other means of loading or moving large quantities of fish. Normally, this requires an opening that will allow access by fish transport equipment. Minimum size should allow easy access of a 1-ton truck with a hauling tank installed on the truck.

All equipment must have FDA approved surfaces, paint, or gels. Walls and other surfaces should be covered with material that is moisture resistant. In any aquaculture facility, evaporation of water from open tanks will occur.

Adequate ventilation or an HVAC system will be necessary to remove moisture to protect equipment and prevent the facility from appearing as an indoor rainforest.

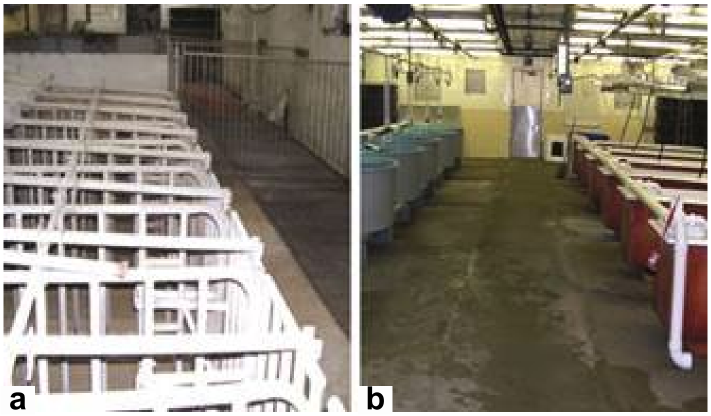
Most equipment can be adapted for 120 or 220 volt electricity. Some facilities will have single- or three-phase 440 volt electricity available. Facility operating costs will vary depending on size and types of equipment used for removing wastes and moving water. Use of 220 or 440 volt electricity can reduce operating costs because of lower amperage usage. All facilities must have methods for removal and treatment of solid wastes. Solid wastes may be treated in lagoon systems or other approved systems determined by individual state regulations.

Most facilities have concrete floors and they must be reinforced to handle the additional weight of tanks filled with water. Floors should also include drain systems that can adequately handle large volumes of water, especially if fish-rearing tanks are periodically drained to capture fish, or for cleaning. Figure 18 depicts a typical arrangement of an indoor facility with all components needed for production in a RAS.

Conclusion

As shown in Figure 11, existing animal production facilities and buildings can be converted to commercial aquaculture enterprises using the techniques described in this guide. However, raising and producing fish in a RAS requires skills and knowledge that differ from those needed in traditional livestock enterprises. As a new aquaculture producer, in addition to acquiring the needed skills and knowledge, you must develop marketing channels for the aquaculture products you plan to produce before you make any investment.

Also, start small. Make a minimum investment to gain initial skills in aquaculture, equipment maintenance, water quality management and aquaculture product marketing. Learn about fish culture and how to operate and manage a RAS. The skills and knowledge gained will enhance a producer's chances of success and potentially lead to a profitable enterprise. Profitability will ultimately depend on keeping costs low and successfully marketing the fish products.



Figures 11. Retrofitting an existing building such as a swine barn (a) for aquaculture production (b) can lead to a profitable enterprise.

Resources

Quality aquaculture information is available from the Southern Regional Aquaculture Center, http://srac.tamu.edu. The information is organized so that species descriptions, techniques, systems, and other data may be easily found. Most of these free fact sheets are compilations of many years of research. Some SRAC fact sheets specific to RASs are listed below.

Other fish farmers can be an excellent resource to new and experienced producers alike. Discussing issues and learning from the experiences of others can be a great help. A list of aquaculture sites and fish farmers is available from the Missouri Aquaculture Association at http://moaquaculture.org. Other state associations may provide similar contacts.

The Missouri Department of Agriculture's Aquaculture Program, http://mda.mo.gov/abd/aqua, offers helps and guidance on getting started, meeting state and federal regulations, and marketing. It also provides an online resource directory. Many other states offer similar programs and assistance.

The Missouri Department of Conservation's Wildlife Code (Title 3, Division 10 of the Missouri Code of State Regulations) (sos.mo.gov/adrules/csr/csr.asp), provides a list of approved aquatic species and regulations for their production in Missouri; similar listings are noted in the states in the North Central Region. Producers should always check for similar information in whatever state they plan to develop their business.

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