Classroom Size System Design and Components

Dennis P. DeLong
Extension Aquaculture Specialist
Dept. of Bio. & Ag. Engineering
College of Agriculture and Life Sciences
North Carolina State University
Raleigh, North Carolina

NC STATE UNIVERSITY

System design considerations:

- Almost no instances of unlimited resources to start a program
- Design will be dictated by constraints
  - Funding for equipment
  - Funding for operations and utilities
  - Space
  - School schedule

System design considerations:

- Design for certain species
  - Flounder require shallow tanks
  - All other species can use similar tanks
- Available space is usually very limited
  - Existing greenhouse, shop area, garage
- Available funding usually low
  - Competition for funds by existing programs
- Combination with other programs
  - Horticulture (aquaponics)

NC STATE UNIVERSITY

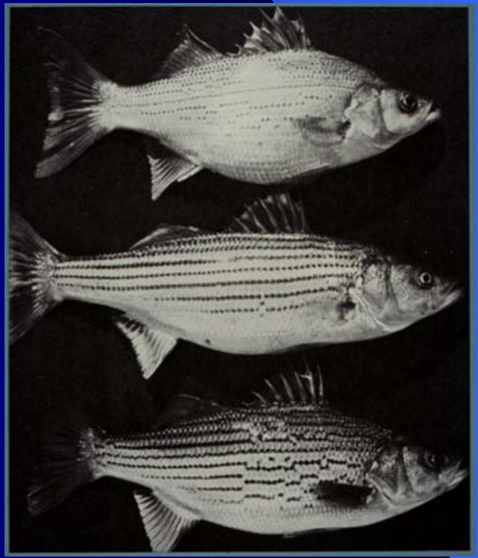
Potential fish species to culture

- Criteria for selection
  - Availability
  - Hardiness
  - Disease resistance
  - Temperature requirements
  - Disposition at harvest time

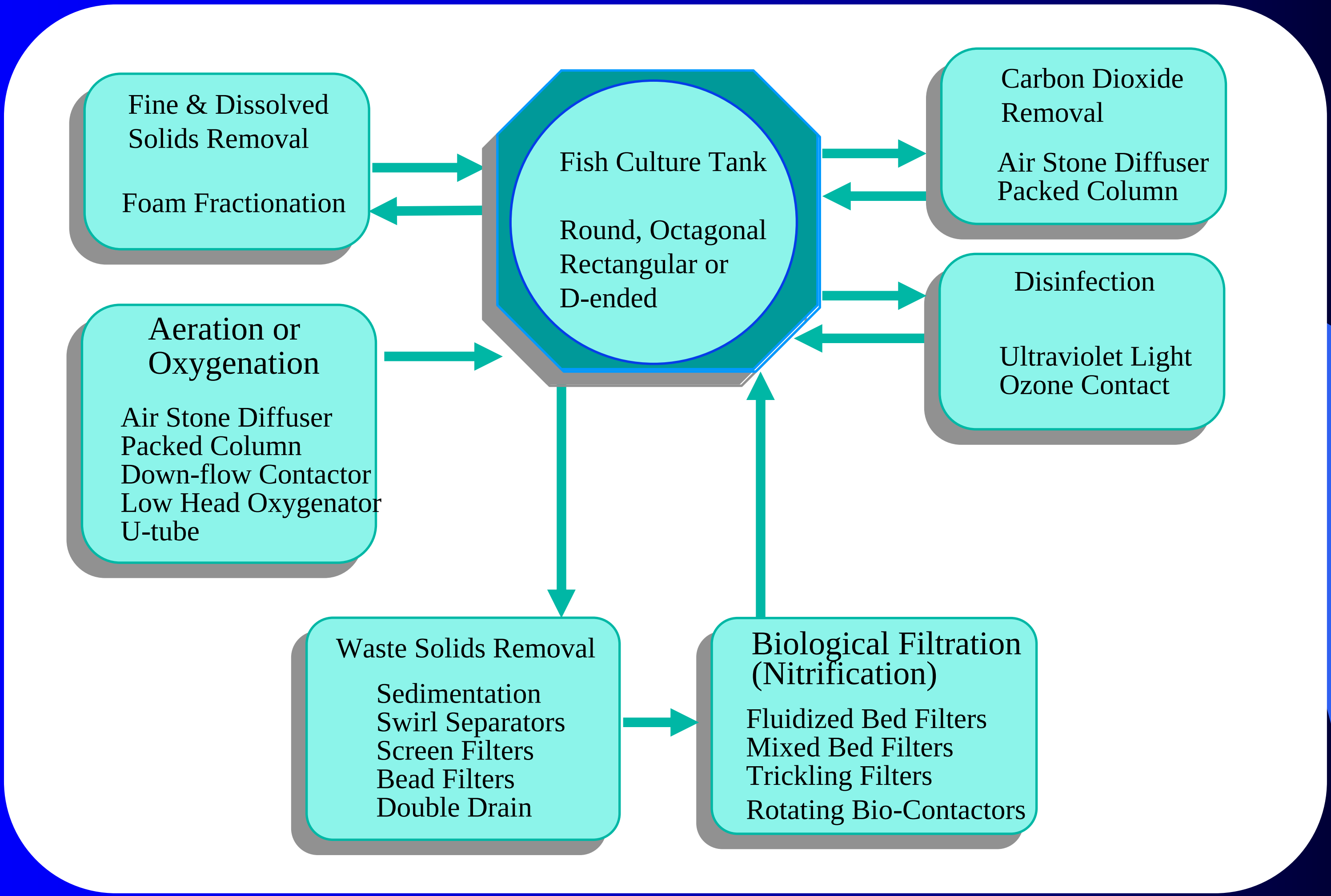
NC STATE UNIVERSITY

Potential fish species to culture

- Tilapia
- Hybrid striped bass
- Southern flounder
- Yellow perch
- Ornamentals
  - Goldfish
  - Koi
  - Guppies



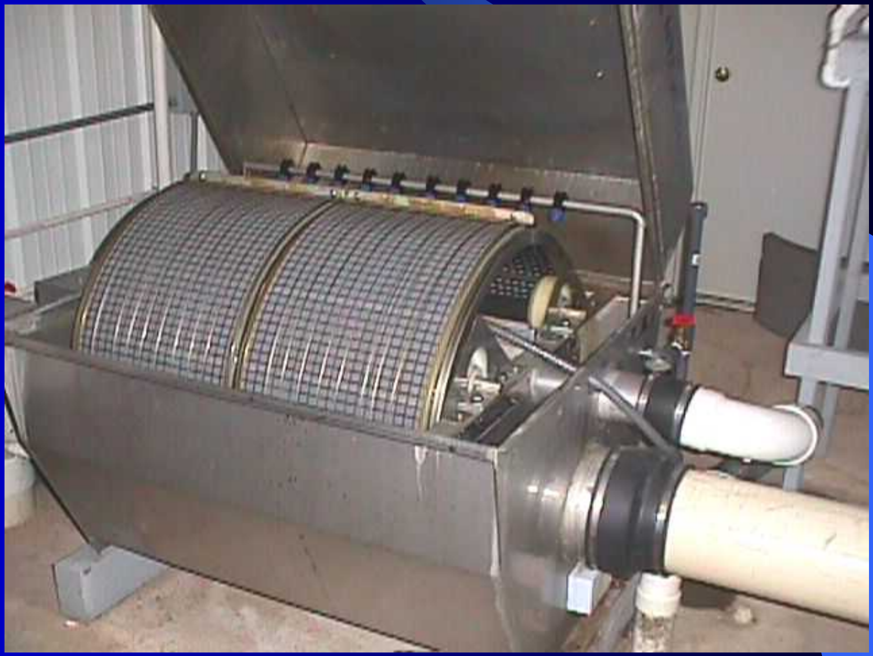
Required Unit Processes



NC STATE UNIVERSITY

Waste Solids Removal

- Sedimentation
- Swirl separators
- Screen filtration



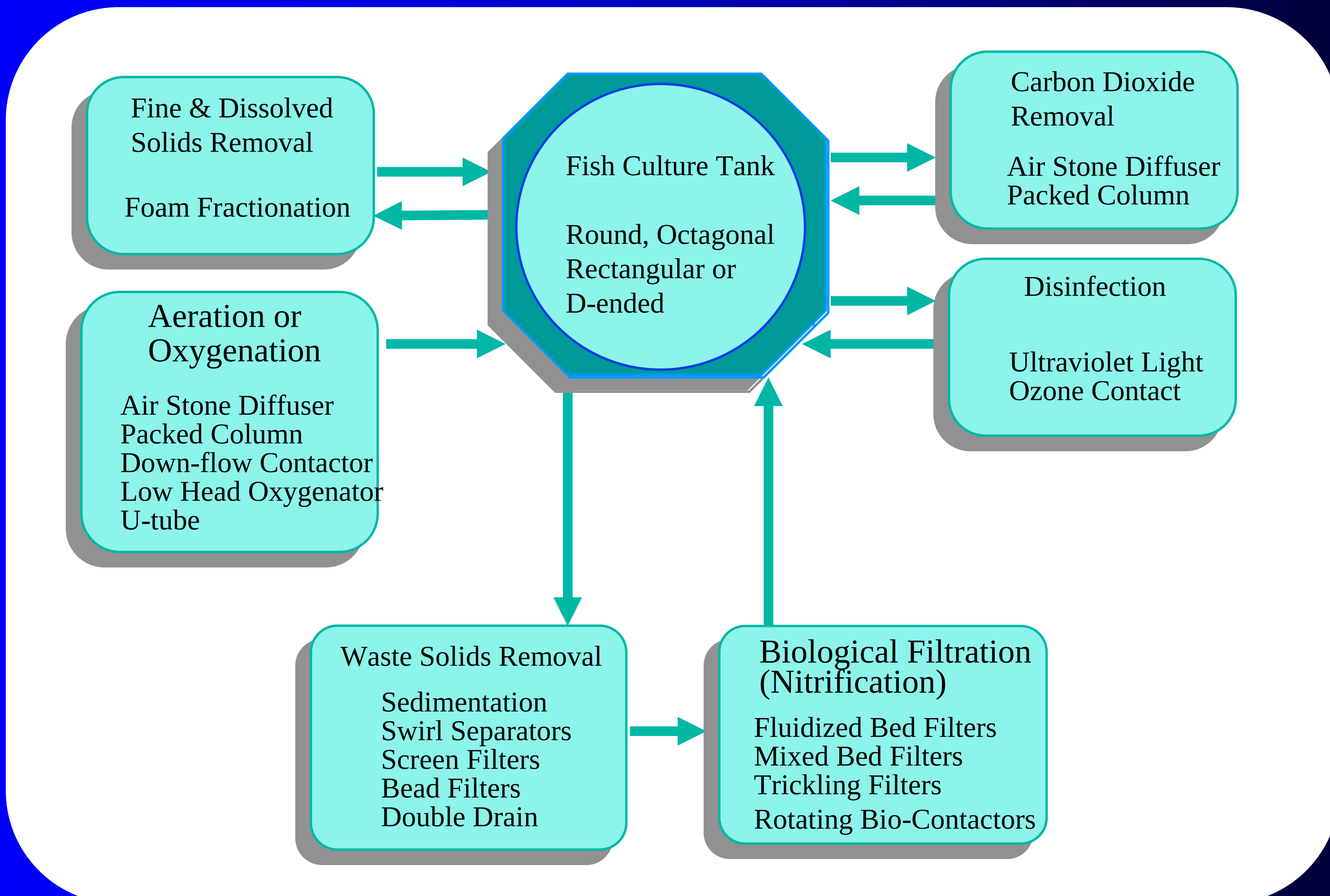
NC STATE UNIVERSITY

Waste Solids Removal

- Bead or granular media filtration

From: www.beadfilters.com

Required Unit Processes



NC STATE UNIVERSITY

Biological Nitrification
Why do we need it?

- Fish consume feed
- Feed contains protein
- Metabolic processes produce waste
  - Solid waste (feces)
  - Liquid waste (small amounts of urine)
  - Excretion through gills (ammonia)
- Waste products are toxic and must be removed

NC STATE UNIVERSITY

Types of Biofilters

- Trickling filters
- Submerged media filters
- Fluidized bed reactor
- Mixed bed reactor
- Rotating biological contactors (RBC's)

From: www.marinebiotech.com

From: www.aquaticeco.com

Suitable filters

- Bubble-washed Bead filters
  - Solids removal
  - Biological nitrification
  - Simple to operate

BBF-XS8000

4 cu. Ft. of media

Source: Aquaculture Systems Technologies

http://aquaculture.ctpllc.com/index.php

NC STATE UNIVERSITY

Sizing the system

- Physical dimensions available
- Number of tanks
- Density in tanks
  - Example:
    - Product size of 1.5 pounds
    - 500 – gallon tank
    - 0.25 pounds per gallon (with aeration)
    - 0.50 pounds per gallon (with oxygenation)
    - 500 gallons × 0.25 pounds per gallon = 125 pounds total
    - 125 pounds ÷ 1.5 pounds per fish = 83 fish to harvest
    - 83 fish ÷ 0.85 (85 percent survival) = 98 fish stocked

Sizing the biofilter

- Manufacturers of small biofilters generally will know the nitrification capacity of the biofilters they sell
- X pounds of feed per cu. ft. of media
- 98 fish @ 1.5 pounds = 147 pounds of feed
  - 1.5% of 147 pounds = 2.2 pounds of feed per day
  - 2.2 pounds per tank × 2 tanks = 4.4 pounds of feed per day to filter

BBF-XS8000

4 cu. Ft. of media

Source: Aquaculture Systems Technologies

http://aquaculture.ctpllc.com/index.php

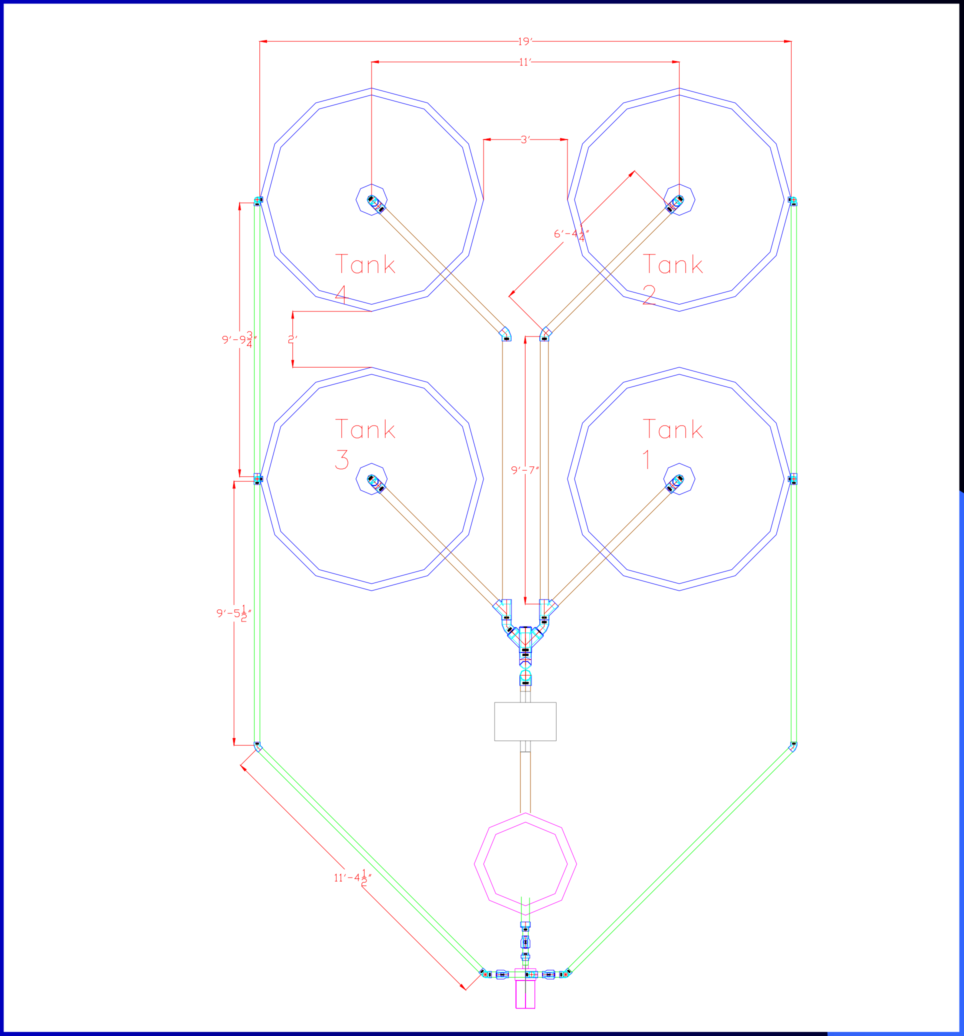
NC STATE UNIVERSITY

Selecting tanks

- Cost-effectiveness
- Ease of shipping
- Durable materials
- Self-cleaning design
- Tank liners

Small system

- Four tanks
  - 450 gallons each
  - 1,800 gallons total



Aeration and Oxygenation

- Most operations will only be able to afford aeration
- Maximum density limited to 1/4 pound per gallon
- Aeration re-suspends solids
- Use of supplemental oxygen is preferred, but will probably be cost prohibitive
- Oxygenation will allow doubling of maximum density

Monitoring and backup systems

- Live animals require constant attention
- After hours on call
  - evenings, weekends, holidays
- Summer vacations, winter holidays
- Liability of having students on premises unsupervised

Recirculating Aquaculture Systems Teacher's Resource Web Site

- Created and maintained by David Cline
  - Extension Aquaculturist, Auburn University
  - http://www.aces.edu/dept/fisheries/education/ras/index.htm

NC STATE UNIVERSITY

SRAC Publication No. 4501

Southern Regional Aquaculture Center

August 2005

Constructing a Simple and Inexpensive Recirculating Aquaculture System (RAS) for Classroom Use

David Cline*

Many teachers would like to add aquatic science and/or aquaculture programs to their curricula. These programs add a hands-on element that can be integrated with math, science, and a number of other disciplines (see Table 1). For example, students may learn planning, finance, marketing and sales when studying aquaculture as a business. Aquaculture's relevance in history and its potential to help feed the earth's ever-growing population link it to various social studies. Teachers who use aquatic systems in their classrooms find them highly effective in translating academic principles to practical applications.

One of the simplest ways to initiate a program of this nature is to bring a recirculating aquaculture system (RAS) into the classroom. An RAS maintains aquatic species while filtering and reusing the water. An RAS may be as simple as a single small aquarium or as complex as a multi-unit production system. An RAS suitable for a classroom is simple and inexpensive to build.

While the greatest value of the RAS is as a teaching tool, the experience of working with an RAS can also motivate students to participate and develop new life skills. Aquaculture projects can encourage cooperative learning, bring together students of diverse backgrounds, and link seemingly disparate skills. Some schools sell fish and plants to generate revenue for their programs. This helps students learn sales, marketing and other entrepreneurial skills. Teachers often report that students become so engrossed in working with the systems they forget that they are studying science and math. The students take a great deal of pride in raising fish and they learn responsibility by working with live animals.

Table 1. Subjects that can be taught using a recirculating aquaculture system.

Biology	Chemistry	Physics
Math	Economics	Plumbing
Mechanical Systems	Construction	Sales
Marketing	Hydraulics	Language Arts
Business Planning	Finance	Home Economics
Food Sanitation & Safety	Nutrition	Physiology
Morphology	Fish Health	Fish Reproduction
Genetics	Art	History
Sociology	Carpentry	Masonry
Hydroponics	Computer Technology	Public Relations

*Auburn University, Auburn, AL

System components

A simple RAS system can be constructed from items available at nearly any home improvement store. Step-by-step instructions for building a system are described and illustrated below. There are many other options and variations one might use, but the system shown here has been classroom tested. Every RAS must include components to hold the fish, remove the solid wastes (mechanical filter), remove the dissolved nitrogenous wastes (biological filter), circulate the water, maintain the temperature, and aerate the water if necessary. Figure 1 illustrates these components and shows the path the water will follow as it travels through the system. Photo 1 shows the completed system.

Photo 1. Completed system.

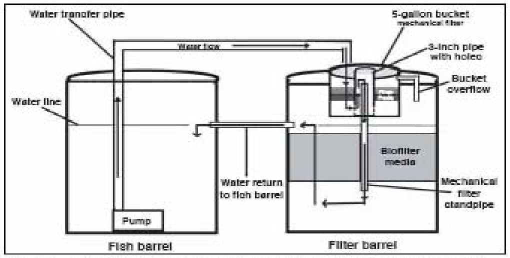


Figure 1. A simple RAS system illustrating the components and showing the path the water follows as it travels through the system.

The first component is the culture vessel or fish barrel where the fish are housed. The water is lifted from the bottom of the fish barrel (by the pump) to a plastic bucket supported by plywood on the top of the filter barrel. In this bucket (mechanical filter) the water must pass through several layers of filter material that capture the uneaten feed and solid feces. Once through the filter pads, the water leaves the bucket by going through holes in the bottom of a 3-inch pipe and then out the stand pipe in the center of the bucket. The water then travels to the bottom of the filter barrel and must pass though the biofilter media (to remove nitrogenous wastes) before returning to the fish barrel.

These are the tools required to build the system:

- PVC pipe cutter or hacksaw
- Extension cord
- Goggles or safety glasses
- Saber saw or Sawzall®
- Electric drill
- Ruler or tape measure
- Hole saw to cut 1 ¼ and 1 ½ inch
- Drill bits, ¼-inch
- Teflon® tape
- Marker
- Sandpaper
- Rubber gloves
- Screwdriver (to match bolt heads)
- Pliers or ⁵⁄₁₆-inch ratchet

NC STATE UNIVERSITY

Table 2. Parts list for a small recirculating aquaculture system.

Materials

Quantity	Size	Description
2	55-gallon	Plastic barrels
1	5-gallon	Plastic bucket
1	2-foot x 2-foot piece	½-inch plywood
1	200 to 600 gallons per hour	Water pump with ¾-inch outlet
1 (optional but desirable)	2 outlets	Deep-water air pump
2	1- to 2-inch	Airstones
2	30 inches long	Airline tubing to fit pump and airstones

Piping

Quantity	Label	Length	Description
1	A	22 inches	1-inch pvc pipe – filter downspout
1	B	10 inches	1-inch pvc pipe – filter level control pipe
1	D	2 inches	1-inch pvc pipe – bucket overflow female to down elbow
2	E	7 inches	1-inch pvc pipe – bucket overflow downspout, water return
1	F	27 inches	¾-inch pvc pipe – pump horizontal
1	G	35 inches	¾-inch pvc pipe – pump vertical riser
1	H	3 inches	¾-inch pvc pipe – pump downspout to filter
1	C	13 ½ inches	3-inch pvc pipe – outer sleeve of filter level control pipe

Fittings

Quantity	Label	Size	Description
4	I	1-inch	Slip/threaded female – filter bottom, overflow outside, inside water returns
5	J	1-inch	Slip/threaded male – one at each end of water return, filter overflow, filter bottom
1	K	1-inch	90-degree elbow – filter overflow
2	L	1-inch	Tee eliminators (from Aquatic Ecosystems) to fit in 1 ½-inch hole, or equivalent bulkhead fittings for 1-inch pipe
1	M	¾-inch	Slip/threaded female – for pump outlet
3	N	¾-inch	90-degree elbows – pump/water transfer fittings, water return directional

Window (optional but desirable)

Quantity	Label	Size	Description
1	O	6-inch x 20-inch	Piece of ¼-inch Lexan®
20	P	5/16-inch x ¾-inch	Stainless steel bolts
20	Q	5/16-inch	Stainless steel nuts
20	R	5/16-inch	Stainless steel washers
20	S	5/16-inch	Washers
2	T	Tubes	Plumbers Goop® contact adhesive and sealant

Instructions

1. Gather and organize necessary tools and parts.
   a. Gather necessary parts and plumbing supplies. (see Table 2).
   b. Cut the pipes to the specified length using PVC-pipe cutters or hack saw.
   c. Label the pipes and fittings with their letter designations.
2. Prepare barrels.
   a. Obtain barrels, preferably from a food or drink processor/bottler, and rinse them thoroughly. You may also use soap barrels from a carwash. Do not use chemical barrels as there may be residue that could be toxic to the fish and/or humans consuming the fish.
   b. Using a saber saw or Sawzall®, cut the top from one barrel (filter barrel), leaving a 1- to 2-inch rim around the top edge. The rim helps maintain rigidity. (Photo 2b)

Photo 2b.

   c. Cut one-half of the top out of the other barrel (fish barrel), leaving a 1 - to 2-inch rim around the opening. (Photo 2c)

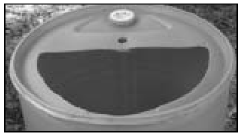


Photo 2c.

   d. Using a 1 ¼-inch hole saw (this is an attachment for an electric drill), cut a hole 1 inch back from the center of the remaining half of the barrel top (fish barrel). This will help hold the piping that goes from the pump in the bottom of the fish barrel to the filter barrel. (Photo 2c)
   e. Smooth rough cut edges with sandpaper to remove burrs and sharp edges.
   f. Using a 1 ½-inch hole saw, cut one hole in each barrel 30 inches from the floor. Gently remove burrs and smooth very lightly with sandpaper. These holes are for the water return from the filter barrel to the fish barrel. (Photo 2f) *Note: If you use traditional bulkhead fittings be sure to check for the appropriate hole size.*

Photo 2f.

   g. Insert the tee eliminators (L) into the holes. The holes need to be as uniform and smooth as possible to allow the tee eliminators to seal them properly. (Photo 2g)

Photo 2g.

3. Filter barrel assembly
   a. Place the 5-gallon bucket upside down in the center of the 2-foot x 2-foot piece of plywood and trace around the opening of the bucket. This will be your guide for cutting the hole in the plywood. (Photo 3a)

Photo 3a.

   b. Using your traced circle as a guide, cut ¼ inch inside the line using your saber saw. Gently remove burrs and smooth very lightly with sandpaper. This will ensure that the lower part of your bucket fits snugly inside the hole while allowing it to be supported by the structural ring on the bucket. You can always make the hole larger, but it is difficult to make it smaller. (Photo 3b)

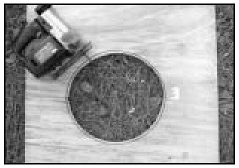


Photo 3b.

NC STATE UNIVERSITY

NC STATE UNIVERSITY

Aquaculture and Hydroponics

- aquaculture + hydroponics = aquaponics
  - culturing fish
  - growing plants with effluent water
  - composting of captured solid waste

- vegetables, flowers, foliage plants

Aquaculture and Hydroponics

NC STATE UNIVERSITY

Aquaculture and Hydroponics

- Area required for fish will be much smaller than that required for plants
- In other words, a small amount of fish will support a large amount of plants
- Probably not desirable to return plant solution to fish
- Supplemental nutrients may be required
- Beware the use of any pesticides

SRAC Publication No. 454

Southern Regional Aquaculture Center

November 1992

Recirculating Aquaculture Tank Production Systems

Integrating Fish and Plant Culture

James E. Rakocy[1], Thomas M. Losordo[2] and Michael P. Masser[3]

Recirculating aquaculture systems are designed to raise large quantities of fish in relatively small volumes of water by treating the water to remove toxic waste products and then reusing it. In the process of reusing the water many times, non-toxic nutrients and organic matter accumulate. These metabolic by- products need not be wasted if they are channeled into secondary crops that have economic value or in some way benefit the primary production system. Systems that grow additional crops by utilizing by-products from the production of the primary species are referred to as integrated systems.

Plants are an ideal secondary crop in integrated systems because they grow rapidly in response to the high levels of dissolved nutrients that are generated from the microbial breakdown of fish wastes. In closed recirculating systems, which employ very little daily water exchange (1 to 5 percent), dissolved nutrients accumulate and approach the concentrations that are found in hydroponic nutrient solutions. Nitrogen, in particular, occurs at very high levels in recirculating systems. Fish excrete waste nitrogen directly into the water through their gills in the form of ammonia. Biofilter bacteria convert ammonia to nitrite and then to nitrate (see SRAC Publication No. 451 on critical considerations). Ammonia and nitrite are toxic to fish, but nitrate is relatively harmless and is the preferred form of nitrogen used by higher plants, such as vegetables.

Integrated systems can be used for the hydroponic culture of high value cash crops such as tomatoes, lettuce and sweet basil. Recirculating systems may also be used for the culture of aquatic plants.

Aquatic plants

Aquatic plants grow rapidly in recirculating systems that are located outdoors, in greenhouses or in buildings with adequate artificial light. Plants are typically grown in shallow tanks that are separate from the fish rearing tank. Three types of aquatic plants can be cultured: floating, emergent and submerged.

Floating plants, which are naturally buoyant, grow with their roots suspended in the water and their leaves in the air. They reproduce vegetatively (without seeds) by dividing in half and grow so rapidly that they can completely cover the surface of the tank within a short time. When this occurs, about one third of the plants

Leaf lettuce grown in deep flowing channels is an ideal crop for integrated recirculating systems.

[1]University of The Virgin Islands;
[2]North Carolina State University
[3]Alabama Cooperative Extension Service

Sources of further information:

- The National Council for Agriculture Education
- NC Cooperative Extension Service
- Southern Regional Aquaculture Center
- NC Dept. of Agriculture & Consumer Services
- Aquatic Eco-Systems
- R&B Aquatic Distribution

NC STATE UNIVERSITY