Classroom Aquaponics

Dr. Michael Bechtel, Eric Berns, Zack Pogorzelski
Department of Biology, Wartburg College, Waverly, Iowa, 50677

Wartburg College

PHASE I: Introduction

The original focus of the Aquaponics Project (2016) was to gain valuable information for sustainability of aquaponics in the context of a homeless shelter. Founded primarily as a humanitarian endeavor, the purpose of this project was to create a hands-on, self sufficient system. This system would utilize fauna to produce nitrogenous waste (ammonia) in high enough volumes to sustain vegetative growth. Through the use of aerobic bacteria, the ammonia fish waste would be converted into nitrates (a form more readily taken up and used by terrestrial plants) which would vastly improve the vegetative growth supported by the system.

PHASE I: Investigation

The largest reservoir (300+ gallons) is used to house all Blue Tilapia (*Oreochromis aureus*) within the system, 63 in total. The tilapia are fed a manufactured pelletized diet to support growth and produce waste. A stand pipe in the rear corner of the tank pulls out a majority of the nitrogenous waste which naturally accumulates at the bottom of the reservoir.

The waste then flows into a 45-gallon reservoir used to house 10 Red Claw Crayfish (*Cherax quadricarinatus*), which act as bottom feeders. The crustaceans receive supplemental feeding through pelletized food while consuming the solid waste from the first reservoir, breaking it down further to an appropriate size for the bio filter. Floating grow-beds atop this reservoir and the accumulating solid material on bottom, provide an ideal environment for crayfish to live and reproduce. Overflow from this tank travels into a double bio-filter system.

This bio-filter system contains plastic mesh which captures solids and provides a place of adherence for bacteria, allowing the bacteria to convert the waste (ammonia) into nitrates. The use of dual bio-filters proved beneficial as solids accumulate quickly on the mesh which creates an anaerobic area in single filter systems not suitable for nitrate conversion.

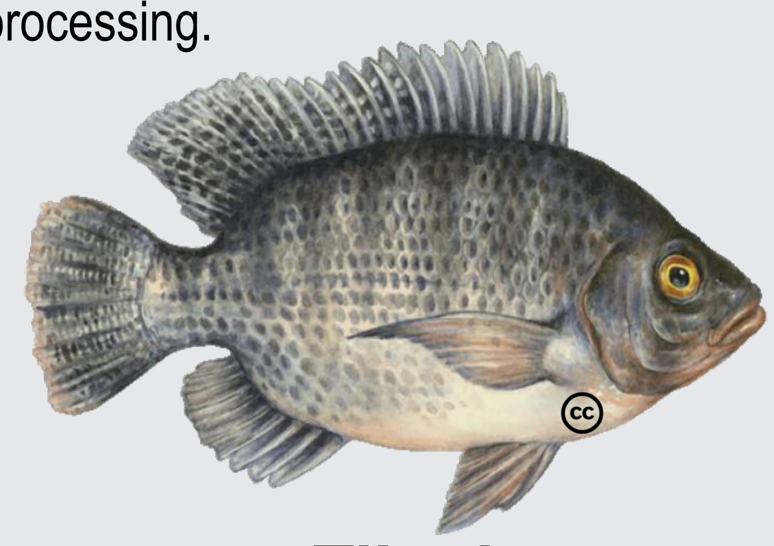
The bio-filter system overflows into a sump reservoir containing an aquarium pump which cycles water into the grow-beds. The cycled water – now rich in nutrients – fertilizes the plants, greatly increasing growth. The grow-beds empty back into the tilapia tank, beginning the cycle anew.

PHASE I: Implications

● Plants took less than 2/3 of the normal time to grow compared to conventional soil farming, delivering higher yields and production. ● A closed-loop recirculating system loses less water than conventional soil farming. Water loss is caused primarily by transpiration and evaporation. ● Reduction of surface area conserves about 90-95% of the water in the system. ● Pesticide use is eliminated as vegetation does not come in to contact with typical terrestrial pests. ● The system produces fauna and vegetation year round when in a stable, indoor environment. Fresh food is produced on-site and does not require processing.

Fauna

Red Claw
Cherax quadricarinatus



Tilapia
Oreochromis aureus

Prawn
Macrobrachium rosenbergii

Catfish
Ictalurus punctatus

PHASE II: Introduction

After finding the apparatus to be an effective learning and teaching tool, the new extended focus of the Aquaponics Project (2017) was to bring exceptional learning opportunities to the classroom. Aquaponics combines several tested educational theories together, including: biophilia (E.O. Wilson, 1984), overarching phenomena (Next Generation Science Standards), and active learning (Revans, 1990). Aquaponics provides hands-on opportunities applicable to all STEM fields, leading Wartburg College to reach out to local education institutions and interested individuals.

PHASE II: Investigation

Connections were forged with a local high school senior, Noah Solheim, and a local sixth grade teacher, Mr. Travis Angell. At the time, Solheim was conducting individual research, while Angell was incorporating aquaponics into his classroom. Both the individuals shared ideas, experiments, and enthusiasm in an effort to create smaller scale aquaponics systems usable in an educational setting.

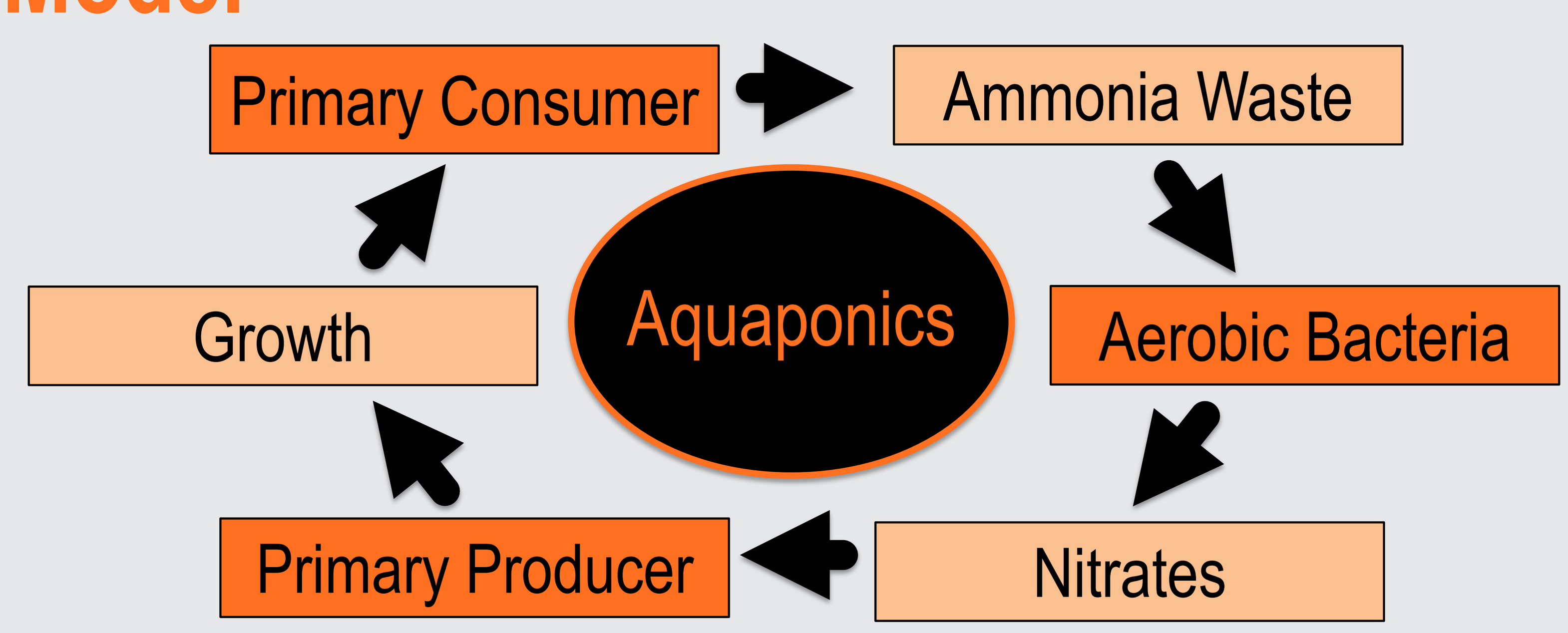
The aquaponics systems ranged from 10-gallon pre-fabricated window units to 40-gallon DIY experimental units. All created systems were smaller than the college's 300-gallon+ system housed in the institution's greenhouse. The smaller units mandated smaller species of fish, but were proven to easily house: guppies (*Poecilia reticulate*), endlers (*Poecilia wingei*), mollies (*Poecilia sphenops*), platies (*Xiphophorus maculatus*), swordtails (*Xiphophorus hellerii*), and goldfish (*Carassius auratus*). Smaller units could also support fruit or leaf producing plants, even with the size and nutrient restrictions.

The conducted experiments were open-ended and self-driven. No curriculum existed for the building or the use of the aquaponics system at this time. Several students at varying levels were interested in particular components of the systems and created their own models as well. One group of students created a 10-foot tall window system with 20 separate 6-inch plant containers and a "catch all" 20-gallon fish aquarium at the bottom.

PHASE II: Implications

● Aquaponics has connections to all STEM fields and could be used by several student groups simultaneously. ● Running the system involves hard academic skills and soft psychomotor skills. ● Cost and size can be a limiting factors for incorporating aquaponics into the average classroom. A 300-gallon tank is not appropriate for most secondary classrooms. ● System dynamics must be matched with educational level to sustain interest and involvement. Small units (such as a 2-gallon container with floating plants and a pair of guppies) may not properly engage secondary students. ● Support, in the context of open two-way communication, is important to share ideas about modifications; pitfalls and improvements.

Model



PHASE III: Introduction

The final iteration of the Aquaponics Project (2018) involved the combination of all prior research into a cohesive educational tool. Three different systems were developed for specific educational levels: K-5 will use the 2-gallon container size, grades 6-8 will use the 30-gallon table top size, and the 9-12 apparatus will be the 75-gallon floor model. Thirty cross-curricular and NGSS-aligned lesson plans were crafted to be used along side these systems at a high school level, with plans to develop lesson plans for the middle and elementary levels shortly after.

Acknowledgements

We would like to take this opportunity to thank Mr. Ryan Henkel for igniting a passion of aquaponics in his professor. Special recognition is due to Mr. Travis Angell (Waverly-Shell Rock science instructor) and Noah Solheim for their help forming the connections between the undergraduate level and secondary/middle schools. This program would not exist as it is today without their contributions. We also would not be where we are today without our community supporters like Mr. Derek Happel. There are many assistants/ researchers that also deserve mention including Angelina Carrasquillo, Candace Baker, Jean Hakizimana, and Evan Van Vleck. Lastly, we would like to thank the Wartburg College IACUC for allowing us to perform research with animals.