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.

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

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.

*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.

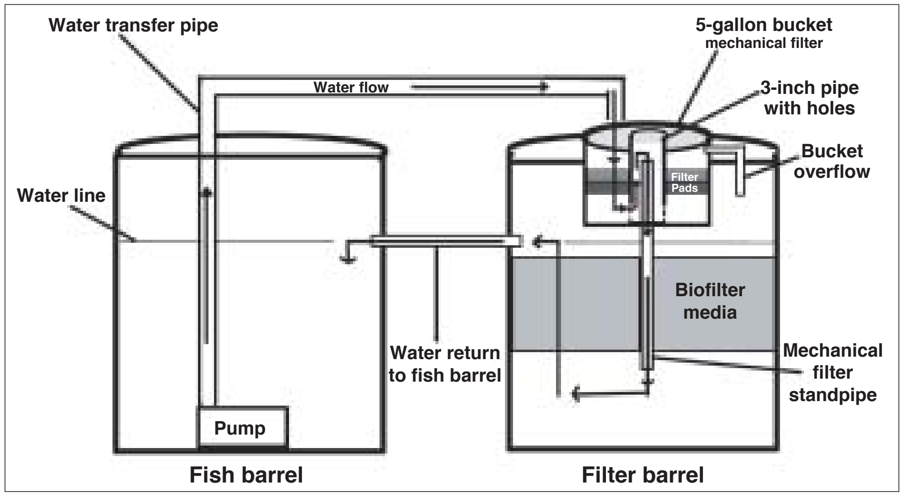

Figure 1. A simple RAS system illustrating the components and showing the path the water follows as it travels through the system.

Photo 1. Completed 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 $^1/_4$ and 1 $^1/_2$ inch
- Drill bits, $^1/_4$-inch
- Teflon® tape
- Marker
- Sandpaper
- Rubber gloves
- Screwdriver (to match bolt heads)
- Pliers or $^3/_{16}$-inch ratchet

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	3⁄16-inch x ¾-inch	Stainless steel bolts
20	Q	3⁄16-inch	Stainless steel nuts
20	R	3⁄16-inch	Stainless steel washers
20	S	3⁄16-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)

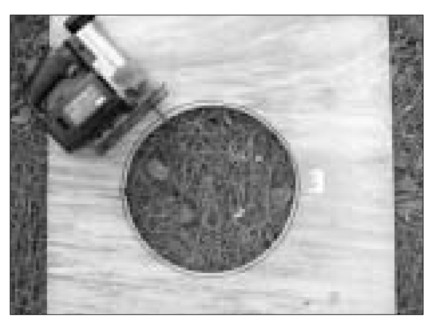

Photo 3b.

c. Using the hole saw, cut a 1 1/4-inch circular hole in the center of the bottom of the 5-gallon bucket. Gently remove burrs and smooth very lightly with sandpaper. This bucket will serve as the mechanical filter and will direct water to the biological filter below. (Photo 3c)

Photo 3c.

d. Cut another 1 1/4-inch hole in the side of the 5-gallon bucket between the structural rim and the top of the bucket about 2 inches from the top. Gently remove burrs and smooth very lightly with sandpaper. This hole will be the overflow into the filter barrel in case the mechanical filter gets plugged. (Photo 3d)

Photo 3d.

e. Fit a 1-inch male/slip fitting (J) through the hole in the bottom of the bucket and secure it on the inside with a 1-inch female/slip fitting (I). This joint does not have to be watertight because any leaks will fall into the filter barrel. (Photo 3e)

Photo 3e.

f. Repeat this procedure for the hole on the side of the bucket. This joint, however, should be as watertight as possible to prevent water from leaking between the fitting and the bucket. (Photo 3f)

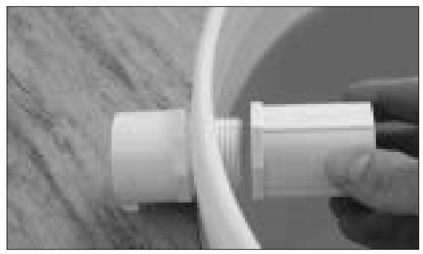

Photo 3f.

g. Slip the 22-inch piece of 1-inch pipe (A) into the male/slip fitting on the bottom of the bucket. This pipe will direct water from the mechanical filter to the bottom of the biological filter. (Photo 3g)

Photo 3g.

h. Slip the 10-inch piece of 1-inch pipe (B) into the female/slip fitting on the inside bottom of the bucket. This will be the overflow from the mechanical filter into the biological filter portion of the barrel. (Photo 3h)

Photo 3h.

i. Using the 13 1/2-inch piece of 3-inch pipe (C). Draw a line around the pipe 3 inches from one end. Holding the pipe securely, drill a number of randomly spaced 1/4-inch holes in it between the line and the end of the pipe. (Photo 3i)

Photo 3i.

j. Place the 3-inch pipe, holes toward the bottom, inside the bucket over the top of the 1-inch center pipe. This outer pipe forces the water to travel through the mechanical filter media to the bottom of the bucket before overflowing into the barrel below. (Photo 3j)

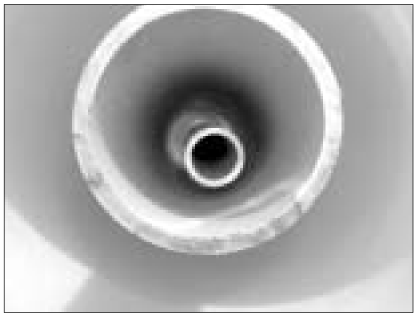

Photo 3j.

4. Mechanical filter emergency overflow assembly
   a. Place the 2-foot by 2-foot board over the top of the filter barrel.
   b. Place the bucket into the hole in the plywood. It should rest securely on the structural rim of the bucket. If the hole in the plywood is too snug, trim the hole as necessary.
   c. Fit the 2-inch piece of 1-inch pipe (D) into the male/slip fitting on the outside of the bucket. Push it in as far as possible.
   d. Place a 1-inch, 90-degree elbow (K) on the other end of this 2-inch piece and secure it with the opening of the elbow directed at the plywood. (Photo 4d)

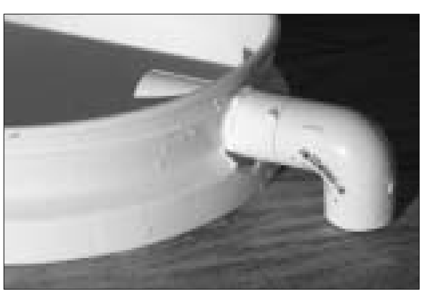

Photo 4d.

   e. Using the outer edge of the elbow fitting as a guide, trace a circle onto the plywood. Make sure the downward facing elbow on the plywood is situated so as to allow the attached downspout to fit easily inside the rim of the barrel. (Photo 4e)

Photo 4e.

   f. Cut a 1 1⁄2-inch hole in the plywood using the traced circle from the elbow as a guide.
   g. Slip a 7-inch piece of 1-inch pipe (E) into the elbow, with the other end dropping through the hole in the plywood. (Photo 4g)

Photo 4g.

5. Pump-to-filter assembly
   a. Place a 3⁄4-inch, 90-degree elbow (N) on each end of the 27-inch piece of 3⁄4-inch pipe (F) and turn them so they are facing the same direction.
   b. Slip the 35-inch piece of 3⁄4-inch pipe (G) into one of the 90-degree elbows and the 3-inch piece of 3⁄4-inch pipe (H) into the other 90-degree elbow.
   c. Place the 35-inch piece of 3⁄4-inch pipe through the hole in the uncut half of the top of the filter barrel. (Photo 5c)

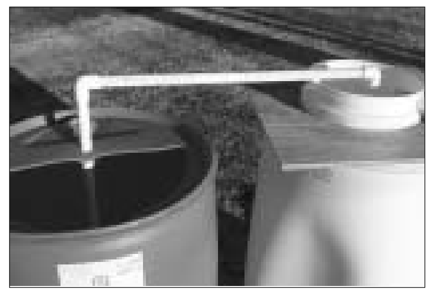

Photo 5c.

6. Attaching the pump
   a. Purchase or locate a pump with a 200- to 600-gallon-per-hour flow rate. *The following steps will vary depending on the pump selected.*
   b. If you have a pump with a 3⁄4-inch threaded outlet, you can attach a female/slip fitting to the pump and slip the 35-inch piece of 3⁄4-inch pipe (G) into the other side.
   c. If you have a pump with a 3⁄4-inch non-threaded outlet, you can wrap Teflon® tape around the pump outlet until it is thick enough to slip inside the 3⁄4-inch riser pipe. You may also wish to attach a 90-degree elbow to the inlet of the pump over the inlet screen and direct it at a 45-degree angle to the bottom (optional). This will help pick up wastes and debris from the bottom of the tank.

d. If your pump has a ½-inch outlet you will need a bushing/reducer fitting that will reduce the ¾-inch riser pipe to match the pump outlet.

e. If you use a pump with a capacity greater than 500 gallons per hour, you may wish to insert a ball valve in the middle of pipe (F) to control the water flow to the mechanical filter.

7. Window installation (optional, but desirable for viewing fish)

a. Place the 6-inch x 20-inch piece of Lexan® near the center of the barrel. Lexan® is more flexible than Plexiglas® and is less likely to crack or break during installation. Using a marker, trace the outline onto the side of the barrel. Have someone else hold the Lexan® flat to the curved barrel. (Photo 7a)

Photo 7a.

b. To mark the area to be cut out, measure and make a mark 1 inch in from each of the corners along the sides. Connect these marks with a straight edge to create an inner rectangle that is 1 inch smaller on all sides than the original outline. This leaves a 1-inch overlap to attach and seal the window. (Photo 7b)

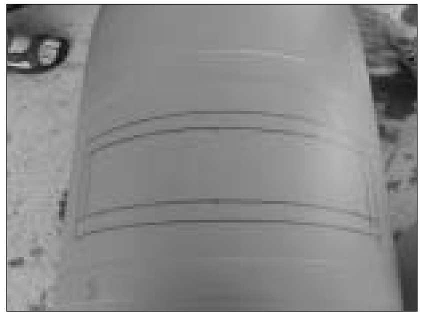

Photo 7b.

c. Cut out the inner rectangle using the saber saw. (Photo 7c)

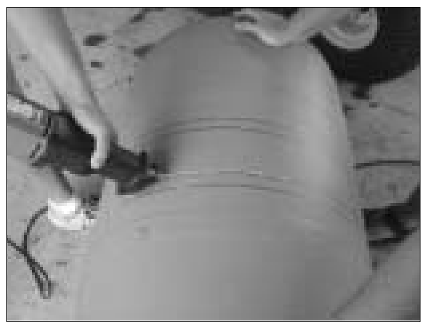

Photo 7c.

d. Smooth any rough edges with sandpaper. (Photo 7d)

Photo 7d.

e. Hold the Lexan® window firmly to the barrel, taking care to line it up.

f. Drill the holes at the corners (½ inch from each corner), first securing them with bolts as you go. (Photo 7f)

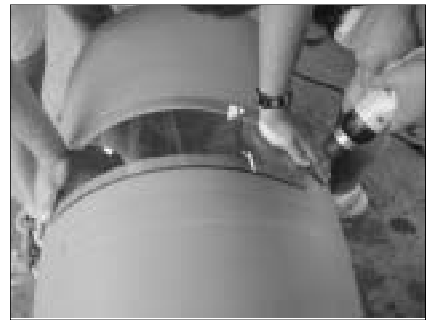

Photo 7f.

g. Drill seven holes across the top (2 ¾ inches apart) and three holes down each side (2 ½ inches apart). (Photo 7g)

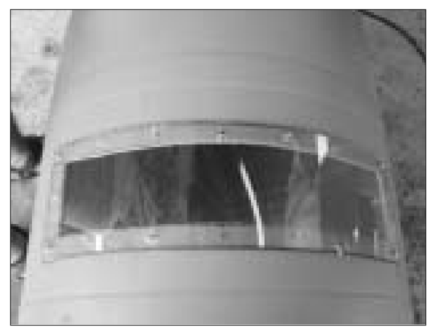

Photo 7g.

h. Remove the window and put on rubber gloves.

i. Apply Plumber's Goop® liberally around the edge of the opening. (Photo 7i)

Photo 7i.

j. Put plenty over the top of the drilled holes. It will take more than half the tube. Work quickly.

k. Replace the window and line up the holes. Place a drop of Goop® over each hole. Working from one end to the other, place a regular washer on the bolt and thread it through the hole. Secure a stainless steel washer and nut to each bolt on the inside of the barrel. Work quickly to thread and secure bolts before Goop® gets too stiff. (Photo 7k)

Photo 7k.

l. Allow Goop® to cure for 24 hours before adding any water to the barrels.

8. Connecting the barrels

a. Thread one of the 1-inch male/slip fittings (J) into each of the tee eliminators. (Photo 8a)

Photo 8a.

b. Make sure not to cross the threads and secure as tightly as possible. You may want to lubricate the threads with water.

c. Place the barrels close together and fit the remaining 7-inch piece of 1-inch pipe (E) into each of the male/slip fittings. (Photo 8c)

Photo 8c.

d. Thread one of the 1-inch male slip fittings (J) into the tee eliminator on the inside of the fish barrel. Fit a ¾-inch, 90-degree elbow (N) into the slip end of the 1-inch male fitting to direct the returning water in a counterclockwise circular flow pattern. (Note: If traditional bulkhead fittings are in place, the 90-degree elbow should slide into the female fitting.)

9. Finishing up (Photo 9)

a. Move the barrels to their final location. Locating the barrels near a drain or sink makes it easier to add or remove water.

b. You may wish to consider gluing the pvc pipe joints of the pump-to-filter assembly. This is the only piping under pressure that could come apart. The other fittings should be tight enough that they don't leak. If you do find a leak, you can go back and wrap the screw fittings with Teflon® tape, glue the pipes together, or use the remaining Plumber's Goop® as a patch.

c. Fill the fish barrel with water to a few inches below the filter return pipe and check for leaks around the window.

d. Put a few gallons of water in the filter barrel and adjust the distance between

Photo 9.

the barrels, making sure the connecting pipe fits snugly between the barrels. The barrels are very difficult to move once full, so make sure to put them where you want them to stay. *Note: The full barrels may weigh more than 800 pounds, so make sure there is adequate structural support.*

e. Plug in the pump (in a GFI-protected plug), circulate the water, and check for and repair any leaks.

Breaking in the system

As with any aquarium or other RAS, there is break-in period. It takes approximately 45 days for a biofilter to colonize with the appropriate bacteria *(Nitrosomonas* and *Nitrobacter*) to break down fish wastes. This break-in phase can be helped along by the addition of a **few** fish to the system. Their waste will provide the food the bacteria need to get established. After the filter is populated with the bacteria, add more fish to the system.

The carrying capacity of the system is generally determined by the filter's ability to remove solids and break down the fish waste, a process called the nitrification cycle. It is described in greater detail in SRAC publication 454, "Recirculating Aquaculture Tank Production Systems: Management of Recirculating Systems." Simply put, if you do a good job of removing the solids from the system with the mechanical filter, the amount of surface area present in the biofilter will determine how much bacteria you can grow, how much you can feed the fish, and, thus, how many pounds of fish the system can hold. A general rule of thumb is that it takes at least 5 square feet of biomedia to handle 1 pound of fish being fed at 2 percent of body weight per day.

Selecting mechanical and biofilter media

The media for this system were not specified so that individuals could experiment with different media and see what works best for them. Inexpensive possibilities for mechanical filter media include sponges; pillow filling (spun nylon), available in craft stores; floor scrubbing and polishing pads (with no soap or polish residue); or a commercial fiber mat material. Look for a nontoxic material that will allow water to pass though while retaining solids. Also look for materials that can be easily cleaned.

There are a number of possibilities for biofilter material as well. Nontoxic material with a high surface area-to-volume ratio is a good place to start. Finding these materials and calculating the surface area is a great activity for students. Aquaculture supply houses have many materials, but you may be able to find something locally as well. Examples of creative biofilter materials include cut-up soda straws, PVC pipe rings or shavings from a lathe, plastic forks, plastic egg cartons, Styrofoam® packing peanuts (remember they float), etc.

Using 1 cubic foot of commercial biofill (similar to long pvc pipe shavings) that has 250 square feet of surface area per cubic foot, the system could theoretically hold 50 pounds of fish. Using the same volume of 1-inch bioballs with 160 square feet of surface area per cubic foot, the system could theoretically hold 32 pounds of fish. These commercial biomedia materials are relatively expensive ($30 to $60 per cubic foot). However, you would have to cut up 322 feet of 1-inch pvc pipe into 1-inch lengths to get the same amount of surface area as 1 cubic foot of biofill material. The cost of the pvc pipe and the effort to cut it up brings the cost of the manufactured material into perspective.

These fish capacity calculations assume that all other water quality parameters are kept at optimum levels. Holding or growing 50 pounds of fish in this system would require the addition of pure oxygen and a variety of other management strategies beyond the scope of this publication. In reality, under typical classroom conditions, this system can be expected to hold 8 to 12 pounds of hardy fish such as tilapia or koi carp. For more information on tank production of tilapia, see SRAC publications 282 and 283. For more information on koi and goldfish, see SRAC publication 7201. If you select a species that requires temperatures outside the range of normal room temperature, you will have to heat or cool the water as necessary. Adding the optional deep-water air pump with an airstone in each tank will enhance the system's performance by helping to supply oxygen to the fish and to the bacteria in the biofilter.

System maintenance

General system maintenance includes keeping track of the water quality and quantity, feeding the fish, and cleaning the mechanical filter as necessary. If one or more water quality parameters moves outside acceptable levels, the easiest solution is to exchange some of the water. To avoid problems, you might consider changing about 10 percent of the water each week. If your replacement water contains chlorine, it will be necessary to add a chlorine remover to protect the fish and the bacteria on the filter.

Classroom activities

Teachers have used the following activities to demonstrate real-world applications of the math and science principles taught in the classroom.

- Determining the volume of fish culture vessels
- Calculating feeding rates and feed conversion ratios (FCR)
- Calculating fish growth rates
- Calculating water flow and exchange rates
- Converting English units to metric units
- Determining the surface area of filter media and culture tanks
- Testing the water and analyzing its chemistry
- Developing graphs from collected data
- Examining the internal and external anatomy of fish

A similar list of activities could be developed for each of the disciplines listed in Table 1. The possibilities are limited only by the knowledge and creativity of the teacher and students.

Conclusion

A wealth of anecdotal evidence suggests that RAS systems and activities provide exciting opportunities for learning. Teachers who use these systems claim that a number of other valuable, nonacademic lessons are learned as well. They say these systems:

- Motivate marginal students to participate and develop life skills that will enable them to continue their education and/or become productive members of the workforce.
- Give students a sense of responsibility and help them learn the rewards and consequences of that responsibility.

For more information on building and using an RAS for classroom instruction, visit *www.ag.auburn.edu/ras.*

Suggested readings

SRAC 282, "Tank Culture of Tilapia"

SRAC 283, "Tilapia: Life History and Biology"

SRAC 451, "Overview of Critical Considerations"

SRAC 452, "Management of Recirculating Systems"

SRAC 453, "A Review of Component Options"

SRAC 454, "Integrating Fish and Plant Culture"

SRAC 7201, "Species Profile: Koi and Goldfish"

Soares, S. J., J. K. Buttner and Dale F. Leavitt. 2001. Aquaculture Curricula Resource Guide: A Resource Tool for the Aquacul-ture Educator. Massachusetts Deparment of Food and Agriculture, MA. 59 pp.

Special thanks to Hugh Hammer, Tim Adams and Jim Brooks at the Gadsden State Community College Aquaculture Education and Development Center, and to J. J. Newman of the New Hampshire Cooperative Extension Service, for their help with the system design, assembly and photographs.

SRAC fact sheets are reviewed annually by the Publications, Videos and Computer Software Steering Committee. Fact sheets are revised as new knowledge becomes available. Fact sheets that have not been revised are considered to reflect the current state of knowledge.

The work reported in this publication was supported in part by the Southern Regional Aquaculture Center through Grant No. 2003-38500-12997 from the United States Department of Agriculture, Cooperative State Research, Education, and Extension Service.