Aquaponics

Growing Fish and Plants Together

COLORADO AQUAPONICS

Presented by: JD Sawyer

Aquaponics Defined

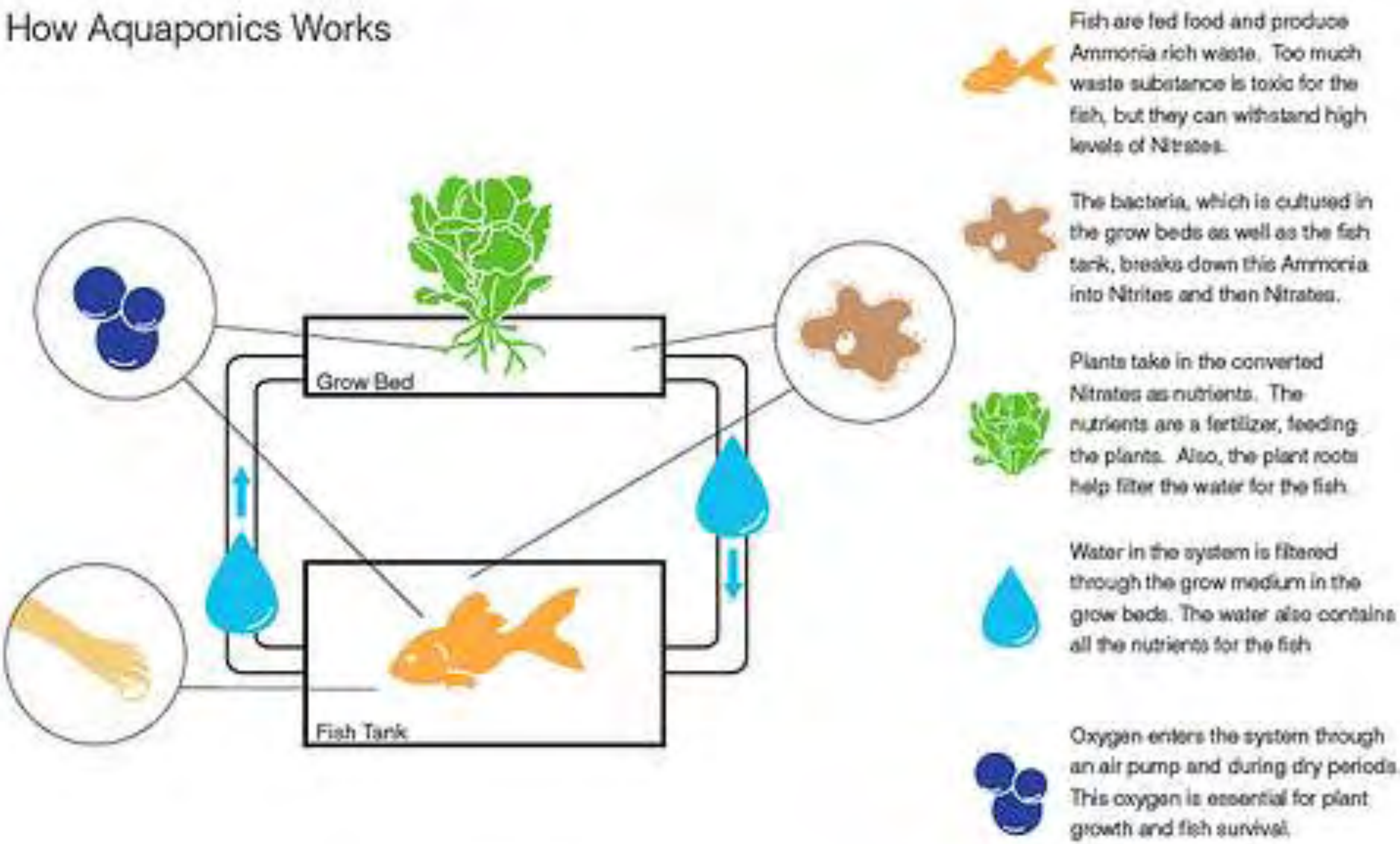
The integration of:

- *Aquaculture* – Growing fish in a re-circulating system
- *Ponos* – The Greek word for growing plants with or without media
  - Most people relate growing plants to hydroponics since both use nutrient rich water and both use soil-less media.

How Aquaponics Works

1. Fish are raised in a tank
2. Water from the fish tank is pumped to the plants
3. Bacteria convert ammonia and nitrite to nitrate
4. Plants absorb the nutrient rich water
5. Filtered water is returned to the fish tank, clean

Fish are Happy!
Plants are Happy!
We get more to eat!


How Aquaponics Works
Grow Bed
Fish Tank
Fish are fed food and produce Ammonia rich waste. Too much waste substance is toxic for the fish, but they can withstand high levels of Nitrates.
The bacteria, which is cultured in the grow beds as well as the fish tank, breaks down this Ammonia into Nitrites and then Nitrates.
Plants take in the converted Nitrates as nutrients. The nutrients are a fertilizer, feeding the plants. Also, the plant roots help filter the water for the fish.
Water in the system is filtered through the grow medium in the grow beds. The water also contains all the nutrients for the fish
Oxygen enters the system through an air pump and during dry periods. This oxygen is essential for plant growth and fish survival.

Why is it Considered Sustainable?

- Waste from fish is used to feed the plants
- Fish and plants create a polyculture producing two products
- Water is re-used in the re-circulating system
- Local food production, enhances the local economy and reduces food transportation
- Continuous organic fertilizer

ATTRA – National Sustainable Agriculture Information Service

Why Aquaponics?

- Uses a fraction of the water, about 10% of soil growing
- No need to purchase, store and apply fertilizer
- No soil-borne diseases, no tilling, no weeds
- Grow two food products together, protein and produce
- High fish stocking density, high crop yield
- No waste – hydroponics waste solution, aquaculture waste fish solids – aquaponics all waste is used
- No pesticides or herbicides, only fish fertilizer
- Food security, grow your own food, indoors, year-round
- Works in draught or places with poor soil quality

Water use comparison

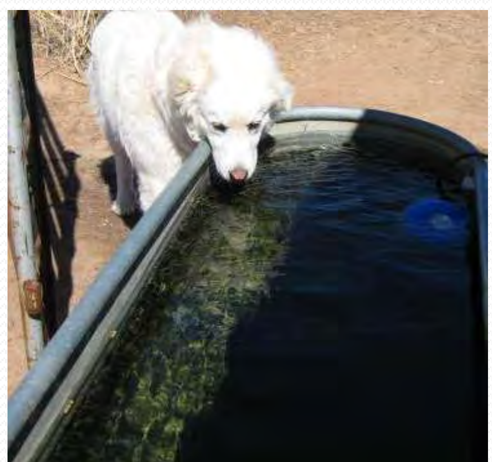
- Open-water net pens—“Infinite” number of gallons per pound of production
- Non-recirculating raceways and tanks—5,000 to 10,000 gallons per pound of production
- Non-recirculating ponds—500 to 1,000 gallons per pound of production
- Recirculating systems—5 to 10 gallons per pound of production
- Integrated aquaponics—Wastewater directed to greenhouses; no discharge

Aquaponics Components

- Fish Tank
- Place to Grow Plants
- Water Pump(s)
- Air Pump
- Irrigation Tubing
- Water Heater (Optional)
- Filtration (Optional)
- Grow light (Optional)
- Fish and Plants

Small Fish Tank

- Aquarium
- Stock Tank
- Half Barrel
- Rubber-made Tub



Medium Sized Fish Tanks

- IBC – totes (make sure you know what was in them before)
- Bath tubs
- Plastic, Steel or Fiberglass Stock Tanks
- Build your own

Big Fish Tanks

- Open Ponds
- Large Stock Tanks
- Swimming Pools
- Fiberglass Tanks

Safe Materials

Make sure all your system components are fish and human safe

- Polypropylene - labeled PP
- High Density Polyethylene - labeled HDPE
- High Impact ABS (Hydroponic Grow Trays)
- Stainless Steel barrels
- EPDM or PVC (poly vinyl chloride) pond liner (make sure its UV resistant and avoid fire retardant material)
- Fiberglass tanks and grow beds
- Rigid white PVC pipe and fittings, black flexible PVC tubing, some ABS
- DO NOT use Copper – Its toxic to the fish

Aquaponic System Designs

- Media-Based Growbed
- Growing Power System
- Raft System
- NFT (Nutrient Film Technique)
- Towers
- VertiGro

Media-Based Growbed

- Gravel
- Hydroton
- Lava Rock
- Packing Foam
- Sponges
- Perilite
- Vermiculite

Media Growbeds

Pros

- Work great for most hobby aquaponics
- Easy to find components, easy to build
- You can grow lots of different plants in one system
- Make as big or small as you want

Cons

- Can build-up anaerobic zones
- May need to be cleaned out occasionally (or use worms)

Aquarium Systems

Barrel-Ponics Examples

Invented by Travis Hughey of
Faith and Sustainable Technologies (FAST)
Uses readily available, cheap 55 gallon barrels

IBC Containers

- Intermediate Bulk Container
- 275 Gallons full
- 175 with top cut
- 12” grow bed
- Inexpensive
- Plumbed for 2” PVC

Other Growbed Examples

Joel Malcolm - Backyard Aquaponics

Picture 1 – New seedlings planted

Picture 2 – 13 days after planting

Picture 3 – 25 days after planting

Growing Power Model

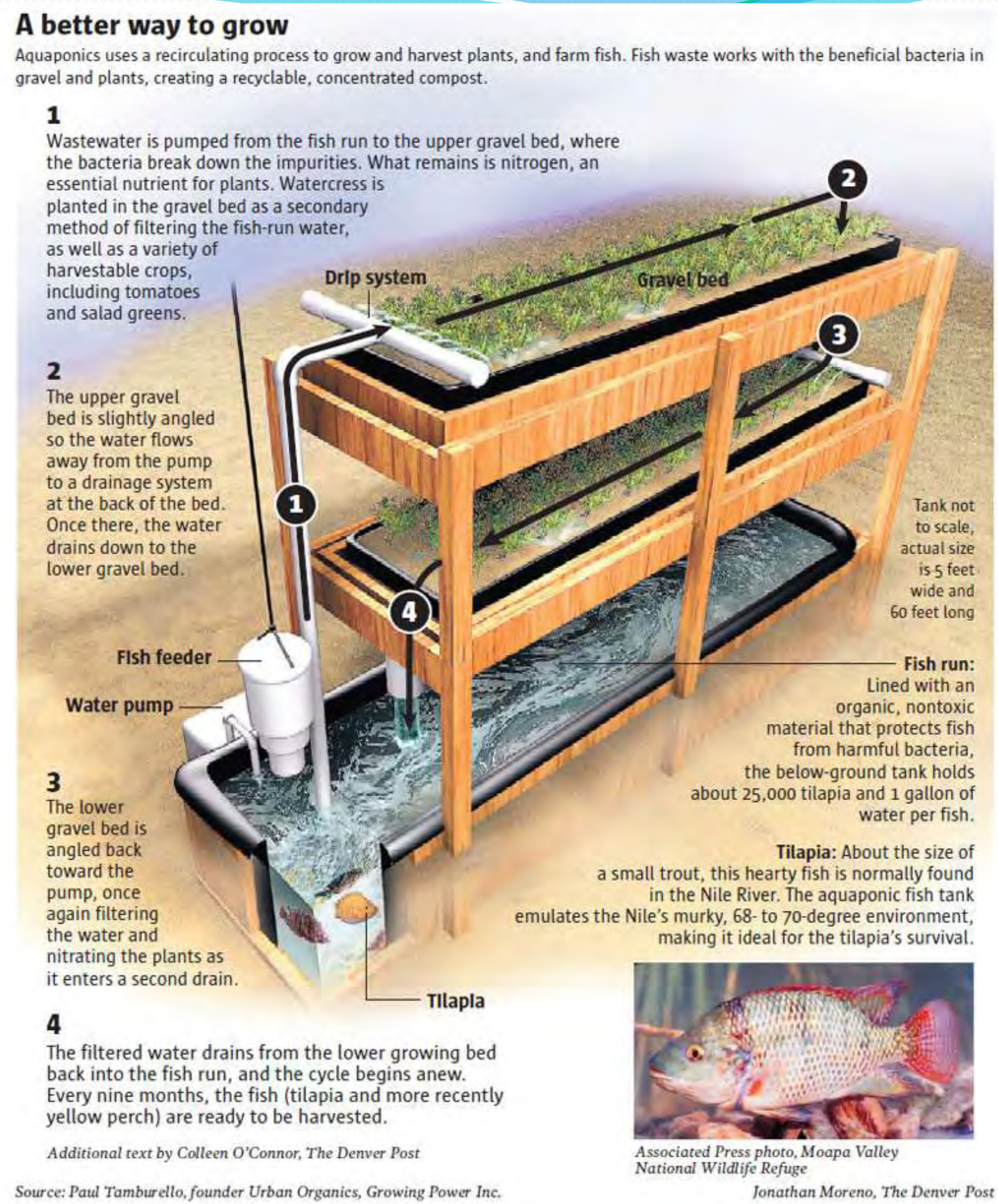
- Non-profit based in Milwaukee, WI
- Founded and run by Will Allen
- Won the MacArther Genius Grant
- Uses multiple tiers over long trough fish tanks
- Water acts as Thermal Mass

Pros

- Good for community sized systems
- Easy to find parts, get volunteers to build
- You can grow lots of different plants
- Use of vermicompost adds lots of additional nutrients

Cons

- Can build-up anaerobic zones that need cleaned
- Water dark due to plants potted in vermicompost
- Could benefit from solids filtration, can't see fish



Raft Method

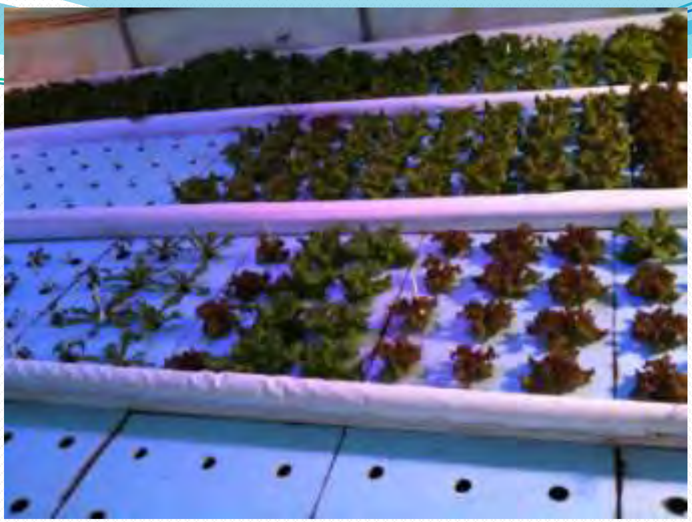
- Method researched and developed at University of Virgin Islands
- Research and commercialized by Nelson and Pade, Montello, WI

Small-Scale Raft Systems

Chicago High School for Agriculture Science (CHAS)

Personal-sized raft systems

Raft Method



Pros

- Great for commercial setups
- Very high yield of both fish and plant crops
  - Small system – 100 lbs of fish, 925 heads of lettuce
  - Big system – 7,500 lbs of fish, 194,400 heads of lettuce
- Typically installed inside a greenhouse
  (although in tropical locations they are outside)

Cons

- Requires more extensive filtration methods
- Usually grows a specific crop like lettuce or basil

Sweetwater Organics, WI

Nutrient Film Technique

Pros

- Materials readily available
- More precise growing conditions
- No concerns for pH changes related to media

Cons

- Requires more filtration
- Doesn't allow as many crop options

Farm Philly – Greensgrow Project

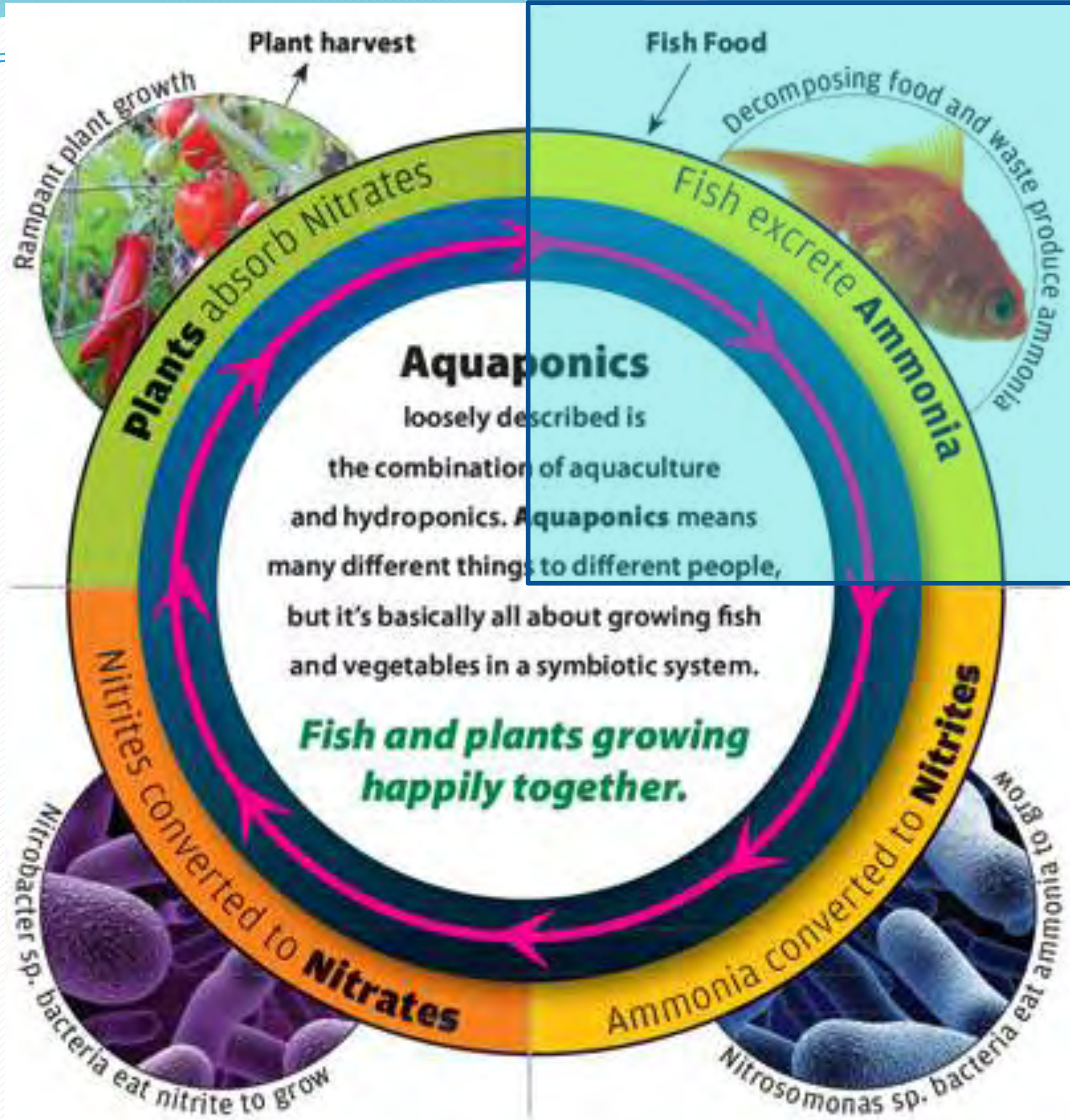
- Roof-top garden using metal gutters attached to a wall.
- Solar powered pump.
- Currently using hydroponic solution.
- Converting to aquaponics soon.

Towers

Built by Nate Storey – Doing aquaponics research and earning a PhD at University of Wyoming

Vertigro System

- Strawberry orchard in Fl.
- Adapted for either hydroponic or aquaponic use



www.backyardaquaponics.com

Fish inputs and outputs

- Inputs: Feed Oxygen and Water
- Outputs: Urine (water), Ammonia, Carbon Dioxide, Feces, Uneaten Feed

- Water Recirculation Cycle
  - Fish tank >> Solids Removal >> Biofiltration >> Aeration/Oxygenation

Keeping Fish Healthy

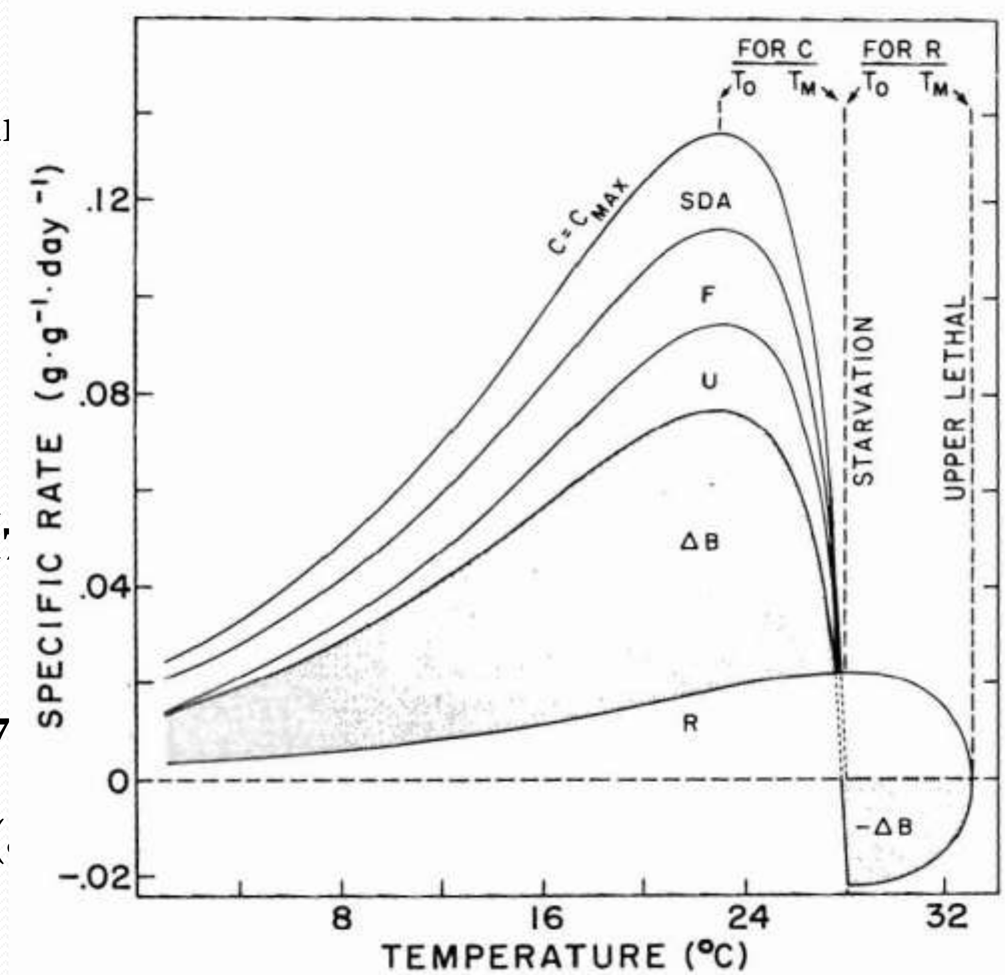
- pH – Most fish like pH between 6-8
- Ammonia and nitrites are very toxic to fish
- Nitrates are fairly safe for fish (and great for plants)
- Fish need oxygen (they can die in 30 min. without it) Battery based aerators are available for power outages
- Drastic temp changes can cause health issues and death
- Sensitive to light (avoid direct light)

Importance of Temperature

- Do not exceed temp changes of more than 3F per day if possible
- Fish can not regulate their body temperature like humans do
- They are dependent on the water temperature for their body temperature

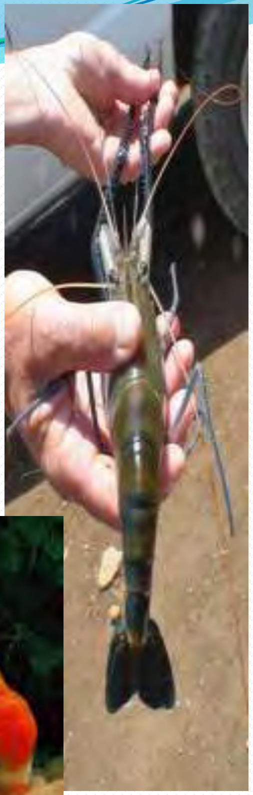
Temperature and growth rate

- CMAX= Max. feeding rate
- SDA = Digestion (specific dyna
  action)
- F = Feces, urine production
  (egestion)
- U = Ammonia production
  (excretion)
- ΔB = Change in fish weight
- **Opt. coolwater temp. = 23 C (**
- R = Respiration
- Max. = 28 C (82 F; starvation)
- **Coldwater fishes = 14-16 C (57**
  F)
- **Warmwater fishes = 28-30 C (**
  86 F)



The Fish

- Aquarium Fish
- Tilapia
- Yellow Perch
- Trout
- Catfish
- Bass
- Bluegill
- Carp
- Koi
- Goldfish
- Freshwater Prawns



Aquarium Fish

- Goldfish
- Koi
- Tetra
- Pacu
- Danios
- Cichlid
- Guppies
- Oscar

Tilapia

- Commonly used in aquaponics
- Warm water fish (74-78*)
- Tolerates pH shifts, temp changes, high ammonia, and low dissolved oxygen
- Omnivorous – pellet fish food, duckweed, veggies from the system
- Grows to plate size in about 6-9 months (ideal conditions)

Yellow Perch

- Good for re-circulating systems
- Likes cooler water (68-74*)
- Tolerates lower dissolved oxygen, adjusts to pH changes
- Eats common pellet fish foods and veggies
- Grows to plate size in about 9 months

Trout

- More challenging to maintain
- Likes colder water (64-68*)
- Can be carnivorous and will eat smaller fish
- Requires high dissolved oxygen levels
- Sensitive to pH changes and water quality
- Eats pellet fish food
- Reaches plate size in 12-16 months

Bass, Bluegill, Catfish

- Often raised in ponds, can be raised in re-circulating system
- Like temperature around 80*
- Eat pellet foods, bottom feeders
- More sensitive to temp, pH and water quality
- Bass harvest 15-18 months
- Bluegill harvest 12-16 months
- Catfish harvest 5-10 months

Koi, Goldfish, Carp

- Great pond fish
- Popular if you don't like to eat fish
- Koi are fancy (expensive) carp
- Tempature 65-75*
- Omnivorous – flake or pellet foods, bugs, plant roots
- Sold for "pets" or to show based on color, shape and scale patterns.

Fish Health Management

- Always exercise good hygiene and biosecurity—prevention, avoidance, selective access, and common sense.
- Quarantine fish from other facilities before stocking them in your system. Monitor their health for several days—treat if necessary.
- The best defense is your fish's own immune system. Provide a low-stress environment and your fish will maintain their health.

Fish Maintenance

- Feed fish 2 - 3 times a day, but don't overfeed
- Fish eat 1.5 – 2% their body weight per day
- Only feed fish what they can eat in 5-10 minutes
- Fish won't eat if they are too cold, too hot or stressed
- Check water quality, add water or do partial water changes if necessary
- Observe fish behavior and appearance
- Some fish become "social" and will "greet you"
- Think like a fish, "What would make you happy?"

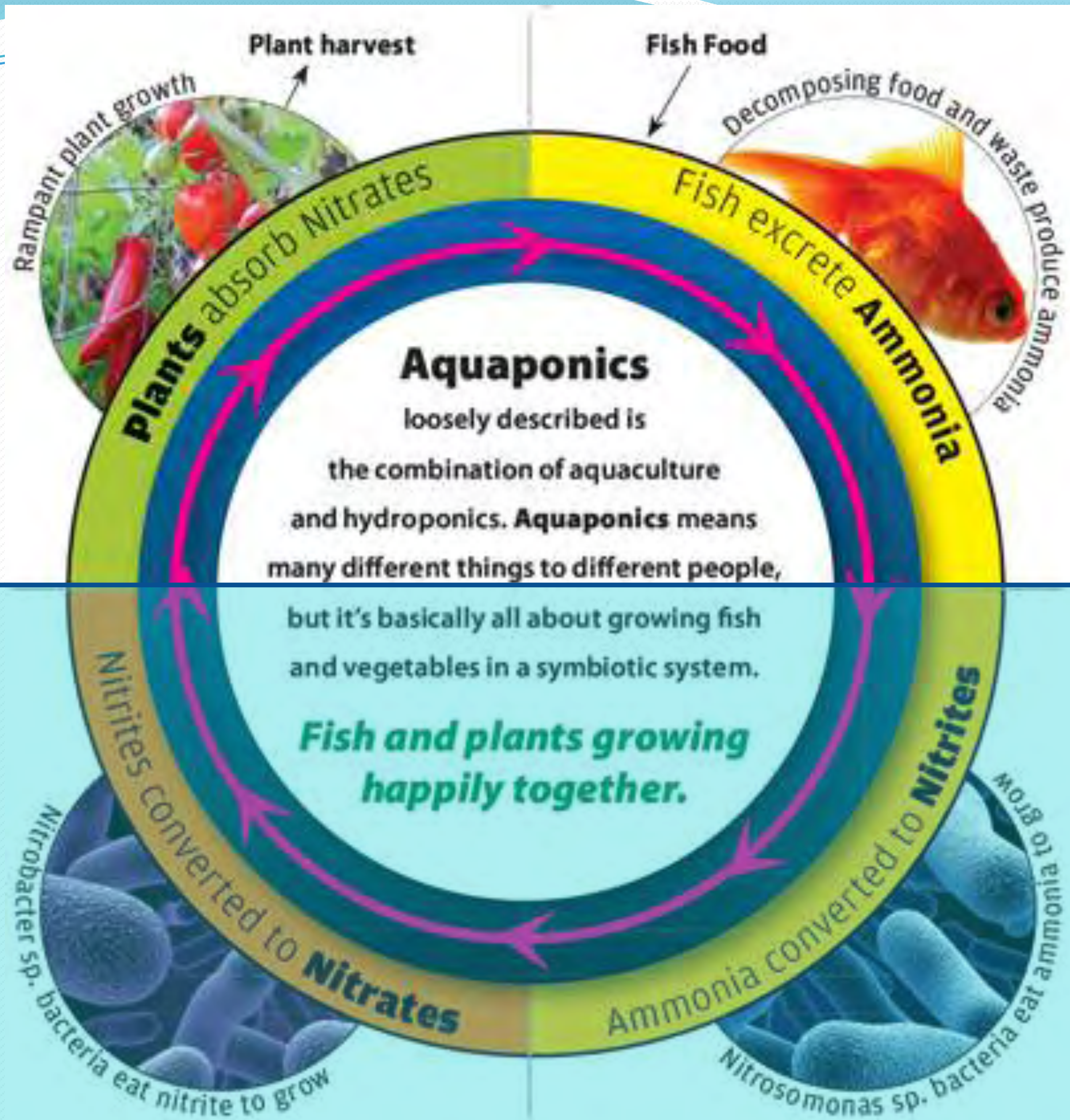
Fish Feeds

- Commercial fish feeds contain exact protein, carbohydrate and other vitamin requirements for specific fish
- Plant based proteins can include soy meal, corn meal, wheat meal etc…
- Most commercial feeds are between 10 to 35% protein
- Alternative feeds should be considered like duckweed, insects, worms or black soldier fly larvae
- Avoid fish meal based feeds as this source is not sustainable

Feed conversion ratios

- The average pounds of feed to produce 1lb of product

- Fish – 1.7lbs
- Chicken – 2.4lbs
- Turkey – 5.2lbs
- Pork – 4.9lbs
- Lamb – 8.0lbs
- Beef – 9.0lbs

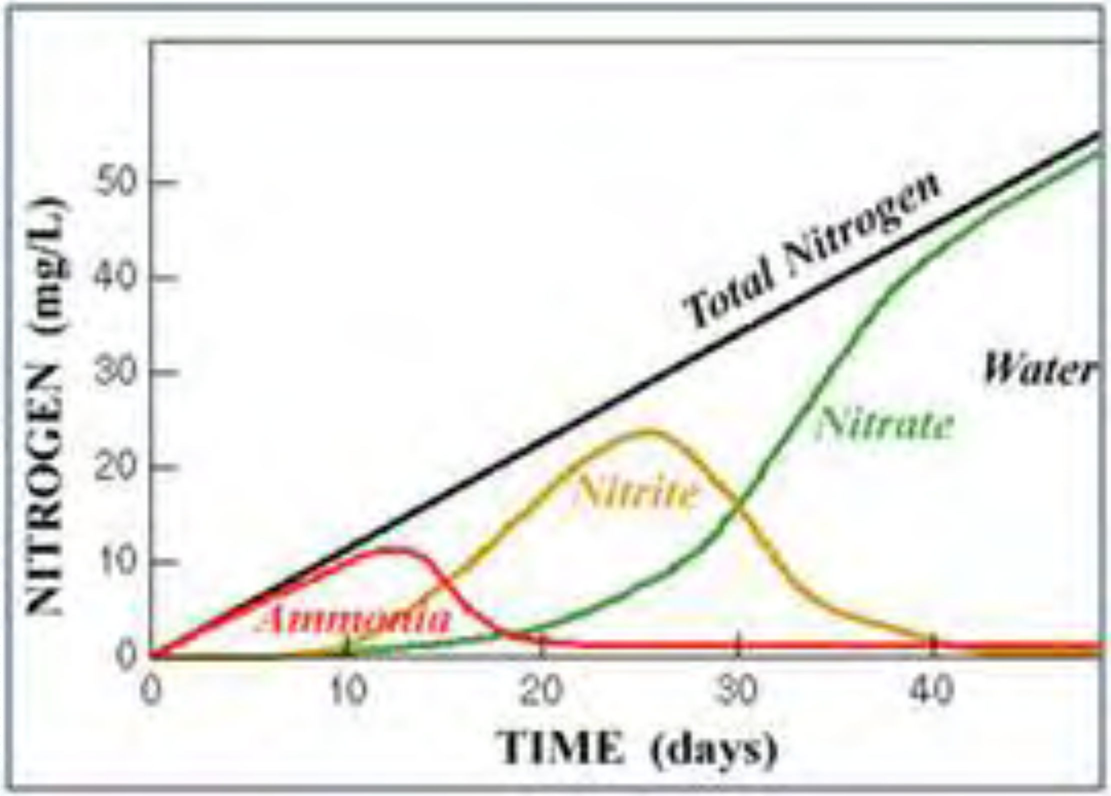

Plant harvest
Fish Food
Rampant plant growth
Decomposing food and waste produce ammonia
Plants absorb Nitrates
Fish excrete Ammonia
Aquaponics
loosely described is
the combination of aquaculture
and hydroponics. Aquaponics means
many different things to different people,
but it's basically all about growing fish
and vegetables in a symbiotic system.
Fish and plants growing
happily together.
Nitrites converted to Nitrates
Ammonia converted to Nitrites
Nitrobacter sp. bacteria eat nitrite to grow
Nitrosomonas sp. bacteria eat ammonia to grow

The Bacteria

- 50% of fish waste is in the form of ammonia released through urine, fecal matter and gills
- Bacteria consume fish waste, decaying plant matter and uneaten food
- Bacteria *nitrosomonas* converts Ammonia (NH_3 or NH_4^+) to Nitrite (NO_2^-) – Nitrite is toxic to fish
- Bacteria *nitrobacter* converts Nitrite (NO_2^-) to Nitrate (NO_3^-) Nitrate is primary source of plant nutrition
- Nitrogen is the good stuff – it is relatively safe for fish and great for growing plants

Bacteria (Nitrification) Cycle

- Rising Ammonia for 10 days
- Then Nitrite levels rise and Ammonia levels fall
- Another 10 days, Nitrate levels rise, Nitrite levels fall
- Total 20-30 days to stabilize



Bacteria Maintenance

- Proper pH 7 – 8
- Best temperature 72 - 75* (ideal 77*)
- No pesticides, algaecides, chlorine, chlorimine, cleaning agents or chemicals
- Started with a fishless or fish cycling

Starting the Nitrification Process

Fish cycle

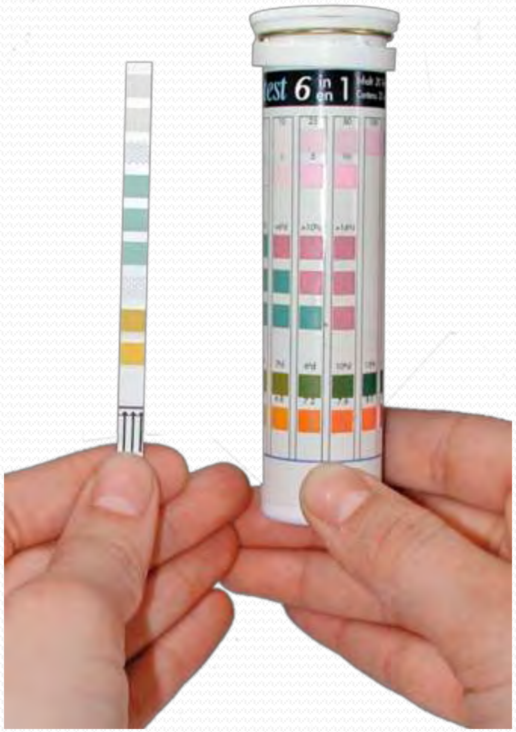
- Run the fish tank with chlorine and chloramine-free water for a few days
- Make sure all components are functioning properly
- Add fish at 20% of stocking density (Aquarium stocking density is commonly 1” per gallon)
- Keep fish food to a minimum for the first 10 days
- Monitor water quality and fish behavior
- Add 20% more fish every 4-6 weeks for best outcome

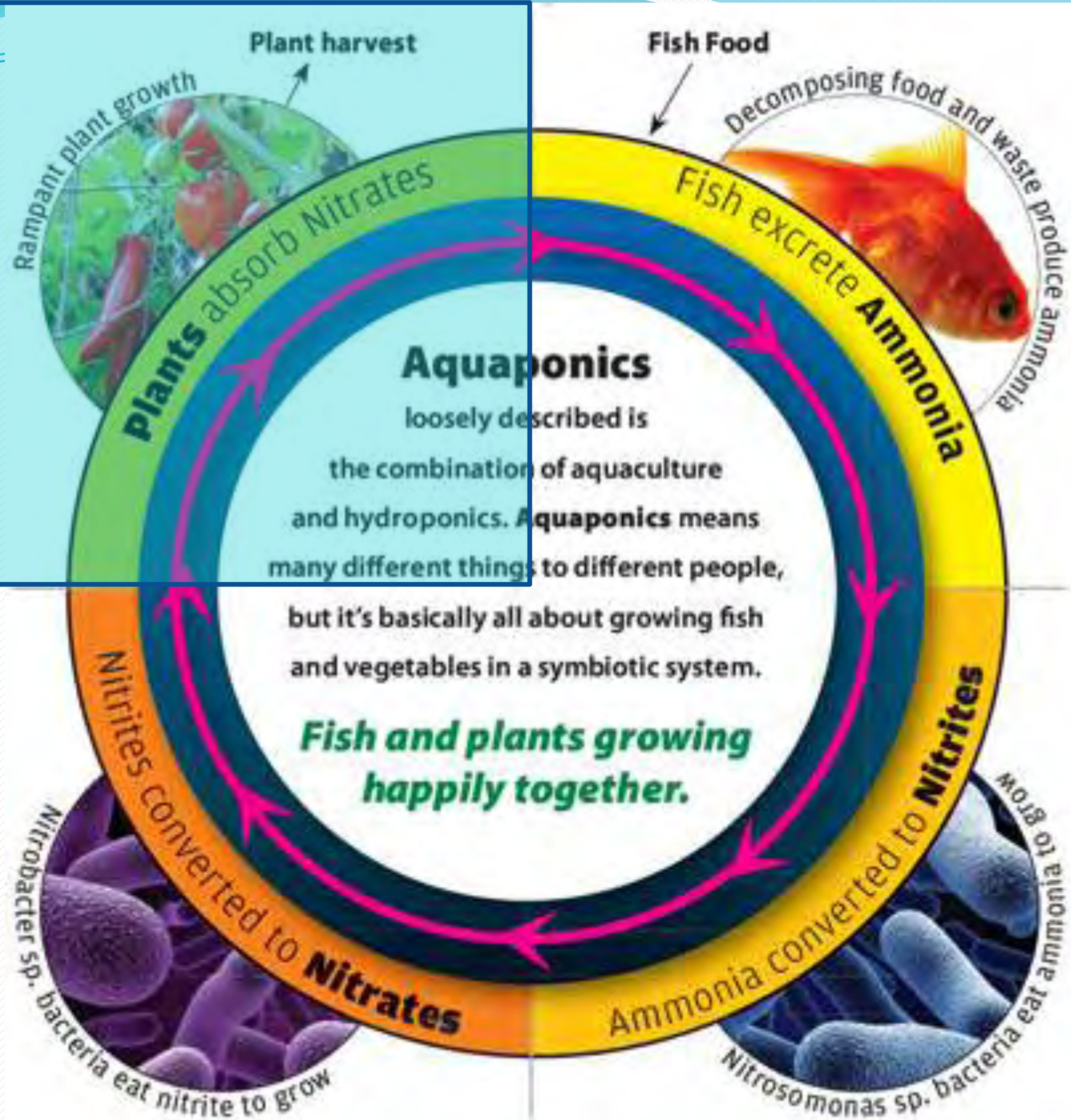
Starting the Nitrification Process

Fishless cycle

- Use commercial ammonia tablets and bacterial supplement
- Use worm tea made from worm castings
- Use pond or stream water (with caution)
- Use the filter pad or water from someone’s aquarium
- Use feeder goldfish (they may not live very long)
- Use urine – yes I realize its weird, but its sterile

Water Testing





www.backyardaquaponics.com

Now for the Plants

Vegetables

- Lettuce
- Beans
- Squash
- Zucchini
- Broccoli
- Peppers
- Cucumbers
- Peas
- Spinach

Herbs

- Basil
- Thyme
- Cilantro
- Sage
- Lemongrass
- Wheatgrass
- Oregano
- Parsley

Fruits

- Strawberries
- Watermelon
- Cantaloupe
- Tomatoes

Flowers

- Most garden varieties

Why do Plants like Aquaponics?

- Nutrients constantly provided
- Warm water bathing the roots
- Don’t have to search for water or food
- Less effort needed in putting out roots
- All the energy goes into growing UP not DOWN
- No weed competition

What influences the amount of available nutrients to plants?

- Density of fish population
- Size of fish
- Temperature of water
- Amount of uneaten fish feed in water
- Availability of beneficial bacteria
- Amount of plants in the system
- Media present in system
- Water flow rate

Lettuce

- Lots of different varieties
- Really easy to grow
- Ready to harvest in about 30 days
- Shallow root system
- Pick what you need
- Grows in either media or raft system
- Ideal Temp 60-80F*, can tolerate down to 45F
- Temps over 80F* lettuce bolts

Tomatoes

- First 6 weeks are easy
- Flower to fruit, need more nutrients
- Determinate plant – set fruit at one time, 2' x 2' plants
- Indeterminate plant – continual harvest, 25 + foot vines

- Very popular hydroponic varieties, like aquaponics Mostly determinate used
- Ideal temp 78*,
  pH 5.8-6.8, tolerate up to 7.2

Cucumbers, Zucchini, Squash

- Grow fast
- Long vines take over the space
- Trellis plants
- Try to find self-pollinating varieties
- Or pollinate yourself with a Q-tip or shake
- Ideal Temp 75-78* day and 68* at night
- Harvest in about 2 months



Strawberries

- Great vertical growers
- Easier to plant and harvest than traditional ground crop
- Does well in artificial light
- Can be sensitive to temperature which effects flowering and fruit sugar
- No pesticides or fertilizers needed
- Ideal pH 5.8 - 6.2

Basil

- Most popular aquaponic herb
- Fast and easy to grow
- Good market price and high demand
- Likes good light, but shade mid-summer
- Lots of varieties
- Continuous harvest
- Ideal temps 68-75*
- Use fresh or dried

Watercress

- Good filtration plant
- Hardy plant, grows fast
- Aquatic, natural grown along stream banks
- Good cash crop, in demand
- Prolific re-seeder, re-sowing itself annually
- Continuous harvest
- Ideal temps 68-85*
- pH 5.8 – 6.5

And a Bunch of Other Stuff

System Startup Checklist

1. Decide on type and size of system to build
2. Draw designs, research where to get parts, plan
3. Buy and assemble components
4. Start plants from seed or find source for seedlings
5. Fill system with water and circulate (at least a week)
6. Add plants to system and watch them grow
7. If using a fishless cycle, begin nitrification process
8. Add fish to system about 20% of stocking density
9. Monitor water quality, partial water changes as needed
10. Maintain system

Media system calculations

- Ideal Grow bed volume to fish tank volume ratio typically 2:1
- Can go up to 3:1 or as low as 1:1
- Ideal grow bed depth is 12”
- How do you calculate the volume?
  - Determine cubic feet of the grow beds and fish tank (Length x width x height)
  - Convert to Gallons by multiplying cubic feet x 7.48
    - 1 cubic foot = 7.48 Gallons

Example Scenario

- You have a 50 Gallon fish tank. How do you determine the size of your grow beds using the 2:1 ratio?
- Following the 2:1 grow bed to fish tank ratio you will need approximately 100 gallons of grow bed volume
- Divide 100 gallons by 7.48 to determine cubic feet
  - Cubic ft = 14' (rounded up)
- Assuming ideal grow bed depth of 1 ft you can conclude that a single 2' x 7' grow bed would work
- Or two 2' x 3.5' grow beds
- If depth is 6" you can double the grow bed area to 28 s.f.

Fish Stocking Density

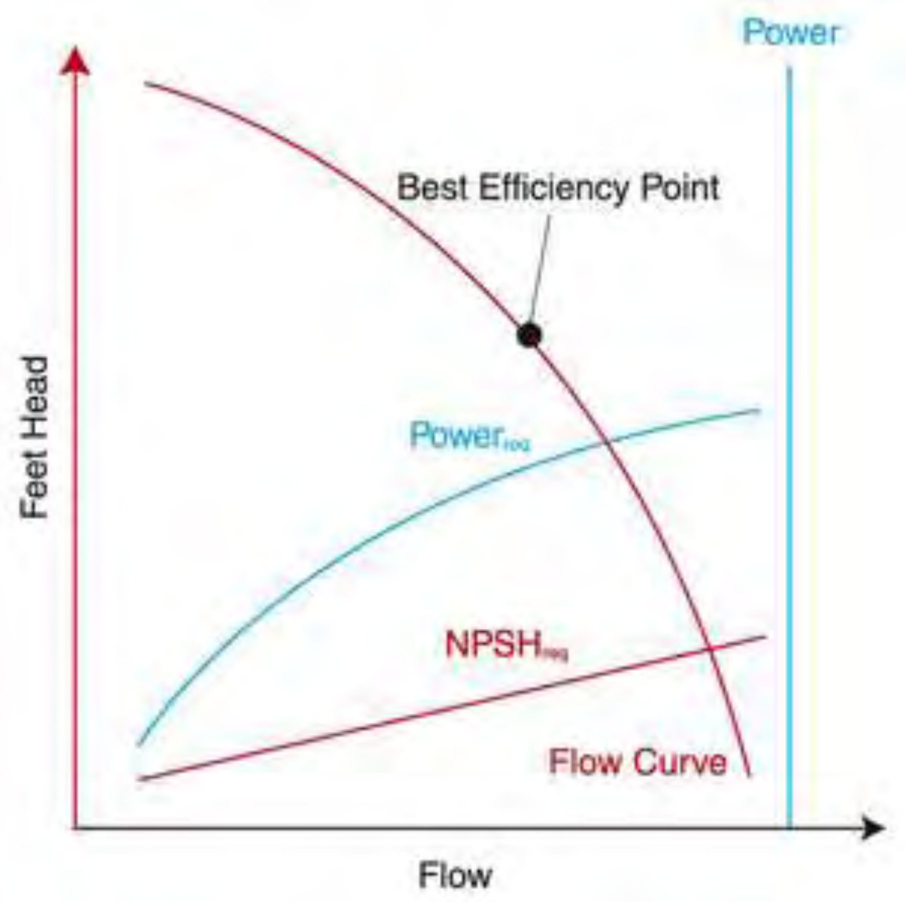
- .25lb fish per gallon (conservative) to .5lb per gl (moderate)
- Important to know final grow out weight of fish to determine appropriate stocking density
- Tilapia avg harvest size = 1.5lb (from UVI data)
- Example:
  - Tank size = 300 gallon
  - Total fish weight = 300 x .25lb = 75 lbs
  - Number of fish = 75lb/1.5lb = 50 fish
  - Startup fish at 20% total capacity (50 x 20%) = 10 fish

Fish Feeding

- On average, fish eat about 1.5% of their body weight daily.
- If you have 75 lbs of fish in system, multiply 75lbs x 1.5% = 1.125lbs of fish feed daily
- If needed, convert lbs to grams (1lb = 454 grams)
- 1.125 lbs = 510 grams
- Don't just rely on the math. Observe your fish eating to help determine the proper amount of feed

Pump sizing

- Pump should cycle total volume of tank water once each hour at the head you are requiring of it for continuous use pumps
- If pump is on a 15 minute timer, it should be sized to pump total tank volume in 15 mins (4x)



Aeration sizing

- CFM cubic ft per minute is a measurement of the volume of air flow
- PSI is the pressure required to deliver the correct amount of air flow for proper aeration
- Simple rule of thumb has 1 cfm per 300 Gallons
- Several different ways to calculate: either per lbs of fish or water volume or per diffuser type etc…

System Maintenance

1. Feed the fish daily, monitor fish health
2. Test water quality (every other day for the first month, then about once a week, then as needed)
3. As needed clean out filter screens, filter tanks (if using), tubing, water pump, growbed media, etc.
4. Check plant health, trim back, harvest or take cuttings
5. Check plants for bugs or nutrient deficiencies

Other Handy Tips and Tricks

- Always wash your gravel media before putting in the system – otherwise you will get very cloudy dirty water
- Test the pH of the gravel media you want to use
- Use vitamin C and an air pump to bubble out chlorine and chloramine from tap water
- Use worms (red wigglers) in media beds to breakdown solids and reduce anaerobic zones
- Never use cleaning products, pesticides, algaecides, fertilizers or like substances in fish tanks or grow beds

More Handy Tips and Tricks

- If you get aphides on your plants – spray with diluted vinegar and water solution
- Avoid direct sunlight on fish tanks, cover the top to avoid algae and make fish happy
- Never change more than 1/3 of water at a time. More than that will destroy the good bacteria in the system.
- Cover outdoor plants during a frost, and shade from the scorching summer sun.
- Make sure you have backup power available for pumps and aerators

Web Resources

www.coloradoaquaponics.com - That's us

aquaponicsgardening.ning.com – Community blog

attra.ncat.org/attra-pub/aquaponic.html - ATTRA

www.growingpower.org – Will Allen, Milwaukee, Wi

www.aquaponics.com – Nelson and Pade, Montello, Wi

www.backyardaquaponics.com – Joel Malcolm, Australia

www.aquaponics.net.au – Murray Hallam, Australia

www.aquaponicsusa.com - California

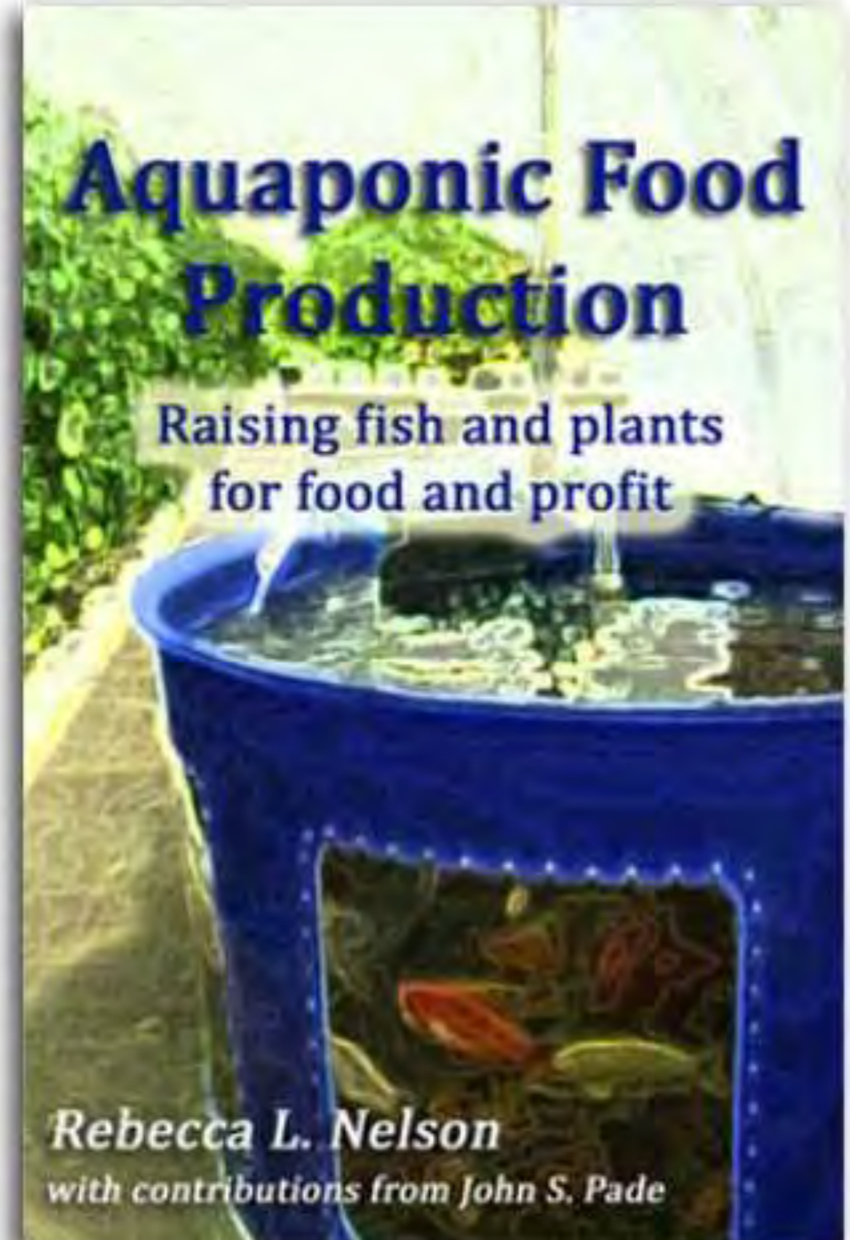
www.friendlyaquaponics.com – Hawaii

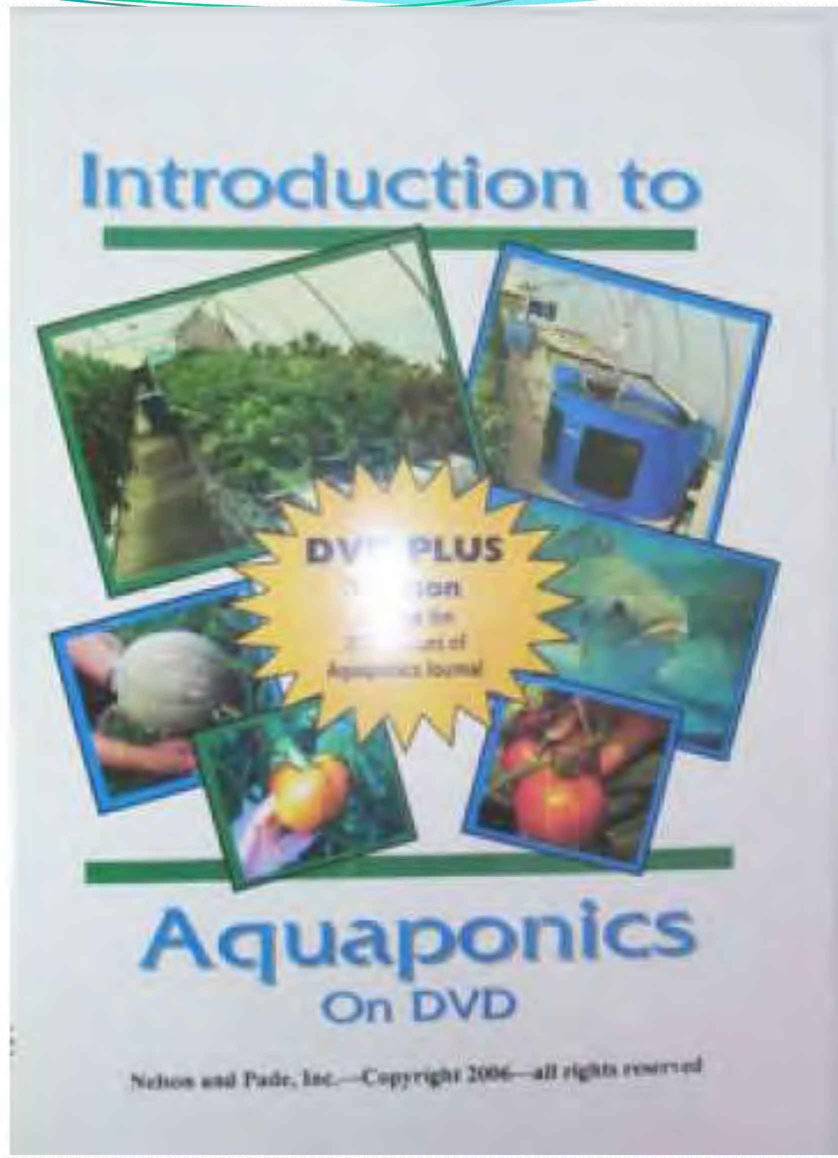
www.uvi.edu – University of Virgin Island

sweetwater-organic.com/blog - Milwaukee, Wi

A little about us…
Colorado Aquaponics

- Aquaponics training and workshops
- Small scale creative systems design – build
- Community scale aquaponics consulting, design, project management and construction administration
- Economic Feasibility, Business Planning and Budget preparation


Aquaponic Food Production
Raising fish and plants
for food and profit
Rebecca L. Nelson
with contributions from John S. Pade


Introduction to
Aquaponics
On DVD
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