SRAC Publication No. 455

Southern Regional Aquaculture Center

November 1997

Pond Recirculating Production Systems

Andrew M. Lazur and Deborah C. Britt*

Water conservation and reuse has become a major issue in aquaculture in recent years. Concern over increased demand on aquifers, costs of operating wells, environmental impact of aquaculture effluent, and the desire to increase production efficiency continues to drive advances in technology and management practices. Several of the management strategies developed to address these issues include enhancing water circulation in ponds and developing intensive, recirculating tank systems. The combination of these two technologies is referred to as pond recirculating systems.

Pond culture is the most widely used production technology in world aquaculture. The lower stocking and feeding rates per unit of water and lower investment and production costs have contributed to the present expanse of pond production worldwide. A pond's natural ecosystem, including photosynthetic algae and beneficial bacteria, drives important biological processes that impact the daily oxygen cycle and provides a natural biofilter which breaks down harmful nitrogenous wastes. Successful fish production in ponds requires a thorough working knowledge of these biological processes and their effect on water quality. Understanding the amount of nutrients, primarily feed, that can be safely applied to a system is important in ensuring that the algae and bacteria will not be overloaded in their ability to filter wastes.

Recirculating tank system research has provided major leaps in fish culture intensification, technology, and the understanding of water quality management. Much of this progress is necessitated by the desire to maximize profit by increasing production, lowering costs, and conserving water.

Recirculating systems require a significantly greater input of specifically engineered components including water pumps, supplemental oxygenation, and biofilters to replicate a pond's biological processes. However, the need for water conservation, lower feed conversions, reduced disease treatment costs, and closer proximity to markets makes recirculating tank systems attractive in certain areas (see SRAC publications 451, 452, 453 and 454 for more information on recirculating tank systems). Pond recirculating production systems utilize certain advantages of both pond and tank production technology to achieve increased production with reduced inputs.

Water circulation within ponds

Circulating water within a pond impacts water quality in several ways. A major objective of water circulation is to destratify, or mix, the deeper, cooler, oxygen-deficient waters with the shallow, warmer waters rich in dissolved oxygen. This practice improves water quality throughout the depths of the pond, reducing the risk of low dissolved oxygen due to turnovers. This process is especially important in ponds deeper than 6 feet which often stratify during warmer months. Circulating water also increases the suspension of nutrients which can stimulate plankton growth and increase microbial activity. Fry growout or nursery ponds can benefit by continuous but gentle water circulation which aids in maintaining a more even distribution of nutrients. This dispersement prompts healthy plankton populations which are important food organisms for fry growth.

The benefits of water circulation in ponds depend on existing water quality and production levels. Pumping water from a nearby source such as a bayou, river, or estuary is a common practice to replenish oxygen and flush ponds of excessive nutrients, such as ammonia, when growing

*University of Florida Fisheries and Aquatic Sciences Department

crawfish and shrimp. In many cases, however, flushing ponds does not improve water quality significantly, particularly in large ponds. Additionally, the cost associated with this practice is often not economically feasible. Earthen or plastic baffles can assist water flow throughout the pond thus improving water quality (see Figure 1).

Use of mechanical aeration has increased the amount of fish produced in ponds. Oxygen concentrations are increased during the normal, low, nighttime period when algae respiration is significant. Aeration also contributes to water circulation. Some production systems, such as intensive shrimp culture, depend on aerator-driven circulation as a key water quality management tool. Paddlewheel aerators placed in each pond corner create a unidirectional flow (see Figure 2).

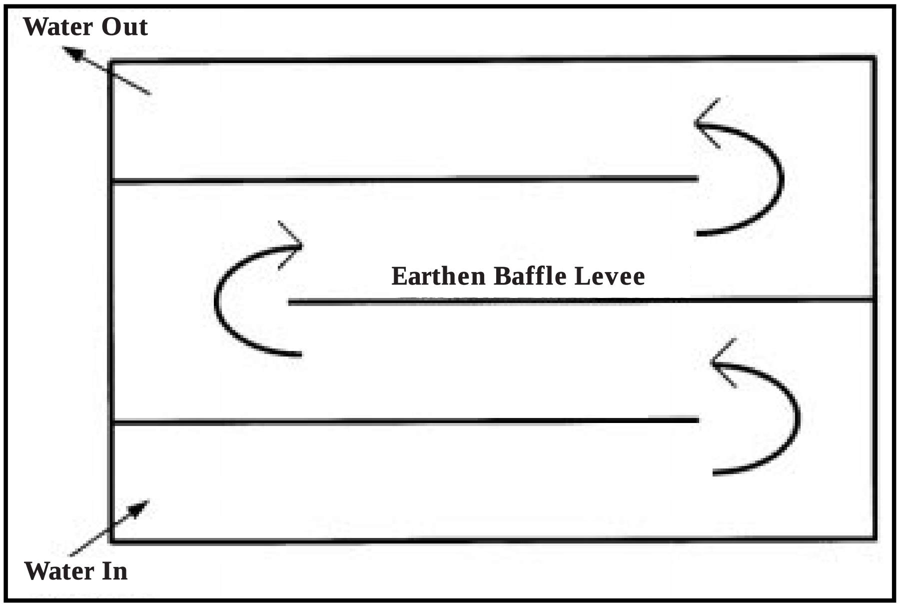

Figure 1. Common water exchange design using baffles in pond.

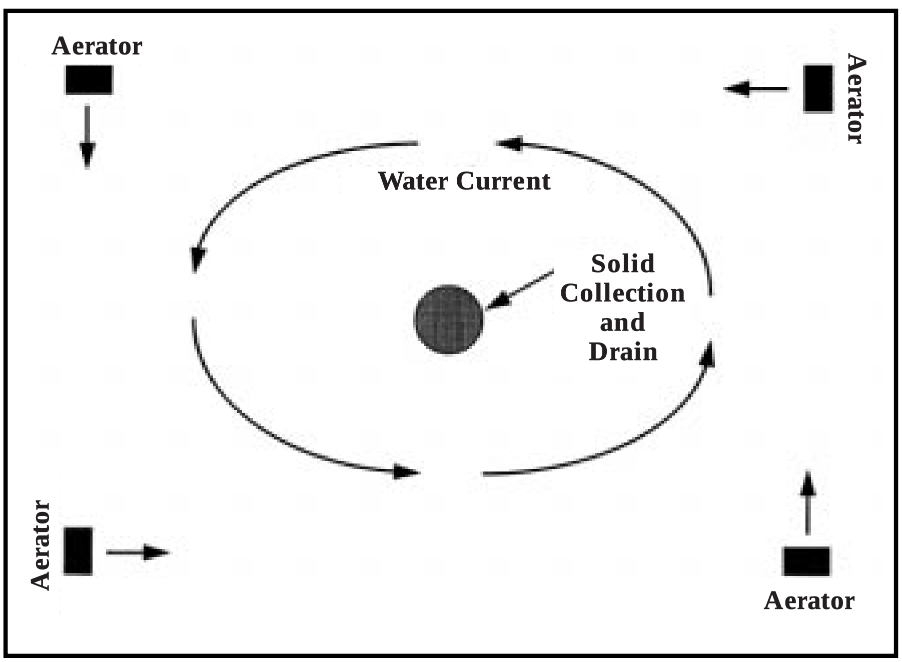

Figure 2. Paddlewheel aerator-driven water circulation used in shrimp production ponds.

This circulation tends to force solids to collect to a central drain. Aeration rates of 5 to 10 horsepower per acre are necessary to provide both aeration and water circulation depending on stocking density and daily water exchange.

Permanent crawfish ponds with earthen baffles use aeration and water circulation to direct water flow. Proper placement of aerators in the pond is essential to maximize water circulation (see Figure 3). In ponds without baffles, studies have shown that placing a paddlewheel aerator at the middle of the pond's longest levee maximizes circulation within the pond (see Figure 4).

Diffused air systems, such as airlift pumps, are often used to suspend nutrients in fry ponds and to destratify deep ponds (see Figure 5). They are also effective in moving water both vertically and horizontally.

The use of specifically designed water circulators or blenders has received attention in recent years for use in catfish, crawfish, and shrimp ponds. These propeller type units pump or move high volumes of water with low power. Water flows of 1,700 to 11,000 gallons per minute are attained with 1 and 3 hp units, respectively (see Figure 6).

Water circulators can be used in combination with aerators in production systems where both aeration and water circulation are desired. Water circulators are often operated during afternoon hours coinciding with peak photosynthesis. Consequently, oxygen-supersaturated surface water is mixed with deeper waters which increases the total pond oxygen budget prior to the normal, late night, and early morning low oxygen period. Water circulation may reduce the time and cost needed for nighttime aeration which uses aerators with greater horsepower ratings.

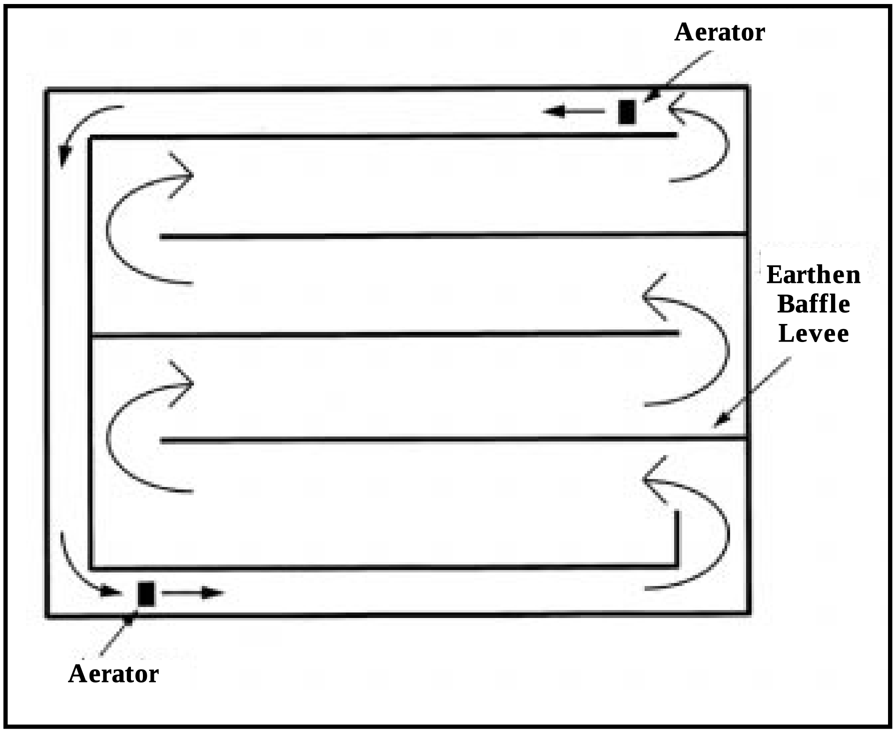

Figure 3. Water recirculation pond design using baffles and paddlewheel aerators to move and direct water flow.

Another impact on water quality from water circulation is an increase in microbial activity because of the mixing of nutrients within the pond and over the pond bottom. This effect may be beneficial in enhancing the recycling of nutrients in the pond which may reduce levels of certain toxic metabolites such as ammonia and nitrite.

Pond recirculating systems

A variety of pond production systems that incorporate complete water recirculation have been developed in recent years. Fundamental to this technology is reducing water use, increasing production efficiency, and attaining a greater level of production sustainability by using the biological processes of phytoplankton and other aquatic plants. These systems vary in design according to production goals and topography. One common practice involves using a pond or series of ponds as a green water reservoir to supply water to fish production in raceways or tanks (see Figure 7). Some systems incorporate a ditch or wetland system using algae or wetland plants as filters to reduce nutrient levels in water prior to returning it to the pond.

These types of pond recirculating systems allow for polyculture of herbivorous species such as tilapia or bighead carp which can be contained separately in raceways or other ponds (see Figure 8). This segregation reduces handling stress associated with separating the fish at harvest. Another potential advantage is the increased marketing control due to being able to more easily harvest the fish from raceways rather than seining an entire pond. However, since water is pumped continuously through raceways at 0.5 to 4 exchanges per hour, increased electricity inputs are required as compared to traditional pond culture and, therefore, fish production costs may be higher. Cost considerations should be conducted to evaluate whether the advantages of these systems are profitable.

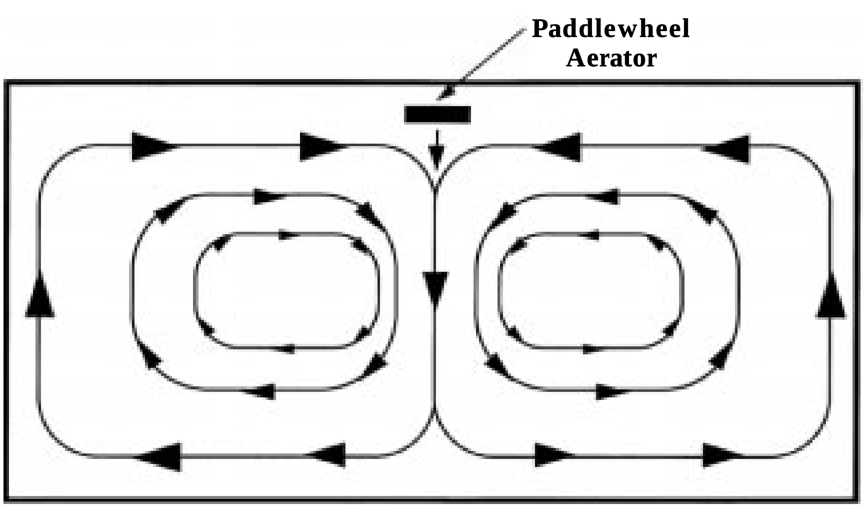

Figure 4. Recommended placement of a paddlewheel aerator in a pond to maximize water aeration and circulation efficiency.

Aquatic plant treatment components

The use of aquatic plants to treat or assimilate nutrients from aquaculture production water is a relatively new concept, and specific recommendations for the ratio of production to plant treatment area are limited. This ratio, whether a green water reservoir or wetland plant system, to fish production unit volume, will vary depending on the type of aquatic plant and its ability to assimilate nutrients, the fish species, feeding rates, and water circulation rates. Phytoplankton are relatively efficient at assimilating nitrite, ammonia, and phosphorus as food sources.

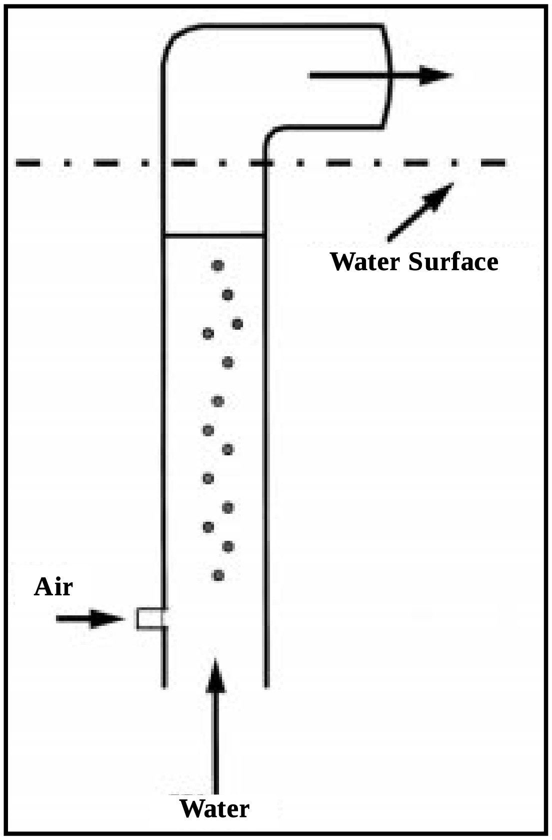

Figure 5. Airlift pump.

However, in a static pond or pond recirculating system, a daily limit of nutrient loading exists. Even with intensive aeration, a point will be reached where phytoplankton or wetland plants cannot assimilate all of the nutrients. This excess could result in toxic concentrations of nitrogenous wastes.

Wetland plant species such as bulrushes, cutgrass, maidencane, and rice have been shown to improve water quality. Preliminary studies have shown that wetlands are effective in reducing BOD, phosphorus, suspended solids, and nitrogen using hydraulic residence times of 4 to 10 days for catfish production pond effluent. However, the area of wetland required would approach or exceed the fish production area, therefore, significantly increasing costs. Future studies may provide needed information on cost effectiveness of using wetland systems for natural nutrient filtration. Over time, wetland systems can fill with solids which will require periodic removal. Use of marketable plant species which require periodic harvesting can reduce solids accumulation and provide an income to cover costs of the wetland system (see SRAC Publication No. 467, *Cost of Alternative Effluent Treatments for Catfish Production*, for information on economics of effluent treatment).

Intensive automative technology

Another pond recirculating system design, being developed by Clemson University, utilizes computer controlled technology to regulate water circulation through a 1/3 acre pond reservoir with baffles and into fish production raceways (see Figure 9).

Termed the Partitioned Aquacul-ture System, or PAS, the unit's water circulation is regulated by a low horsepower, hydraulic-driven paddlewheel type circulator. The rotation speed of the circulator and, hence, flow rate through the system, is regulated electronically by water quality devices that monitor dissolved oxygen. The water flow averages 0.1 foot per second but can be increased during periods of low oxygen to provide maximum oxygen levels in the water column. Water retention times can be controlled to range from 1 to 10 hours. Other advantages include controlling the water flow and optimizing algal or phytoplankton growth.

The fish production raceways in the PAS offer advantages similar to other raceway systems. These benefits include increased control over water quality, predators, and feeding; reduced disease treatment costs; and reduced labor input. One main raceway in the PAS is used for production of a principal fish species such as channel catfish. An additional, parallel raceway is used for a herbivorous fish or shellfish species which feeds on phytoplankton. Water flow rates in the raceway

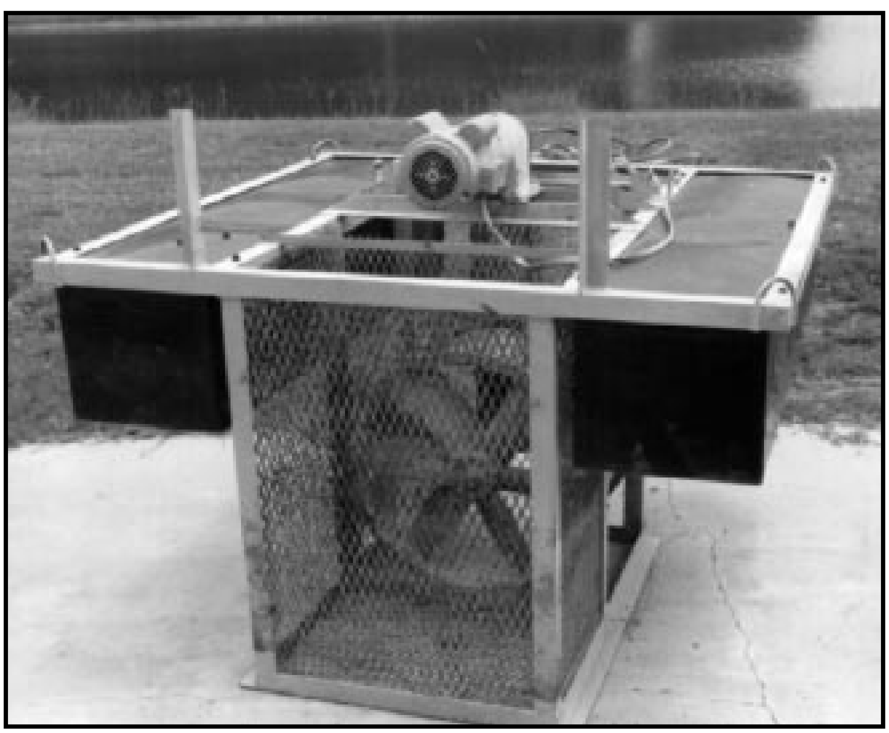

Figure 6. Example of commercially available water circulator.

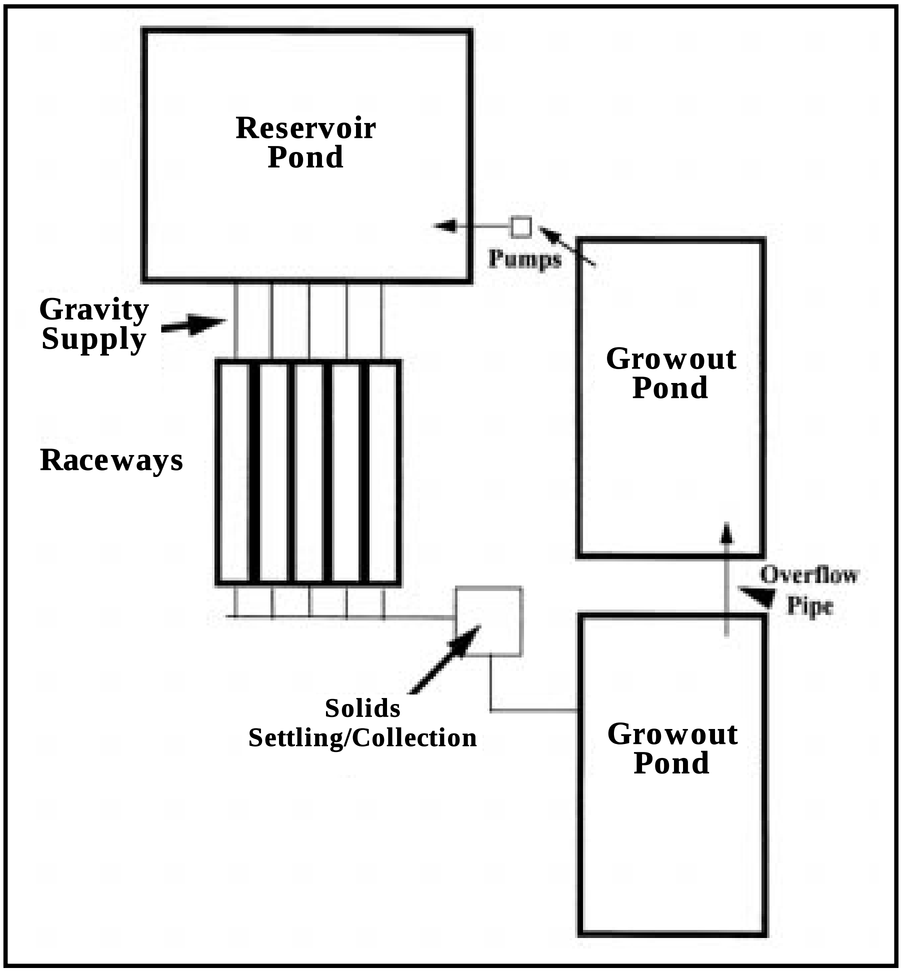

Figure 7. Example of multiple pond/raceway recirculation system.

can be regulated by electronically controlled gates.

Supplemental aeration is supplied to the raceway by floating, vertical pump aerators. A sump to collect solid fish waste is located immediately after the raceway and can be cleaned periodically by mechanical vacuuming. Removal of solid fish wastes aids in significantly reducing oxygen demand, and the waste can be used as a supplemental source of nitrogen and phosphorus fertilizer for terrestrial plant crops.

Research results of the PAS are promising. Fish production is being improved as field studies continue. Present studies have achieved production levels of 14,000 pounds of catfish and 2,000 pounds of tilapia per acre with new tests planned to increase fish production. Reduced water requirements, control over algal populations and oxygen production, raceway production benefits, and partial recovery of nitrogen for use as fertilizer makes this system attractive and compatible with present and future conservation concerns.

Summary

Circulating water in ponds is an effective tool in destratification that improves oxygen levels throughout the pond and increases microbial oxidation of organic matter. Pond recirculation system technology is relatively new with many potential designs. Key to the systems is mechanical water circulation (pumps, aerators, or circulators) within a pond or pond / raceway combination.

Several potential **advantages** include:

- reduced water use and production effluent
- improved water quality
- easier accessibility to fish from raceways
- increase in species diversity
- increased sustainability

Several possible **disadvantages** of these systems include:

- need to pump or mechanically move water
- higher fish production costs compared to open pond culture due to increased pumping costs
- unproven economic feasibility in some cases

Recirculating pond systems will continue to develop in the future as water reuse becomes more important. Despite the positive impact on water quality, there has been little research to show that pond recirculating systems have significantly greater fish production over traditional open pond aquaculture.

Specific design criteria will vary depending on individual site, production objectives, and regulatory requirements. Farmers should carefully consider the costs and benefits prior to developing a pond recirculating system.

Additional Reading

Constructed Wetlands for Treatment of Channel Catfish Pond Effluents. M. F. Schwartz and C. E. Boyd. Progressive Fish-Culturist 57:255-266. 1995.

Cost of Alternative Effluent Treatments for Catfish Production. SRAC Publication No. 467.

Nutrient Recovery and Reuse for Water Quality Control in the Partitioned Aquaculture System. D. E. Brune, J. A. Collier, and T.E. Schwedler. Sustainable Aquaculture 95. Pacon International, Honolulu, Hawaii. 1995.

Recirculating Aquaculture Tank Production Systems. SRAC Publication Nos. 451-454.

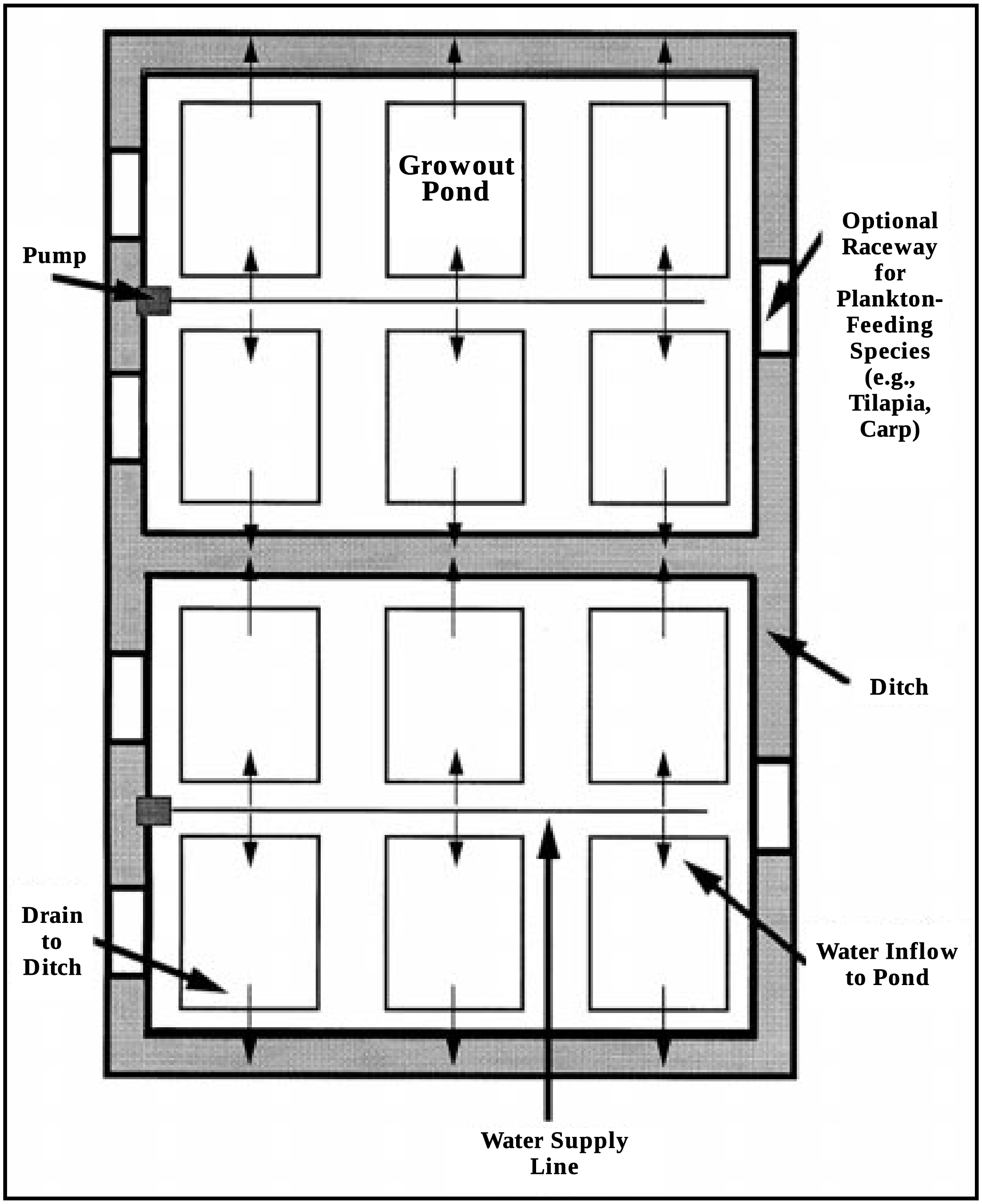

Figure 8. Example of pond/ditch recirculation polyculture system.

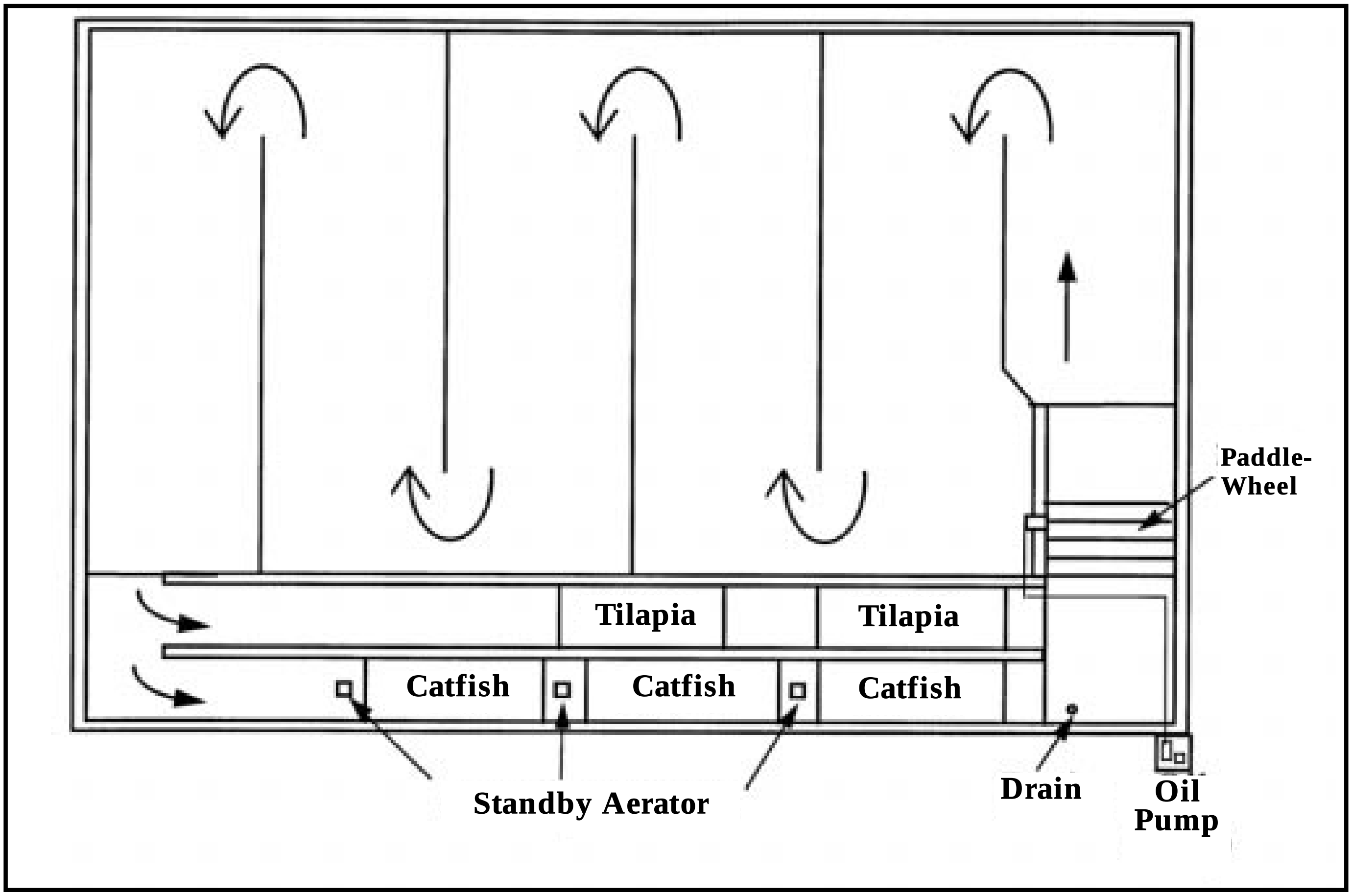

Figure 9. Overview of Partitioned Aquaculture System (PAS) (Clemson University).

The work reported in this publication was supported in part by the Southern Regional Aquaculture Center through Grant No. 94-38500-0045 from the United States Department of Agriculture, Cooperative State Research, Education, and Extension Service.