Aquaponic System Design and Management

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Natural Resource Ecology and Management

What is Aquaponics?

Aquaculture

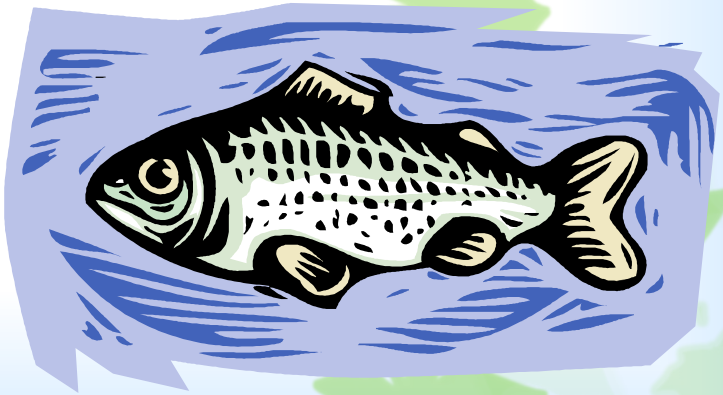
Hydroponics


Why do
Aquaponics?

Aquaculture is Limited

- Water quality and quantity
- Growing Season
- Effluent mitigation
- Energy inputs
- Markets
- Feed Costs
- Fry/fingerling availability
- Labor

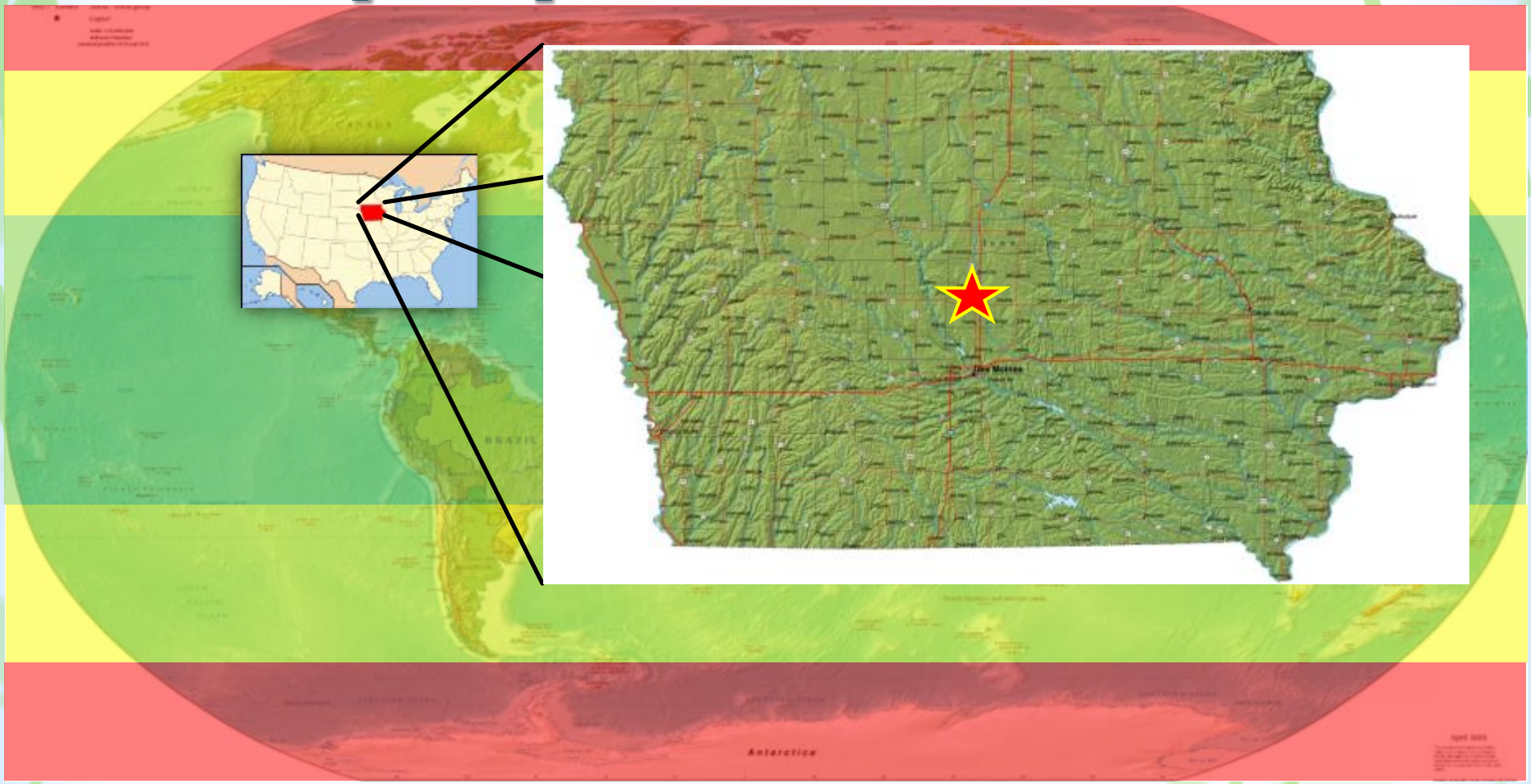
Where Aquaponics Can Help!



Benefits of Aquaponics

- Nutrient management/ effluent mitigation
- Plants grow 2x as fast
- Year round production possible
- 75% smaller footprint
  - Less space required per plant
  - Vertical production allows more efficient use of space
- Prolonged individual plant life
- 90% Less water consumption
- Soil pathogens eliminated
- Plants can be grown at desired height
- **No weeding!!!!**

Where is aquaponics done?



BIG PROBLEMS!!!

This means we need environmental control!

- Light
- Temperature
- Humidity/Evaporation
- Air Flow

Guidelines for Aquaponic Producers

1. Use a feeding ration for design calculations

- The optimum feeding rate ratio depends on many factors such as type of hydroponic system, plants being cultivated, chemical composition of source water and percentage of system water lost during solids removal.
- The optimum feeding rate ratio for a nutrient film technique hydroponic system is roughly 25% of the ratio used for a raft system.

1. Use a feeding ration for design calculations cont...

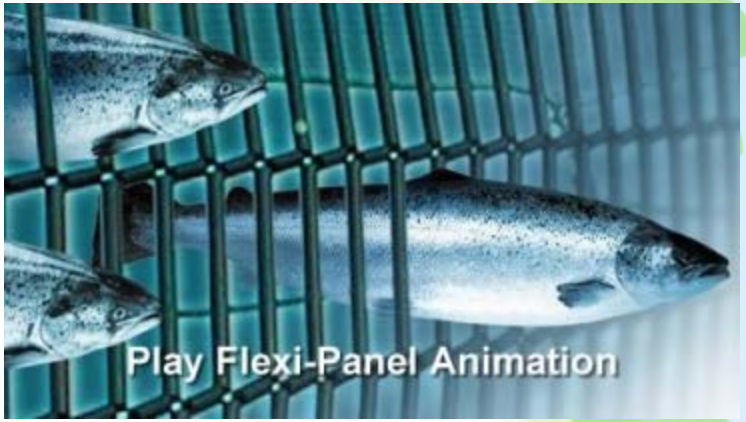
- Ratio between fish and plants is based on the feeding rate ratio (amount of feed fed to the fish daily per square meter of plant growing area)
  - For a raft hydroponic system the optimum ratio varies from **60 to 100 g/m^2/day.**
- For example, if the fish are being fed 1,000 g per day on average, the area devoted to hydroponics production should be 16.7 m^2 for a feeding rate ratio of 60 g/m^2/day.

2. Keep feed input relatively constant

- Multiple rearing tanks, staggered production
  - four tilapia rearing tanks

2. Keep feed input relatively constant cont…

- Single rearing tank with multiple size groups of fish
  - 6-month growout tank would have 6 size groups of fish
  - monthly grading and harvest of fish
  - restock equal number of fingerlings



3. Supplement with calcium, potassium, and iron

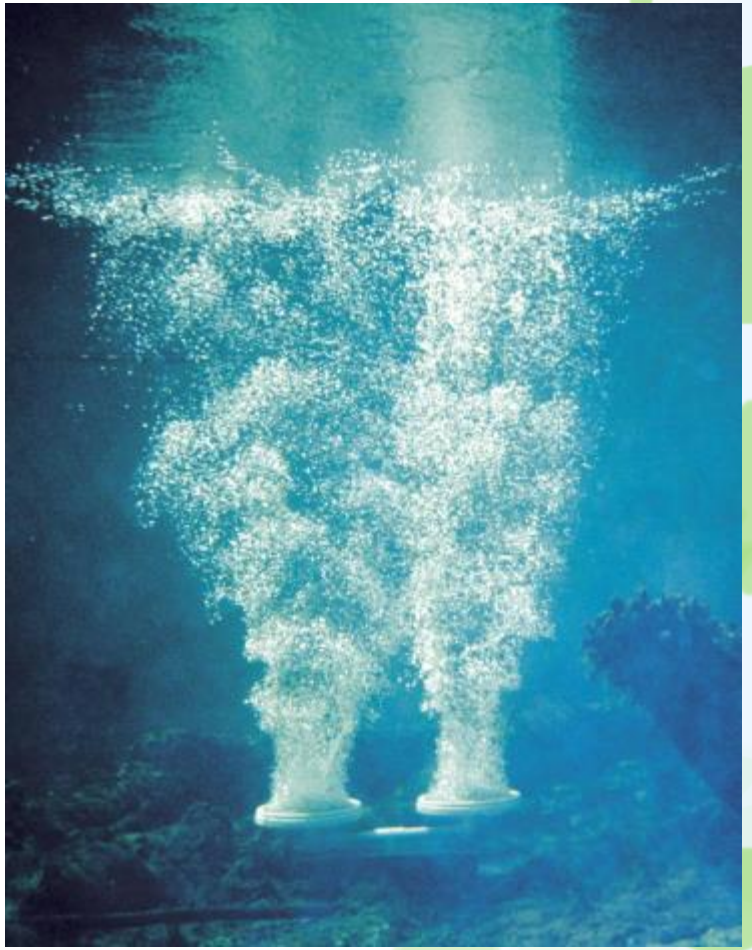
- Plants require 13 nutrients for growth, and fish feed supplies 10 nutrients in adequate quantities.
- **Iron**
  - Chelated Iron (EDTA)
- **Calcium**
  - Agricultural Limestone
    - Calcium Carbonate ($CaCO_3$)
  - Hydrated Lime
    - Calcium Hydroxide ($Ca(OH)_2$)
  - Calcium Chloride ($CaCl_2$)
- **Potassium**
  - Muriate of Potash
    - Potassium chloride (KCl)
  - Potassium Hydroxide (KOH)

Nutrient Deficiencies

Yellowing, reduced growth rates, and reduced flavor quality can be caused by nutrient imbalances

4. Ensure good aeration

- The fish, plants and bacteria in aquaponic systems require adequate levels of dissolved oxygen (DO) for maximum health and growth.
  - Maintain DO at >5 mg/liter



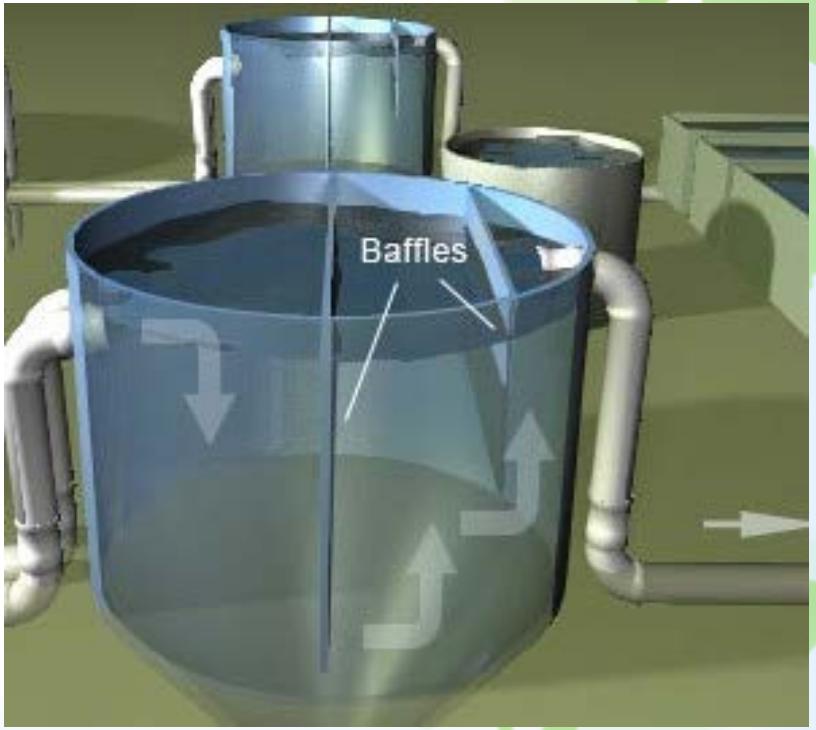
Aeration

- **ADD AERATION WHENEVER POSSIBLE!**
- Aids in oxygenation and off-gassing of unwanted toxins
- Helps fish, plants, and bacteria perform critical biological processes

- **Aeration options**
  - Diffuser stones
  - Venturi action
  - Packed columns
  - Waterfall action

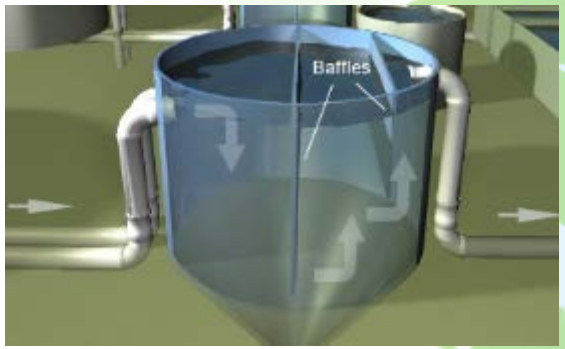
5. Remove solids

- Approximately 25% of the feed given to fish is excreted as solid waste, based on dry weight.
  - If solids are not removed:
    - Depletes dissolved oxygen
    - Clogs pipes
    - Kills nitrifying bacteria
    - Causes ammonia problems



Mechanical Filtration

- Options
  - Filter pads
  - Settling chambers/ Clarifiers
  - Sand and bead filters
  - Screen filters



6. Be careful with aggregates

- Organic solids may tend to clog aggregates such as pea gravel, sand and perlite
  - Creates anaerobic conditions (low DO)
  - Kills plant roots
  - Kills beneficial bacteria
  - Can be mitigated by adding worms to aggregate substrate to process organics

7. Oversize pipes

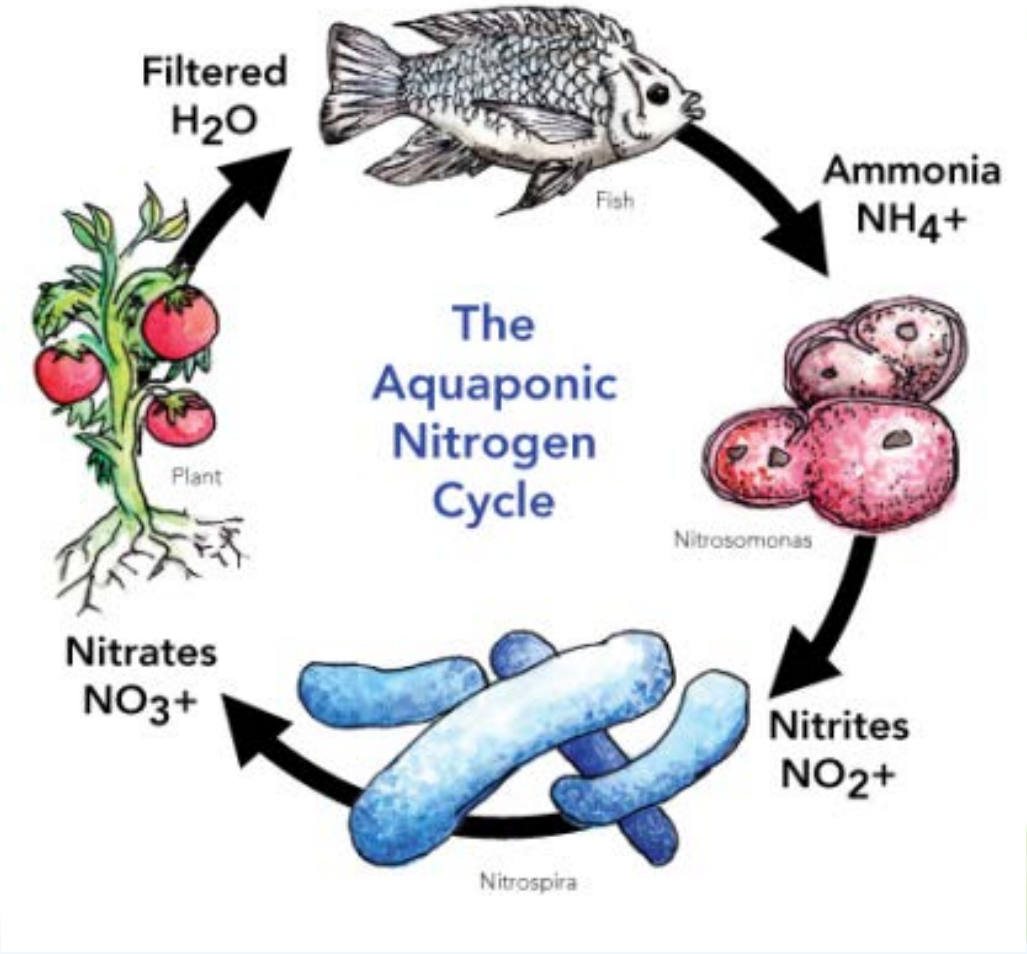
- Use oversized pipes to reduce the effects of biofouling
  - dissolved organic matter promote the growth of filamentous bacteria
    - restricts flow within pipes
  - Spaghetti tubes will likely clog
  - Tilapia in drain lines reduce biofouling by grazing on bacteria
  - Pipes downstream from solids removal are less likely to clog
  - Lower water temperatures reduce biofouling

8. Use biological control

- Pesticides must not be used to control insects and plant diseases because many are toxic to fish and none have been approved for use in food fish culture.
- Therapeutants for treating fish parasites and diseases may harm beneficial bacteria and vegetables may absorb and concentrate them.
- Biological control methods are the only option for controlling insects and diseases.

8. Use biological control

9. Ensure adequate biofiltration

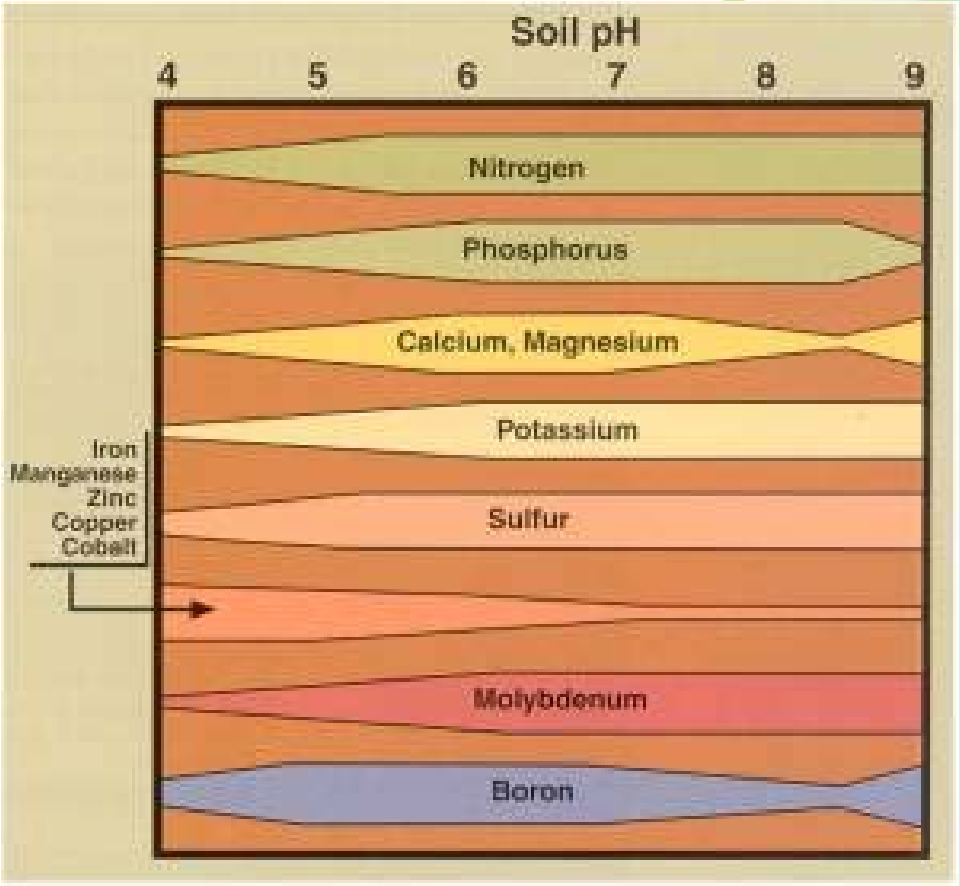


Biological Filtration

- Biofiltration is critical for the conversion of toxic ammonia to the nitrate plant fertilizer
  - Best to over-size the biofilter
  - Options:
    - Trickling biofilter
    - Fluidized bed
    - Rotating contact biofilter

10. Control pH

- Nitrification is more efficient at pH 7.5 or higher and practically ceases at pH values less than 6.0.
- The optimum pH for nutrient solubility is 6.5 or slightly lower.
- High pH plants display nutrient deficiencies
- Low pH ammonia accumulates to levels that are toxic to fish

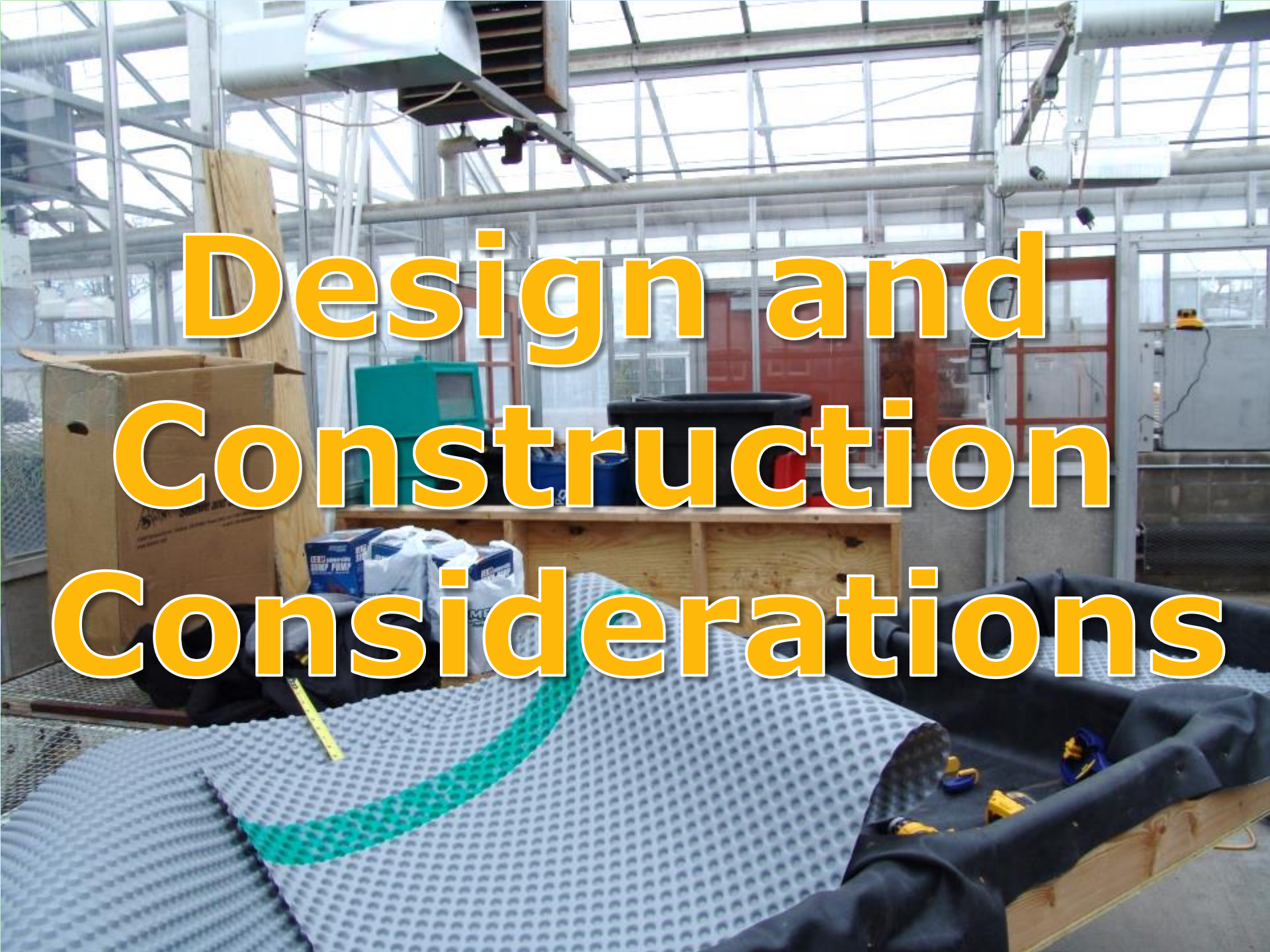


11. Use only one pump

- Take advantage of gravity
- Lower energy usage

Pumps

- *Efficiency is key!*
- Use one pump and let gravity do the rest
- Always have a backup pump!!!
- **Impeller pumps**
  - Inline
  - Submersible
  - Mag-drive
- **Airlift pumps**
  - Blower
  - Compressor
  - See “Paradigm shift with Airlift” https://learn.extension.org/events/1064


Design and
Construction
Considerations

Water

- **Water is heavy!**
  - ~8.35 lb/gal
  - 1 kg/L
- Take advantage of gravity flow whenever possible
- Put tanks on the ground or support them adequately with good construction materials

Water Source

HAVE YOUR WATER TESTED BEFORE SETTING UP A SYSTEM!!!

Municipal Water

- May contain chlorine or chloramine – **TOXIC to fish**
- Chloramine must be broken up with a sulfur compound
  - Sodium sulfite or Sodium thiosulfate

Well Water

- May contain pesticides, contaminants, or toxins
- Will likely be low DO and high CO_2

Rain Water

- Low hardness and may be affected by acid rain
- May need to add ocean salt for fish osmotic balance (0.25 – 1 ppt)

Surface Water

- May contain pesticides, contaminants, or toxins
- **May contain diseases, algae, fungi, fecal coliforms, etc.**

Tanks

Tons of choices!

- Choose the most appropriate tank for the scale of your operation
  - Tank size and shape is dependent on fish and plant species and harvest style
  - 40-gal square tanks are 20% of system volume at ISU

Hydroponic Unit

- Where the plants are grown
- Must maintain moisture and high oxygen concentrations for plant roots
- Options:
  - Floating raft
  - Flood and drain
  - Nutrient film technique
  - Towers
  - Aeroponics

Greenhouses

- Controlled environments culture
  - Take advantage of natural light
  - Control culture temperature of plants and fish
  - Extend/year-round growing season
  - Reduce pest issues
  - Increase food safety
- Options:

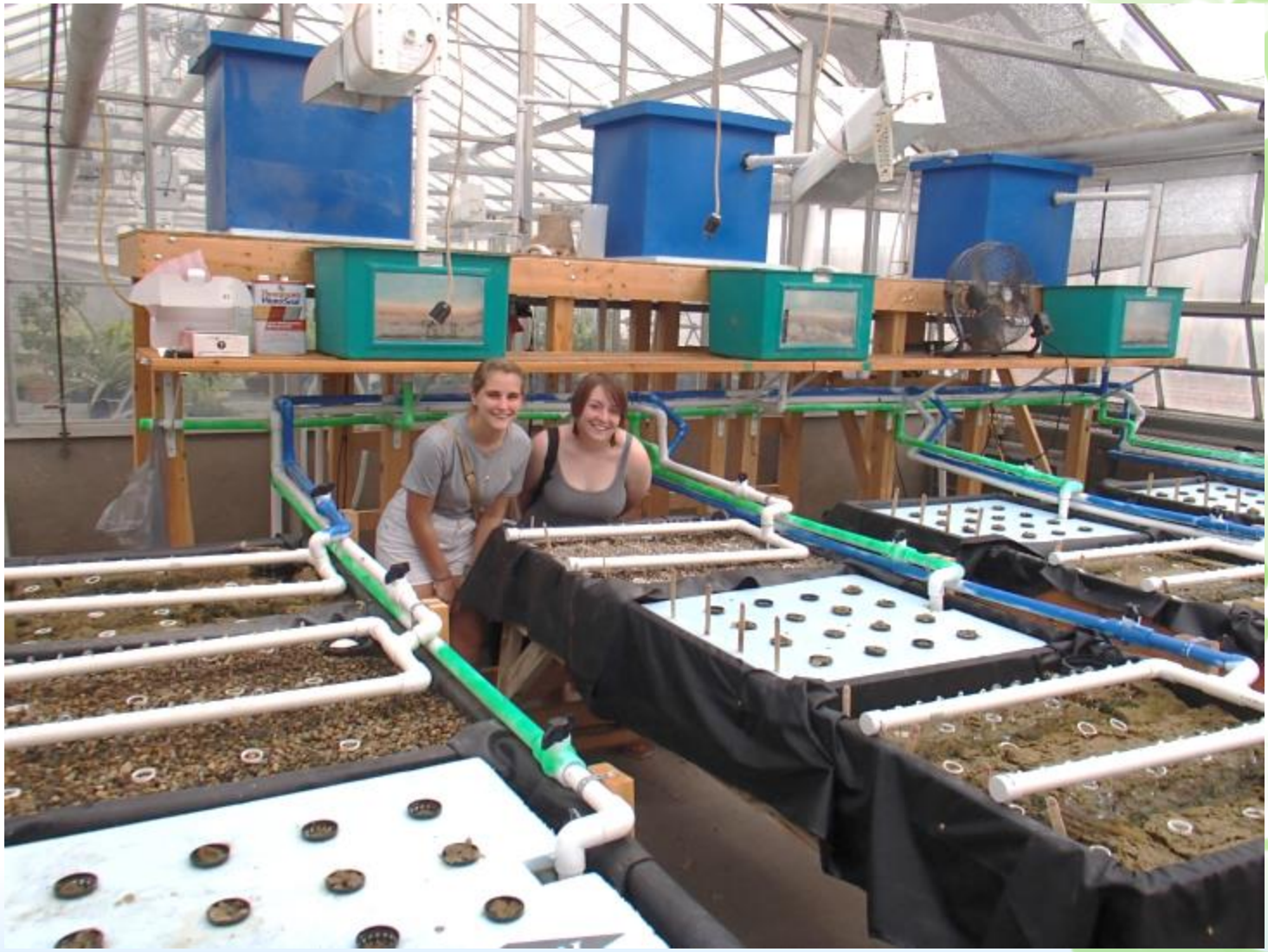
Supplemental Lighting

- Necessary for winter months and indoor culture
- Efficiency is critical to economic viability
- Light spectrum and photoperiod affects fruiting of plants
- Options:
  - High Pressure Sodium
  - Florescent
  - Halogen
  - Light Emitting Diodes (LED)


Management
Considerations

Automation is nice...

...but not necessary



...there is NO substitute for physical inspection

Water Quality

Daily Testing

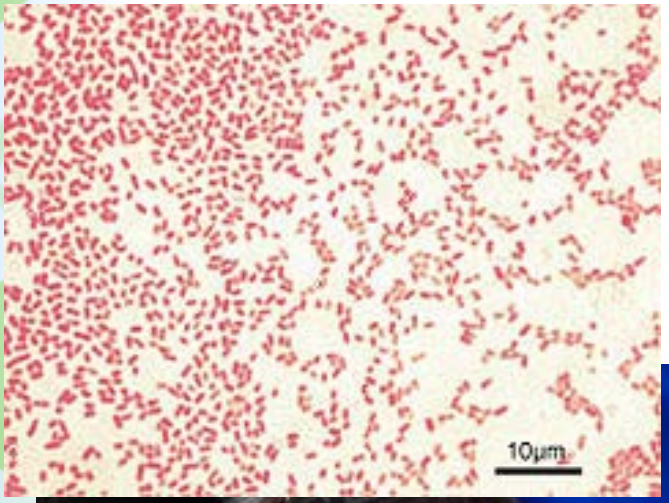
- Dissolved oxygen (DO)
- Temperature
- pH
- Total ammonia nitrogen (TAN)

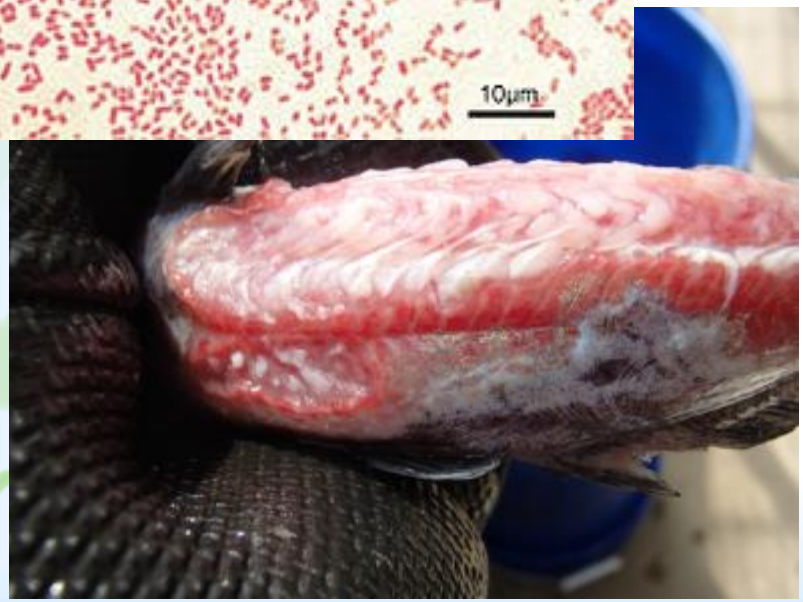
Weekly Testing

- Nitrite
- Nitrate
- Phosphorus
- Potassium
- Iron
- Alkalinity
- Calcium hardness

Disease Issues

Aeromonas





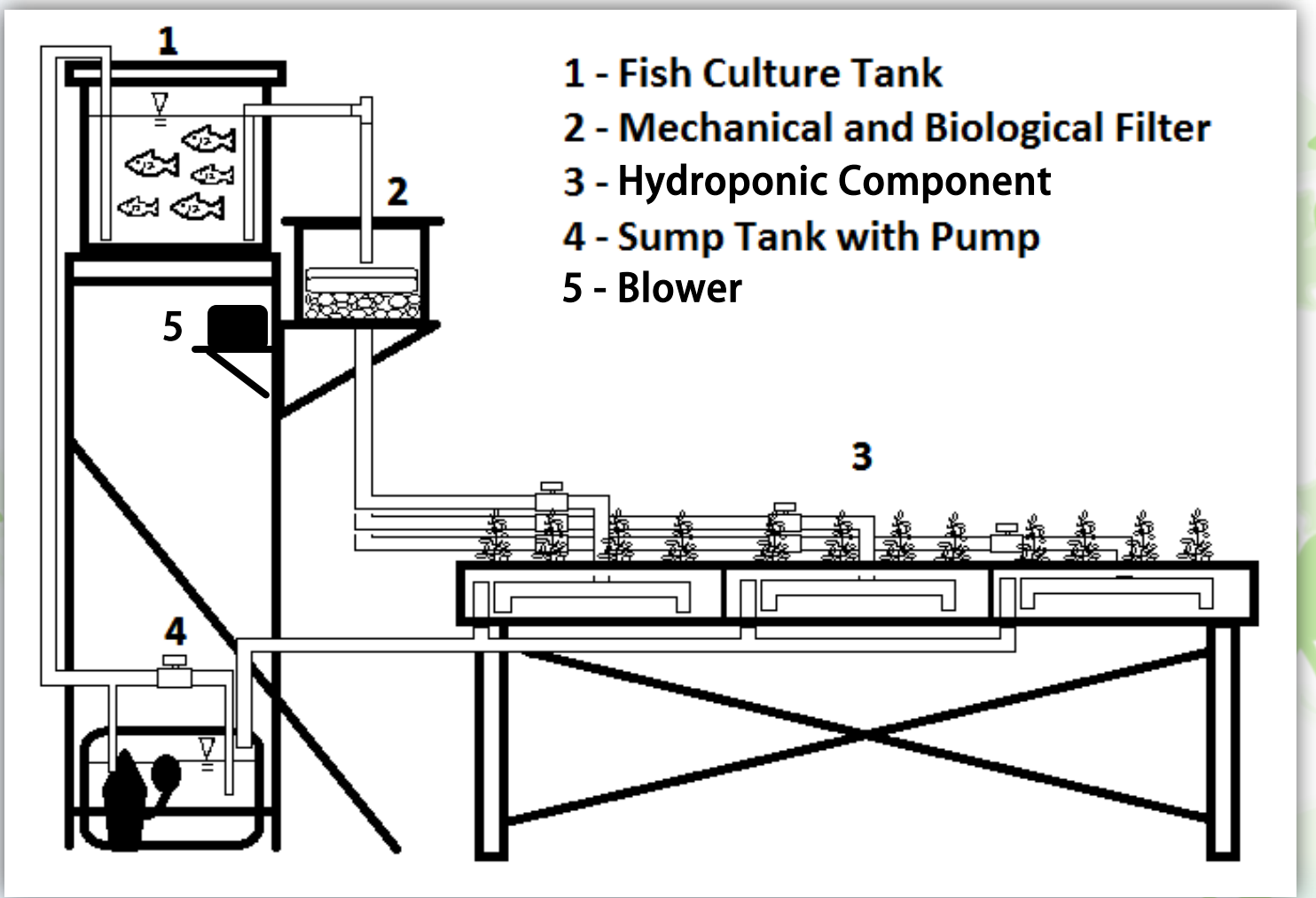
Pythium

Biosecurity

- ***Preventions is best!***
  - No foreign water, fish, plants, nets etc.
    - Regular sterilization of surfaces and equipment
- Maintaining healthy water
  - **Regular solids removal**
  - **Ultraviolet light sterilization**
  - **O-Zone sterilization**

ISU System

How does it work?



Fish Tanks

- Dimensions – 50x65x74 cm
- Water Volume ~ 158 L (42 gal)
- Directional flow (1” PVC)
- Bottom outflow ($1\frac{1}{4}$” PVC)
- Emergency overflow ($1\frac{1}{4}$” PVC)
- Aeration via Airstone
  - 8x3x3 cm
- Covers (1 cm plastic mesh)
- Max fish biomass = 120 kg/m^3

Filter Tanks

- Dimension = 56x40x35 cm
- Water Depth = 3 cm
- Biofilter Material Vol. = 0.063 m^3
  - Bio-Fill™ – 800 m^2/m^3 ➡ 51.6 m^2
- Solids filter pads

Plant Trays

- Tray Dimension = 83 cm x 76 cm = 0.63 m^2
- Inflow manifold = 75 cm x 35 cm
- 3 mm holes, spaced 3.5 cm

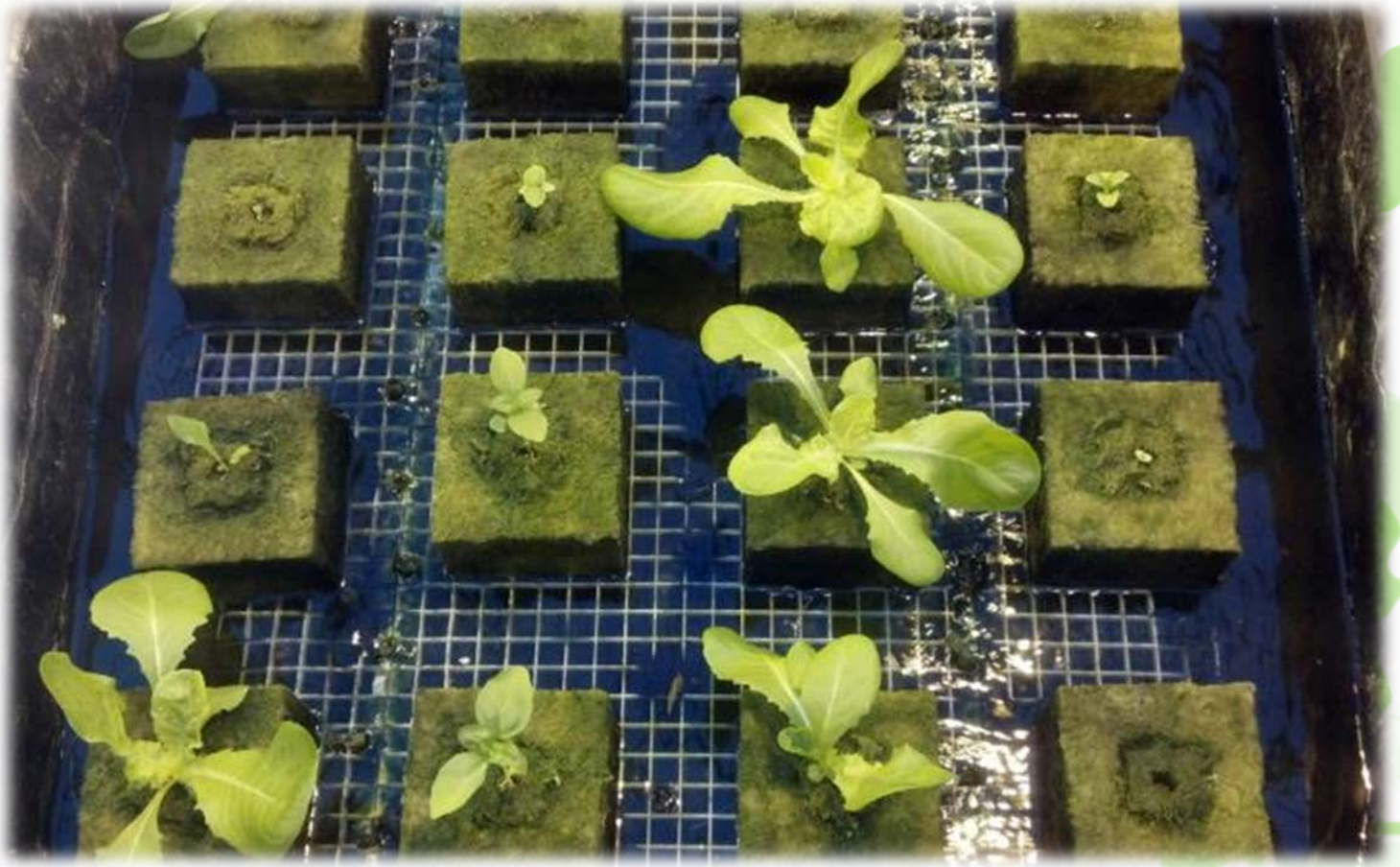
Sumps

- 50 gal stock tank
  - ~ 167 L (44 gal) capacity
- 1/3 Horsepower sump pump
- Shunt-valve
- Auto Shutoff
- Auto Refill via head tank
  - Head Tank Vol. = 170 L (45 gal)
- Nutrient supplementation
  - Iron
  - Calcium
  - Alkalinity

Types of Growout

Nutrient Film Technique (NFT)

Rockwool



NFT Key Characteristics

- Rockwool cubes – 98% Air by volume
- Blocks 10 cm (L) x 10 cm (W) x 7.6 cm (H)
- ~1cm water depth of blocks
- Wicks up water from below
- Tray water volume = 41 L (11 gal)

Flood and Drain/Ebb and Flow

Pea Gravel

Flood and Drain Key Characteristics

- Pea Gravel from local quarry
  - Diameter = 0.5 – 1.5 cm
- Flood and drain cycle = 20-30 min

Deep Water Culture

Floating Raft

Floating Raft Key Characteristics

- Water Depth = ~ 15 cm (6 in)
- Tray Volume = ~ 92 L (24 gal)
- Average Flow Rate = 6.3 L/min (1.7 gal/min)

Lighting

- High Pressure Sodium Lamps
  - 400 watts
  - 1.5 m above tables
  - 2 per bench
    - 8 total
- Photoperiod
  - 16L : 8 D

Species Grown

Nile Tilapia

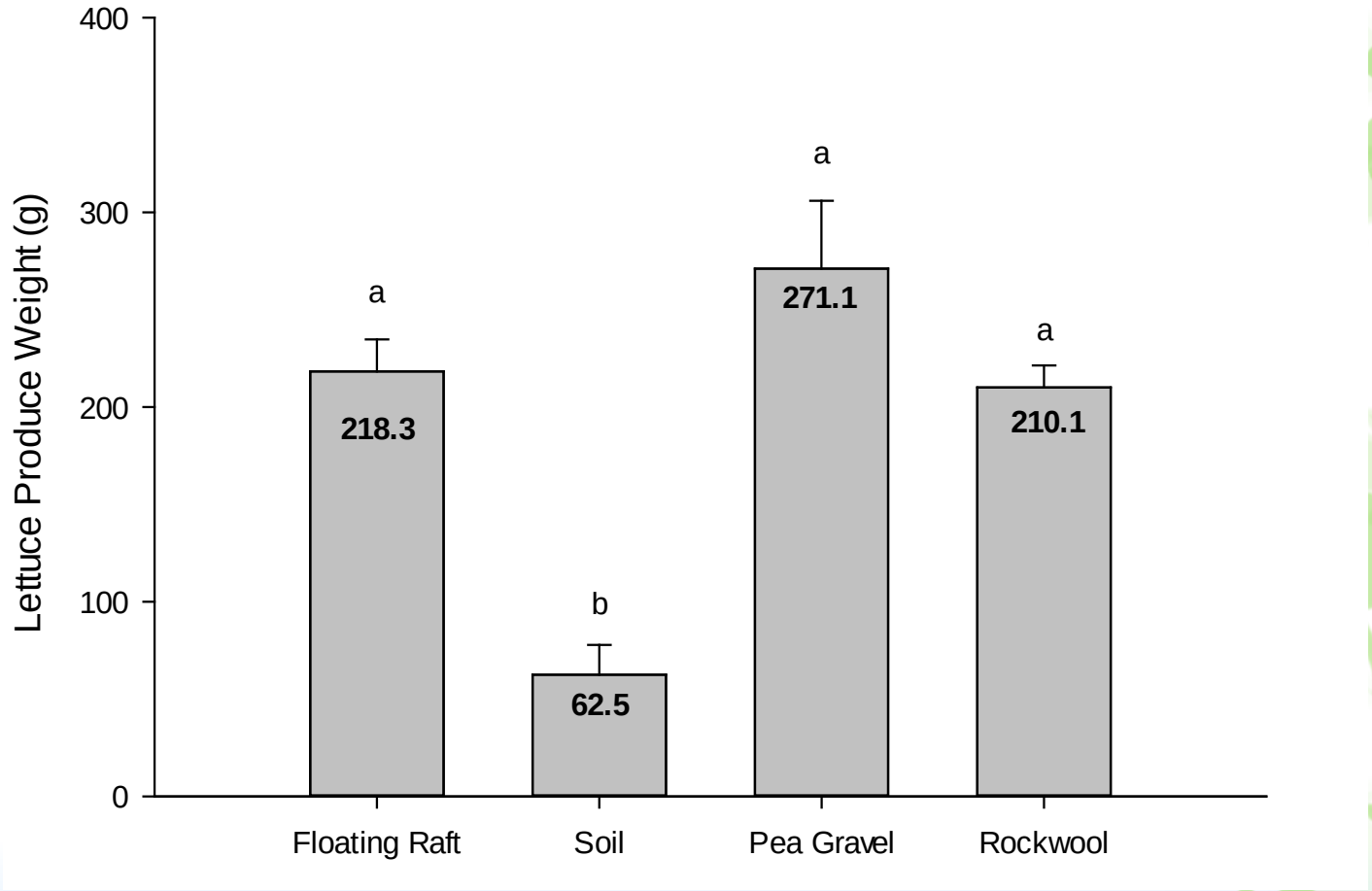
Oreochromis niloticus

Buttercrunch Bibb Lettuce

Italian Largeleaf Basil

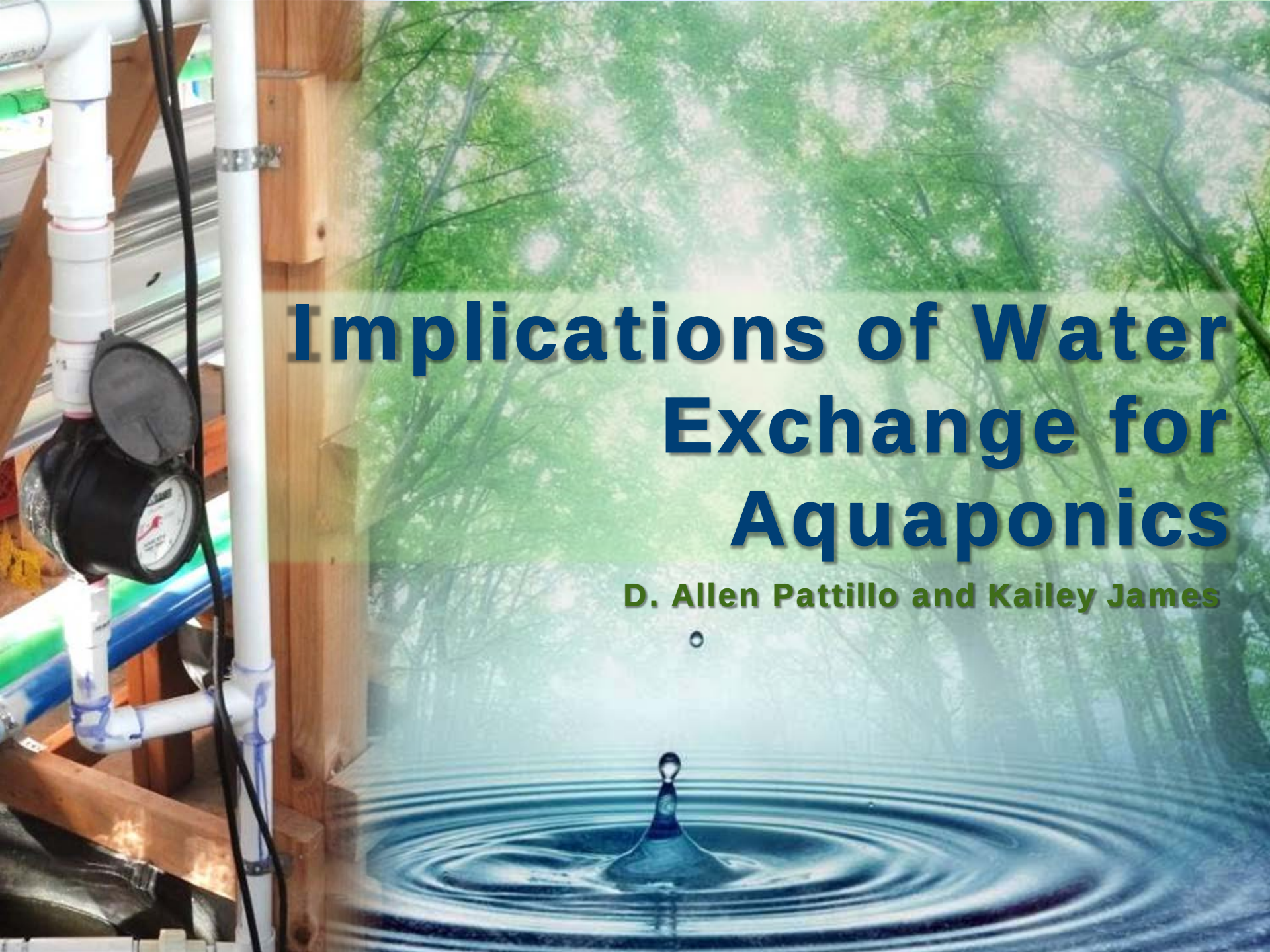
In March of 2012…

Average Individual Lettuce Produce Weight



Tilapia Harvest

Current Research



Implications of Water Exchange for Aquaponics

D. Allen Pattillo and Kailey James

Summer 2013


Channel Catfish


Italian Large-Leaf Basil

Results still being analyzed

Comparison of Light Sources for Aquaponic Economic Viability

D. Allen Pattillo and
Kurt A. Rosentrater

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Questions?

Cumulative Water Usage