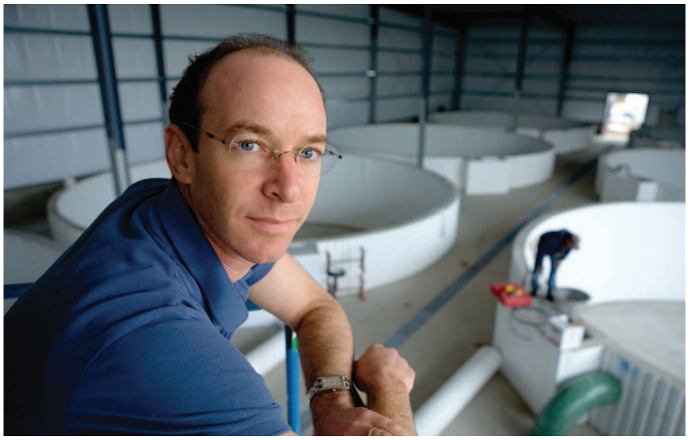
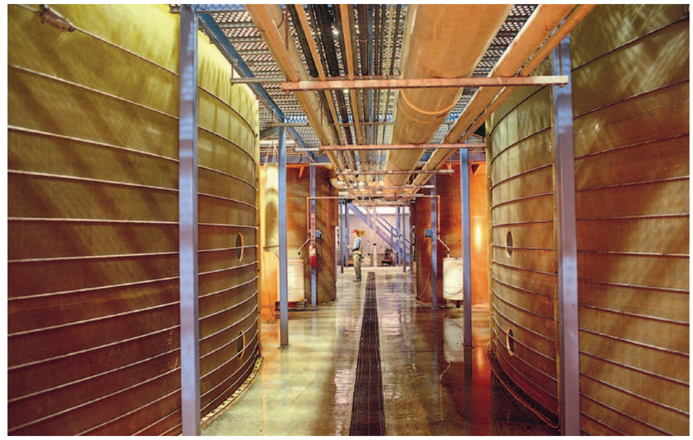
So, You Want to Be a Fish Farmer?

Josh Goldman



The author at the Australis Aquaculture facility.



Grow-out tanks (500 t) at Australis Aquaculture's recirculating aquaculture production facility.

As aquaculture becomes an increasingly important part of the food system, the idea of raising fish on land using recirculating aquaculture systems (RAS) has come to hold considerable interest for many people. Some people possess an admirable desire to contribute to society by raising food in a sustainable manner; others seek ways to breathe new life into underutilized farm assets, while others see an exciting business opportunity in a rapidly expanding "industry of the future."

Whatever their motivations, people seek our advice on an almost weekly basis as they contemplate growing fish for profit. Given this interest, and the magnitude of the commitment required to enter the business, I thought it would be helpful to share some observations in an effort to identify the primary drivers of success, while highlighting the factors that have caused the vast majority of commercial RAS projects in the US to fail. I share this information to help the RAS community gain a more complete understanding of the skills required to mitigate the operational risks associated with commercial recirculating aquaculture.

A Little Background

As the founder of Australis, I have been raising fish in RAS for more than 30 years. In the early 1980s, I led one of the first research programs focused on developing a scientific understanding of RAS and, together with my team, assembled and refined many of the processes and the basic treatment sequence that is utilized in RAS systems globally. Given our early start and the lack of integrators at that time, we designed, built and operated our own systems, which, while painful in many respects, led to the steady accumulation of critical experience and greatly reduced capital requirements relative to known commercially available systems. Over time, as the primary engineering and environmental requirements began to be worked out, we produced and evaluated more than 30 species of freshwater, diadromous and marine fish.

Australis is one of a very small number of North American RAS operators that has sustained a profitable RAS business for a long period. Over these years, we've faced an extraordinary array of challenges. Many of these took us by surprise, were difficult to work through and required considerable dedication, time, effort and capital to address. I offer this review so that potential producers can do their homework and make an informed appraisal to determine whether RAS are a good fit.

A Brief History of Recirculating Aquaculture

Although aquaculture in ponds and natural enclosures has been practiced for centuries, intensive aquaculture has a much shorter history. Modern recirculating aquaculture has its roots in the 1970s in a German program that demonstrated that carp could grow under very intensive conditions, provided fish had access to a continuous supply of high-quality water. Subsequently, the Danish Aquaculture Institute undertook a pioneering effort to develop many of the technical foundations of the field. Their efforts supported the development of one of first commercial industries to use RAS for production of European eel *Anguilla anguilla* as food. This sector benefits from an extremely robust animal, which commands a very high market price, and stable demand based on traditional northern European consumption patterns.

The success of the European eel industry inspired efforts in the US that sought to develop water saving and environmentally sustainable alternatives to conventional flow-through and pond-based aquaculture. Notable early research programs were conducted by the New Alchemy Institute, which developed the simple yet elegant "solar algae pond," the Rodale Institute, which developed a low-cost tank-based system for "backyard aquaculturists," and my work at Hampshire College, where I was fortunate to receive support from the Pew Foundation. Engineers and scientists at the US Fish and Wildlife Service, as well as a number of public research institutions played critical roles in building on these foundations. Notably, aquaculturists and engineers at Virginia Tech, LSU, Cornell and the Freshwater Institute, among others, made highly significant contributions, developing what has grown into a sophisticated discipline and engineering specialty.

From a farmer's perspective, modern RAS relies on very high-volume, yet low-cost filtration to maintain excellent water quality that is required to support the health and growth of aquatic animals. That can be a tall order. To meet production targets, the producer must add hundreds or thousands of kilograms of nutrient-dense feed into a tightly closed system. The filtration system must continuously treat water to high standards so that it contains no more than a few parts per million of suspended solids, ammonia, nitrite and typically less than 30 parts per million of CO_2.

Because this filtration process has to deliver consistent results over the course of an extended production cycle, the systems require a degree of reliability that can be difficult to achieve at a human, mechanical or biological level. Our competitors, who rely on the natural environment to maintain appropriate and suitable conditions, will generally have little to no direct costs to maintain the production environment in a pond, river or net-pen. I often say that RAS are intensive care units for fish. Like patients in the ICU, fish are totally dependent on us for life support, which means mistakes operating the facility are just as unforgiving as they would be in an ICU, except that we have thousands or millions of patients—and relative few doctors and nurses.

Perhaps it is for these reasons that so few commercial RAS projects have succeeded. Table 1 summarizes the operational status of the majority of US-based RAS projects that I am aware of that were developed over the past 20 years. This list almost certainly misses numerous smaller projects that also were developed during this timeframe. In aggregate, these projects represent a combined investment likely exceeding $1 billion dollars and a tremendous human effort to bring this new approach to aquaculture production to market.

TABLE 1. Status of commercial fish farms in the US based on RAS technology.

Company	State	Status	Farm Type	Species
Maine Aquafarms	ME	Closed	Site Built	Arctic Char
WV Salmon & Trout	WV	Closed	Site Built	Arctic Char, Atlantic Salmon
WV Aqua	WV	Closed	Site Built	Arctic Char, Brook Char
Cell Aquaculture (3 farms)	AL, NV	Closed	Pre-Fab	Barramundi
C-Box	NV	Closed	Pre-Fab	Barramundi
Waterland Fisheries	Md	Closed	Pre-Fab	Barramundi/Tilapia
Australis Aquaculture	MA	Operating	Site Built	Barramundi
Blue Ridge Fisheries	VA	Closed	Site Built	Catfish, Hybrid Striped Bass
East End Hutterite Colony	MT	Closed	Site Built	Coho salmon
Teton Fisheries	MT	Closed	Site Built	Coho salmon
SweetSpring Salmon	WA	Closed	Site Built	Coho salmon
Hunting Creek Fisheries	MD	Operating	Site Built	Goldfish, Koi
Mt. Parnell Fisheries	PA	Operating	Site Built	Goldfish, Koi
Kent SeaTech	CA	Closed	Site Built	Hybrid Striped Bass
AquaFuture	MA	Closed	Site Built	Hybrid Striped Bass
Integrated Food Tecnologies	PA	Closed	Pre-Fab	Hybrid Striped Bass
St. Croix Waters Fishery	WI	Closed	Site Built	Salmon,Hybrid Striped Bass, Yellow Perch
Local Ocean	NY	Closed	Site Built	Sea Bream, Sea Bass, Other Marine
Magnolia Shrimp	KY	Closed	Site Built	Shrimp
Michigan Tilapia RAS	MI	Closed	Site Built	Shrimp
Blue Oasis Pure Shrimp	NV	Closed	Site Built	Shrimp
Little River Trails	NC	Closed	Site Built	Flounder, Hybrid Striped Bass
Great Bay AquaFarms	NH	Closed	Site Built	Flounder, Winter Flounder, Black Sea Bass
Bluebeyond Fisheries	CA	Closed	Site Built	Tilapia
Solar AquaFarms	CA	Closed	Site Built	Tilapia
Southern States Cooperative (~10+ farms)	GA	Closed	Pre-Fab	Tilapia
Iowa RAS	IA	Closed	Site Built	Tilapia
JR Simplot	ID	Closed	Site Built	Tilapia
ADM	IL	Closed	Site Built	Tilapia
Tippco	IN	Operating	Site Built	Tilapia
Aqua Green	LA	Operating	Site Built	Tilapia
Orleans Parish Prison	LA	Closed	Site Built	Tilapia
Bioshelters, Inc.	MA	Closed	Site Built	Tilapia
Fresh Culture Systems (multiple farms)	PA, MD	Closed	Pre-Fab	Tilapia
Southern States Cooperative - MD	MD	Closed	Pre-Fab	Tilapia
Minaqua	MN	Closed	Site Built	Tilapia
Hutterite Tilapia RAS 1	MT	Closed	Site Built	Tilapia
Hutterite Tilapia RAS 2	MT	Closed	Site Built	Tilapia
Astor Farms	NC	Operating	Site Built	Tilapia
Brock Farms, Inc.	NC	Operating	Site Built	Tilapia
Circle G Farms	NC	Operating	Site Built	Tilapia
DPK, Inc.	NC	Operating	Site Built	Tilapia
Farmers Catch	GA	Operating	Site Built	Tilapia
Southern Farm Tilapia	NC	Operating	Site Built	Tilapia
Sutton Farms	NC	Closed	Site Built	Tilapia
Taylor Fish Farm	NC	Operating	Site Built	Tilapia
Tim and Mike Barns Farms	NC	Closed	Site Built	Tilapia
Triple M Aquaculture	NC	Closed	Site Built	Tilapia
Fish n Dakota	ND	Closed	Site Built	Tilapia
Cayuga Aquaventures	NY	Closed	Site Built	Tilapia
Fingerlakes Aquaculture	NY	Closed	Site Built	Tilapia
WJ Aquaculture	PA	Operating	Site Built	Tilapia
Hutterville Farm	SD	Closed	Site Built	Tilapia
Simeron	TX	Closed	Site Built	Tilapia
Blue Ridge Aquaculture	VA	Operating	Site Built	Tilapia
Southern States Cooperative - VA	VA	Closed	Pre-Fab	Tilapia
Loess Hills Aquaculture	IA	Closed	Site Built	Trout, Walleye, Bass
Integrated Aquaculture	PA	Closed	Site Built	Yellow Perch
Shandaggan Farm	PA	Closed	Site Built	Yellow Perch
Bell Aquaculture	IN	Closed	Site Built	Yellow Perch, Trout, Salmon
Virginia Cobia Farms	VA	Closed	Site Built	Pompano/Cobia

What Went Wrong?

Despite the best intentions, knowledge and commitment of the staff and major financial commitment by owners and investors, very few of these projects have been successful over the long run. Acknowledging the high proportion of failures, it is reasonable to ask what went wrong to learn from these experiences and minimize the risk of repeating history. Having spent 30+ years working on RAS projects globally to address operational challenges, I have distilled what I consider to be the 'big five' issues that seem to universally plague tightly closed RAS projects and have caused so many to fail.

1. Siting. Inadequate water supply has played a key role in the

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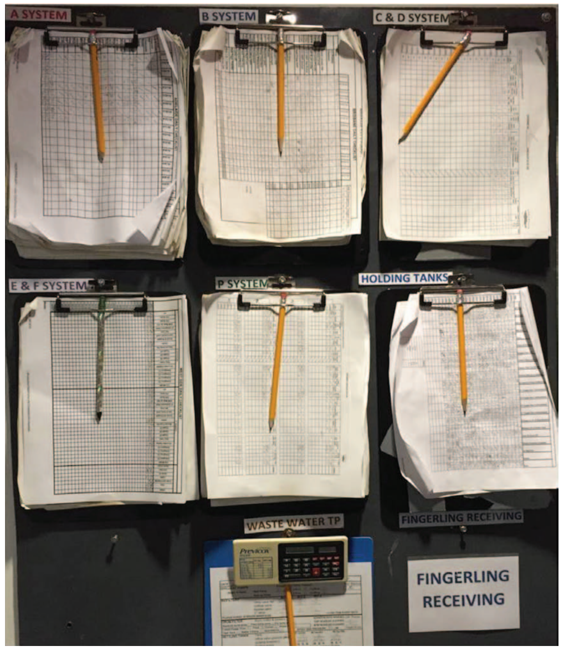
failure of many RAS projects. Suitable sites should provide constant access to high-quality water as well as a low-cost means of treating and discharging effluent. The water requirements of a fish farm are quite different from that of almost any other activity. Conventional production wells are rarely pumped on a continuous 24/7, 365 basis. Those that are typically suffer from reductions in output over time due to accelerated fouling, which requires regular and costly maintenance and rehabilitation. A reduction in water exchange can lead to nitrate and metal accumulation, alter other chemical parameters and destabilize production. Sustaining adequate water exchange is also typically critical to maintaining stable temperatures for warmwater and coldwater species and must be carefully considered as part of siting, design and operational plans. Emerging though still sparse research suggests that maximum safe nitrate levels of 75 ppm (as N) should be applied as a design parameter to avoid negative respiratory and/or immunological effects. Redundant sources of high-quality water, in excess of base design requirements, should be built into the development plan.



Checklists are an essential tool to ensure conformity with operational standards.

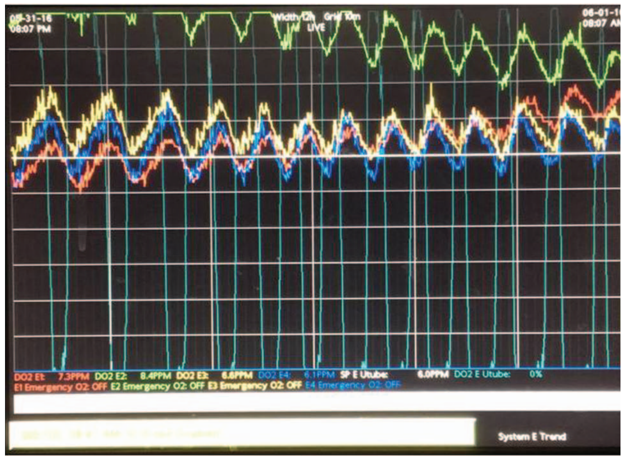
2. Achieving and Managing Production Capacity. The failure to achieve production targets is unquestionably the most frequent early problem faced by RAS projects. These facilities have high fixed costs that are largely time based and independent of biomass production. Delays in reaching breakeven or interruptions in supply can be very expensive and disruptive to customer relationships. Many issues contribute – siting, feed and fingerling quality, fish health, water quality, and operator skill typically play a role – but insufficient (or unbalanced) capacity of the filtration system is arguably the most frequent challenge encountered. Sub-optimum or variable water quality often leads to fish health problems and slower-than-target growth rates. Underfeeding, to reduce pressure on an overloaded filtration system, reduces output and increases unit production costs. Optimization of the relationship between filtration capacity, tank size, fish growth rates and grading requirements must be built into the planning process. The larger the harvest weight the greater the need for optimization of this factor. Professionally designed, site-built projects have tended to fare somewhat better but generally require a pilot phase that identifies problems, not all of which are necessarily addressed during scale-up. Scale-up of site-built facilities usually has the unintended effect of making small problems larger and often results in a protracted debugging process. Projects that rely on prefabricated systems have tended to be value-engineered to reduce capital costs to make them marketable at a profit by the manufacturer, but often at the expense of flexibility, reliability and capacity. Because pre-fabricated systems typically rely on numerous smaller units, correcting deficiencies tends to require redundant modifications, making these costly to rectify.

3. Management and Staffing. Successfully operating RAS systems requires specialized knowledge across many disciplines. A successful team will need mechanical and electronic skills, a strong working knowledge of water chemistry, fish nutrition and health management, to name a few. In my experience, building a team capable of effectively managing across this range of disciplines is one of the most challenging aspects of establishing a successful operation. While academic programs in aquaculture can help build a foundation, fish farmers are "made" though experience and it takes a many years to acquire sufficient experience to address risks and manage effectively. Surgeon Atul Gawande explains in his book *The Checklist Manifesto* that many disciplines have become too complex to manage informally and RAS is a case in point of what Gawande writes about. As such, it is best managed through a combination of highly structured checklists or standard operating procedures to minimize the frequency of avoidable errors and a culture of openness and collaboration to address unforeseen challenges. Our US production manager is fond of saying "It's not about the fish, it's about the people." Until there are doctoral programs in RAS management, the development of highly capable managers will remain a major challenge.

4. Product Quality. Warmwater RAS typically operate with limited water exchange to conserve heat. As a result, they encourage the growth of bacteria that produce off-flavor compounds (primarily MIB and geosmin) that can rapidly bioaccumulate in fish tissues. These compounds can be detected by consumers at concentration as low as a few parts per billion. A muddy or musty flavor is the fastest way to lose customers. Protocols to ensure a constantly clean flavor – particularly for species with high fat levels that stubbornly retain these compounds – is not a trivial problem and should be built into the infrastructure and production plan from the outset. Testing to determine the time and system requirements to archive undetectable levels of off-flavor compounds is an essential requirement for success.

5. Selling Profitably. After reaching the stage of having a reliable output of marketable product, developing profitable markets is the next key requirement for success. Americans consume only about 10 percent as much fish as meat, and of the fish we do eat, consumption is dominated by tuna, salmon, cod, catfish and tilapia. This leaves less than one pound per capita for the hundreds of other species that share this corner of the market. Because more than 90 percent of the seafood that Americans consume is imported, primarily from countries with low production and processing costs, prices are competitive. For this reason, virtually all domestic RAS producers sell to specialty live markets. While live markets reward suppliers with a premium for products that can survive the challenges of transport, distribution and holding, this sector is fully supplied because it is the only viable market for most domestic producers. Adding to this, the Asian grocery stores that sell live fish are typically located in urban areas where tank space is at a premium, so competition is fierce. Anyone wishing to enter the live market is generally going to have to displace an established producer who already has a relationship with their customers. The bottom line is that live markets are very inelastic and highly competitive and have limited potential to absorb additional product volumes.

Some projects were established with the expectation of processing fish from a network of farmers who participated in an integrated project. While the market for fillets is vastly larger than that of live product, every US RAS project that was based on the expectation of selling processed fillets has found that their costs were too high to be competitive in the global marketplace.



A screen shot of a control system showing trends of multiple water quality parameters.

Small . . . isn't always beautiful

Unlike poultry, hog or cattle farming – sectors with a strong contingent of independent producers – most fish grown by western aquaculture farms are raised by mid-to-large size organizations. Why the difference? The integrators who process and sell terrestrial meat prefer to leave the business of farming to independent growers. This apportions most of the risk to growers and leaves the more complex and capital-intensive activities (breeding, processing and marketing) to the integrator or more specialized businesses. The growers give up a degree of control but benefit through participation in a well-structured supply chain that allows them to focus on what they do best.

In contrast, Western aquaculture is dominated by larger producers. This pattern occurs because only larger producers have been able to assemble the experts, specialized knowledge, technology and capital needed to operate successfully, given the inherent complexities of the business. For many aquaculture species, the genetics (and therefore the accessible biological performance) of the animals is still fairly close to a wild state, and the degree to which nutritional requirements and health management protocols and vaccines are available or have been optimized varies widely.

Over the past two decades there have been numerous efforts to sell packaged farming systems that were intended to apply the integrator model to aquaculture. Each promoted a novel technology and promised growers the chance to make significant profits. Unfortunately, experience to date has shown that production and processing costs were always greater than anticipated and demand was slow to develop. As a result, the efficient supply chain upon which the system depended never materialized and things ended badly.

The Bottom Line

The ultimate question is whether fish can be sold at a profit because this is the foundation for economic sustainability in any business. It is essential that costs are known, not just for operation, but also for the critical elements of the supply chain upon which a grower depends. Where will key inputs such as fingerlings and feed come from and how reliable is the quality and supply? Are there alternatives if the primary supplier fails to meet expectations? Where will the fish be processed and at what cost? Who will the customers be and how stable is demand and pricing in those markets?

Fillets typically generate a 32-60 percent yield, depending on species and product format, leaving as much as two-thirds of the live weight as an unmarketable or lower-value by-product. If fillets are the final product form, there should be confidence that there is a robust and scaleable market, willing to pay a price that makes sense in the marketplace and that is sufficient to operate profitably. The expectation of sustaining high prices as output increases should be tested against competing products, which are already successful in the market. If these sell for less than anticipated, after factoring in processing yield, packaging and distribution costs, a potential producer might want to think again.

RAS systems are proving to be the best available technology for smolt production and nursery operations of marine fish, and are being widely adapted for these purposes. Producing juveniles in RAS has the advantage of protecting the fish when they are most sensitive to parasites and viral diseases and when growth rates are highest. Higher specific growth rates during the juvenile phase minimizes the 'area under the curve,' defined as the inefficiency of investing in and operating systems whose full capacity is not required or used until maximum feed and biomass levels are reached. Additionally, because values are much higher for juveniles on a unit weight basis, it is affordable to invest upwards of US$30,000/t of output for smolt systems. This level of investment would prove uncompetitive for full scale grow-out where the market price of the finished product is much lower. This level of difference in capital cost between RAS and conventional systems (which run closer to $3,000/t) are unlikely to be compensated by improvements in biological performance, despite what some proponents claim.

Over many years of operating and advising RAS producers, I have seen and experienced numerous unforeseen challenges. These required ingenuity, patience and capital beyond what operators and investors could have ever imagined at the outset. I believe this is a near universal aspect of the RAS experience—for those who have persevered as well as for those who have not. By studying this history, I hope readers gain a deeper appreciation of the "big five" challenges of siting, achieving capacity, management and staffing, quality assurance and selling profitably to achieve commercial success in RAS grow-out operations. An integrated approach to understanding and managing each of these areas is critical, even as many of the underlying technologies have become more efficient and reliable.

Notes

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