Recirculating System Aquaculture – What You Need to Know

Fred Wheaton

Director, Northeastern Regional Aquaculture Center, Professor, Department of Environmental Science and Technology, 2113 Animal Science Building, University of Maryland, College Park, Maryland 20742-2317
Phone: 301-405-6511; Fax: 301-314-9412; fwheaton@umd.edu

Introduction

Aquaculture and recirculating aquaculture in particular, may be a strong and viable business. However, aquaculture appears to have some special attraction for many people. Exactly what this sort of mystical attraction is for some people toward aquaculture is hard to quantify and is probably based on a series of items rather than one aspect. Lack of understanding, naiveness about the science and art of aquaculture, a love of lakes and oceans, the appearance of a highly profitable operation, and many other factors are probably involved. For some reason, aquaculture, fish farm, shellfish farm and similar terms encourage otherwise reasonable people to become involved or invest in an enterprise which they would never consider if it were an agriculture or industrial enterprise with a similar business plan.

Aquaculture appears so attractive to some people they will become involved even if the enterprise does not have a viable business plan. There are, of course, some people (often referred to as snake oil sales persons) whose ethics allow them to take advantage of people having this emotional and rosy outlook about aquaculture. Thus, before deciding to become an aquaculturist or before investing in an aquaculture enterprise, one must learn how to evaluate aquaculture enterprises, what a person must know to properly evaluate a proposed enterprise, the potential of the enterprise, the risks involved, and how you personally wish to be involved if at all.

Regardless of the reasons for being interested in becoming an aquaculturist or investing in aquaculture, particularly recirculating aquaculture, one must do so with a full understanding of what it entails, the costs and risks involved, and the potential pay back possible if there is to be any possibility of success. This is not something that is learned in a day or two and interested people must be willing to make the intellectual, personal, and economic investment necessary to fully understand what they are facing before becoming heavily involved in aquaculture.

Aquaculture as a Business

Aquaculture garners up images of aquariums, fishing in farm ponds, koi ponds in the backyard, and similar nostalgic images for many people. This is a type of aquaculture but in many cases this is the image of a hobby. Hobbies are nice activities for relaxation, enjoyment, and self fulfillment. However, they are not commercial aquaculture. The hobbyist has no requirement to make money and rarely does. However, the commercial aquaculturist must make money or he will go out of business. Thus, aquaculture must be operated as a business.

Many people get into aquaculture because they want to raise fish, shellfish or aquatic plants. This is admirable and is a good place to start learning but it is not sufficient to make a successful aquaculture enterprise. Commercial aquaculturists are probably interested in raising aquatic organisms, but in fact they are in aquaculture to make money. If this is not your ultimate goal then you will probably become a hobbyist or become a contributor to the list of failed businesses. Commercial aquaculturists must be business people who are in it to make money. You can be a commercial aquaculturist without making money, and in fact many do not make money, at least for some limited time period. The length of the non-money making period (i.e. your start-up period) you can tolerate depends on the financing you have, the crop you are growing, how patient your investors are, how deep their pockets are, how much confidence they have in you, and many other factors. Many investors are looking for a return in a year or less and at least a 20 percent return on their investment. No start-up aquaculturist can meet these requirements and giving investors the impression you can is the kiss of death. It will take that long to get your building constructed and the systems started up. This does not even include the time from when you put the first fish in the system until they are ready for market, typically a year or more.

Initiating a Recirculating System Enterprise

Species to Produce

There are over 20,000 species of aquatic organisms. Of these 20,000 species, the biology of maybe 20 to 30 species is well enough known and defined that we could raise them in recirculating systems. For example, biological studies have been published on oysters for over 80 years and oysters have been harvested from the natural environment for over 2,000 years. However, we do not know what constitutes a balanced diet for any species of oyster, and if we did know, we lack knowledge on the form, particle size, and other information needed to commercially deliver the diet to the oysters. The only feed we can provide oysters today is a few species of plankton on which we know they will survive and grow. We do have commercially available feeds for a few species including catfish, trout and tilapia. Thus, knowledge of the biology, diseases, lack of commercially available feeds and many other holes in our knowledge of aquatic species limit species suitability for culture in recirculating systems. The potential aquaculturist must be satisfied that the biology of the species selected is well enough understood to allow production of the crop, the diseases potentially encountered by the species selected are avoidable or treatable, and the environmental needs of the crop are well enough known to allow systems parameters to be set to provide rapid growth and efficient production of the crop.

Markets for the products produced also limit the species that can be commercially and profitably grown in recirculating systems. Thus, lack of a market precludes production of the species. Markets must be assessed before any decision can be made as to what species to produce. If you cannot sell your crop, you can not make any money. There are many aspects of assessing the market and there are many references in the literature on marketing that perspective aquaculturists should consult (Anonymous, 2007; NRAC, 2003; Shaw, 1990; Lockwood, 1998; Ray, 2001). Market assessment might include a variety of methods such as consultation with potential buyers, market surveys, etc. Marketing of aquatic products has some unique aspects including the highly unsaturated fatty acids contained in many products that limit shelf life and rapidly produce undesirable odors. Consumer perception can be another facet of marketing an aquatic crop. Consumer attitudes as to wholesomeness of the product, food preferences, socioeconomic or religious considerations, and other often overlooked attributes of aquatic crops may effect marketing. For example, at one time catfish were very difficult to sell in the northeastern part of the U.S. because consumers associated consumption of catfish with a low economic status. The resistance had nothing to do with flavor, quality, wholesomeness, or other attributes of the product marketed, but was still a major marketing problem. This problem has since been overcome by good educational programs for consumers and good advertising by the industry.

Water Source

The most critical aspect of an aquaculture system is the availability of adequate water, in terms of quantity and quality. Water must be available to support the crop being grown, for emergency use, and for any expansion anticipated. All recirculating systems require water to fill the systems and some flow to make up water lost due to leakage, seepage if this occurs, evaporation, and water discharged to control water quality and water lost when fish are shipped. Lack of an adequate quantity of water will at best limit production and at worst lead of failure of the business. Water quality must allow the crop to thrive and it must be adequate, or can economically be made adequate, to allow the growing conditions and the products produced to meet all health and safety standards. Water quality will include such items as pH; temperature; alkalinity; metals; bacterial, viral, and pathogen concentrations; and pesticides and other toxin concentrations. All of these water quantity and quality questions must be resolved before siting an aquaculture facility.

Waste Discharge

Provisions for waste handling must be included in any planning for a recirculating system. The case is often presented that recirculating systems will not have any waste discharge. Granted, recirculating systems will not produce the liquid waste volume produced by a flow through system. However, recirculating systems will have some liquid discharge, with the amount depending on the system size and design. Waste will also include such things as mortalities (fish that have died), solid fish manure wastes, food that was not used in time, and other materials. Permits often are required for discharges and provisions for disposing of all wastes using environmentally benign and good neighbor methods are necessary and will go along way in reducing siting problems and problems with neighbors and the community.

Materials Handling

Commercial aquaculture facilities must handle feed, fish, fingerlings, supplies and other materials. In small systems that may use 50 kg of feed a day and have 500 kg of fish to move once per month or so, materials handling is not a major problem. However, commercial aquaculture facilities often sell over 100,000 kg of fish per year (about 2000 kg per week) and feed well over 1 million kg of feed per year. Handling this amount of materials requires planning, mechanization, good truck access, well timed deliveries, and facilities.

Potential Risks

Recirculating aquaculture still is considered a risky business by most people. Risks arise from a variety of areas. Weather, unless it is sever such as a tornado or hurricane, is not a major risk to most recirculating systems because they are located indoors and are protected from most weather events. The greater the knowledge base about the organism being grown including it biology, diseases, feed availability, environmental needs, and other factors the lower is the risk of crop loss. Because recirculating systems require high animal or plant densities to be economically feasible, diseases once introduced tend to spread rapidly, often resulting in catastrophic losses. Accidental reduction in oxygen levels, increased carbon dioxide levels, system component failure, loss of electricity and related problems increase risks. These risks may be lowered by use of automated alarm systems and/or 24 hour on site personnel, back-up systems for oxygen, power, and other critical components. Human error is one of the most frequent causes of crop losses. Careful selection and excellent training of personnel are the best methods of lowering this risk. Good biosecurity processes and procedures also lower risks of crop loss due to introduction of unwanted predators, diseases, and pests.

Recirculating aquaculture usually is carried out in a building on land. However, there is interest in developing offshore recirculating aquaculture systems. Some people believe such offshore systems can be operated at less costs, usually by reducing pumping costs. Such systems will have to satisfy the permitting requirements for offshore facilities, currently in a state of flux in the U.S., and deal with the multi-use concerns related to use of the water column, waste discharge, and related regulations. It is too early to tell if off shore recirculating systems are feasible, profitable, and can meet the regulations when they are established.

The Recirculating System

Once a market has been identified and the species to be produced is determined, decisions about the facilities and systems to be used must be made. There are several options to develop the production system. If the expertise exists in-house the systems can be designed and constructed by the company that will operate it. Alternatively the aquaculturists can hire a contractor to design and/or construct the facility and system. A third option is to purchase a turn-key already designed and constructed system and install it on site. Each of the alternatives has its strong and weak points.

There are many reliable and trustworthy suppliers of systems, components of systems, system designers, and contractors in the aquaculture industry. Unfortunately, there also a small number of individuals and/or groups that will sell you anything and it may or may not be useful for your application. Selecting from the former group and avoiding the latter group is critical in getting a system that works well and will provide the production stated by the supplier. One needs to remember that a good system with good management has a good chance to succeed. A good system badly managed will fail and a bad system badly managed will fail more quickly. Proven successful experience is the best guide in selecting contractors, designers, and suppliers. One needs to check out the qualifications of people before entering into agreements with them to design, build or supply a whole system or parts of it for a recirculating aquaculture system.

Any successful recirculating system will have certain characteristics including: 1) reliability, 2) cost effective from the standpoint of both capital and operating costs, 3) it will be efficient in use of energy, oxygen and other inputs, 4) it will provide a means to feed the fish easily and in the manner the aquaculturists plans to feed them, 5) it will allow handling the fish for loading and removing the fish with a minimum of stress on the fish and minimum labor, 6) it will provide the optimal (or close to it) environmental parameter levels the crop needs, 7) it will maintain water quality at well above parameter levels that will stress the crop and do so at the maximum biological load the supplier or designer indicates the system will handle, and 8) adequate monitoring and control equipment is incorporated in the design to monitor and control water quality parameters at desired levels. The system should be self cleaning (e.g. solids are removed by water flow), all fish contact surfaces of the system are smooth so the fish will not be injured by rough or sharp surfaces, water flow will be minimized but adequate to remove waste products, and if important, provide adequate flow to condition the fish. If purchasing a turn-key system be sure to check with operators of existing systems of the same design to determine if the systems can handle the maximum load stated and will produce the production claimed.

Scale-up of a system in size can also be a problem if not carefully done (Wheaton, 1996). There have been numerous examples in the aquaculture industry of people doing their development work in a model scale system (e.g. two meter diameter tanks) and scaling them up to the prototype (e.g. 6 meter diameter tanks) that lead to disaster. The model scale system works very well, but the prototype system fails completely. These problems usually occur when scale up does not follow known scale up principles (e.g. the tank diameter is scaled up but the depth remains the same in both model and prototype). Scale up from a model to a prototype has very definite hydraulic rules that must be followed if the model is to predict prototype operation, and this scale often depends on parameters other than only linear length dimensions.

Management

There probably have been more failures in recirculating aquaculture systems due to poor management than due to faulty system design. Management of the system effects not only the operation of the system but also the economics of the entire operation.

Recirculating aquaculture systems typically have higher capital costs than less intensive aquaculture systems. Thus, the up front costs are high as capital is required to create the facilities needed, get the equipment purchased and installed, and make sure the system operates properly before a crop of fish, shellfish, etc. are placed into the system. Failure to make sure the system works as you believe it will before placing a crop in the system will probably result in loss of the first crop sometime prior to planned harvest. This will probably happen even if the system performs flawlessly, because you and your employees have not learned how to operate the system or how to adjust the system to meet changing needs of the crop. Thus, knowing how the system responds to changes, especially in an emergency, before a problem appears is a critical part of managing a recirculating system. Having critical spare parts on hand for rapid replacement is also a good supplemental insurance policy.

Biological Load

One of the most sensitive parameters influencing profitability of a recirculating system is the system's biological load. Biological load is usually given in terms of kgs of fish in the system or kgs of feed the system can handle. To be profitable it is desirable that the biological load in a recirculating system be above 90 percent of the maximum at least 75 to 80 percent of the time. One management scheme commonly used is to place fingerling into the system at slightly above the density required to reach maximum biological load just prior to fish harvest. A few more fish than are required to reach maximum load at harvest are included as some mortality usually occurs during the growth period. Fish growth typically follows an exponential curve with faster daily weight gain (in terms of grams gained per day) occurring as the fish get larger. Such a management system loads the system at a small percentage of the biological maximum at the start of the production cycle and the percentage slowly grows until harvest. Averaged over the production cycle the biological load in a tank under this management system is low (maybe 50 percent or less) of the maximum biological load. Typically the system operating costs are essentially the same regardless of the load. Hence this management scheme drives up the operating costs per kg of fish produced (more tanks are used for less fish). Because less kgs of fish are produced per tank per year, the capital costs are spread across a smaller number or weight of fish. Thus, the capital cost per kg of fish produced increases. The major advantage of this management system is that it requires little handling of the fish.

A management system that aims to load all tanks in use at 90 percent or better of maximum biological load at least 90 percent of the time requires greater handling of the fish as they have to be moved from tank to tank as they grow to reduce the load in any individual tank. This has higher labor costs and larger mortalities due to handling stress, but usually the savings in operation and capital cost more than offsets these increased costs. However this management system requires better management of individual tanks and better management of the overall group of systems. It also requires better planning, greater knowledge of the fish and their growth and performance, more reliable and consistent performance of the recirculating systems, and better records of feeding, production, tank population, and water quality.

Records

Aquaculturists often are interested in raising a crop and do not really like to do paperwork. However, if a recirculating system is to be profitable the production costs and sale costs must be known as well as the details of these costs. This can only be achieved by having good records of feed fed daily, water quality (preferably on an hourly basis) by tank for such parameters as pH, ammonia , nitrite, and nitrate concentrations, alkalinity on a daily basis; suspended solids on a weekly basis; fingerling number and cost placed in each tank; water quality adjustments in terms of what was done, when it was done and how much of a chemical or other adjustment was made; average fish weight in each tank; water temperature; and total number and weight of fish in each tank at least on a weekly basis, cost of feed per kg and kgs fed per day; sale price of fish by tank with both number, average weight with dates sold; total weight of fish per tank; and cost of oxygen per kg; how much was used daily and preferably in each tank; cost, weight used per week and material for all other inputs into the production process. Labor time and cost need to be determined in a form that allows the operator to adequately allocate labor to each tank or group of fish. Capital costs need to be determined such that they can be distributed over the various lots of fish. A daily log should be kept where observations by the culturist of fish behavior is recorded by tank each day.

Records can be used not only for an economic analysis but can be used effectively to help determine what went wrong and when it went wrong in a specific tank where the fish became sick, stressed, or died. This aids in determining the cause of problems and finding methods to prevent reoccurrences of the problem. Records are also useful in cases where regulatory agencies question some activity in the enterprise. Records help substantiate claims. Knowledge of how many or what weight of fish were sold to what supplier on what days can be used to track sales, customer habits, and in forecasting future product demand as a function of customer and/or time. Records are also absolutely necessary to track cash flow and keep the business on track financially.

Integration of the Parts

One of the primary functions of the enterprise manager is to integrate all of the parts of the business so they function as a unit. The market has to drive the production so the enterprise meets customer demand. This means production must provide the right product in the right form for the market but it also must be at the correct time. This requires planning, organization, adequate financing, good labor management, and a host of other activities that must function together to produce a successful business. Whoever manages the business must be capable of bringing all of the activities to a successful conclusion and they must be done in the correct sequence and at the correct time. This is a difficult task and requires good planning, organization, people skills, marketing, experience, and a willingness to work when the job needs to be done and not just during regular work hours.

Needs of Industry

The international aquaculture industry has been growing at an average compounded rate of 8.8 percent since 1950 (Marine Aquaculture Task Force, 2007). Unfortunately, the greatest growth has been outside the U.S. even though the U.S. is a major importer of seafood. Fully 80 percent of the edible seafood supply in the U.S. is imported (Fisheries of the U.S, 2006). Although the U.S. aquaculture industry is now a $1 billion industry (NOAA, 2007), 40 percent of the seafood imported into the U.S. is farm raised (Marine Aquaculture Task Force, 2007).

Although the U.S. aquaculture industry has been growing rapidly, the industry has several challenges to surmount. They have need for managers that can manage aquaculture facilities. These people need to have strong interdisciplinary backgrounds including biology, engineering, business, and related disciplines; and they need to understand how to grow fish, shellfish, aquatic plants or other aquatic crops. More economical feeds that minimize fish meal use are needed not only to reduce production costs but to address the concerns of using fish to produce fish and the concern about over harvest of fish to produce fish meal.

Disease control and biosecurity are continuing concerns. Disease causes significant losses in the industry for all species and there are few drugs cleared to treat fish to be used for human food.

Developing disease resistant strains of fish and shellfish, and developing vaccines and other methods to prevent diseases are high industry priorities. Genetics is of great interest to develop faster growing, more uniform aquatic organisms (i.e. more domesticated strains), which will lower production cost and increase facilities use and feed efficiency. Genetics is also of interest in developing polyploidy organisms that are sterile so they direct more energy into growth rather than gamete production.

There are continued industry concerns about over regulation and the institution of regulations that hinder aquaculture development by limiting access to the water bottom, water column, or the shoreline for use by aquaculturists. Environmental regulations are also of concern as they often raise costs, are not applied evenly, or may be based on multi-use conflicts that are perceived to be but are not real environmental problems. Regulations that make for an unfriendly business climate also discourage commercial aquaculture enterprises. Eliminating some of the uncertainty currently plaguing marine offshore aquaculture in terms of ownership of fish and facilities, environmental limitations and regulations, and access to the water would encourage aquaculture development.

Industry is always interested in lowering costs. Technological developments that reduce costs, labor, and/or investment is on industry's priority list. Industry is also interested in having a knowledge base developed on potential new aquaculture species sufficient to determine if these species have commercial potential. Improved feeds, improved culture and processing technologies as well as development of value added products that industry could produce to make them more competitive are also of interest.

There is also a need to educate consumers, industry people, and the public as to the benefits of seafood consumption and to clear up much of the confusion about the risks and benefits of seafood consumption. Education of the public about the risks and benefits of aquaculture development on the environment is needed to allow rational decisions to be made by policy makers and the public about permitting and aquaculture development.

Conclusions

1. A commercial aquaculture venture must be treated as a business if it is to be successful.
2. There are many aspects of an aquaculture business besides raising the crop including understanding marketing, biology of the crop, engineering of an excellent system, understanding the risks involved, being a good manager of an aquaculture enterprise, and several other aspects. Perspective aquaculturists must understand these requirements and be able to effectively integrate this knowledge into good management.
3. Good management requires good records and any aquaculturist interesting in being successful must be willing to develop and maintain a good record keeping system.
4. The aquaculturist must select a species that meets the identified market and a successful enterprise will have an excellent water source, be able to secure all of the permits needed for the business, and develop or purchase an excellent recirculating system.
5. There is no substitute for experience in operating a successful aquaculture business.
6. Recirculating aquaculture businesses in general have several areas where they need assistance including improved genetics, diseases control, reducing energy use, reducing

both operating and capital costs, improved feeds that depend less on fish meal, dealing with environmental constraints, and many other areas.

References

Anonymous. 2007. Fish farmers: are you in business to make money. Aquaculture Magazine. 3(2):32-39.

Fisheries of the U.S. 2006. National Marine fisheries Service, National Oceanographic and Atmospheric Agency, Department of Commerce, Washington, D.C.

Lockwood, G. 1998. Capital markets and aquaculture failures. Aquaculture Magazine. 24(6):37-45.

Marine Aquaculture Task Force. 2007. Sustainable marine aquaculture: fulfilling the promise: managing the risks. www.whoi.edu/sites/marineaquataskforce. Tacoma Park, Maryland.

NOAA. 2007. MOWW 10-year plan for marine aquaculture. National Marine fisheries Service, National Oceanographic and Atmospheric Agency, Department of Commerce, Washington, D.C.

NRAC. 2003. Aquaculture marketing analysis and opportunities in the Northeast Region. Aquaculture White Paper No. 3, Publication No. 03-003. Northeastern Regional Aquaculture Center. University of Maryland, College Park, Maryland.

Ray, L. 2001. Common sense marketing. Aquaculture Magazine. 27(3):43-50.

Shaw, S. 1990. Marketing a practical guide for fish farmers. Fishing News Books. Oxford, United Kingdom.

Wheaton, F.W. 1996. Scale-up of aquaculture facilities. Presentation at the First International Conference on Recirculating Aquaculture, Roanoke, Virginia.