Aquaponics at Greylock Works: Feasibility Analysis

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Introduction

Project Scope and Client Goals

Clients Lee Venolia and Susan Abrams aim to feed their local community with ultra healthy food through building an aquaponics system located at Greylock Works in North Adams, MA. The clients' initial goals for this project were to evaluate the local market capacity for tilapia and greens in local restaurants and grocery stores, evaluate the feasibility and options for fish processing, and investigate feasibility of eliminating plastics from the aquaponics facility.

The ultimate scope that we agreed upon was to conduct research, interviews, and site visits to evaluate the feasibility of differing business and operational models. We will report our findings through three evaluation matrices. Our approach includes evaluating the specifics of various business and management models, operational models, and energy usage from a variety of sources. For the operational models, we will consider aquaponics vs. hydroponics vs. aquaculture, species of fish, types of greens, feasible production scales, and processing and markets for the fish. For the business model we will consider the intention of the facility, and whether the operation will be educational, non-profit, for-profit, or an independent business. Our final main considerations are energy usage and green alternatives, as well as viable funding sources. We also address fish processing, local market availability, and capacity of the site location.

Interview Methodology

We conducted outreach to 13 aquaponics facilities, 4 hydroponics facilities, and 2 aquaculture facilities. We conducted informative interviews with Shushan Valley Hydroponics, Victory Aquaponics, and 302 Aquaponics, and Keith Wilda at Great Falls Aquaculture, and listened to a presentation by Sam Fleming, founder of 100 Gardens. We visited the Berkshire House of Corrections Aquaponics Center in Pittsfield, MA, and Radix Ecological Sustainability Center in Albany, New York. In our interviews, we asked a series of questions relating to energy, management, profit, markets, growing methods, and more (Appendix A). We also conducted phone interviews with the seafood distributor, BerkShore, and fish processors Tai Huik and Sean Hilpi to evaluate options for fish processing and transport. We conducted an in person interview with the general manager of Wild Oats Market, as well as phone interviews with the owner of Mezze Bistro & Bar and the head of Williams College Dining to evaluate local market viability for greens and fish.

Literature Review

Aquaponics History

Aquaponics is the process of growing fish and plants in the same system, fostering a symbiotic relationship. That relationship depends on the nitrogen cycle in the water: the nutrients in fish waste are used to fertilize the plants and the plants in turn filter the water and return it to the fish. These systems have been gaining popularity in the United States since the first large-scale commercial operation opened in the 1980s, but have existed historically across the globe.

Aquaponics systems have existed for thousands of years. There is evidence of floating crop beds from the Aztecs' chinampas and Chinese rice and fish systems from over a thousand years ago. Aquaponics used in industrial farming today has deep histories in Vietnam and Malaysia (Goodman 2011).

Current State of Aquaponics Industry

With organic fruit and vegetable sales growing and increased interest in environmental sustainability, along with growing concern about the impact of the climate crisis on conventional agriculture, the aquaponics industry has had a compounded annual growth rate of about 10% over the past five years. Currently, Mordor Intelligence estimates aquaponics retail sales to equal about $113 million. The growth has spread throughout the U.S. For example, in Wisconsin, where one of the largest aquaponic facility manufacturers is, 500 new aquaculture sites were built, 300 of which were dedicated to aquaponics, specifically (Mordor 2022).

The aquaponics industry started out very small and the first push of dedicated research began in the 1980s. In 2012, there were only 71 farms in 21 states across the U.S. About 75% of farms were very small scale with revenues less than $25,000 (Engle and Beam 2022). A report by researchers at the University of Oklahoma finds that most aquaponics facilities that exist have little interest in economic feasibility and instead place an emphasis on home gardening or sustainability. Reviewing literature up until 2017, they found no clear conclusion about financial feasibility.

Key Economic Concerns

There are a number of key economic concerns surrounding aquaponics facilities in the U.S.. While this report presents information about economic feasibility that we received via surveys, researchers have also outlined the economic concerns in literature. The primary concern is finding dedicated facility managers (Beem 2017). Managers need to be fully dedicated and extremely knowledgeable about the facility. They need to be on call at all hours of the day and be present daily to monitor the delicately balanced system. Additionally, the start-up costs for aquaponics facilities can be daunting. While revenue can often meet operational costs, high start-up costs can often be too high to pay off. Careful planning of expenses and revenue should be factored in. Lastly, the operational costs of a facility must be closely accounted for (Beem 2017). Energy, labor costs, and inputs can have drains on operational budgets that need to be accounted for properly.

These concerns are supported by a more recent study done by Terrascope (2022). Terrascope found that the significant start-up costs of aquaponic facilities can be a major financial challenge, similar to more traditional agriculture practices. Terrascope found that in small systems (less than 30,000 square feet) labor can take up half of costs and energy can take up another twenty to thirty percent of costs, depending on the facility and location (2022).

Case Studies

There are some examples of profitable aquaponics systems. For example, John Reid and Josh Goldman owned and operated Bioshelter Inc. in Amherst Massachusetts for 20 years, beginning in the 1990s. BioShelters was a 60,000 square foot facility with one-third dedicated to fish and two-thirds dedicated to plants. In total they had almost an acre of plants under the greenhouse. Reid and Goldman were able to make about 20% on margin, growing tomatoes, peppers, cucumbers, basil, mint, and cilantro. When they started producing for Stop & Shop, they transitioned to producing only basil to meet demand. By the end of their operation, their products were sold in 650 super markets. They had a 50-year lease with the property owner and hoped to potentially double in size. However, the owner sold the facility in the middle of their lease and they had to shut down. Today, John Reid is currently developing Waterfield

Farms, an aquaponics system in Rotterdam, NY. This is projected to be a facility with 280,000 square feet of greens and 80,000 square feet of fish. Springworks Aquaponics in Lisbon, ME, has had success across the Northeast and currently produces 1 million heads of lettuce and 60,000 lbs. of tilapia per year in their 500,000 square foot facility.

In a 2011 paper for MIT Master's in Urban Planning, Elisha Goodman wrote one of the most in-depth cost-benefit analyses of aquaponics in the United States. She noted that most systems use tilapia for their durability and broad range of temperature, ph levels, and oxygen levels. Also, the ideal crops are plants with low nutrient requirements like lettuce, herbs, and greens. Goodman (2011) did not find evidence of profitability or financial sustainability in the aquaponics market. First, there is a long history of "aquashysters" who are interested in selling systems when they do not anticipate them to be profitable. Goodman warns anybody looking to enter the aquaponics market must have a strong plan for their cash flow and profitability model.

Two case studies Goodman featured are Sweet Water Organics and Growing Power in Wisconsin. Both facilities were among the largest in the United States at the time and had the advantage of economies of scale. Of note, Sweet Water was built into an old industrial building in Milwaukee, similar to Greylock Works. Goodman concluded that she did not think either model could become profitable and had only seen one example of strong profitability in Australia (a 100,000 square foot facility). Both facilities were structured as 501(c)(3) and still struggled financially.

Sure enough, in 2013, five years after opening, Sweet Water closed down (Daykin 2013). It was reported to be unprofitable and could not pay back debts. One of its downfalls was the energy consumption of intense grow lights. In 2018, Growing Power closed. It was receiving many grants from huge corporations, but likely expanded too quickly and was not selling enough products to sustain this growth (Satterfield 2018).

More recent studies of the aquaponics industry have found avenues for profitability. A research team from the Leibniz Institute in Germany found that a facility of about 6,000 square feet was not profitable but when scaled up, it became profitable (Baganz et al. 2020). The researchers worked for about one year in a facility in Warren, Germany, measuring production and inputs. This study of course uses German pricing and costing models but is one of the most in depth and recent analyses. The study does find that scaling the facility to roughly 2,000 square meters (or 20,000 square feet) would reach profitability and even pay back capital investment. Their study highlights a few specific recommendations. They mention the concerns of high start-up and operational costs, specifically labor, feed, and energy. They recommend that knowledgeable, dedicated employees with business backgrounds are "indispensable." Lastly, they discuss the importance of developing close relationships with a wide range of buyers to ensure a consistent revenue stream.

Other recent studies have found a lack of certainty in either direction. A meta-analysis from Greenfield et al. (2019) found variability in reporting. They classify papers by their descriptions of contributions to reducing costs or increasing profits. While they do not draw conclusions regarding profitability, they draw three main conclusions from the literature. First, larger systems are consistently more viable than smaller systems because of economies of scale. Second, profitability is sensitive to prices of retailers and wholesalers. When selling a specific green, a $1 change in pricing can change revenue drastically. Lastly, detailed business plans are important to understanding commercial aquaponics. They recommend improving business plans over time with more detail, but starting with specific assumptions and targets.

Fisheries Collapse

Overfishing, fueled by an increased global demand for fish and destructive modern fishing technology, could lead to a total collapse of global fisheries and catastrophic loss of marine species by 2050 (Oceaneos - Restoring Ocean Life | Collapsing Fisheries). The loss of fish has devastating cascading effects on marine ecosystems as a whole. Modern fishing trawlers can easily gather an unsustainably large catch each day, and a lack of regulations on the amount of fish that can be collected results in extreme overfishing globally (Oceaneos - Restoring Ocean Life | Collapsing Fisheries). Industrial fishing has reduced ocean fish populations to 10% of pre-industrial levels, and nearly 80% of global fisheries are exploited, depleted, or in a state of collapse (Oceaneos - Restoring Ocean Life | Overfishing).

Aquaculture has been posited as a way to combat fisheries collapse by cultivating fish and allowing wild fish stocks to recover. However, a concern is that when farming higher trophic level fish, fishmeal is required as a food source, thus stressing the wild fish stocks that are exploited for fishmeal (Oceaneos - Restoring Ocean Life | Collapsing Fisheries).

Plastics

One of the central concerns of our clients is the minimization of microplastics and plastic leaching in the proposed aquaponics system at Greylock Works. A fully plastic-free aquaponics would be a completely innovative system, as there are no plastic-free aquaponics systems known to date. Nelson and Pade is the leading commercial aquaponics kit supplier for both large and small scale systems. It offers systems specifically designed for schools, educational facilities, home systems, and microfarms with an appealing 'expandability' model.

These kits represent the wider problem with plastics in aquaponics. Plastic is frequently used in the large tanks, styrofoam floating growth medium, liners, piping, and in the water filters. In an aquaponics system, there is concern of microplastics and toxic plastic additives entering the system, especially through floating media, processing, and filters. Plastic leaching is a concern throughout the entire system, where photodegradation causes harmful chemicals used in plastic manufacturing to enter the system and propagate through the fish and greens.

Impacts

One of the first studies investigating microplastics in aquatic environments evaluated the digestive cycle of blue mussels (Thompson, 2018). They hypothesized that the mussels would pass the plastics they consumed as it was 'unnatural fiber'. However, particles of microplastic remained in the shellfish until the end of the trial (Thompson, 2018). The true harm of microplastics is that they do not just linger in our body before exiting. They have the potential to move out of our digestive tract into the bloodstream and other organs. This can cause inflammation, chemical leaching, and organ damage (Thompson, 2018). The discovery of microplastics within food systems and human bodies is relatively recent, so the true impacts are not fully understood.

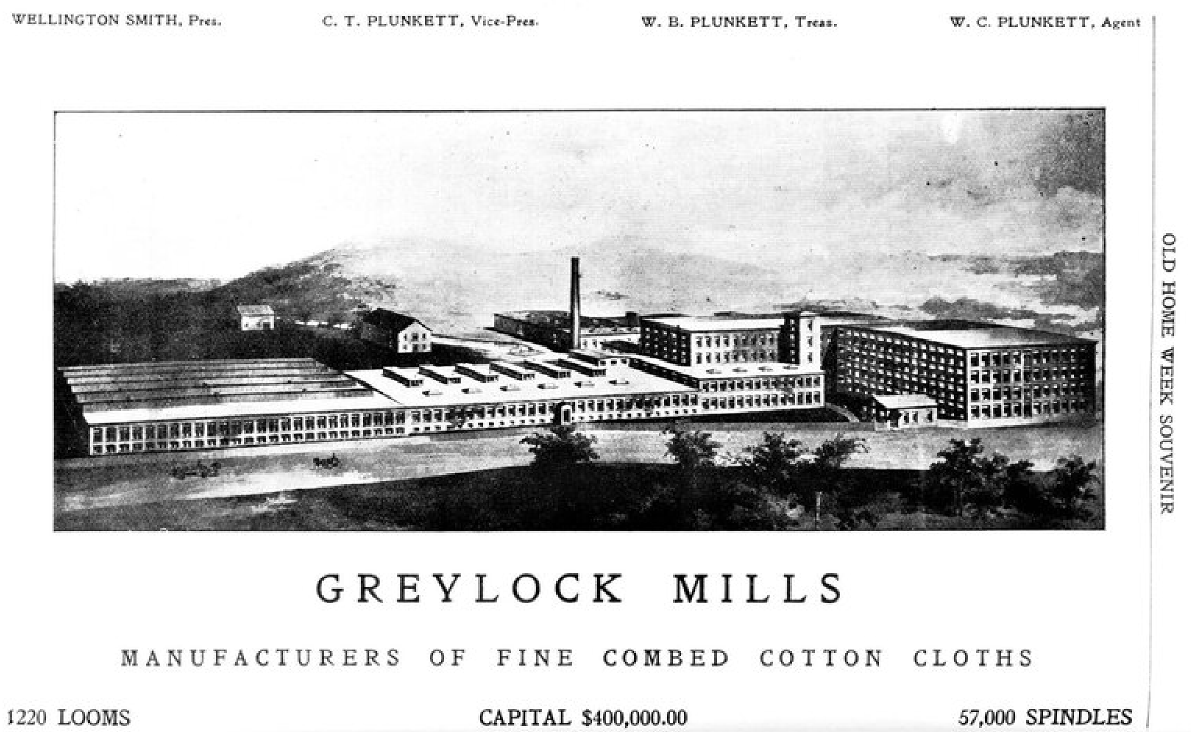
Ongoing Research

Hof University of Applied Sciences has been conducting ongoing research to evaluate if a plastic-free aquaculture system is feasible. The project is called BioBioCarrier, which uses biodegradable aquaculture growth media for water treatment completely without petroleum-based plastic (Wiesmayer, 2021). Using biopolymers instead of petroleum-based plastic would eliminate the issues of leaching, but the impacts of plastic fragmentation is not yet known. The production of biopolymers is a new field and the study has not released their complete findings.

Site Description: Greylock Works

Site History

Greylock Mill was established in 1846 by McLellan, Hunter & Co. as a cotton production plant (Moak, 2021). Over the years, it has changed ownership, function, and undergone construction and alterations. At one point in the 1930s, the factory employed around 3,000+ under Berkshire Fine Spinning Associates (Moak, 2021). Salvatore Perry and Karla Rothstein, the current owners of Greylock Works, purchased the Greylock Mills campus in 2014 and have been redesigning the property with incremental projects, including event spaces, breweries, and studios.



Source: 1909 North Adams City Directory

Physical Site Description

Greylock Works is an 8.8-acre total campus, with one building designated for the Aquaponics at Greylock Works project. The North Butler building, assigned to the project, is 10,000 square feet with two combined 50’ x 100’ buildings. The site is ideal for construction with minimal constraints from the property owners, who support creative alterations to the space. These changes include removing the cement flooring and replacing the current roof with a transparent material. The buildings currently have a thin sheet metal roof with open holes. There are two current proposed changes to the site: First, the roof will be removed or replaced with a transparent material to let in sunlight to the crop beds as well as office spaces housed in the main building. Second, there is a proposal for a ten foot pathway on two edges of the North Butler building to provide loading dock space and move goods into the adjacent buildings.

Aquaponics at Greylock Works

The North Butler buildings could accommodate an aquaponics facility of roughly 8,000 square feet. The aquaponics setup must be located inside a greenhouse within the building. Any site within the buildings will need to have its own separate frame that can be supported by the existing structural frame. This will facilitate control of temperature and humidity, critical factors in aquaponic farming, by reducing the operational volume. Without heat or cooling, the building would be at ambient temperature. Without wind, the building can be a bit warmer than outdoor temperatures in the winter, but still nearing freezing, and can reach temperatures up to 90 degrees in the summer, and thus will require considerable energy costs to maintain ideal growing and water temperatures year round.

Greylock Works Synergies

Greylock Works has many potential synergies with the goals of the aquaponics system. Sal and Karla have designed the campus to spark innovation and collaboration across the community. The incorporation of events, residential spaces, restaurants, food production, artisans, and entrepreneurship create an ideal community for businesses, especially in the food and agriculture space. They are also incredibly supportive of creative ideas. Potential synergies may include partnerships with restaurants and food producers, CSAs with condo residents, or possibilities to capitalize on tourism and events on the campus. Aquaponics, as a sustainable agricultural practice, would contribute to Sal and Karla's vision as well as potentially increase tourism.

Building Logistics

There are 4 small, elevated windows on the East and West walls of the building, but no light enters the space through the North or South sides. The roof could be opened to allow more light in, and the clients propose to also open the side walls at the top, but the closed sides of the building would still drastically reduce the amount of sunlight. This could contribute to additional lighting costs necessary for plant growth. There is a possibility to install photovoltaics on the Greylock Works campus to help with electricity costs, but the climate control and lighting costs will still be tremendous. While the full vertical space cannot be used, the owner has suggested making use of some of the vertical volume in the facility. This could involve burying fish tanks underground and building raised beds for greens above the tanks, or installing multiple layers of plant beds. This serves the double purpose of maximizing the use of space and helping to stabilize water temperature. Another proposed technique is installing mechanical shades that will help to eliminate heat loss from the space during the winter. A garden has been proposed by a previous Environmental Planning class for the roof of the adjacent Weave Shed building. The owners are still interested in developing that project, so this may represent a potential location to explore possible collaborations.

Costs

The Butler Buildings, as part of the Greylock Works campus, would cost the tenants rent. This would make them distinct from other facilities that typically do not factor these costs into their operational models. The owners, Sal Perry and Karla Rothstein, are eager to support the development of business on the campus and have suggested they could have flexible rent payments during the initial phases of the project. The final rent payment would be a combination of rent, common area maintenance (CAM), and tenant improvement costs that could raise rent prices. These would include helping pay for taxes as the property taxes increase due to improvements to the space.

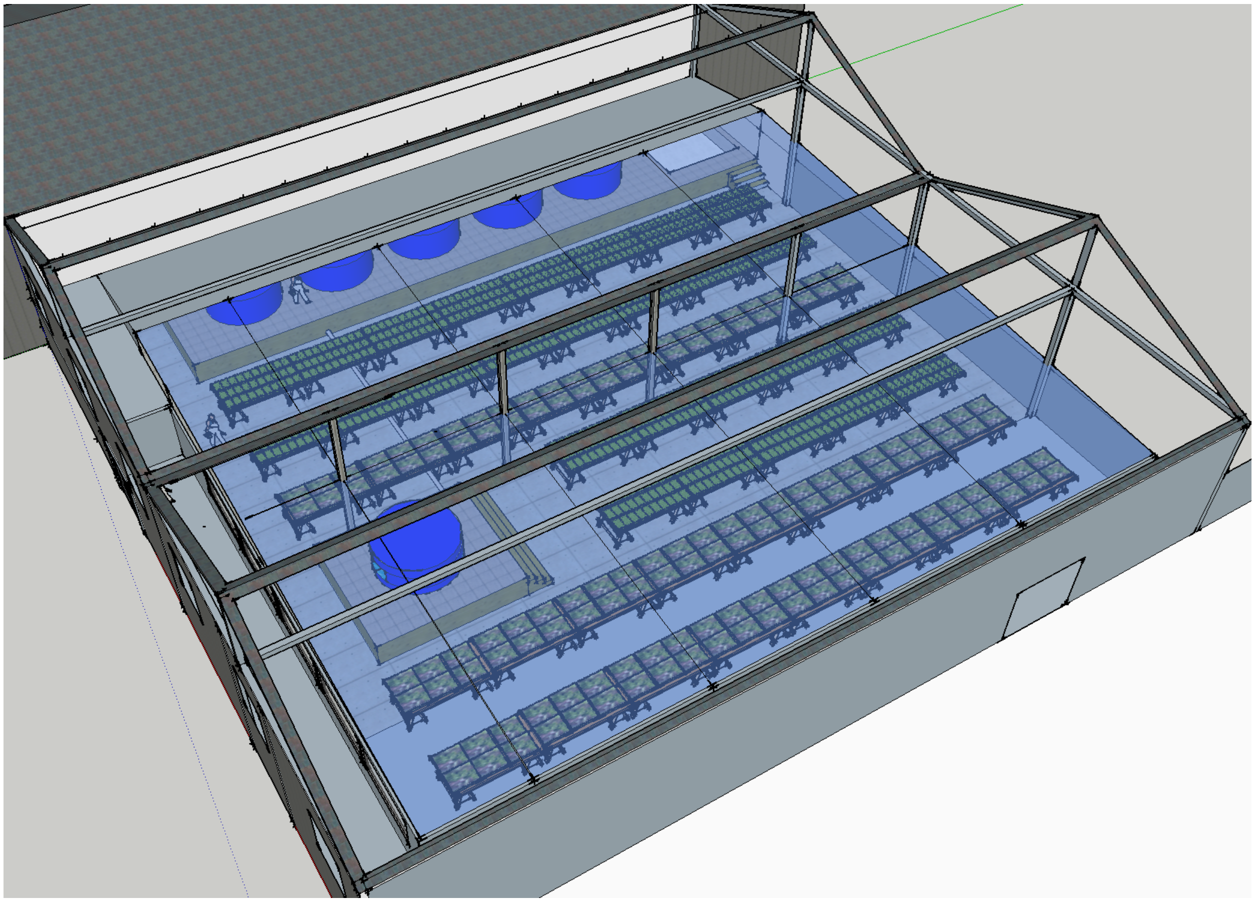
Greylock Works North Butler building

West wall of North Butler building

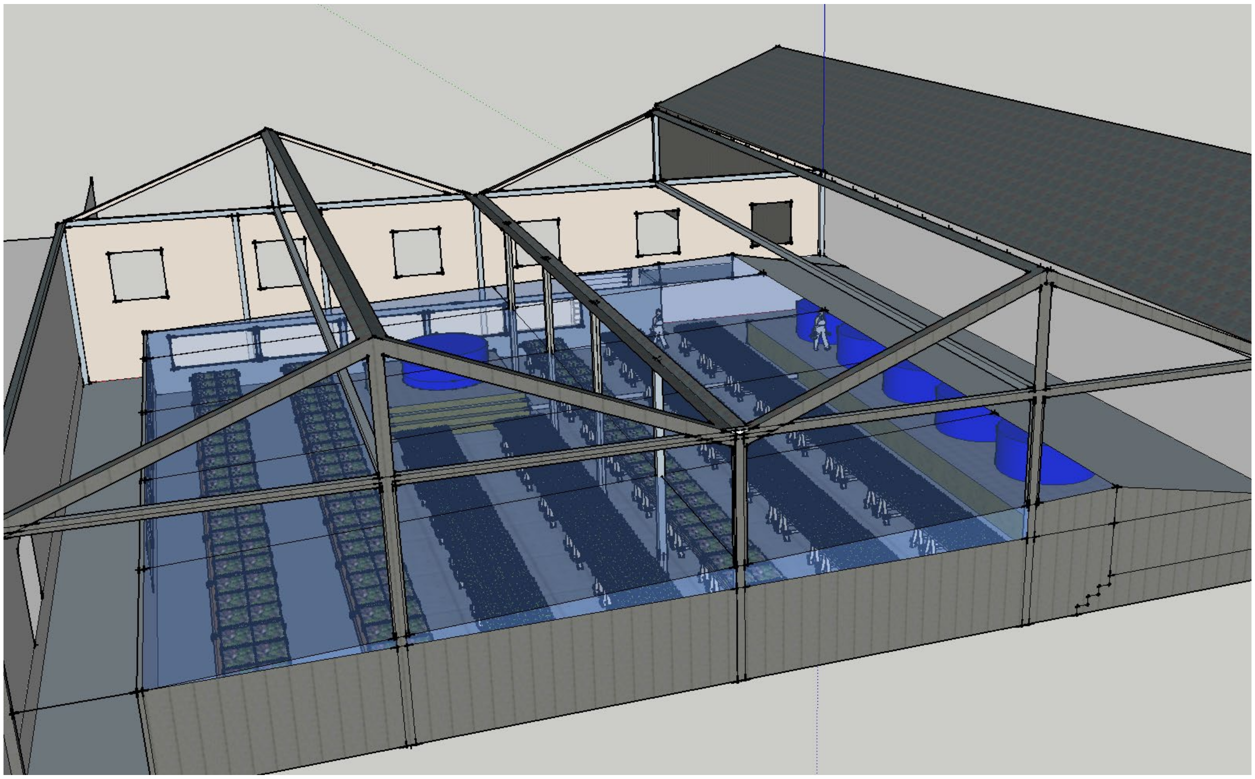
East and North walls of North Butler building

Members of the team meeting with Salvatore Perry in the North Butler building

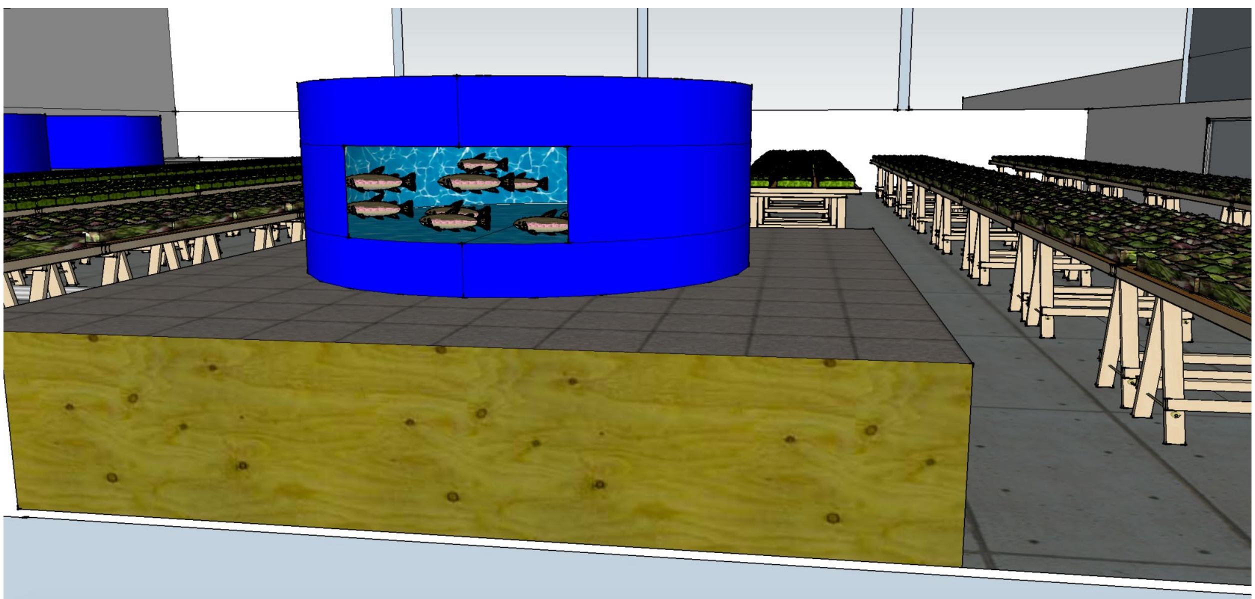
Initial Proposed Facility Layout



SketchUp layout image from above the facility (Susan Abrams).



SketchUp layout image through the west wall of the facility (Susan Abrams).



SketchUp layout close up image of fish tank (Susan Abrams).

Site Visits

Berkshire County House of Corrections

Meetings

In early September, the Environmental Planning class visited the Berkshire House of Corrections Aquaponics Lab. Robin McGraw and Jason Turner led a tour of "The Lab", which features four 1,000-gallon tanks, which each hold 350 fish. We also followed up via multiple phone interviews with Jason and Robin.

Background

The full greenhouse is 60 ft. by 60 ft. (3600 square feet), but is not optimized for growing space as it serves as an educational facility. Hybrid tilapia move from a fingerling tank to a grow tank once they reach maturity. Each tank can hold up to 350 fish. Eventually they are sold live and transported to various markets. Overall, The Lab is a very successful educational program for inmates and visiting students. The Berkshire County House of Corrections plans to expand its educational curriculum and potentially host community teach-ins.

Facility Specifics

It has two grow beds that are 32 feet long and 16 to 24 feet wide. This allows them to grow about 2100 heads of lettuce at a time and harvest about 500 per week. Seven different organizations receive their lettuce, including the correctional facility, food pantries, and food banks. They have about 10,000 gallons of water that grows about 800-1000 fish at a time. They sell about 750 pounds of fish every six months to a local wholesaler. These fish are sold live. Both Robin and Jason say that the hardest components of the facility were getting a routine and schedule. Now with a set schedule and growing process, The Lab takes slightly less time to maintain and has a more stable operation. This still requires about 3 full-time employees to operate the space.

Generally, the facility is maintained at 75 degrees year round. This is done with water heaters and propane heaters and in the summer requires fans and cooling. There are grow lights to boost plant growth, slated for upcoming energy efficient upgrades. There are no solar panels or green energy used. Ideally, Robin would like to use a waste wood chip burner to heat the facility, which would cost about $150,000 to install.

Scale and Operational Model

The Lab operates as a non-profit and only has revenue from fish sales. It also has greatly diminished costs because of its connection to the state and the jail. The facility had start-up costs of about $700,000, paid by an initial grant, private, and donor funding. Robin says that if this facility had more interest in profit over education, then it would have cost about $1 million. It costs between $100,000 to $150,000 per year to run the facility, including feed and energy costs, but that does not include labor or rent because those come from a separate budget. Energy usage is a large cost, typically around $2,500 a month. The Lab hopes to obtain a dry chip heater, which is more cost effective.

Lessons and Takeaways:

1. The connection to the state and correctional facility and its status as a non-profit provide crucial funding that allows The Lab to maintain itself financially. This enables it to pay for labor, go without rent, and receive an operating budget.
2. The Lab receives very minimal amounts of revenue. Selling the fish is a tiny source of revenue that is largely negligible.
3. The non-profit model does create a productive environment for inmates within the jail and has modest educational reach beyond inmates. There are additional benefits for the community through producing greens (mostly lettuce) for local food banks and food pantries.
4. The Lab is a great place to model our cost estimates around, as it is in the same climate and of a comparable size.

Radix Ecological Sustainability Center

On October 20, we visited Radix Ecological Sustainability Center, a community and education-focused urban garden and aquaponics system. We were given a tour by Scott Kellogg, the Educational Director of Radix. Radix is a non-profit educational organization that aims to “promote ecological literacy and environmental stewardship through educational programs based around demonstration of sustainable technologies” (Radix, “About Us”). In addition to its garden and aquaponics system, it runs a community compost program, educational programs for local schools, and participates in Albany's youth employment program, encouraging city youth to gain work experience. Radix is located on ½ acre of formerly vacant land near downtown Albany, and it has a 20x60 ft solar greenhouse, which houses the aquaponics system. The solar greenhouse generally does not require additional energy to heat it, instead relying on the temperature stabilizing capacities of its earth floor and the water in the aquaponics system, which includes a very large closed water tank that retains heat from the sun. However, it also has a back-up propane heater for emergencies.

Scale and Operational Model

The aquaponics system at Radix is extremely small scale, consisting of just one tank of goldfish and carp and one bed of watercress. The system contains about 800 gallons of water that cycles every hour. Watercress is the main crop because it is naturally an aquatic green and is well suited for the aquaponics system without any use of special growing techniques. Watercress is cold-hardy and only produces during the fall and winter, so it is able to thrive in the minimally heated solar greenhouse. Watercress is sold for $20/lb as part of the CSA farm share. Radix does not sell fish, and Scott chose goldfish and carp because of their cold hardiness and low trophic level. He feeds the fish commercial catfish chow, which Scott admitted was not the most sustainable option, but one of the cheapest.

Scott emphasized mimicking natural ecosystems as much as possible within the aquaponics system, including the sourcing for the Radix system. He harvested his initial watercress from a local stream and has continued cultivating from that cutting. Radix uses collected rainwater to supply the fish tank. When we asked for advice about sourcing our fish he suggested that we "go fishing to get started". He also suggested that we harvest sediment from a stream to populate the aquaponics system with beneficial microbes.

Unique Methods

Radix grows azolla and duckweed, both aquatic nitrogen fixing plants, on a floating island in the fish tank. The azolla and duckweed help to filter the water, and can be fed to the fish or ducks. In keeping with the goal of approximating natural ecosystems, the aquaponics system at Radix incorporates snails into the fish tank, which help to filter the water and also provide a source of food for the fish. The snails multiply very quickly and the fish manage the population by eating them.

One fascinating element of the system at Radix was its use of “logoponics”. Logs seeded with shiitake mycelium are submerged in the fish tank overnight, which enriches the logs for fungal growth. This process can be repeated every 8 weeks. Radix has 8 rotating logs and submerges one each week so there is a constant producing log.

Radix was the first time we encountered the idea of using an aquaponics system to grow aquatic plants. Growing aquatic plants is not the most profitable option, but it requires less management as the plants are accustomed to growing in water. Scott suggested the following aquatic plants that could be grown in an aquaponics system: watercress, azolla, duckweed, taro root, water spinach, water chestnut, water parsley, cattail, and arrowhead tubers.

Lessons and Takeaways:

1. Growing naturally aquatic greens is practical for aquaponics and has high growth success rates.
2. A small scale, educational aquaponics venture is highly successful when paired with devoted educators.
3. Some aquatic plants’ root systems can act as a plastic-free biofilter.
4. Incorporating other organisms on differing levels of the food chain can naturally enhance the system.

Interviews

Shushan Valley Hydro Farm: Shushan, NY

On October 26, we had a conversation with Phyllis Underwood, the co-owner of Shushan Valley Hydro Farm about her current operation. Phyllis and her husband, Wayne, once owned and operated a dairy farm on the property. Looking for a change, they sold the dairy equipment and herd and installed a 6,000 square foot greenhouse on the property near their home 27 years ago.

Operation

The facility is now made up of three greenhouses with a total of 18,000 square feet of hydroponics growing space. Two-thirds of the area (12,000 sq. ft.) is tomato plants and the rest is split between herbs and cucumbers (3,000 sq. ft. for each). All the greenhouses and almost all supplies are from CropKing in Lodi, OH. This enables Phyllis and Wayne to track all the inputs in a computerized system. This includes live updates on energy use, water conditions, and plant health.

Shushan's systems are dependent on continuous monitoring because of their planting setup. They plant in October and harvest throughout the year. Around July, they remove the plants and replenish the system so they start over with new plants come October. Phyllis describes how this set up assists with sales because they can provide fresh produce during the winter when it's hardest to find elsewhere. Because their system relies on durable plants, they grow tomatoes, cucumbers, and herbs. They grow their herbs in bato bucket systems and use perlite for their cucumbers and tomatoes.

In 2018, when adding the third greenhouse, Phyllis considered adding an aquaponics system. She went so far as contacting fish providers and other experts. Her plan was to use arctic char because they live in water that matched the temperature of the well (57^{o} Fahrenheit). Ultimately, she decided against introducing fish into her facility. She was very concerned about the fragility of the fish. Unlike the crops, she claimed that if the fish were unoxygenated for even a few minutes they may die, disrupting the whole system.

Energy

One of the complications with Shushan Valley's current setup is the high energy costs. Phyllis disclosed that 80% of total costs are split up evenly between three costs: lights, heat and employees. Although she uses LED lights, she does not use any renewable energy and receives all inputs from the grid. Tomatoes need a minimum of 15 hours of sunlight a day and cucumbers need a minimum of 18 hours of sunlight a day. To do this, especially during the winter, Shushan Valley takes advantage of discounted off-peak electricity rates and powers its grow lights from 11 pm. to 7 am.

Labor and Market

Shushan has 4 full-time employees and 7 employees total. They were entirely self-funded from the sale of the dairy equipment and took out a small bank loan using farm acreage as collateral. They mostly sell to farmer's markets and some wholesalers, and have no problem selling their product in the area.

Takeaways

1. Energy is a major cost. Shushan is trying to lower costs with off-peak electricity consumption, but is not incorporating renewable energy sources.
2. Hydroponics systems require sanitizing the water, adding in minerals, nutrients, and substances like perlite. This requires extra chemicals and products that decrease the sustainability of the system.
3. Shushan does not have a problem obtaining buyers for their products. While they are not selling fish, their veggies are sought after by restaurants and at farmers markets. They are marginally profitable.
4. Shushan is a certified organic farm that uses biologicals to control pests. Phyllis believes it would be "impossible" to do hydroponics or aquaponics without plastic.

Victory Aquaponics: Londonderry, NH

Facility

On October 26, we spoke with Ross Williams, the owner of Victory Aquaponics, and went on a virtual tour of his facility. It is run by a father-son duo with the support of assistants sourced from World Wide Opportunities on Organic Farms (WWOOF). The greenhouse is 96 ft x 32 ft and there are five 650-gallon tanks that house tilapia and goldfish. The structure of the facility is unique: the fish are housed underground, below the greenhouse. In the upper greenhouse, kale, swiss chard, varieties of lettuce, bok choy, cucumbers, watercress, and sorrell are grown aquatically. Both solid and floating media are used to support plant growth. They also grow algae to feed the baby fish.

Cone bottom tanks are used to filter debris out of tanks and pump water through the system. A filtering tank separates out solids, clean water exits the tank, and then is pumped up to the greenhouse. No mechanical filter is used, but bird netting catches solids and worms. They add around 600 gallons of fresh water per week and do not have to flush systems out. In addition to the coupled fertilization system, they use gray water to fertilize an additional greenhouse. After seeding, plants are grown in floating styrofoam beds (2x4 ft) using grow grips in 75x 8 ft deep water beds (1 ft deep). Seedlings are started in much denser boards, with 70 holes per board. They are then brought to 56 holes per board before being moved to the final full growth boards. One seedling board is equal to 9 full growth boards.

Plants are also grown in a solid medium, where buckets with holes punched in the side are cyclically flooded and drained. There is the option to have water coming in continuously, but the water drains faster than it comes in from the filters. They have optimized their system to water flooding 5 times per day. In the bucket are porous fired clay, which expands to trap water and helpful bacteria, and recycled glass the texture of pumice stone. Seedlings begin in a mixture of vermiculite and perlite under LED lights in a room in the basement.

Product

The facility sells greens mostly wholesale at farmers markets, but also supplies a few local grocery stores. They sell their fish live to a transporter who delivers the whole fish to markets in Boston, where they are in high demand. Tilapia are ideal for aquaponics systems because they thrive in a crowded environment. However, they require water at a minimum temperature of 68 degrees, which means heating is required in the winter. There are 300 adult tilapia per tank, sold at $3.25 per pound. At least 500 pounds of tilapia are sold to the purveyor at one time. Goldfish are also raised, but it is unclear if they are being sold as ornamental fish. Goldfish produce the nitrates needed to fertilize plant growth and can survive in very cold water.

Cost

The project was independently funded by the owners, but they mentioned they acquired USDA grants to build a second greenhouse for non-aquaponic use. It was communicated that aquaponics could not be used with USDA grants for their greenhouse. In the future, they plan to install a solar powered well using a USDA grant.

Heating costs are one of the major concerns with aquaponics, but keeping the fish tanks underground can help with temperature regulation. In addition, they use a gasifying wood boiler to heat most of the greenhouse. The boiler has a coil that runs hot water through the facility, heating the air. Abundant wood is available for no cost to the facility as they use byproduct from their property, reducing costs in this area. When the temperature dips below 45 degrees, an auxiliary propane heater is used. In the greenhouse, supplemental Lumigrow LED lights prevent the greens from bolting in the winter. Energy is a huge cost to this facility, compromising a large portion of their expenses. The business is close to profitability, with the owner joking that he looks forward to the day he will make minimum wage.

Lessons and Takeaways:

1. Energy costs are a major concern for Victory despite having free access to fuel. In addition, they have reduced labor costs through hiring WWOOF-ers and still remain unprofitable.
2. Burying fish tanks in the ground reduces temperature regulation costs.
3. Solid medium is a viable option for reducing plastic contact and contamination with greens.
4. As seen with Radix, growing aquatic greens is an excellent way to boost green growth rates.
5. Tilapia are sold whole to a purveyor.

302 Aquaponics: Dover, DE

On October 26, Doug Wood gave us a virtual tour and interview of his facility in Dover, Delaware. After the death of his mother, Doug was looking to change career paths. He had played with hydroponics as a hobby and he decided to travel to tour Nelson and Pade Inc. 's facilities in Montello, WI. (Nelson and Pade is the foremost aquaponics systems and supplies seller in the U.S.). Doug was convinced by the symbiotic relationship of aquaponics. He liked hydroponics on a small scale, but was concerned with using large amounts of fertilizer. Doug also expressed interest in limiting the chemical intake and carbon footprint by producing locally grown food in an aquaponics facility. The concern of overfishing and the desire to create more sustainable vegetable and fish farming were Doug’s final motivations to start an aquaponics facility.

He planned on buying two systems, each of 10,000 square feet. It took about a year to get the first system up and running and so he delayed buying the second. This turned out to be lucky as COVID-19 hit three weeks after he opened the first greenhouse. Both systems were large capital investments and funded exclusively by Doug and his wife.

Operations

Doug grows 7 varieties of lettuce and raises tilapia. In year 3 of growing, 302 aquaponics has 2 greenhouses for 20,000 total square feet. He has four beds in each greenhouse that are 16 feet x 72 feet and 18 inches deep. In total, 302 aquaponics has about 10,000 plants. Its output is about 1000 heads of lettuce per day and 300-400 pounds of tilapia every three weeks. The tilapia is brought to a processor in Philadelphia, about 80 miles away, after being purged. The processor then brings his fish back to him so Doug can sell specifically 302 Aquaponics fish. 302 Aquaponics currently sells its greens and fish to 3 local independent grocery stores and around 20 roadside farm stands. They sell at farmers markets during the summer and have contracts with 3 Delaware school systems to serve their lettuce in local schools.

Sales

302 sells lettuce for around $2.50-$3 wholesale and $5 directly to customers. Tilapia sells for $2.75/lbs commercially and $12/lbs once it has been processed into fillets. Doug admitted that the tilapia can be hard to sell, but once customers taste his fish, they typically return for more. The larger contracts on greens can be helpful and he is still looking for a buyer of this scale for his fish.

Energy

Regarding energy, Doug reported the tilapia require warm water typically between 72 to 75 degrees fahrenheit. In the winter, he will occasionally heat the water to as high as 80 degrees because the temperature stabilizing effects of the water can keep the overall greenhouse temperature high. The greenhouse needs heat in the winter and 302 uses an air chilling system in the summertime. Delaware's kilowatt rate is fairly low, but energy is still one of the highest costs at 302. Doug spends about $3000-$4000 per month on electricity for lights and other inputs. He spends about $2000-$3000 per month on propane. He looked into a wood furnace but did not expect positive outcomes. Doug is going to look at solar again soon but he last estimated it would cost about $700,000.

Budget

Doug is currently bringing in about $500,000 in yearly sales and his goal is to reach $750,000. Doug and his wife are paid only by profits, and they have one salaried full-time employee. They also employ about 10 part-time employees from 8-12 daily from Delaware State's local agricultural program.

Lessons and Takeaways:

1. Energy, again, is a huge cost.
2. Running an aquaponics facility takes a lot of work to get up and running and to bring close to profitability. It took 1 year of planning and 3 years of work to get to this point. Doug stressed the need for a dedicated leadership team that was going to sacrifice pay and countless hours to keep the facility afloat.
3. Supporting the local community with local fish and greens through aquaponics is feasible. It takes careful planning but 302 is supporting farm stands, grocery stores, and even schools.
4. Finding a fish processor is key. Processing was not something 302 could do itself and this has been a vital resource.
5. Doug responded to a follow-up text and said he had a hard time picturing the facility without styrofoam or plastic. These inputs have been vital resources. He has tested his fish for microplastics and found no evidence, although we do not know the extent or accuracy of his testing.

Great Falls Aquaculture, MA and NH

On November 2, we spoke over the phone with Keith Wilda, the operator of a number of aquaponics and aquaculture facilities across the northeast. He works with two business partners to run five sites across Massachusetts. He started in aquaponics and aquaculture 30 years ago.

West Barnstable, Cape Cod Facility

Keith lives full time at a Cape Cod facility that serves as a trout hatchery with a small greenhouse research facility. The trout here are used primarily for stocking ponds. While there are important differences with Keith's design and the proposed site at Greylock Works, we were able to learn from his experience. First, he runs the facility 80% on solar energy that he funded partially through an MDAR grant. The solar panels are put over the long narrow tanks called raceways. This solar system produces about 26 kw of energy.

Keith also advises using a "decoupled" aquaponics system. He uses the gray water from the fish to irrigate a hydroponics system in the research station. While this system is not directly symbiotic because the fish do not receive the water back, he says it is helpful for his risk management practices. When he needs to treat the fish in some way, this does not affect the hydroponics and vice versa. He also spoke about the importance of knowing your equipment very well. He built his own equipment with filters and monitors so that much of the system is operable by phone.

Charlestown, New Hampshire Facility

The New Hampshire indoor facility has both aquaculture and aquaponics. While the facility currently covers about 1 acre (~40,000 square feet), they plan to grow to 80,000 square feet in the next year. They also sell trout at this facility, mostly to restaurants. They bring their fish to be processed in Turners Falls. The greenhouse at the facility is not yet operational but will eventually have a "decoupled" system in place. For normal aquaponics, Keith advises growing about 2 square meters of leafy plants per 100 grams of fish.

Because he aims to keep the water temperature at 60 degrees year round, the tanks are buried underground to use geothermal heating and cooling. In the winter, he relies on propane to heat the water and facility. While he has not yet implemented solar panels, he plans to add them to the facility through grants and utilizing the tax cuts from the Inflation Reduction Act.

Turners Falls Facility

The central facility that Keith helps operate is in Turners Falls. This facility is a large commercial facility. The Turners Falls Facility has upwards of a 1 million barramundi and sells about 22,000 lbs/week. They sell barramundi at $5.85/lbs, less than the desired price for Tilapia. This facility uses 5,000 lbs of feed/day. Importantly, his feed conversion is about 1.2 lbs of feed per 1 lbs of fish. They have a large fish processing plant on site. While most of their fish is sold live, their trout is brought here to be processed.

Key Takeaways

1. General advice is to create a larger facility. Keith argued that anything under 20,000 square feet was not ideal, but had seen great educational facilities that are about 3,000 square feet.
2. Coupled systems can limit what you grow. Fish water alone generally meets the nutritional needs for leafy greens like lettuce and basil, but decoupling can expand your options and reduce risk.

3. Risk management is critical. He has numerous ways to protect against failure, including backup generators, extra feed stores, and sourcing from multiple fish feed companies. Risk management also is made easier with the decoupled system that allows him to treat the fish or plants with extra nutrients if needed, and allows for a problem in one side of the system not to disrupt the other.
4. He advises using the whole volume of the greenhouse. You pay to control the whole volume so working vertically and not having empty horizontal space is critical. Diversifying plants can help with maximizing space usage.
5. He does not believe plastic poses a risk to his fish. The barramundi in Turners Falls are tested regularly and he has not found evidence of microplastics. He also has seen very small scale facilities work with less plastic with glass tanks, but relies heavily on plastic piping and styrofoam beds in his facilities.

MCLA Vadnais Environmental Issues Lecture - Sam Fleming

Background

On November 1, Sam Fleming gave a lecture titled 'Righting the Course' as MCLA's Vadnais Environmental Issues Lecture. Sam has a decade of experience with aquaponics, is the STEM advisor for the Aquaponics Association, and has installed aquaponics systems across the U.S and Haiti, including 17 schools and two correctional centers. One of his main advising projects was helping Robin McGraw plan and install the aquaponics facility at the Berkshire House of Corrections. He assists with educational curriculum and programming as well as system design and installation.

Sam gave three main motivations for using aquaponics systems:

1. Global fisheries collapse
2. Conserving freshwater that is wasted in traditional agriculture
3. Increasing agricultural yields as the global population expands

History

Delving into a brief history of aquaponics, Sam highlighted Chinampas, extensive rice-fish farming in Asia, and the research that started in the 1980s surrounding 'sandponics', or integrated aqua vegeculture systems (IVAS). In this method, sand acts as a biofilter with a high surface area to capture bacteria. He highlighted Superior Fresh, a large commercial aquaponics venture in Wisconsin, as the future of aquaponics. This facility is 130,000 sq. ft. and grows genetically modified salmon. Superior Fresh has contracts with a large gas station chain as their sole supplier of packaged salads.

Programming

Sam highlighted the success of his educational aquaponics strategy. He discussed 100 Gardens vision and school curriculum, which is used with K-5, middle school, highschool, and CTE schools. 100 Gardens has a clear goal of empowering people across a spectrum of life experiences, including a special needs program and a focus on disadvantaged populations. Sam demonstrated the ability to modify and install smaller aquaponics systems in schools without the use of greenhouses. A new venture in North Carolina is the Innovation Barn, a circular economy where there are no waste products from any of the included businesses.

Takeaways

1. Sam remarked that small scale facilities are rarely profitable and that scaling up means better energy costs and a smaller ratio of open airspace that can affect temperature.
2. In aquaponics systems, electricity generally makes up 30-40% of costs, feed composes around 20% of costs, with labor being the next biggest cost.
3. Greens constitute the bulk of profit.

Mass MoCA - Repurposing old mills

We spoke with Dave Tatro, the facilities manager at Mass MoCA, about the potential to use clean energy in repurposed manufacturing buildings. Currently, Mass MoCA uses a combination of solar panels and small wind turbines to generate their own energy, and they purchase additional clean energy in order to supply 100% of their energy needs using green sources. The wind turbines on their campus and solar panels on their roof were put in place using some donations and grants from Massachusetts roughly 15 years ago. Because of how old they are, Dave was unsure exactly their size or where they were sourced from. However, Dave estimates they supply 10-15% of Mass MoCA’s energy needs each year. Dave has led the project in recent years to receive a contract from Brookfield, MA. to pay for their solar energy. While this is not directly connected to the grid, they receive the credits for purchasing renewable energy. Dave has also tried to lower energy usage by replacing the lights with LEDs and replacing their boiler with a more efficient system. Generally, he recommends trying to use efficient lighting and heating but has found on-site solar can be difficult to cover all energy use because of the size limitations. He reminded us that he still relies on non-renewable heating and cooling.

Takeaways

1. Repurposing industrial buildings can require enormous amounts of energy especially because of their large volume.
2. Green energy is a viable solution to help generate electricity and grants from the state can help pay for it. Off-site green energy can also be a productive solution.

Local Market Analysis

Wild Oats Market

On October 27, we visited Wild Oats Market and spoke with the general manager, Netselgeye Lytle. We discussed the possibility of Wild Oats selling fish and/or greens from the local aquaponics facility proposed at Greylock Works. Wild Oats currently does not sell tilapia, but Netse said that a local, sustainably raised product might have enough customer appeal that he would consider it. He said that "Wild Oats prides itself on supporting the local economy" and that sourcing products locally is the primary motivation of the store, followed by sourcing organic products. The store does not have the ability to process whole fish, so fish would have to be processed elsewhere before being sold at Wild Oats as fillets. He was also excited about the possibility of aquaponics being able to fill a void of local fresh greens during the winter.

The top selling greens at Wild Oats are green curly kale, lacinato kale, mesclun, arugula, spinach, parsley, and cilantro. Herbs that are in need of year-round local production are basil, parsley, and cilantro. The store does not have a reliable year-round basil supplier, but if it did, it would be a top seller.

Takeaways

1. Wild Oats is enthusiastic about partnering with the proposed local aquaponics facility at Greylock Works.

2. In order for Wild Oats to sell tilapia it would need to be processed and customer demand would have to be demonstrated, as the market does not currently sell tilapia.
3. The aquaponics facility could fill a void in the market by providing local, fresh greens in the winter, especially basil.

Mezze Bistro & Bar

On December 1, we spoke with Nancy Thomas, the owner of Mezze Bistro & Bar. She discussed the strong local farm-to-table values of Mezze, with an emphasis on soil-grown, seasonal vegetables and greens. Because she thinks soil-grown greens taste better, Mezze is not interested in purchasing aquaponic or hydroponic grown greens, regardless of time of year. Mezze currently purchases and is satisfied with steelhead trout from Hudson Valley Fisheries, an aquaculture facility. However, she was more hesitant about purchasing tilapia, as even when it is raised in an aquaponic system, there is a “marketing problem” that remains. She also indicated that the restaurant’s partnership with Hudson Valley is a sporadic one, as the menu changes frequently.

Takeaways

1. Mezze is not interested in purchasing greens unless they are grown using traditional, soil based methods.
2. Mezze enjoys the aquaculture raised steelhead trout from Hudson Valley Fisheries, and would be hesitant to purchase tilapia because of the additional marketing challenges.

Williams College Dining

On December 5, we spoke with Temesgen Araya, the head of Williams College Dining Services in Williamstown. He stated his main objective as creating healthy and nutritious meals for students from local sourced farms and producers in sustainable ways. He agreed AGW fits closely into Williams mission and the mission of many buyers in the area. However, when buying and cooking for the scale of the college, scale, consistency, and safety are critical.

For fish, he currently buys from various producers throughout the world, including Alaska, Europe, and Asia. Different varieties of seafood come from different areas and he does not currently have a local source. He is exploring and excited about a possible partnership with BerkShore to provide more local fish. Regarding greens, Williams currently obtains lettuce and other leafy greens from Little Leaf Farms in Devens, MA. Little Leaf is a ten-acre hydroponic farm that provides greens to Williams through a partnership with Marty's Local. Williams pays $15-$20 per 3-lb bag of lettuce. Because of these current options and the small scale of the proposed Greylock Works facility, Temesgen does not expect to be able to buy from AGW but would remain open to discussion.

Takeaways

1. Williams Dining is very conscious of where its food comes from and how it is produced and already has or is pursuing sustainable options for sourcing greens and fish.
2. Williams needs a large and consistent supply and these demands may exceed the capacity of AGW, but the College might be open to a partnership later on.

Fish Buying and Processing

Tai Huik

Tai Huik runs a fish market near Boston. Victory Aquaponics currently sells its fish to Tai and recommended him as a reliable buyer. Tai travels across the northeast to aquaculture and aquaponics facilities as well as fish hatcheries. Once he picks up the fish, he sells them live at his market. In the Boston area, Tai does pickups with 1000-pound minimums, but in western Massachusetts, he requires 2,500 pounds. He pays $5.50/lb for tilapia, $6/lb for rainbow trout, and $7.50/lb for barramundi.

Sean Hilpi

Sean runs a fish-buying service that operates primarily in New York, but he travels to The Lab at the Berkshire House of Corrections to pick up their tilapia. It is unclear where he sells the tilapia. He pays $2.70/lb for live Tilapia and requires a minimum of 600 pounds. He typically gets about 750 pounds twice a year from The Lab. He would be willing to buy other types of fish but did not provide exact numbers for price or weight minimums.

BerkShore

Wes Malzone runs BerkShore FishMongers which is now owned by Wulf's Fish. BerkShore buys fish caught in the Boston area and transports them to Berkshire restaurants and markets. It offers one of the most reliable sources of fresh fish in area markets and restaurants. BerkShore customers include Wild Oats, Guido's, and River Valley Coop, as well as Amherst and Smith Colleges, and possibly Williams College in the near future.

Wes believes there is a vital need for aquaculture as the ocean fisheries become less stable in the next decades. He had tried to work with Keith Wilda from Great Falls Aquaculture's Turners Falls location, to pick up their fish and process them in Boston, but this did not work out because of some complexities. Wes believes a partnership with AGW might be possible with enough fish, but the fish would need to be purged and brought to Pittsfield at 3 or 4 am in the mornings. It is unclear how much fish would be needed to make this relationship productive. Wes also thinks it would be complicated to keep AGW fish separate from the other fish at the processing facility, and thus it would be difficult to market the fish locally as aquaponic raised.

Great Falls

Great Falls Aquaculture does some fish processing in the Turner Falls facility. Keith is also processing some fish from his NH facility. While most of his fish are sold live and no outside companies currently process fish at Great Falls, Keith said he might be able to process AGW fish there.

Grants

USDA Urban Agriculture and Innovative Production Grants Program

In 2020, the USDA Agriculture and Food Research Initiative (AFRI) had a call specifically for aquaculture and aquaponics projects that supported "more sustainable, productive, and economically viable agricultural systems" (AFRI Foundational and Applied Science RFA, 2020). The AFRI's program priorities change on a yearly basis, but it is promising to see indoor and emerging agriculture highlighted in 2022.

The total program funding is $9,400,000 and a range of $50,000 - $1,000,000 is awarded to individual projects.

USDA – Farm Service Agency Microloan Programs

The USDA Farm Microloan program offers funding to "small, beginning farmer, niche and non-traditional farm operations", specifically including hydroponics and aquaponics (USDA, 2022). There are two loans offered: an operating microloan for operational expenses, and ownership microloan for a range of various expenses. Up to $50,000 is available for each loan and repayment timelines extend up to 25 years.

MDAR - Climate Smart Agricultural Grants

The MDAR grants offer a wide range of funding for different renewable energy projects at agricultural facilities. The Climate Smart Agricultural Grant combines three previous grants into one application: the Ag Climate Resiliency & Efficiencies (ACRE) Program, the Ag Environmental Enhancement Program (AEEP), and the Ag-Energy Program (ENER). The grant can fund up to 80% of total project costs and up to $50,000. This can cover photovoltaics with battery storage (for new or existing PV), integrated greenhouse solar PV glazing, renewable clean heating & cooling technologies, wind systems, and more.

MDAR - Farm Energy Discount Program

MDAR does not provide much information about the Farm Energy Discount Program but their website asserts that small agricultural facilities are eligible to discount 10% of electric and natural gas energy bills. This does not include propane or fuel oil bills.

MDAR - Other Grants

MDAR contains a variety of other grants which may benefit an aquaponics facility, at various sizes and locations: it provides grants for small start-up agricultural facilities as well as many sizable grants to improve food access in urban and rural communities. These grants can be for either nonprofit or for-profit models, but applications are not currently being accepted. Most grants run on fiscal year cycles so can administer grants each year. In particular, the Massachusetts Food Venture Program could provide an important source of funding for AGW. MFVP provides awards of over $100,000 to facilities providing food to low-income rural and gateway city communities, but they often go to organizations completing food processing, distribution, and retail.

Evaluation Matrices

The following three evaluation matrices consider a few of the complexities of aquaponics facilities and their inputs, including their operational and business models, fish species, and vegetation potentials. These matrices attempt to answer many complex questions using a simple outline based on our more detailed conclusions.

Operational Model Matrix

Models							
System	Size	Goals	Consumer Market	Maintenance	Labor	Plastic Involvement	Overall Feasibility
Large For Profit	Full envelope (8000-9000 sq. ft)	Develop fresh, organic, low plastic use, high end greens and fish for surrounding communities	Restaurants, Wild Oats, farm stands, farmers markets, Williams College	High, constant (24/7)	2 full time, 4-10 part-time workers	Fully necessary, needed to bring down costs	Very low feasibility
Large Non-Profit	Full envelope (8000-9000 sq. ft)	Develop fresh greens and fish for surrounding communities that have donation components to schools or pantries and teach about aquaponics farming	Restaurants, Wild Oats, farm stands, farmers markets, Williams College, and donations	High, constant (24/7)	2 full time, 4-10 part-time workers	Highly probably, needed to bring down costs	Low feasibility (greater with labor looking to contribute without pay or no rent)

Small Non-Profit	~3000 sq. ft	Teach local students about aquaponics and the environment, incorporate local college students or volunteers into the farming process, and become a tourist feature for Greylock Works	Largely donation of greens to local schools and pantries, fish sold to processor	Potential for constant maintenance	2-3 full time workers	Variable, potential to demonstrate plastic free facility	Low feasibility (likely need no rent payments and some form of continuous grant revenue)
Miniature, Demonstrative Non-Profit	~500 sq. ft	Teach local students about aquaponics and the environment and become mild tourist attraction	Potential for small personal buying, donations	Moderate (with use of hardy fish and greens), would still need daily check ins	2-3 part time volunteers	Unlikely (perhaps PVC for ease of use)	Moderate to high feasibility

Fish Matrix

Fish								
Species	Temper-ature	Mainten-ance	Timeline	Market Price	Processing	Demand	Diet	Feasibility
Tilapia	68-75 deg	medium	1 lb in 7-8 months	$5.50/lb live, $12/lb fileted	sold live to be processed	generally low, but might be higher demand for aquaponic grown	fry fed algae, adults fed plant-based chow	High (low maintenance, high density, low cost diet)
Rainbow/ Steelhead Trout	50-68 deg	high	1 lb in 7-8 months	$6/lb live, $26/lb fileted	sold live to markets or to be processed	high, used as salmon replacement	carnivorous: meat-based trout feed	Moderate-low (high maintenance, high cost diet)
Barramundi	74-86 deg	high	2lb in 7 months	$5.85/lb live	sold live to markets or to be processed	high demand at Asian markets	carnivorous:- shrimp, small fish, crayfish, worms, pellets	Moderate-low (high maintenance, high cost diet, high water temp)

Koi/Goldfish	cold hardy	low	long lived	n/a (potential to sell ornamental)	n/a	n/a (how much demand if sold ornamentally ?)	catfish chow	Moderate (easy to maintain and feed, but slow growing and no market)
Carp	cold hardy	low	long lived	n/a	n/a	n/a	catfish chow	Moderate (easy to maintain and feed, but slow growing and no market)

Greens Matrix

Greens			
Type	Grow Medium	Approx.Growing Cycle	Nutrient Intensive
Lettuce Heads (various varieties)	Floating	Short	Low
Herbs	Floating/ Seed bed	Short	Low
Bok Choi (purple or green)	Floating	8-11 weeks	Low
Basil	Floating	Short	Low
Kale	Floating/Solid	5-6 weeks	Low
Baby Sorrel	Floating or Solid	17-30 days	Low
Microgreens	Seed bed	Short	Low
Watercress	Floating/Seed Bed	Short	Low
Cucumbers	Solid	55 Days	High
Tomatoes	Solid	5 weeks	Medium
Quinoa	Solid	Months	Medium
Wasabi	Solid (clay balls)	Up to 24 months for full maturity	Low/Med.
Strawberries	Vertical	4-6 weeks after blossom	Med./High

** Growing cycle assumes all nutritional and light needs are met, and depends on the species of fish coupled with the plants

Cost Estimates

These cost estimates are based on data from The Aquaponics Lab at the Berkshire Country House of Corrections and 302 Aquaponics. They do not represent a business plan or model and are used merely as an exercise of cost-benefit analysis.

The Lab is 3600 square feet, so its cost metrics will be multiplied by 2.5 times to approximate cost for the 9000 square foot facility at AGW. The Lab is an educational facility not maximized for production, so a large for-profit facility would likely have disproportionately high costs and benefits. However, we will use a proportional scale for the sake of the exercise.

Furthermore, the energy costs per square foot might be greater in the Greylock Works facility compared to The Lab, although we do not know by how much. Enclosed in the Butler buildings with reduced light and increased summer temperatures, AGW would likely require greater cooling and more electric grow lighting than The Lab.

Cost Estimates	**Dollar Value**	**Total**
Operating costs without rent and labor	\$100,000 x 2.5 (square foot scale)	\$250,000
Labor (at least 2 full time and 5 part time employees). Using minimum wage and no benefits.	180 hours/week x 50 weeks/year x \$15/hour	\$135,000 (at \$30,000 for a full time employee)
Rent	Unknown	Unknown
Total Costs		**\$385,000 plus rent**

For capital estimates, we scale The Lab's and 302's investments to create a rough understanding of how much capital can be expected for a facility of around 9000 to 10000 square feet.

Capital Estimates		
302 Aquaponics	\$4 million x 0.5 (square foot scale)	\$2 million

BCHC Estimates	$700,000 x 2.5 (square foot scale)	$1.75 million

For revenue, we can also scale the estimates of The Lab's facility by 2.5. We can also use 302 Aquaponics current revenue scaled down by half, because their facility is 20,000 square feet.

Revenue Estimates		
302 Aquaponics	$500,000 x 0.5 (square foot scale)	$250,000
Total Estimate		**$250,000**
BCHC Estimates		
Fish	750 pounds x 2 pick ups per year x $5/pound x 2.5 (square foot scale)	$18,750
Greens	500 heads/week x 50 weeks/year x $4/head x 2.5 (square foot scale)	$250,000
Total Estimate		**$270,000**

These estimates are not indicative of exact numbers as the scaling is extremely discretionary and we have received our base numbers from phone interviews, not balance sheets. That said, these estimates reflect how many aquaponics facilities get by on cheap labor, no rent, and by selling lots of greens. In the Greylock Works facility, we anticipate these costs to be even higher in the Butler buildings due to added rent, taxes, and energy costs.

We strongly recommend that the clients work to create their own in depth business plan that accounts for costs and revenues. This will confirm or contradict our assumptions and can also serve to demonstrate the potential feasibility. Creating a business plan often helps form a deeper understanding of the intricacies of the project and we recommend outlining a detailed business plan as a next step.

Recommendations

Based on our conversations with aquaponics experts, site visits, market evaluation, evaluation of the space, and cost/revenue estimation, we do not think the Butler building at Greylock Works will be a profitable location for an aquaponics facility, regardless of for-profit or non-profit designation. We expect that the additional energy and rent costs, as well as the relatively small square footage, will make it difficult to generate profit or even break even. Other facilities we explored that are much larger and specifically designed to optimize energy efficiency for aquaponics still have a difficult time generating profit. Most facilities we interviewed were initially self funded and do not pay rent, two additional financial hurdles that would have to be overcome in this space. The additional goal of removing or minimizing plastic use in the facility will add considerable costs as well.

Next Steps

1. Pursue a small scale educational/demonstrative aquaponics system, similar to the setup at Radix. This will remove the pressure to sustain the system with revenue from fish and greens. Eliminating production quotas would offer more freedom to develop and pioneer a plastic-free system and other innovations. More opportunities for financial support may become available through educational grants and local partnerships. Greylock Elementary School is in close proximity to Greylock Works and would be a natural first collaboration. Public schools in North Adams and Williamstown, as well as MCLA and Williams College, could be prospective collaborators. The greens produced could be incorporated into a small scale in-house CSA for Greylock Works condo residents.

   Considerations to take into account for the educational model include that Radix is supported by a number of other educational projects, including a small urban farm and CSA, composting program, and robust student work program. A stand-alone small scale aquaponics system is unlikely to garner enough grant funding as an educational facility. Additionally, the North Butler Building may not be a suitable location for a smaller facility, since it would not fill the space. If an arrangement could be made with Greylock Works to rent only a portion of the Butler Building, that could be a good solution.

2. Another possible solution is to build a designated aquaponics facility and greenhouse at a different location. This would require finding suitable land and additional startup costs, such as a durable greenhouse and extra utilities. However, this might allow the facility to be more profitable if expansion beyond 9,000 square feet were a possibility, and the structure were designed specifically for aquaponics, allowing more light into the facility. Other modifications could be incorporated to allow for complete tank burial to benefit from natural heat retention and vertical growing. This idea would diverge from the original partnership with Greylock Works, but our research suggests that the Butler Building is not a feasible site for a profitable large-scale aquaponics system.

3. Finally, we recommend creating a detailed business plan to develop accurate costs and revenues expected for the specific facility. Our analysis was conducted using cost and revenue numbers from facilities with variables that would not apply to the Greylock Works location. Hiring a consultant with a strong aquaponics and energy knowledge base would be the best next step to map out a revised facility design.

Appendix A: Interview Questions

Operation Questions

- How did you decide which type of system? (aquaponics vs decoupled aquaponics vs aquaculture vs hydroponics)
- What are your biggest challenges with the system?
- What made you choose the system you have? Did you switch?
- What kind of fish do you grow?
- How did you choose the type of fish?
- How many fish? How often and how much do you harvest (rotating or all at once)?
- Where do you buy the fry? For how much?
- Where do you sell the fish?
    - Live? Processed? How much do they sell for?
- Have you had challenges selling/processing fish?

- What kind of greens do you grow?
- What (if any) other greens have you grown in the past and why did you move away from those?
- Where do you sell your greens? For how much?
- How do you grow your greens?
    - Floating? Solid media?
- For aquaponics: how do you prepare fish waste for use in growing greens?
- Where is there plastic in this process?

Energy Questions

- What are the dimensions of the space?
- What is the major energy source for this facility? What is the cost?
- What green energy options are used?
- Why did you choose this option?
- Did you receive funding for using sustainable energy options?
- What is the biggest cost of this operation?
- Which parts of the operation are costing the most(most E intensive)?

Management Models Questions

- How did you decide to be a non-profit/profit?
- Do you think you could be profitable?
- How did you obtain funding to start?
- Where do you sell fish and greens?
    - At what costs and revenues?
- What are your largest costs?

How many employees do you have? Are they full time or part time?

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