Restoration of a Recirculating Aquaponics System

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What is Aquaponics?

Recirculating aquaponics systems are an agricultural technique where the nutrient-rich water produced by fish is utilized to fertilize hydroponic plants. Water from the fish tank is transported to and from the plants via pipes (Figure 1). It proposes both societal and environmental benefits by requiring significantly less water and land than traditional farming techniques (Timmons, 2007). This gives aquaponics a unique potential to provide for urbanized and drought susceptible locations that are unable to meet local food demands.

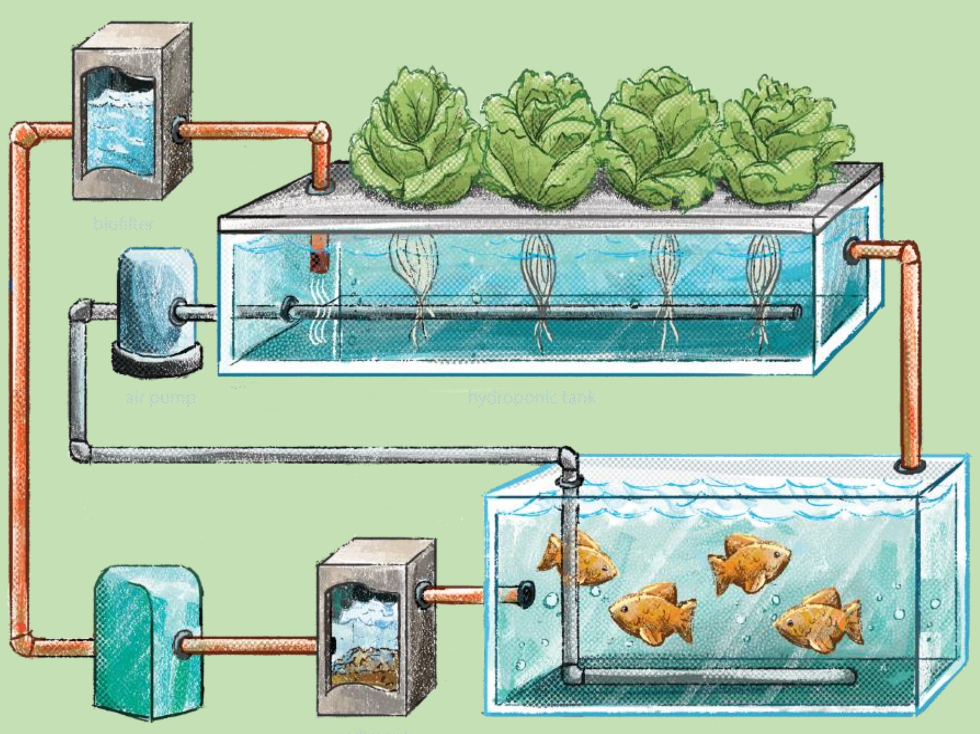

Figure 1. A model depicting the typical setup of a recirculating aquaponics system. Retrieved from: https://earth.org/data_visualization/aquaponics-a-solution-to-food-insecurity/

Operational Challenges

Combining the simultaneous farming of fish and plants in a single system can be a challenge as both species have ideal nutrient and pH ranges. Strict water quality parameters must be used to ensure optimal production and fish health. Most nutrients required for plant growth are sourced from the feed given to the fish who then make those nutrients plant available by digesting and excreting them. However, too much feed can lead to a surplus of excrements from the fish causing dangerous concentrations of ammonia that can drastically lower the pH and lead to ammonia toxicity in the fish. Not enough feed could lead to both malnourished fish and plants. This careful balance can be a challenge to achieve in aquaponics systems.

Restoration Data

Throughout the restoration process of this small-scale aquaponics system, data surrounding the nutrients and pH of the system were recorded. Basic nutrients, such as nitrate, nitrite, ammonia, alkalinity, and pH were recorded at least weekly and later plotted in Excel to compare changes occurring in the system. One of the main focuses to restore the system was to slowly raise the pH of the water to a safe range for the Koi fish and ideal value for plant nutrient utilization. To do this, potassium carbonate was added at least three times a week. The system pH reached the ideal range after approximately 17 days (Figure 3). When pH is low, fish do not want to eat, so as pH increased so did the feed supplied to the fish. An increase in daily feed resulted in an increased nitrate concentration (Figure 4). Feed was increased slowly to ensure that nitrification occurred at a sufficient rate and lethal concentrations of ammonia and nitrite were not produced (Figure 5).

Research Objectives

The main goal of this research was to develop a plan to restore the poorly maintained system back to the ideal parameters as outlined in aquaponics literature (Sallenave, n.d.).

1. Incrementally increase water pH to appropriate range for fish health and plant nutrient uptake
2. Monitor ammonia, nitrite, and nitrate levels to ensure changes made to the system are not endangering the health of the fish
3. Improve nitrate concentration available for plant uptake by increasing overall fish feed

Nutrient Uptake and pH

Plants require a variety of nutrients to be available in different quantities in order to achieve maximum growth rate. Some nutrients are needed in larger quantities, like nitrogen and phosphorus, while other such as zinc and molybdenum are only required by the plant in trace amounts (Provin, 2019). The ability of the plants to uptake and use these nutrients is directly related to the pH of the water (Figure 2). When pH is in the lower range, necessary nutrients like nitrogen, phosphorus, and potassium are unable to be used by the plant even if there is enough present (Timmons, 2007). The system pH was 3.90 at the beginning of the restoration process. This is below even the lowest pH on the nutrient uptake vs pH graph and plants were unable to fully utilize nutrients in the system (Figure 2). This led to stunted growth and poor harvest weights, as well as being extremely dangerous to the Koi fish in the system that have an ideal pH range of 7.0- 8.6 ("pH and your...", n.d.).

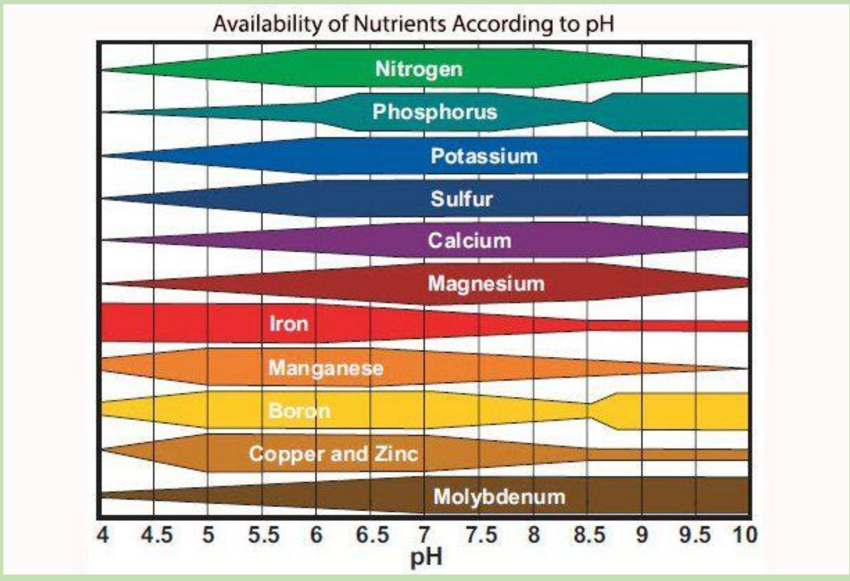

Figure 2. Graph depicting the availability of various nutrients based on pH. Retrieved from: https://www.supernaturalbrand.com/supernatural-brand-ph-buffering-explained/

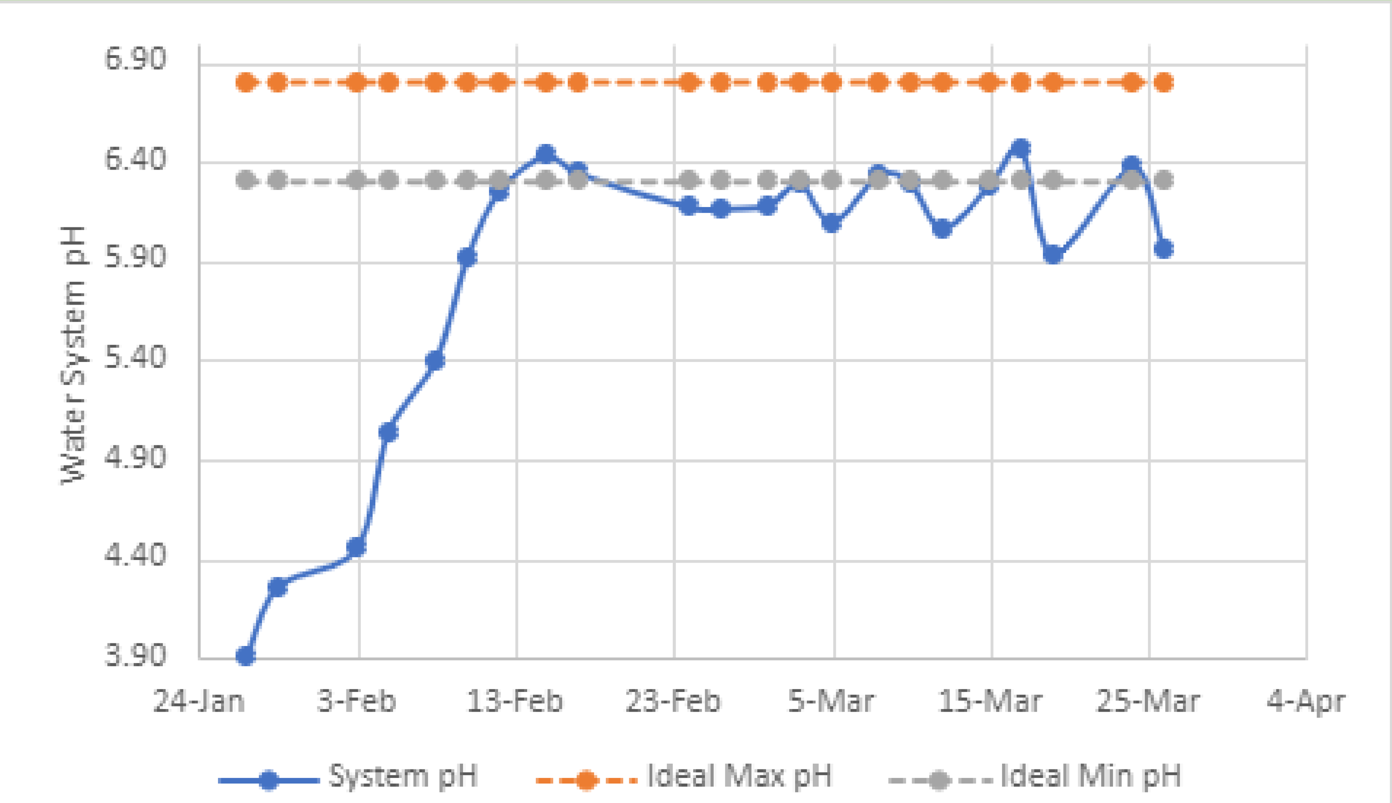

Figure 3. Data graph showing the pH of the system throughout restoration. The pH of the system entered the ideal pH range according to aquaponics literature after about 17 days of gradual potassium carbonate additions.

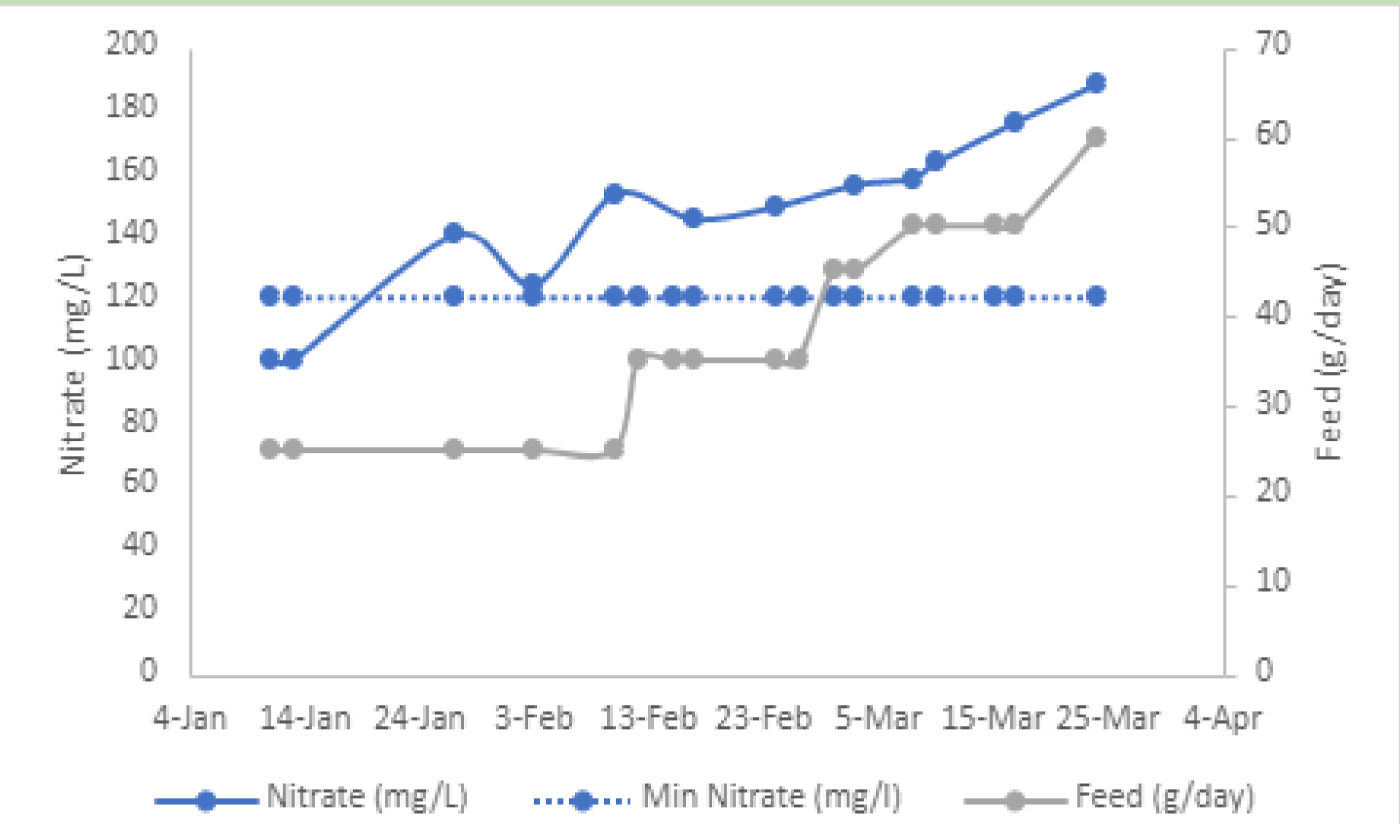

Figure 4. Data graph showing the nitrate concentration and feed given to the fish throughout the restoration process with the ideal minimum nitrate concentration plotted. Note that as the feed given to the fish increased, so did the nitrate concentration in the water as the fish are excreting more nitrogen.

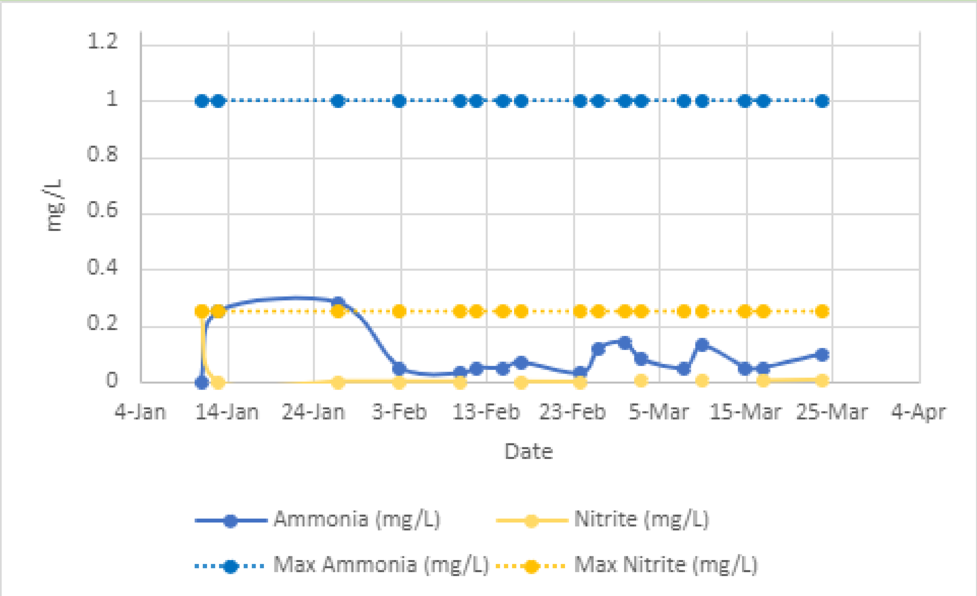

Figure 5. Data graph showing the ammonia and nitrite concentrations in the system throughout the restoration process with the lethal concentration of each plotted. Throughout the restoration process, ammonia and nitrite stayed well below the maximum safe levels, indicating that the nitrogen cycle was taking place properly converting each to nontoxic nitrate for plants to use for growth.

Conclusions

- Recirculating aquaponics systems are a careful balancing act of nutrients and pH based on the ideal ranges of both the flora and fauna present in the system
- While a system may have the necessary concentration of each nutrient for plant development, if the pH is not within the range of ~6.0-7.0, the nutrients are not directly available for use by the plants
- Slowly making chemical changes to the system is important so to not risk the health of the fish as sudden changes can shock their systems
- The methods used in this small-scale university aquaponics system can be applied to other systems experiencing similar challenges

Future Applications

The data and techniques used to restore the small aquaponics system located within the Student Union at Harrisburg University (Figure 6) can act as foundational data in the development of a model for the restoration and management of other systems that are similar in size and conditions. It is important that aquaponics systems are optimized to the ideal conditions for the flora and fauna present in order to observe quick growth rates and healthy fish.

Figure 6. Undergraduate student intern in front of the Nutrient Film Technique(NFT) Channels containing mixed lettuce in various growth stages after restoration of the ideal aquaponics parameters.

Questions?

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