Aquaponic System Design and Management

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IOWA STATE UNIVERSITY
OF SCIENCE AND TECHNOLOGY

Natural Resource Ecology and Management

What is Aquaponics?

Aquaculture

Hydroponics

Aquaponics

- Super-intensive
- Yield
  - 0.3 – 1 lb of fish per gallon of tank space
  - 2-5 plants per square foot of growing area
  - Each fish can support ~ 15 plants
  - Multiple crops for market


Why do
Aquaponics?

Why do Aquaponics?

- Good quality water resources for aquaculture are scarce
- Land is expensive, especially near good markets
- Concerns about biosecurity
- Greater control over effluent production and quality
- Permits the culture of aquatic organisms outside of natural range

Benefits of Aquaponics

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Nutrient Management

- **Effluent mitigation for EPA compliance**
- **Reduce expense of effluent filtration**
- **Maintains high water quality for fish**

Enhanced Plant Growth

- 2x plant growth rate of soil
- Prolonged individual plant life
- Year-round production in controlled environments

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Value of Plants

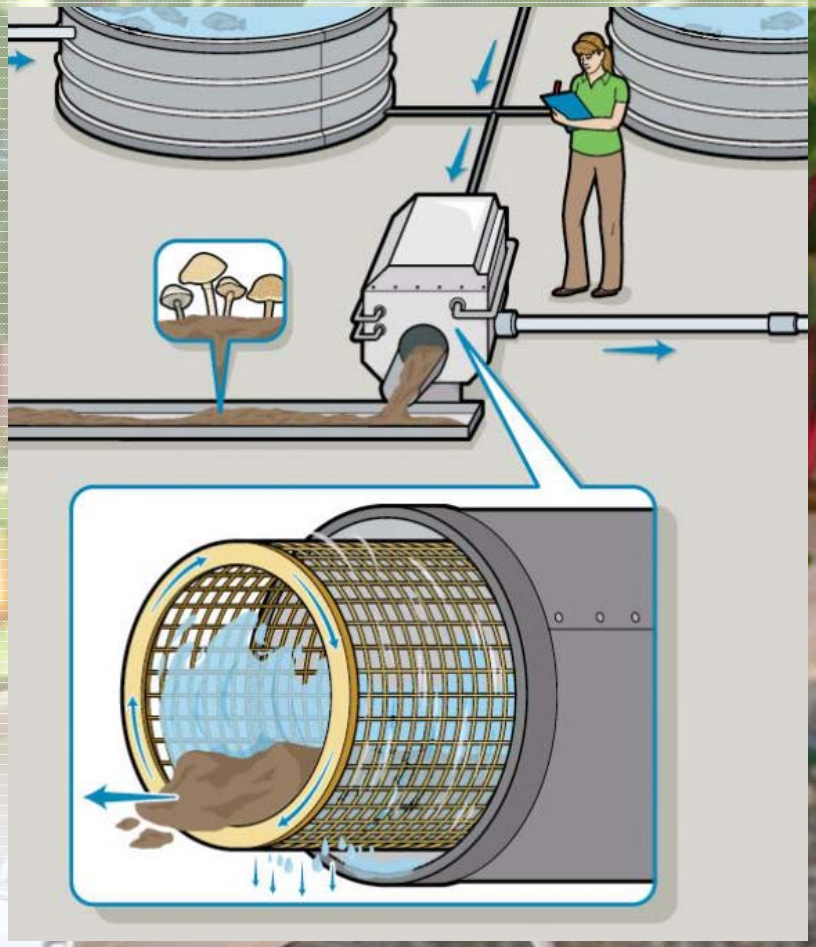
- Plants make up more than 75% of aquaponic production value
- Frequency and consistency of plant production aids in marketing & cash flow

educed Footprint

- ess space equired per lant
- Vertical roduction llows more fficient use f space

Reduced Water Consumption

- RAS
  - 10% daily exchange
- Aquaponics
  - 1.4% daily exchange
  - Water lost in waste purging
  - Potential co-products



Reduced Water Consumption

Romaine Lettuce

- Irrigated Agriculture
  - 10-35 gal/m^2/day
  - in California
- Aquaponics
  - 2-3 gal/m^2/day
  - 78-94% water savings

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Al-Hafedh, Y. S., A. Alam, M. S. Beltagi. 2008. Food Production and Water Conservation in a Recirculating Aquaponic System in Saudi Arabia at Different Ratios of Fish Feed to Plants. J. World Aqua. Soc. 39:4. pp. 510-520.

educed Soil Pathogens

- Most soil pathogens eliminated
- Enhanced plant growth without stress

educed Labor Cost

- fficiency of combined usiness model
- otential for utomation
- lants can be grown t desired height
- lo weeding!!!!

dditional roducts

- omposting worms
- ompost/worm astings
- ompost Tea
- lushrooms
- ish Emulsion
- arbon Credits??
- thers??

Guidelines for Aquaponic Producers

1. Use a feeding ration for design calculations

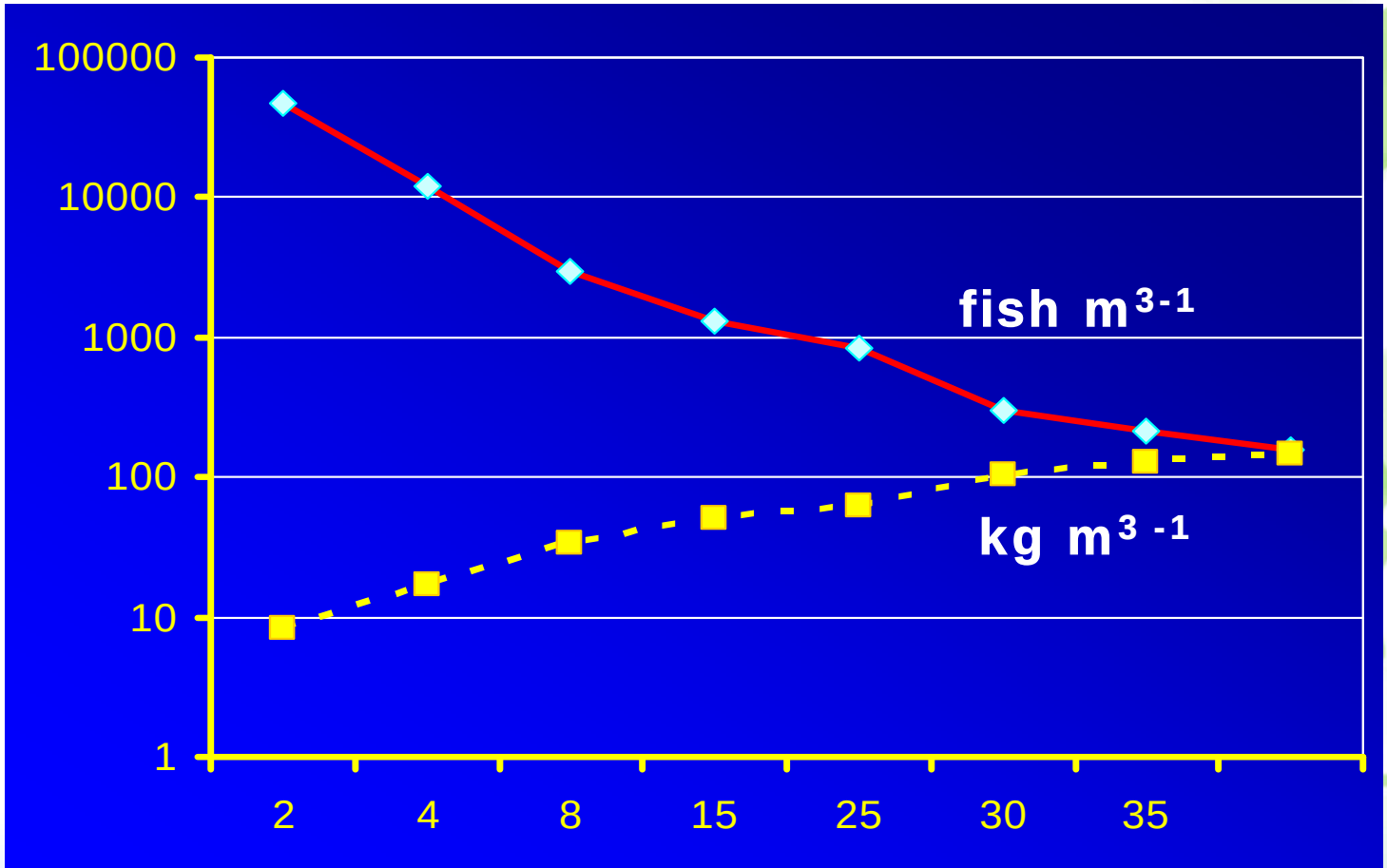
The optimum feeding rate ratio depends on

- hydroponic system
- plants being cultivated
- chemical composition of source water
- percentage of system water lost during solids removal.

Rate for NFT is ~25% of the ratio used for a raft system.

Fish Stocking Densities

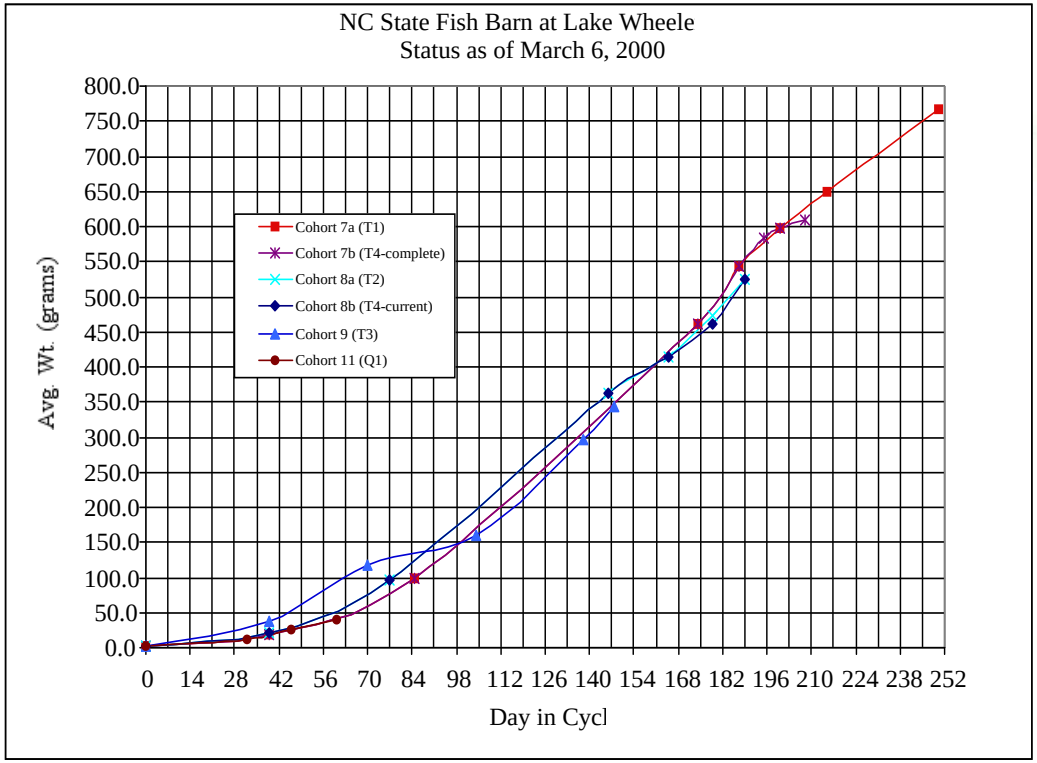
umber of fish and mass determines feeding rates



Don’t Be Impressed by Fish at High Densities.

Fish can be held at high density with low feed even in a poorly designed system

e Impressed by High Feed Rates Per Day

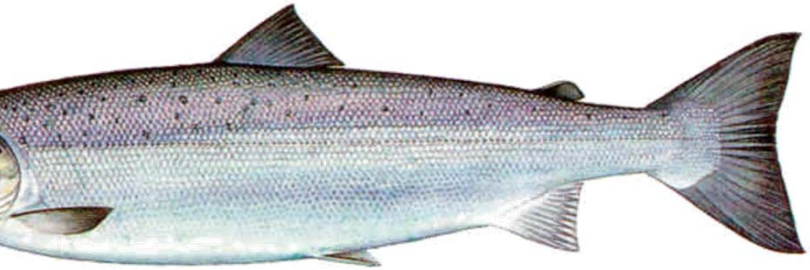


Daily Weight Gain = Daily Feed Rate / FCR

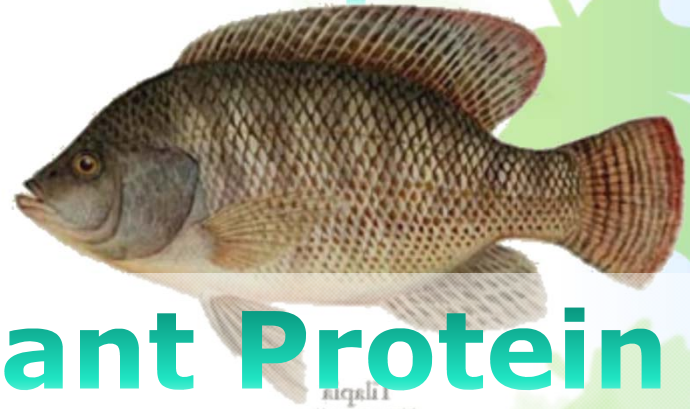
Remember it Takes Feed to Grow Fish

Fish eat different things

Salmon

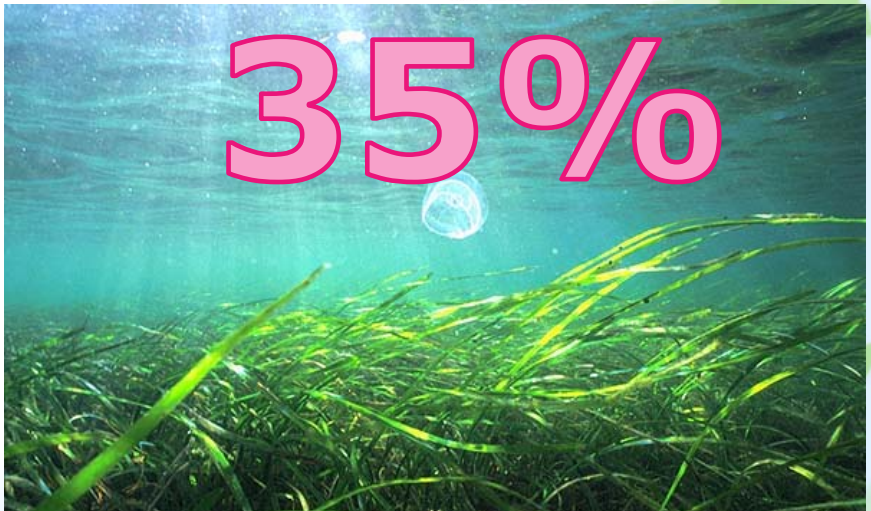


Tilapia



imal Protein

Plant Protein



. Use a feeding ration for esign calculations cont...

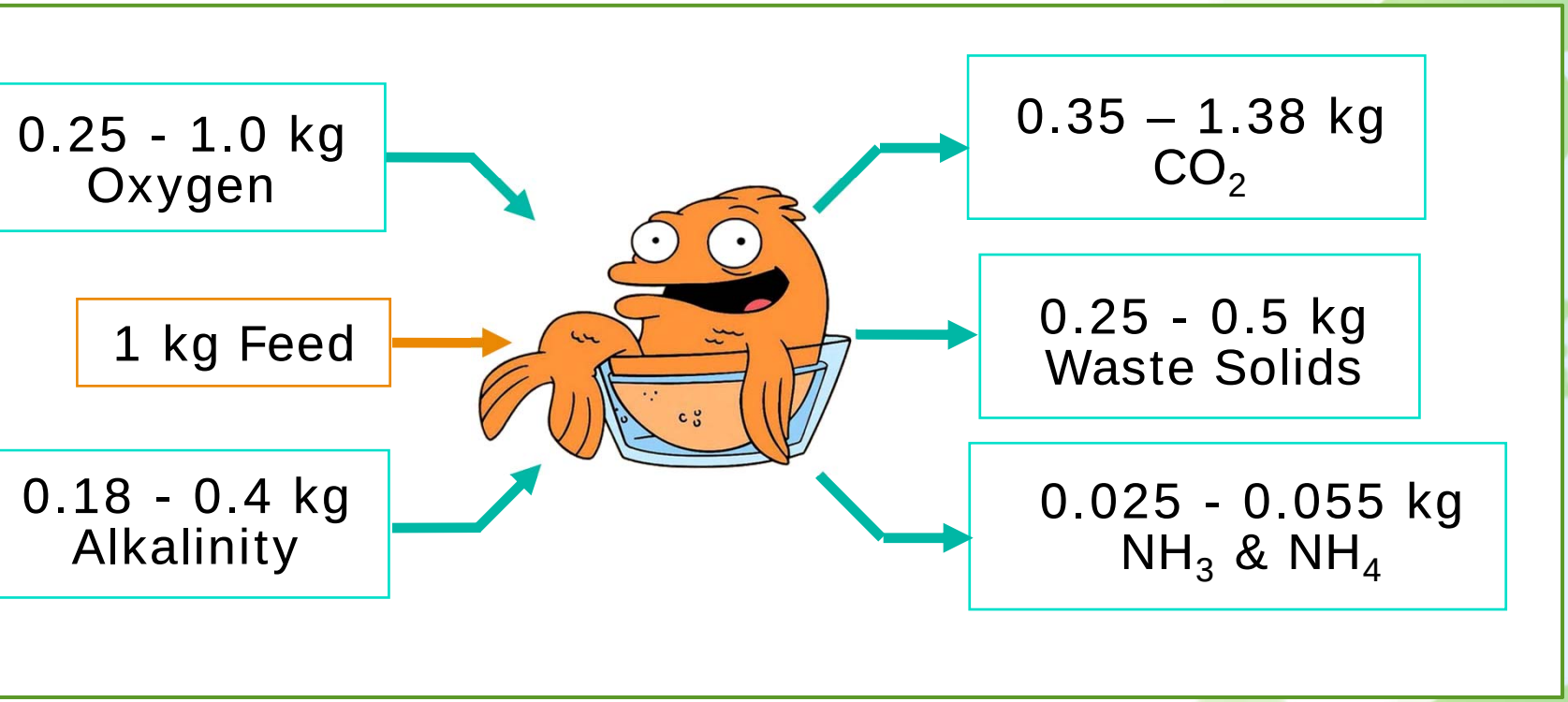
or a raft hydroponic stem the optimum ratio aries from **60 to 100 /m²/day.**

35% Protein Feed

r example:

1,000 g feed per day will fertilize 16.7 m^2 for a feeding rate ratio of 60 $g/m^2/day$.

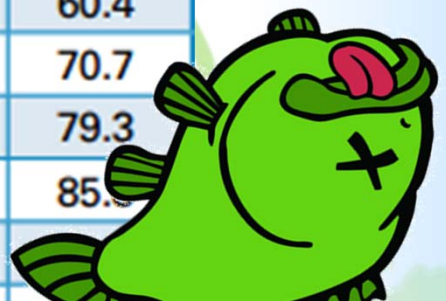
Fish Food has an Impact on Water Quality



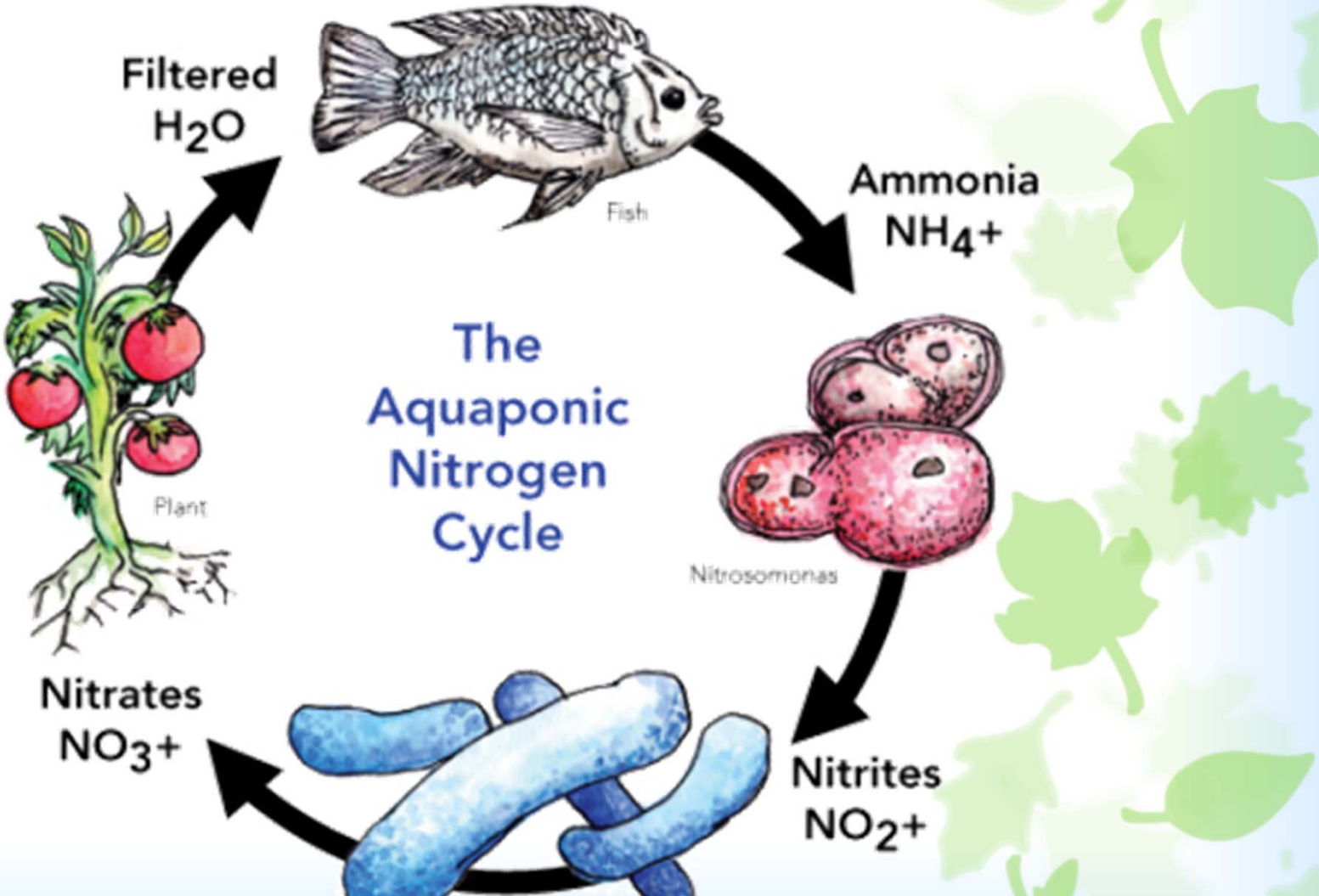
pH & Ammonia Toxicity

Table 1. Relative percentage of total ammonia nitrogen (TAN) in the toxic, unionized form at a given temperature and pH

pH	Temperature (°C)						
	8	12	16	20	24	28	32
7.0	0.2	0.2	0.3	0.4	0.6	0.8	1.0
8.0	1.6	2.1	2.9	3.8	5.0	6.6	8.8
8.2	2.5	3.3	4.5	5.9	7.7	10.0	13.2
8.4	3.9	5.2	6.9	9.1	11.6	15.0	19.5
8.6	6.0	7.9	10.6	13.7	17.3	21.8	27.7
8.8	9.2	12.0	15.8	20.1	24.9	30.7	37.8
9.0	13.8	17.8	22.9	28.5	34.4	41.2	49.0
9.2	20.4	25.8	32.0	38.7	45.4	52.6	60.4
9.4	30.0	35.5	42.7	50.0	56.9	63.8	70.7
9.6	39.2	46.5	54.1	61.3	67.6	73.6	79.3
9.8	50.5	58.1	65.2	71.5	76.8	81.6	85.5
10.0	61.7	68.5	74.8	79.9	84.0	87.5	

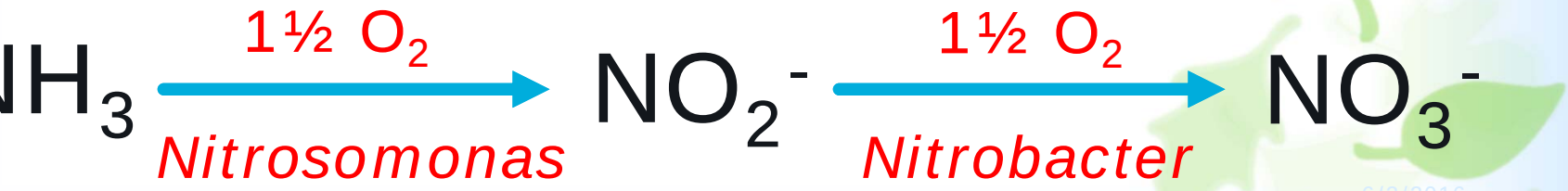


9. Ensure adequate biofiltration

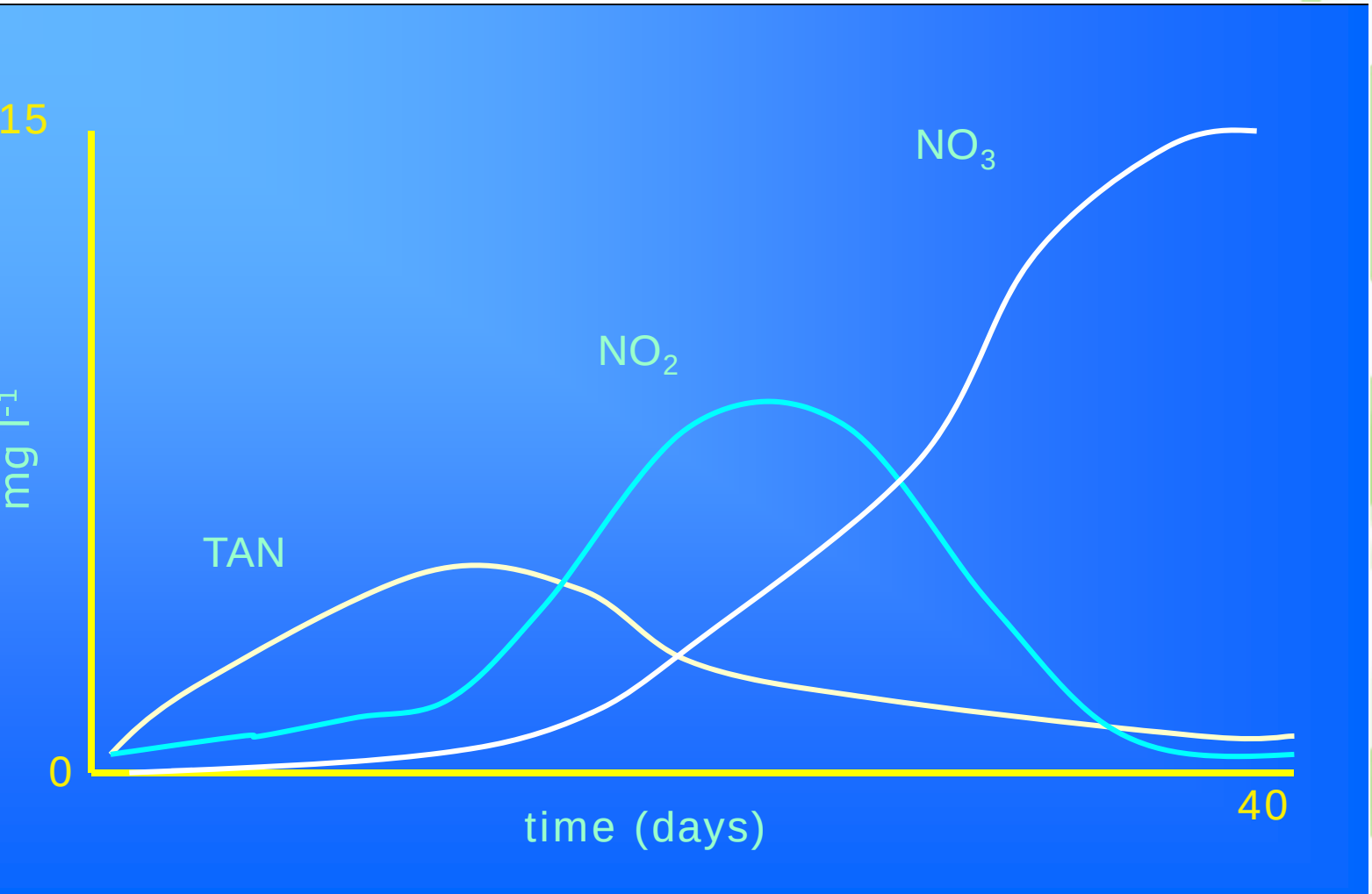


Bacteria Are Important in a Recirculating System

- Bacteria Can Cause Trouble
  - Consume Oxygen
  - Create Toxic Ammonia
  - Cause Disease
- Bacteria Also Make the System Run
  - Biological Filtration



Biofilter Establishment

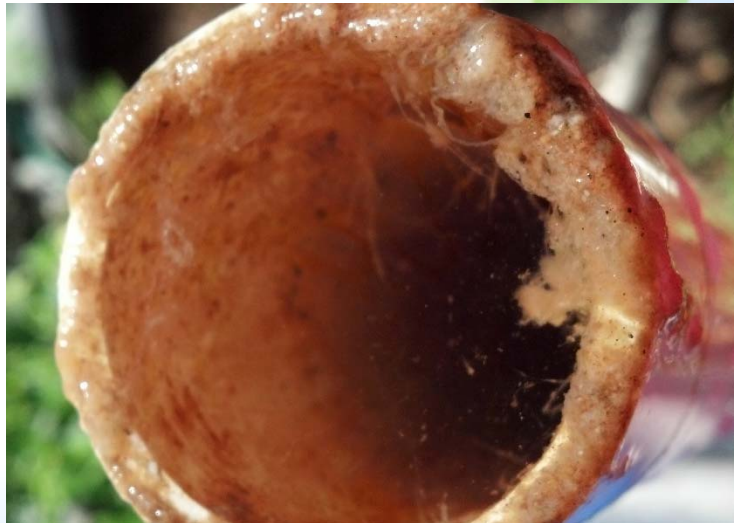


acteria Eat Wastes and Cause Changes in Water Quality

acteria Break Down Uneaten Feed nd Waste to Create:

- Ammonia (toxic to fish)
- Consumes Oxygen (biological oxygen demand)

hese Bacteria e called Heterotrophic



Biological Nitrification is All About:

Surface Area

- Living Space for the Nitrifying Bacteria
- Competition for that Space

Food (ammonia or nitrite)

- > 0.07 mg / L

Good Living Conditions

- DO going into the biofilter
  - > 4 mg / L
- pH
  - 7.2 – 8.8
- Alkalinity
  - > 200 mg / L as $CaCO_3$

Biological Filtration Equipment Options

ofiltration is critical for the nversion of toxic ammonia to e nitrate plant fertilizer

Best to over-size the biofilter

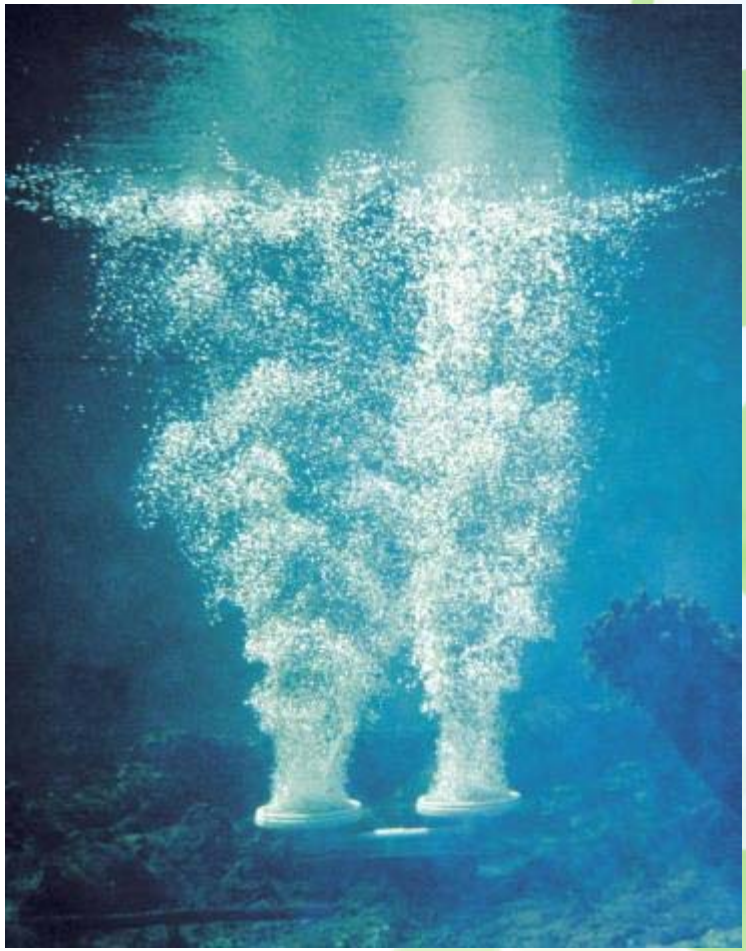
Options:

- Trickling biofilter
- Fluidized bed
- Rotating contact biofilter

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**

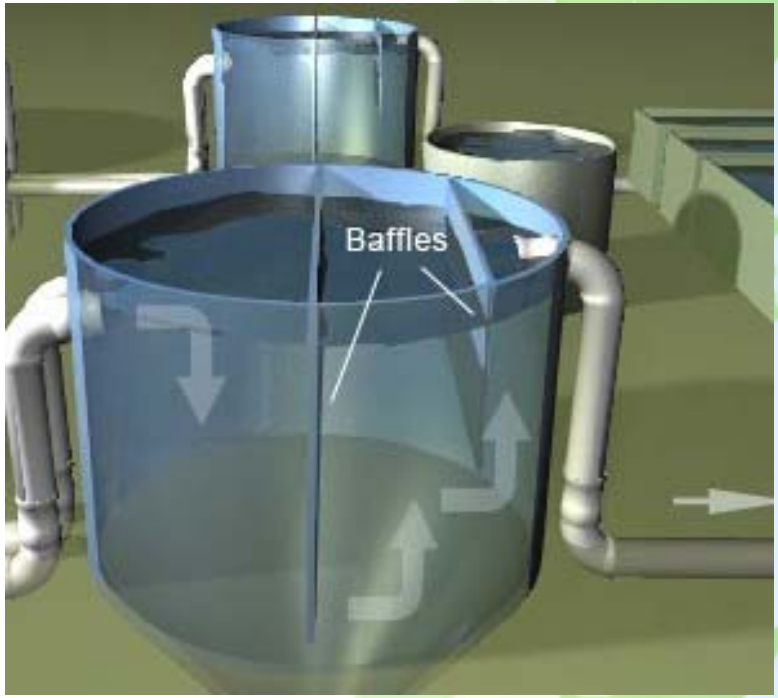


5. Remove solids

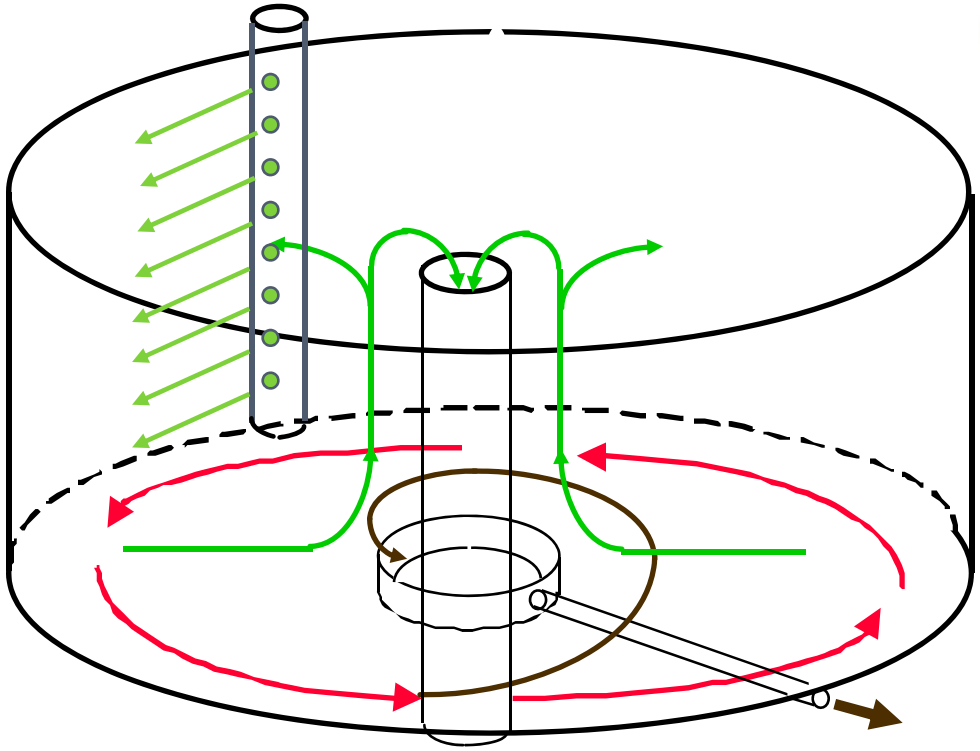
proximately **25% of the feed** given
fish is excreted as **solid waste**,
sed on dry weight.

If solids are not removed:

- Depletes dissolved oxygen
- Clogs pipes
- Kills nitrifying bacteria
- Causes ammonia problems



Vertical Manifolds & Double Drains



Suspended Solids Effluent

Settleable Solids Effluent

Mechanical Filtration

Options

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

- **Minimal clogging** and **automatic cleaning** are ideal, but expensive

2. Keep feed input relatively constant

eed = Fertilizer

Multiple rearing tanks, staggered production

- four tilapia rearing tanks
- Stock & Harvest every 6 weeks
- All-in/all-out production (per tank)

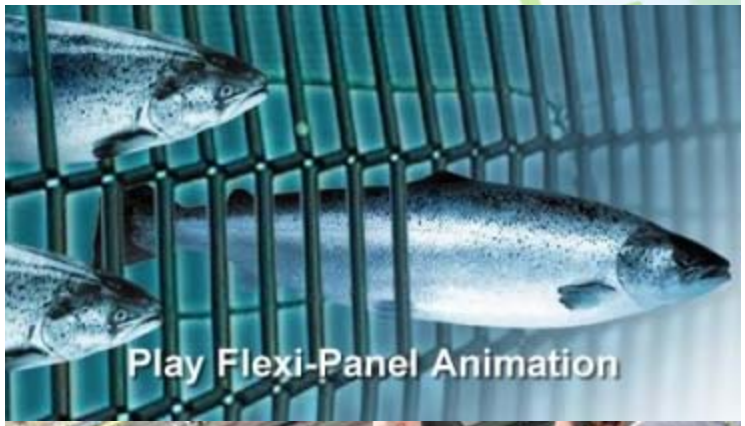
2. Keep feed input relatively constant cont...

gle rearing tank with
ltiple size groups of fish

-month growout tank would have 6
ize groups of fish

nonthly grading and harvest of fish

estock equal number of fingerlings



3. Keep Plant Density Relatively constant

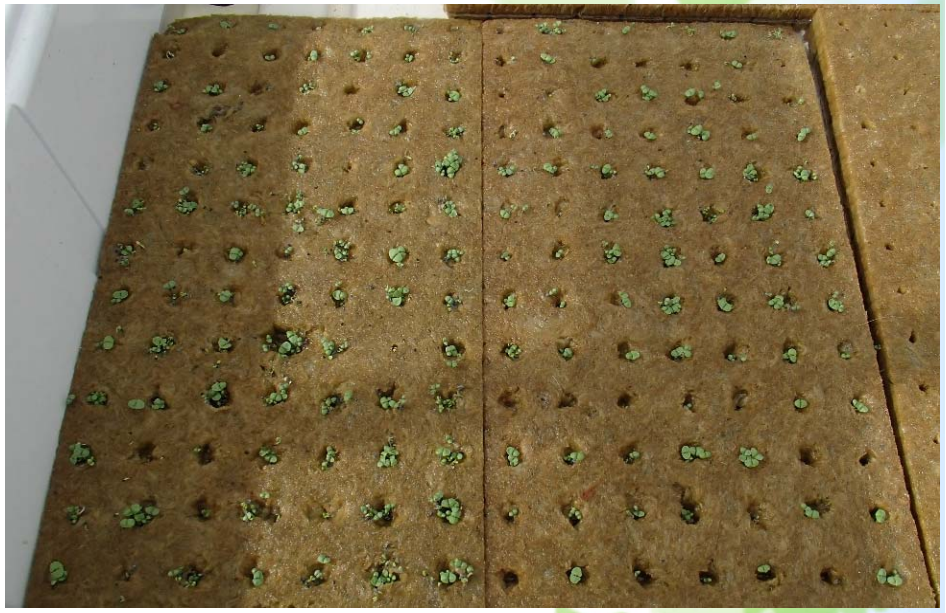
Plants provide
itical filtration!!

gle rearing tank
n multiple size
ups of plants

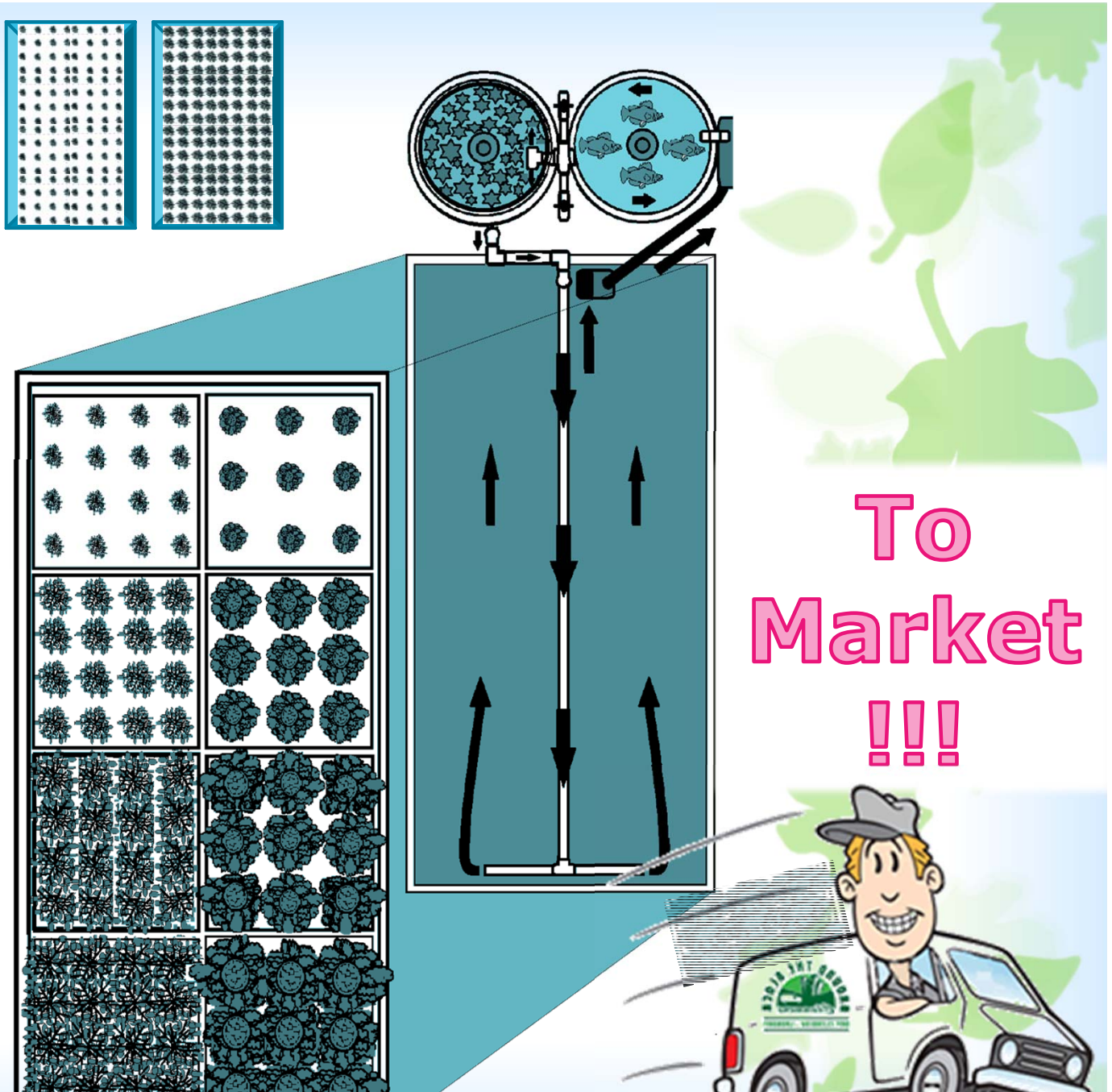
week growout time for
ants will require

arvest plants weekly or
weekly

stock equal number of
edlings



Sow
eeds
eek 1
eek 2
nsplant
eek 3
eek 4
eek 5
eek 6



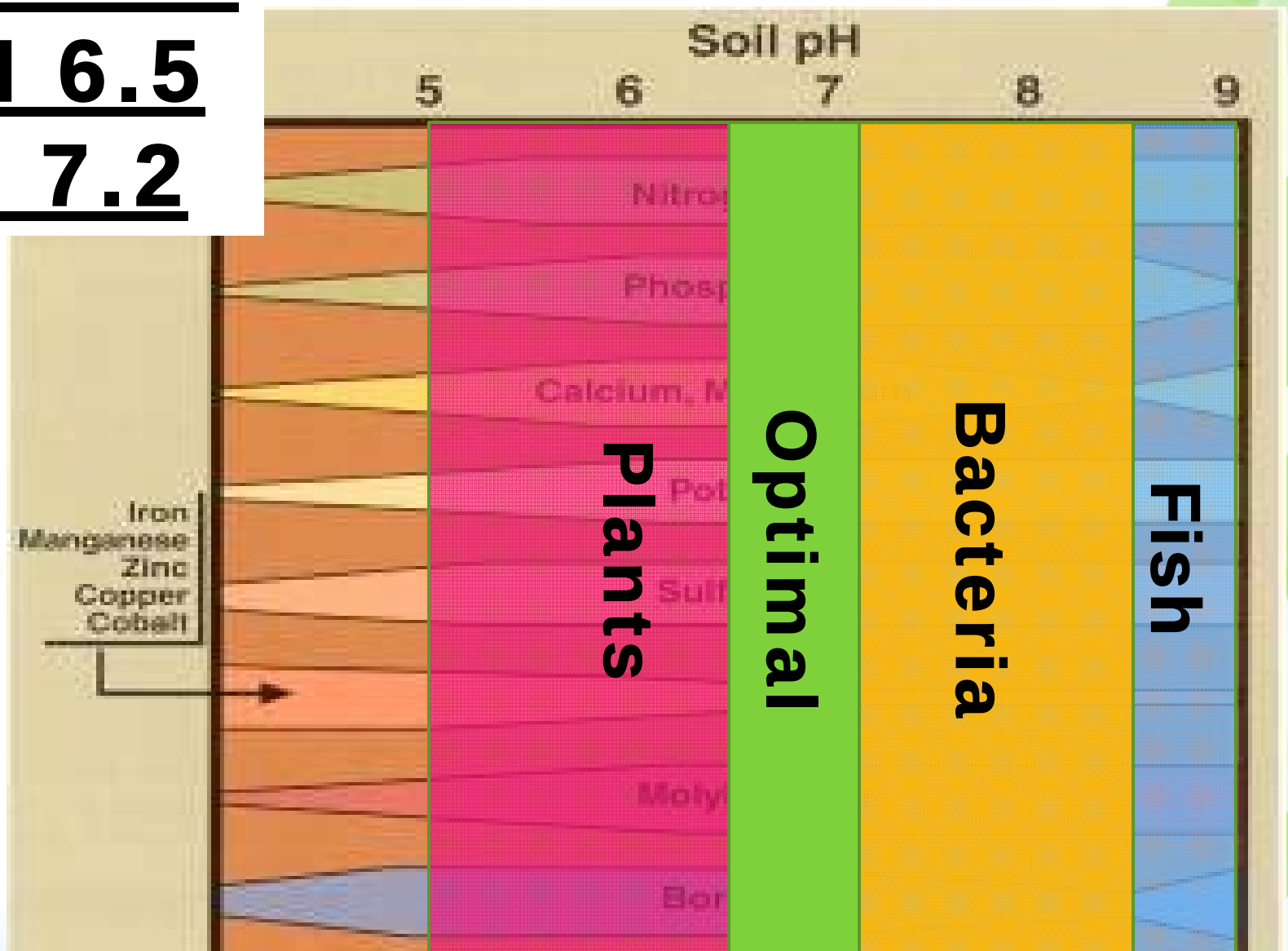
10. Control pH

Affects All Biological Processes

- Nitrification
  - >pH 7.5 ideal
  - Stops < 6.0
- High pH plants display nutrient deficiencies
- High pH ammonia toxicity

10. Control pH

timal
H 6.5
o 7.2



utrient Deficiencies

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

eficiencies related to source water and feed additives

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)

Aeration

ADD AERATION WHENEVER POSSIBLE!

ds in oxygenation and off-gassing of unwanted toxins

elps fish, plants, and bacteria perform critical biological
ocesses

eration options

- Diffuser stones
- Venturi action
- Packed columns
- Waterfall action

emperature Effects
n Dissolved Oxygen

ldwater Fish (> 5.0 mg/L)

Trout
Salmon

olwater Fish (> 4.0 mg/L)

Hybrid Striped Bass
Bluegill
Koi
Sturgeon

armwater Fish (> 3.0 mg/L)

Tilapia
Barramundi
Catfish
Freshwater Shrimp

Table 2. Dissolved oxygen (DO) concentration at saturation at a given water temperature

Temperature		Dissolved Oxygen Concentration (mg/L)
°C	°F	
0	32.0	14.6
2	35.6	13.8
4	39.2	13.1
6	42.8	12.5
8	46.4	11.9
10	50.0	11.3
12	53.6	10.8
14	57.2	10.3
16	60.8	9.9
18	64.4	9.5
20	68.0	9.1
22	71.6	8.7
24	75.2	8.4
26	78.8	8.1
28	82.4	7.8
30	86.0	7.5
32	89.6	7.3
34	93.2	7.1
36	96.8	6.8

Be careful with aggregates

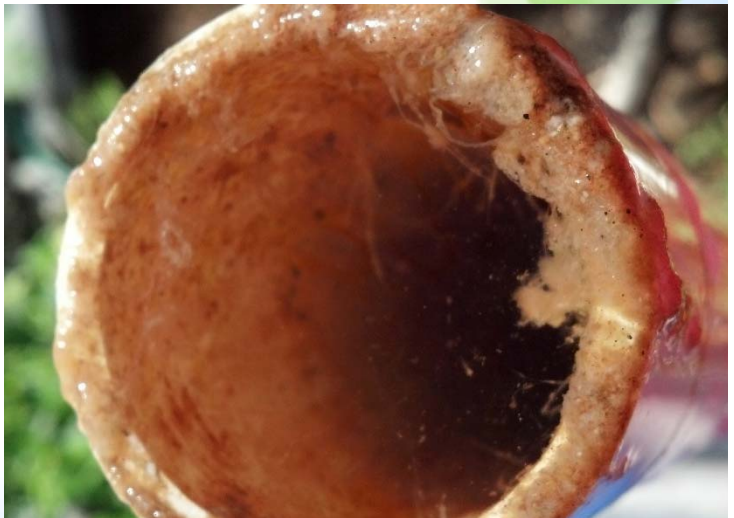
rganic solids may tend to
og aggregates such as pea
avel, sand and perlite

- Creates anaerobic conditions (low DO)
- Kills plant roots
- Kills beneficial bacteria
- Can be mitigated by adding worms to aggregate substrate to process organics

7. Prevent Biofouling

Use **oversized pipes** to reduce the effects of biofouling

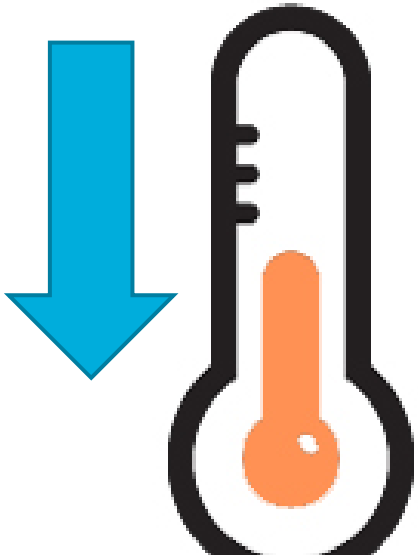
- dissolved organic matter promote the growth of filamentous bacteria restricts flow within pipes



7. Prevent Biofouling

Spaghetti tubes will likely clog - avoid

Juvenile tilapia in drain lines reduce biofouling by grazing on bacteria



Lower water temperatures reduce biofouling

8. Non-Toxic Pest 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.

Cultural Control

hted Insect Traps

Sticky Traps

ltural Control

Diatomaceous Earth

ct Screening

Biological Control

ic Wasp

Praying Mantis

Lady Bug

Lacewing

Non-Toxic Treatments

Bacillus thuringiensis (Bt)

Essential Plant Oils

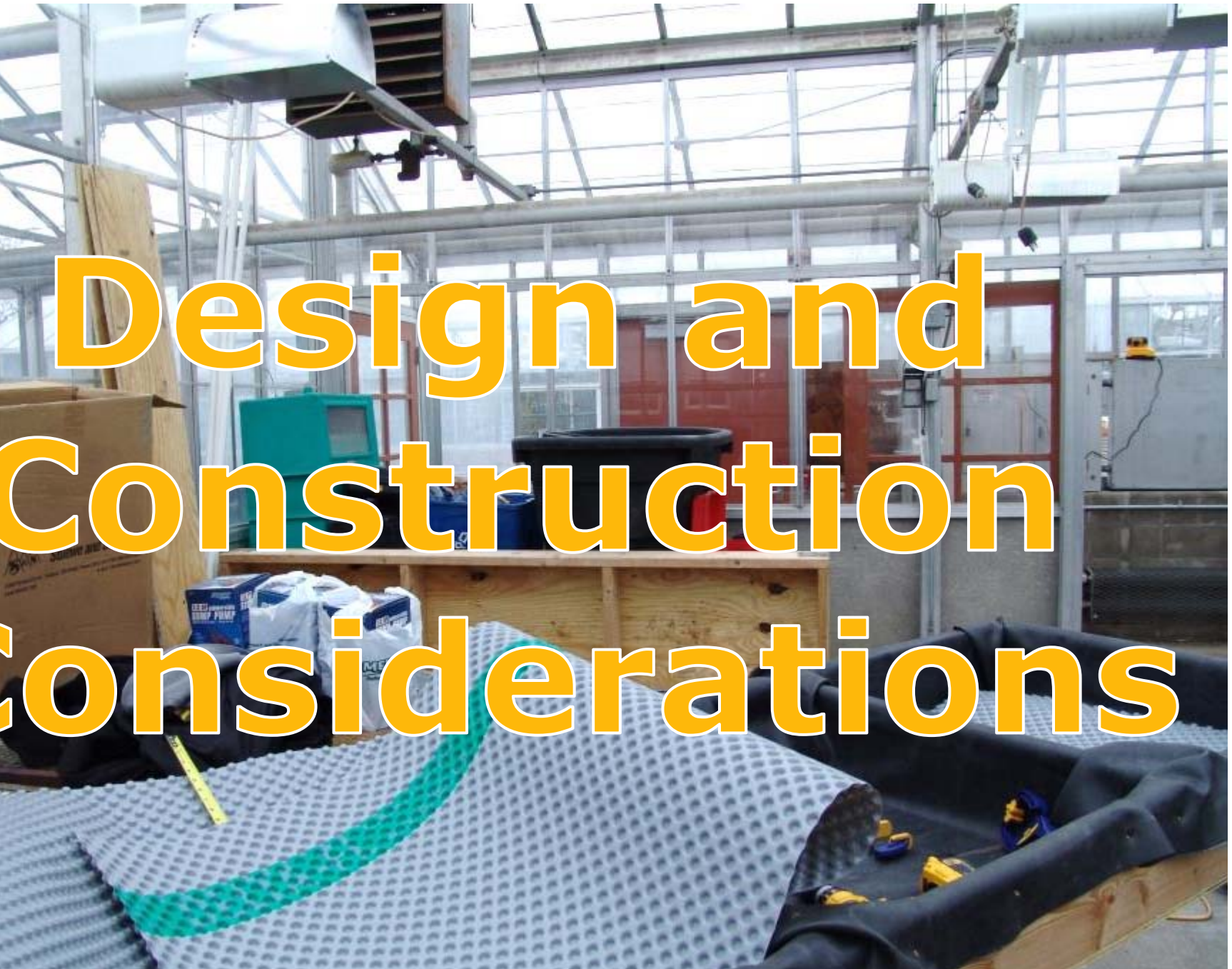
11. Use only one pump

ake advantage of
ravity

ower energy
sage

ake advantage of
ertical growing
pportunities

- Maximize profit per square foot


Design and
Construction
Considerations

our Technology Maintains ife Support and Must:

- Remove Solid Wastes
  - Settleable, Suspended, and Dissolved
- Convert Ammonia and Nitrite to Nitrate
- Remove Carbon Dioxide
- Add Oxygen
- Maintain Proper pH
- Control Pathogens
- Keep up with generation of waste

Water

ater is heavy!

~8.35 lb/gal

1 kg/L

ke advantage of
avity flow whenever
ssible

t tanks on the
ound or support
em adequately with
od construction
aterials

Water Source

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

cipal Water

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

Water

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

Water

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

ace Water

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

Tanks

ns 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

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” ps://learn.extension.org/events/1064

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

ontrolled environments
ulture

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

ptions:

Supplemental Lighting

Necessary for winter months and indoor culture

Efficiency is critical to economic viability

Light spectrum and photoperiod affects fruiting of plants

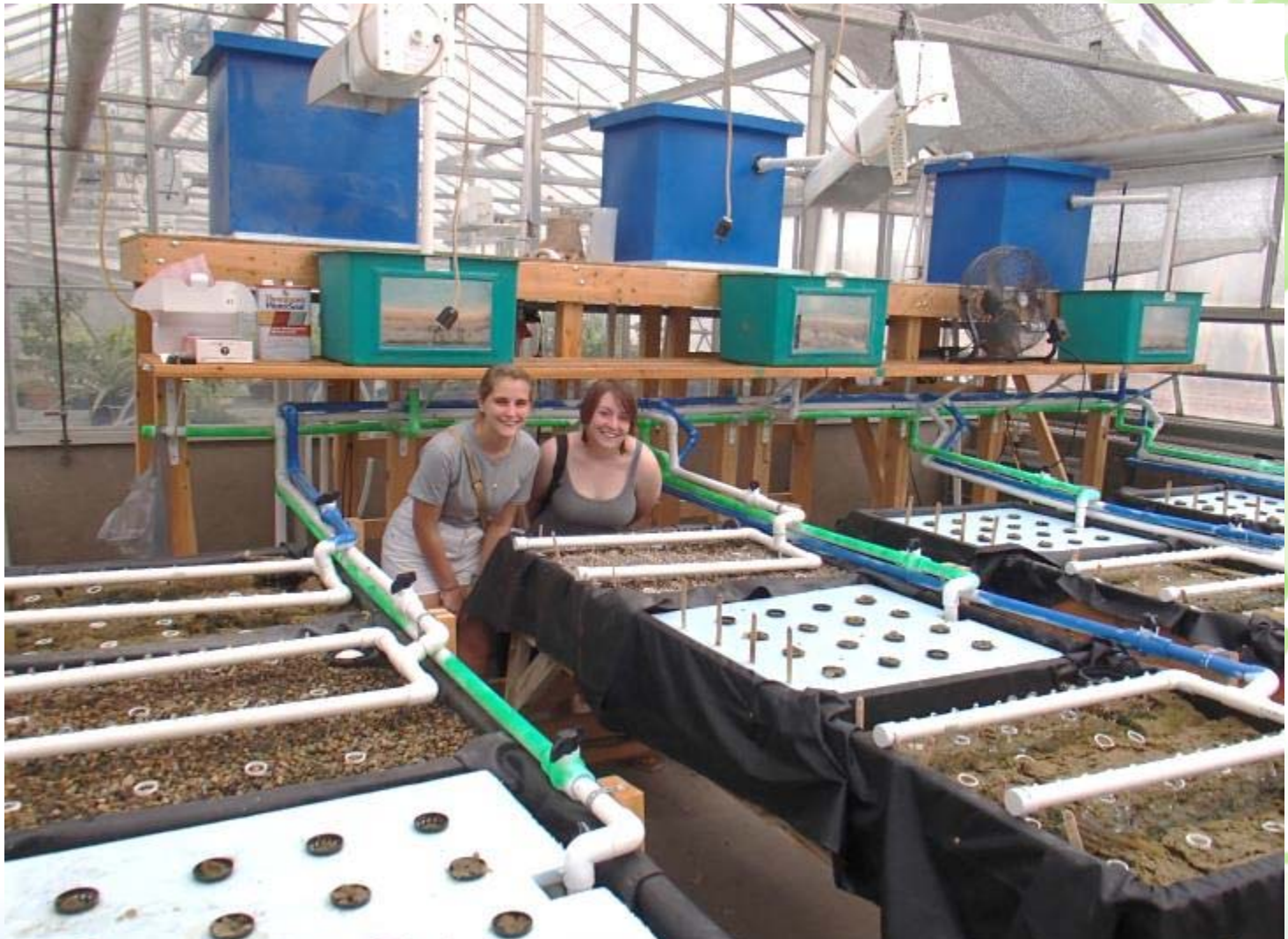
Options:

- High Pressure Sodium
- Florescent
- Halogen
- Light Emitting Diodes (LED)


Management
Considerations

Automation is nice...

...but not necessary



there is NO ubstitute for physical inspection

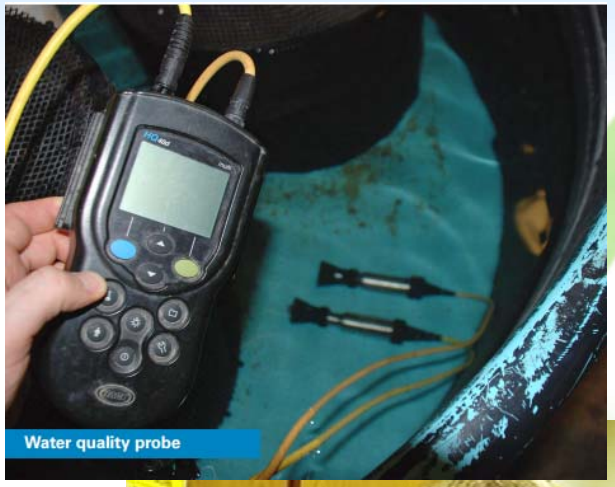
Water Quality

Daily Testing

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

Weekly Testing

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


Water quality probe

ant Disease Issues

Pythium

Common at Warmer Temperatures Especially After Pruning Stress

Tricoderma as potential preventative?

cted

Healthy

sh Diseases

ny Diseases

ny always present in water

vent stress to prevent outbreaks

nitor swimming and feeding behavior

k Fish Don’t Eat – Do Not Feed Them!!

you suspect your fish are sick, take tion immediately!

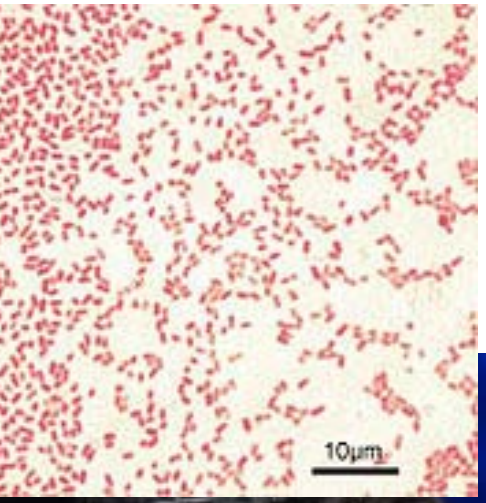
Withhold feed

Contact Veterinarian/Extension Agent

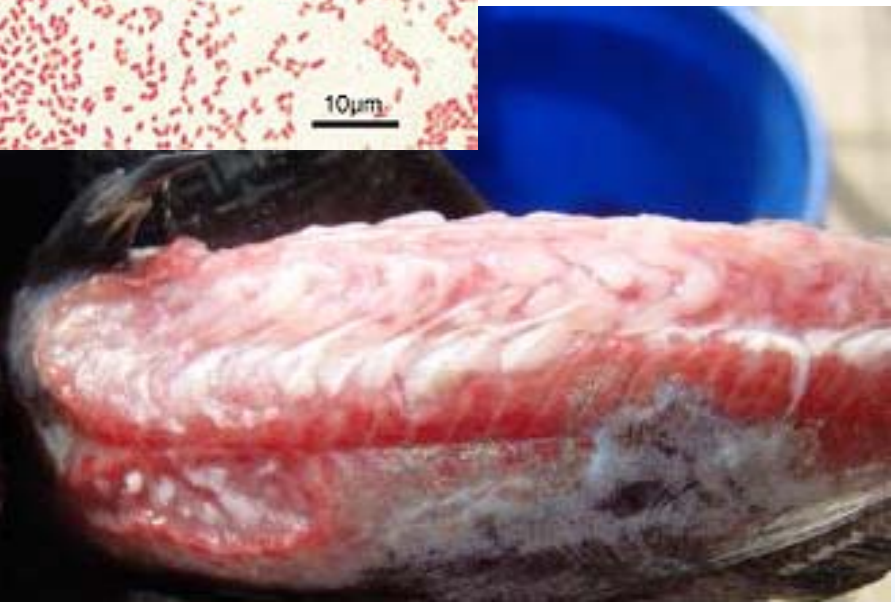
Submit samples to Fish Disease Diagnostic Lab

ish Disease Issues

eromonas



Common at Warmer Temperatures



NaCl (w/o Iodine)

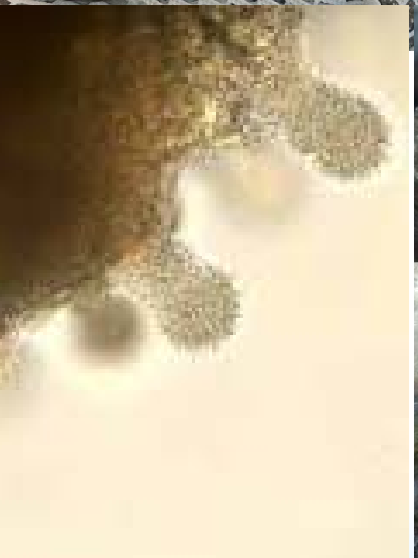
30 g/L (3%) for 30 min bath

Repeat as needed

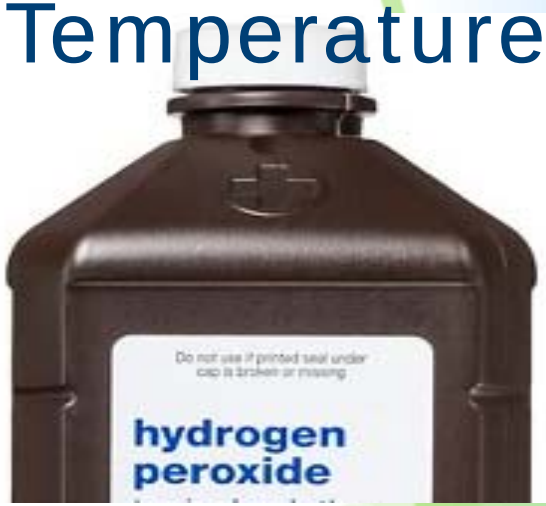
- Do not mix with

sh Disease Issues

olumnaris



Common at Colder Temperatures



- 35% Solution
- 50 mg/L for 60 min – alternate days for 3 treatments
- Test H_2O_2 prior to

Biosecurity

eventions is best!

No foreign water, soil, fish, plants, nets, hands, etc.

- Regular sterilization of surfaces and

  equipment

ntaining healthy water

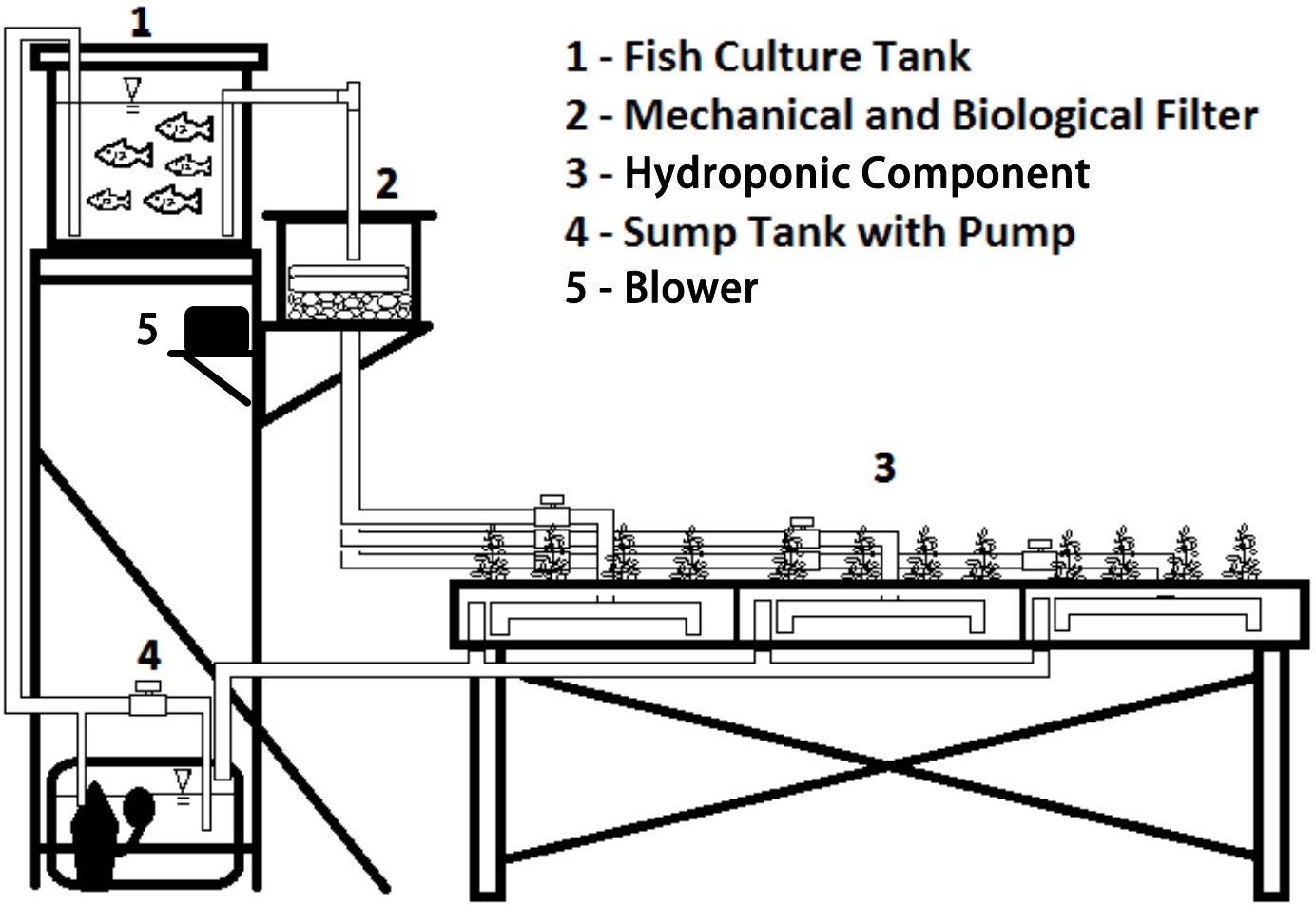
Regular solids removal

Ultraviolet light sterilization

O-Zone sterilization

ISU System

How does it work?



1 - Fish Culture Tank
2 - Mechanical and Biological Filter
3 - Hydroponic Component
4 - Sump Tank with Pump
5 - Blower

Fish Tanks

Filter Tanks

Biofilter Material Vol. = 0.063 m^3

- Bio-Fill™ – 800 m^2/m^3 -> 51.6 m^2

Solids filter pads

Plant Trays

Sumps

Nutrient Supplementation

- Iron
- Calcium
- Alkalinity

Species Grown

Nile Tilapia

Oreochromis niloticus

Barramundi

Lates calcarifer

tercrunch Bibb

Italian Large-leaf Basil

Money-Maker

Fish Harvest

pidly cool
e core
dy temp
below
º F using
ice bath

Store fish
ice until
ocessed

ant Harvest

Hollyer et al. 2009. On-farm Food Safety: Aquaponics. http://www.ctahr.hawaii.edu/oc/freepubs/pdf/fst-38.pdf

ow **G**ood **A**gricultural **P**ractices

RVESTING TECHNIQUE: *ed* hands, or washed red with clean disposable

DO NOT **touch the raft or the water underneath the raft during harvesting. That contaminates your hands or**

For the same reason, *DON'T* touch the root system or growing cup when harvesting.

ant Harvest

pidly cool plant to
d-safe temp.
AP!

an produce
ropriately

re plants under
per temps until
sumed

Questions?

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– www.NCRAC.org

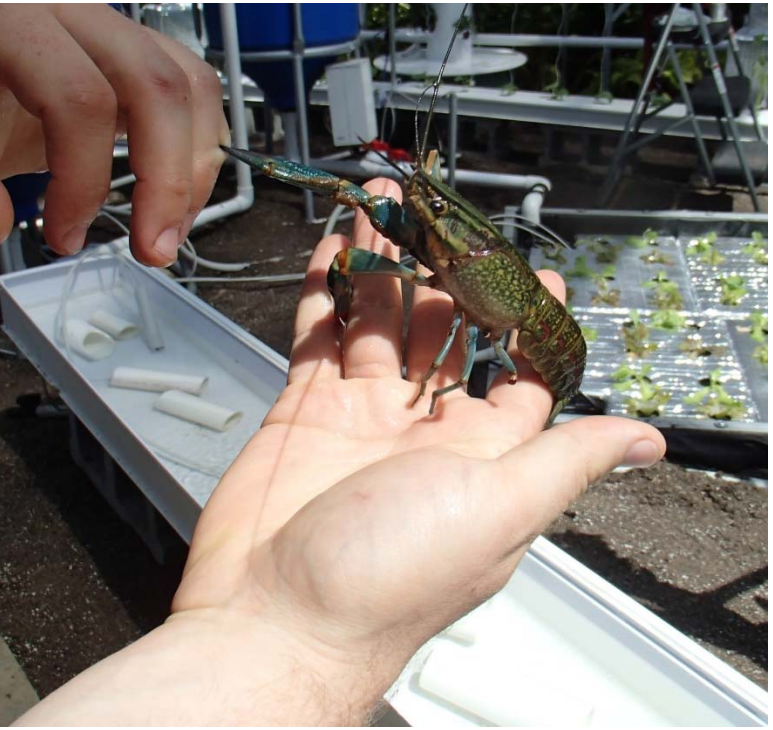
– http://www.nrem.iastate.edu/fisheries/

2014
o-Dome
Project

Reiman Gardens
at Iowa State University

The Critters

Nile & Red Tilapia



Redclaw Crayfish

Towers

Nutrient Film Technique

Floating Rafts

Dutch Buckets