Development of Sustainable Aquaponics Model Systems (SAMS) to Enhance Resiliency of Urban, Indoor, and Emerging (UIE) Food Systems

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INTRODUCTION

- **The Paradigm:** Aquaponics (AP) is a sustainable and innovative farming approach that seamlessly integrates recirculating aquaculture systems (RAS) with hydroponics.
- **The Industry Challenge:** Commercial profitability is heavily hindered by a reliance on low-value tilapia production, high energy costs, and intense import competition.
- **The Solution:** This economic hurdle can be overcome by applying new, high-value breeds that require less production energy.
- **The Missing Link:** To fully optimize production, it is vital to unlock and understand the complex structure and function of the microbial consortia present in the AP systems.

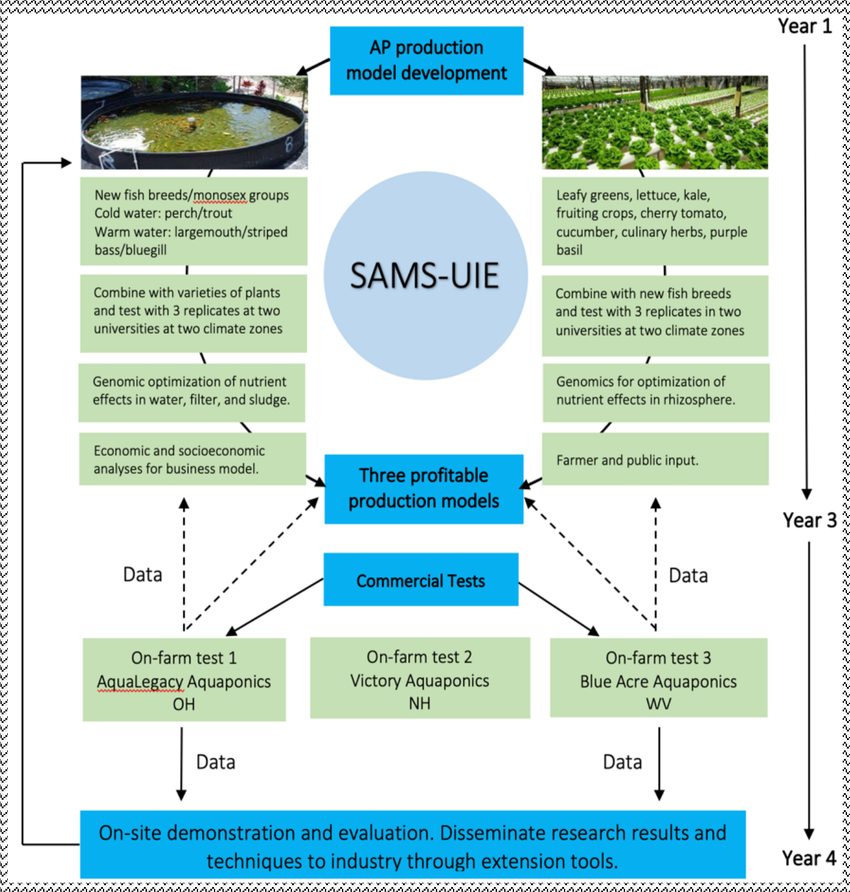


Fig. 1 Project scheme for development and validation of Sustainable Aquaponics Production Model Systems (SAMS) to enhance resiliency of Urban, Indoor, and Emerging (UIE) food systems.

METHODOLOGY & SETUP

- **Experimental Design:** Project scheme is shown in Fig.1.
- **Facilities:** Parallel experiments are carried out in dedicated greenhouse aquaponic systems (Fig. 2 and 3) across two locations: OSU (Ohio) and UNH (New Hampshire).
- ***Fish Strains:*** All-female Yellow Perch (YP), Largemouth Bass (LB), fast-growing Striped Bass (SB) in Ohio. At UNH, cold-water setups evaluated Rainbow Trout (RT) and all-female YP.
- ***Crops:*** Valmaine Romaine lettuce, Lollo Bionda lettuce, Lollo Rosso lettuce, and Winterbor kale.
- **Data Collection & Analysis Suite:**
  - ***Daily:*** DO, pH, temperature, and macronutrients (NH3, nitrite, nitrate, phosphate).
  - ***Weekly/Bi-weekly:*** Micronutrients (Fe, K, Ca, Mg); longest leaf length, photosynthesis, and chlorophyll alpha.
  - ***Microbials:*** DNA sampling gathered across sumps, fish tanks, plant trays, biofilters, rhizospheres, and biodeposits.



Fig. 2 *Aquaponics system set up at OSU (left) and UNH (right) greenhouses*

RESULTS

A. Crop Yields & Seasonal Performance

- **Biomass Variances:** In cold-warm systems with a feed rate of $100g feed (48% protein and 10% fat)/m^3 plant bed/day, Romaine lettuce exhibited significantly higher production than Winterbor kale. However, they grew equally well in dedicated cold-water systems.
- **Seasonal Pairing:** Romaine lettuce achieved higher production and value in the summer, while Lollo lettuce proved ideal for winter cultivation.
- **Crop Invalidation:** Intercropping trials revealed that kale inhibited the sprouting and growth of adjacent lettuce.
- **Nutrient Thresholds:** A fish stocking density of $20kg/$m^{-3}$ proved too low to provide sufficient micronutrients naturally. Regular nutrient amendments are necessary during the coldest months (December–March) due to reduced fish feed consumption.

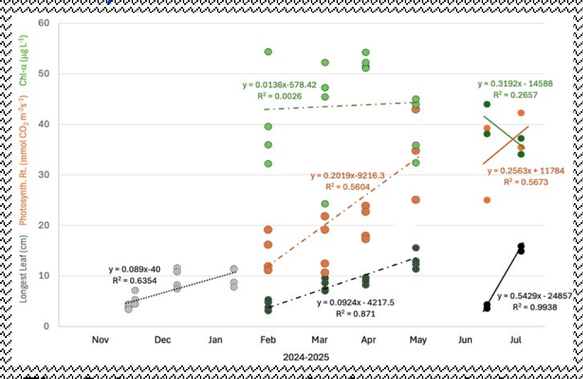


Fig. 3. Lettuce growth characteristics during Year 1 in cold water systems.

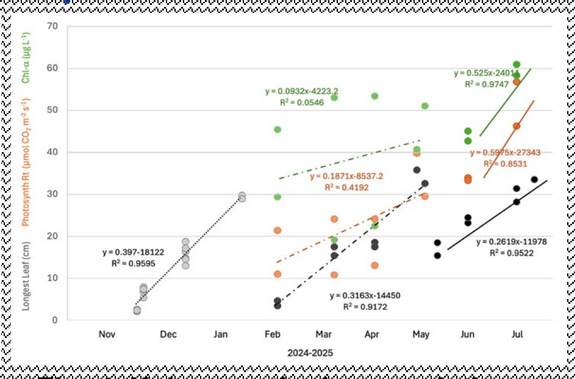


Fig. 4. Kale growth characteristics during Year 1 in cold water systems.

B. Fish Husbandry & Growth

- **Thermal Tolerance:** All-female Yellow Perch grew steadily until water temperatures exceeded 26°C (79°F) and successfully survived peaks up to 28°C (82°F).
- **Year-Round Feasibility:** Both YP and RT proved to be favorable species for year-round cultivation in cold-water aquaponic systems.
- **Stocking Strategy:** Introducing larger Rainbow Trout fingerlings could compress the production cycle, allowing them to reach market harvest size within approximately 9 months of cultivation.

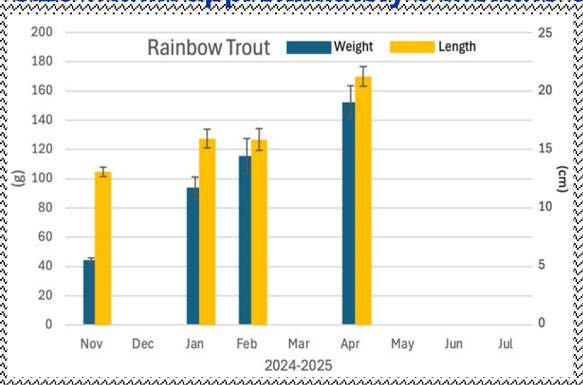


Fig.5. Growth of rainbow trout during Year 1 of aquaponic study

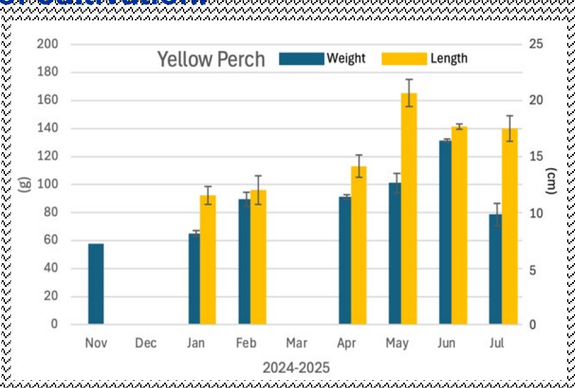


Fig.6. Growth of yellow perch during Year 1 of aquaponic study

C. Microbiome & System Compartmentalization

- **High Diversity:** Indexed more than 3,000 distinct bacterial operational taxonomic units (OTUs) across the systems.
- **Compartment Specificity:** While water columns (sumps, fish tanks, plant trays) shared homogeneous profiles, the physical solid surfaces (biofilters, rhizospheres, biodeposits) differed significantly ($p < 0.001$).
- **Microbial Maturation:** At approximately 3 months, the system microbiome "matures". The microbial consortia cluster distinctly by physical system compartment rather than shifting based on the specific fish or plant species hosted.

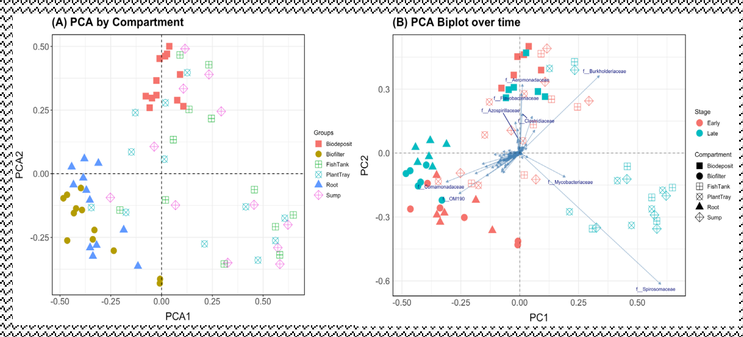


Fig.7. PCA plots to examine similarities among AP compartments. (A) All samples from all compartments included. (B) Early and Late microbiome groupings and the families most influential to the grouping (blue vectors)

CONCLUSIONS

- **System Feasibility:** Cool- and cold-water AP systems with YP and RT are robust and functional in northern climates.
- **Elite Candidates:** All-female YP represent an excellent candidate for year-round, high-value regional production loops.
- **Targeted Inoculation:** Because the aquaponic microbiome stabilizes predictably by physical compartment over time, specific microbially-mediated pathways can be deliberately augmented to enhance target nutrient cycling.
- **Economic Outlook:** Aggregating 73 operational parameters into predictive frameworks (such as IMPLAN) allows for rigorous economic modeling to minimize risk and optimize commercial profitability.

ACKNOWLEDGMENTS

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