Small-Scale Aquaculture and Aquaponics

The New and the Nostaglic

by Steve Van Gorder

Is it possible for a family to grow its own fish just as it is to grow vegetables in the garden? Are there good reasons to consider it? Well, about 25 years ago Robert Rodale, the primary proponent of organic gardening and farming in the United States, asked those questions and decided that the answer should be "yes." He considered how fish is one of the healthiest, most nutritious sources of protein available, low in calories, with high levels of omega fatty acids. But, at the same time, the cost of seafood was increasing and it's quality and safety was in question. The same is true today and, since home gardening provided a source of vegetables to millions of people, maybe it would be possible to "garden" water, just as one can till the soil.

If this is the case, what are the best ways to do it? At what was then the Organic Gardening and Farming Research Center in eastern Pennsylvania (now the Rodale Institute), researchers began by digging a few small ponds, stocking them with carp and catfish and feeding them garden and table scraps. It soon became apparent, considering the fouled water and dead fish, that more studies were needed. The Rodale Aquaculture Project was originated and funded to scientifically study the various methods available to grow fish on a small scale. As the coordinator of the project, I initiated replicated studies of fish culture in pools, greenhouses and farm ponds. Over the next several years, this research resulted in the development of the Home Recirculating Aquaculture System, as well as practical information on greenhouse fish culture systems and cage culture in farm ponds. We were one of the first groups in the United States to discover the attributes of the tilapia and to refine the culture of this tropical species of fish to techniques appropriate in temperate regions. Plus, we began to investigate methods of integrating our fish culture methods with hydroponic vegetable production.

Eight years of replicated research studies were conducted on small-scale aquaculture methods.

The response was tremendous. We disseminated the information that we gathered in our newsletters, through yearly workshops attended by hundreds of enthusiasts and we wrote the book *Home Aquaculture: A Guide to Backyard Fish Farming*. This "how-to manual" described how to build your own backyard fish farm and culture enough fish and hydroponic vegetables to feed your family . . all

with limited energy and water use. Techniques were tried which blended 4,000 year-old culture practices with refined bioengineering techniques. The result was a method for growing fish which was as practical as gardening for producing food for the family.

Well, a couple of decades have passed and aquaculture has become almost a household word. Tilapia are now one of the most popular farm-raised species of food fish in the U.S., with consumers purchasing over 80 million pounds a year. Recirculating aquaculture systems offer one of the best and most sustainable alternatives for culturing fish without the negative environmental consequences often associated with traditional flow-through or netpen operations. And the commercial-scale bioengineering techniques that have been developed, from biological filtration to computer controlled oxygenation systems, have demonstrated the tremendous potential for super-intensive aquaculture in any geographic location.

Commercial-scale recirculating aquaculture systems for super-intensive finfish culture.

But undiminished by this development of commercial and even industrial-scale aquaculture methods, are the prospects for adapting what has been learned to small-scale fish farming. Recently, I updated the *Home Aquaculture* book to reflect the latest advances in design and management of a variety of culture techniques. The book, now expanded and updated as "*Small-Scale Aquaculture*" describes how to raise fish in a variety of situations. For those with no water resources beyond the garden hose, the Home Recirculating Aquaculture System will produce fish in a vinyl-lined swimming pool. For those with a farm pond, it is very simple to culture a years worth of fish in a single 1 m^3 floating cage. If you have a small spring even trout culture is possible throughout the year.

And, if you have a greenhouse, the combination of fish culture and hydroponics (aquaponics) provides a truly symbiotic and effective technique for growing both fish and vegetables!

When fish are cultured intensively in "closed" recirculating aquaculture systems (using less than 10% makeup water daily), there is an accumulation of nutrients within the culture water as a result of the intensive feeding of the fish. The biofiltration of nitrogenous wastes results in the build-up of nitrates and the solid waste of the fish provides additional organic nutrients. The recovery of these nutrients can be accomplished through the integrated culture of aquatic or terrestrial vegetables. Instead of using nutrient solutions comprised of inorganic sources of nitrogen, potassium and phosphorus, the nutrients are provided organically via the fish culture water. When combined with integrated pest management (IPM) techniques, the resulting hydroponic crop will be considered organic and free of herbicide and pesticide residues.

While obviously a logical integration of two water-based culture techniques, the aquaponic culture of terrestrial vegetables requires a great deal of skill and an understanding of the interrelationships between the fish, the fish culture systems, the plants and the hydroponic vegetable production system. We began working in close association with Dr. James Rakocy during our early studies in the 1970's and have taken advantage of his findings. While most of our work involved the integration of aquatic plants, Dr. Rakocy demonstrated methods for using various species of ter-

restrial vegetables and the most effective ways to optimize their growth.

Dr. Rakocy's work takes place on the island of St. Croix, US Virgin Islands, where the weather is conducive to outdoor fish and plant culture year-round (except during hurricane season). For the rest of us, one thing that our aquaponics systems have in common is a requirement for the complete control of temperature and light. Since few sites provide year-round temperatures which are favorable for either fish or vegetable production, we must consider some form of greenhouse structure to provide this environmental control.

For our work, a "gambrel-style" solar greenhouse was constructed which was simple and effective and combined a fairly large below-grade fish culture system with an adjacent area for the culture of various aquatic plant species. This integration resulted in the profuse production of a wide variety of aquatic plants. Watercress, Phillipine water spinach, water hyacinths, water chestnuts, water lettuce, duck week, as well as various ornamentals grew as quickly as we could harvest them. In some cases, as with water hyacinth, the plant growth provided for an improvement in the water quality but no secondary crop. We actually used the duckweed (after drying) as a food for the tilapia. And besides a large crop of delicious water chestnuts and excellent tasting water spinach, we could have fed the world on watercress sandwiches! The ornamentals included some very valuable species for the aquarium and water garden trades.

In recent years, commercial-scale aquaculture systems have been developed here in eastern Pennsylvania which integrated the aquaponic culture of both aquatic and terrestrial vegetables. One large greenhouse served as both a wastewater treatment center and for secondary crop production. Water hyacinth, growing so quickly as to require continuous cropping and composting, was used to clean fish culture wastewater to a point allowing 100% water recycling rates.

Of course, the production of terrestrial crops proved much more demanding. A more inclusive consideration of nutrient additions (foliar sprays) and pest management

Top: If you have a pond, cage culture is one of the simplest methods for growing fish for the family. Second: Even a small spring can be converted into a beautiful trout pond, with fresh fish available year round. Third: Nutrient-rich water from fish culture systems is used to irrigate garden crops and for hydroponic plant production. Bottom: A greenhouse was constructed that provided year-round environmental control for fish culture and aquaponics

techniques was required.

In summary, our early studies integrating small-scale aquaculture with hydroponic plant production demonstrated:

1) Aquatic plants grew profusely when provided with the fertile waters associated with recirculating fish culture. The only considerations were how to provide the roots access to the flow of nutrient rich water, some means of supporting the plant growth and frequent harvesting.

2) Most terrestrial vegetables will require a significant administration of additional care and usually nutrient additions and pest control measures. For this information, rely on the experiences of those contributing to the Aquaponics Journal, most notably Dr. Rakocy!

3) Providing separate space for hydroponic vegetable production can provide protection of the plant roots from grazing by the cultured fish. But the added area represents significant additional construction cost to a greenhouse mainly dedicated to fish culture. Wherever possible, use a 3-dimensional plan which takes advantage of space. Growing vines should be provided with trellises and hydroponics beds built above fish culture areas if possible.

4) Integration of hydroponics with fish culture involves the co-development of both system designs. The amount of feed fed to the fish and the recirculating technologies used to maintain water quality must match the demands of the hydroponics system for nutrients and the requirements for the culture of the plant and animal species involved.

Top: Hydroponic water hyacinth cleans fish culture wastewater. The yellowed growth demonstrates the nutrient removal after a 100' length of root contact. Bottom: Aquatic ornamentals also grew extremely well under aquaponic conditions.

With these points in mind, it was always a great deal more fun and productive when we were able to integrate our fish gardening techniques with the culture of plants in small-scale systems. Even when it simply involves using the wastewater removed daily from the clarifiers as a direct irrigant to the adjacent gardens, the resulting improved growth is amazing! With the simplest of methods it should be possible to implement an appropriate structure and aquaponics method to fit almost any small-scale fish culture method. Taking into account the requisites of both fish and hydroponic plant culture . . . including temperature, light, fish and plant species, aquaculture and hydroponic technique, coupled with an appropriate budget ... the result will always be an exciting and rewarding addition to your small-scale aquaculture project.

About the Author:

Steve Van Gorder has been involved in the development of recirculating aquaculture technologies for over 25 years. He is president of Aquamarine Fish Farms, Inc., which designs and markets hardware and technologies for commercial recirculating aquaculture systems. Mr. Van Gorder is the director of the Alternative Aquaculture Association, which publishes educational and practical information concerning small-scale and integrated methods of aquaculture. He has recently written and published the book "Small-Scale Aquaculture," which updates and expands the best selling book "Home Aquaculture, A Guide to Backyard Fish Farming." For more information, visit www.altaqua.com

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