FISH WATER QUALITY MANAGEMENT IN RAS & AQUAPONICS

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Natural Resource Ecology and Management

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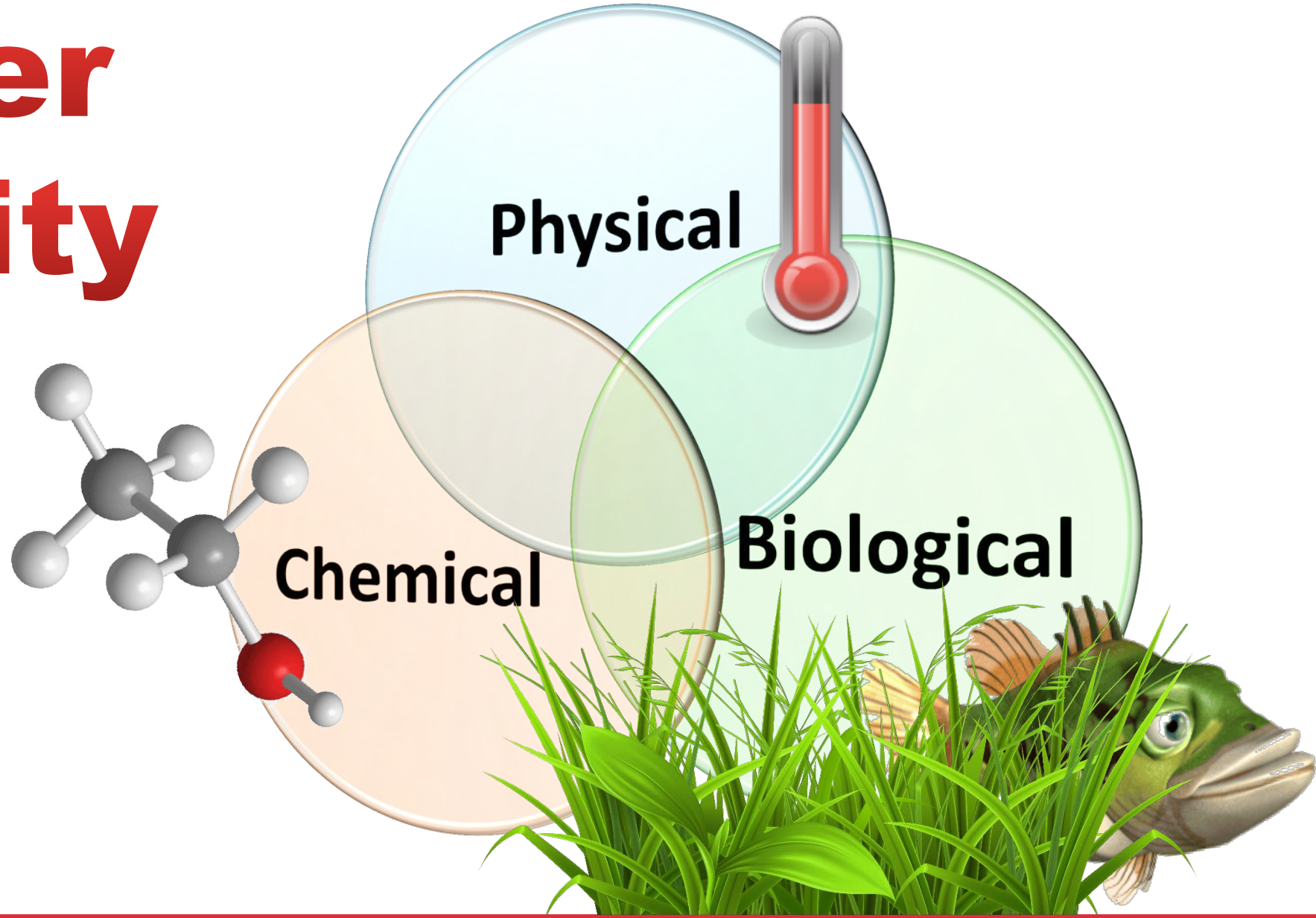
Water Quality

- Physical
- Chemical
- Biological



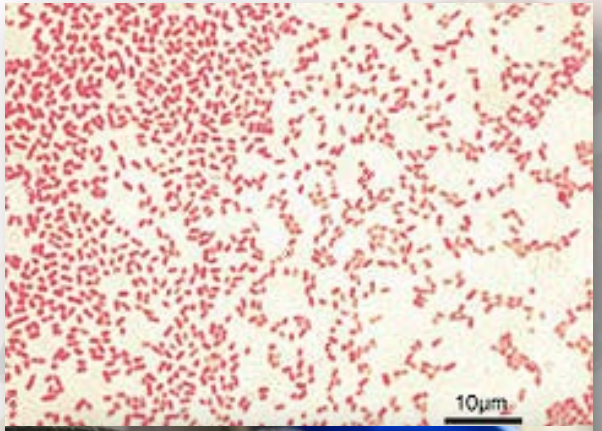
Fish Health

Check Early & Check Often

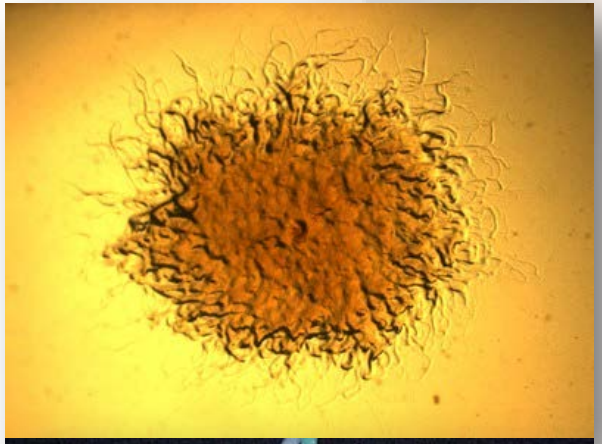
- Monitor and record fish behavior daily
  - Monitor fish for lesions or erratic swimming behavior
  - Inform a fish health professional immediately regarding abnormal fish behavior

Common Disease Issues

Aeromonas



Columnaris



Water Source

HAVE YOUR WATER TESTED

BEFORE SETTING UP A SYSTEM!!!

Municipal Water – De-chlorinate

- May contain chlorine or chloramine – TOXIC to fish

Well Water - Aerate

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

Rain Water – Re-mineralize

- 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 - Disinfect

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

Water Quality

Daily Testing

- Dissolved oxygen (DO)
- Temperature
- pH

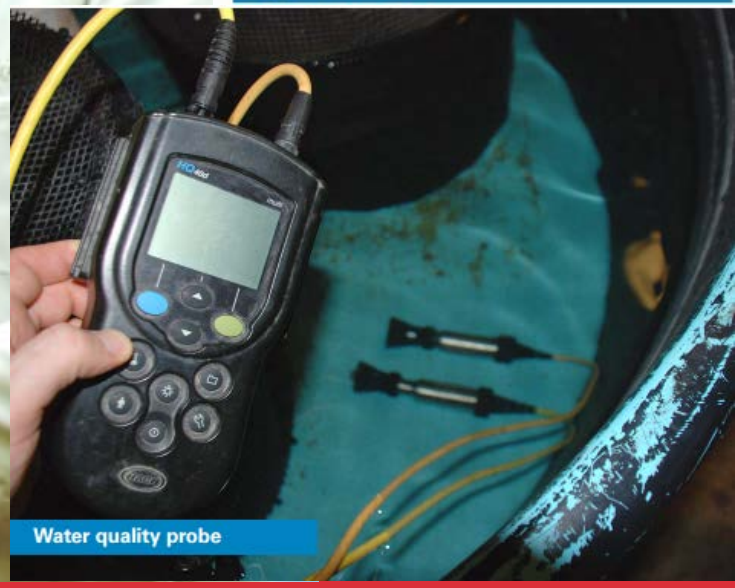
Twice Weekly Testing

- Total ammonia nitrogen (TAN)
- Nitrite
- Nitrate
- Alkalinity

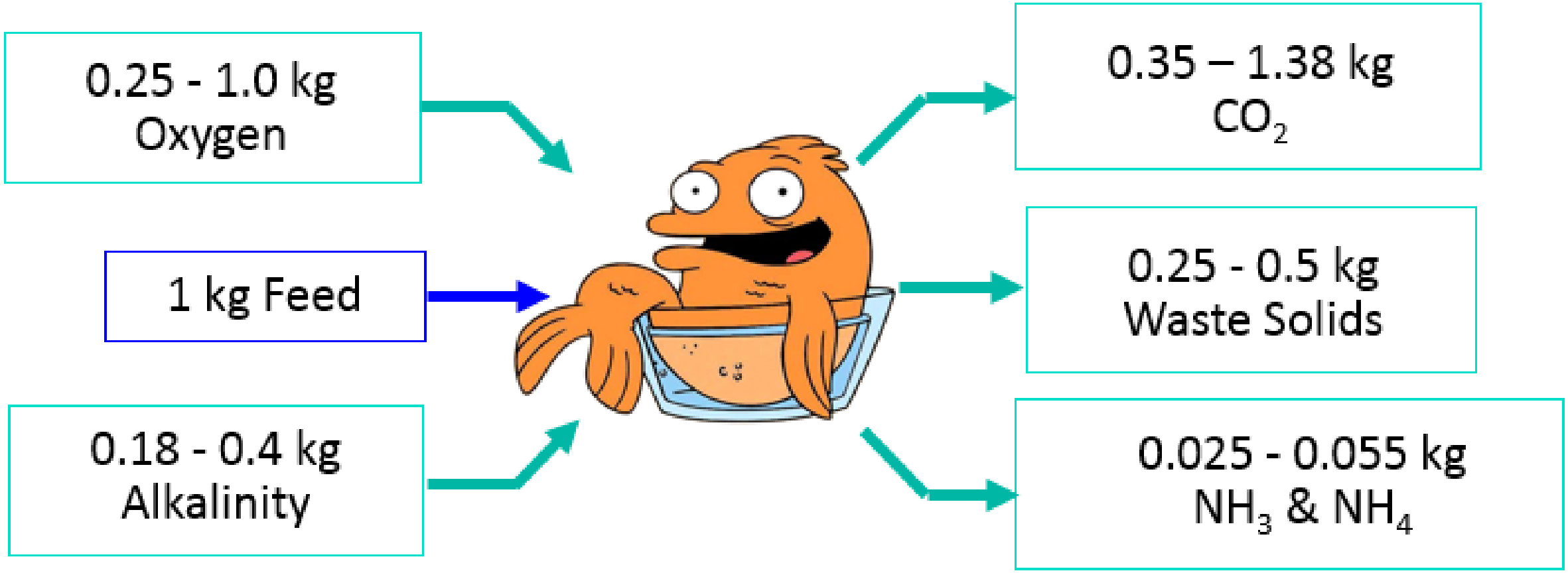
Twice Monthly Testing

- Phosphorus
- Calcium hardness
- Iron
- Potassium

pH test kit


Water quality probe

Fish Food has an Impact on Water Quality



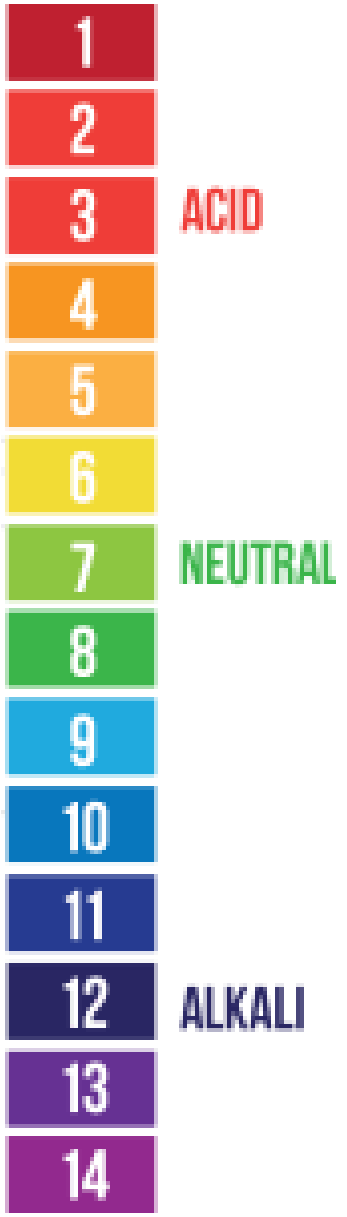
Temperature

- Affects the metabolism of most aquatic organisms
  - Q10 Rule
  - Each species has optimal range for growth
- – Affects chemical parameters in water
  - Dissolved Oxygen
  - Ammonia Nitrogen

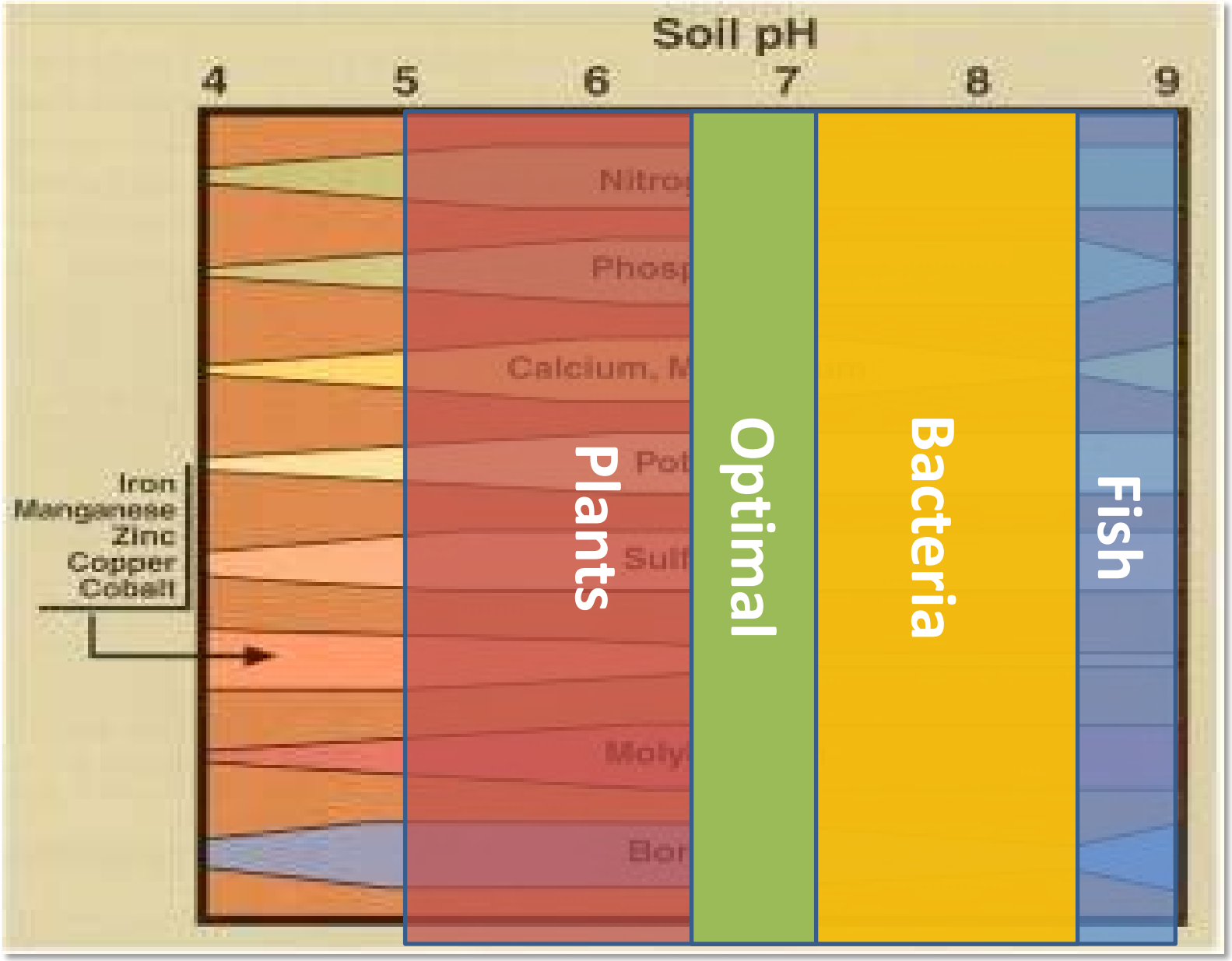
pH

Affects All Biological Processes

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



Optimal pH 6.5 to 7.2



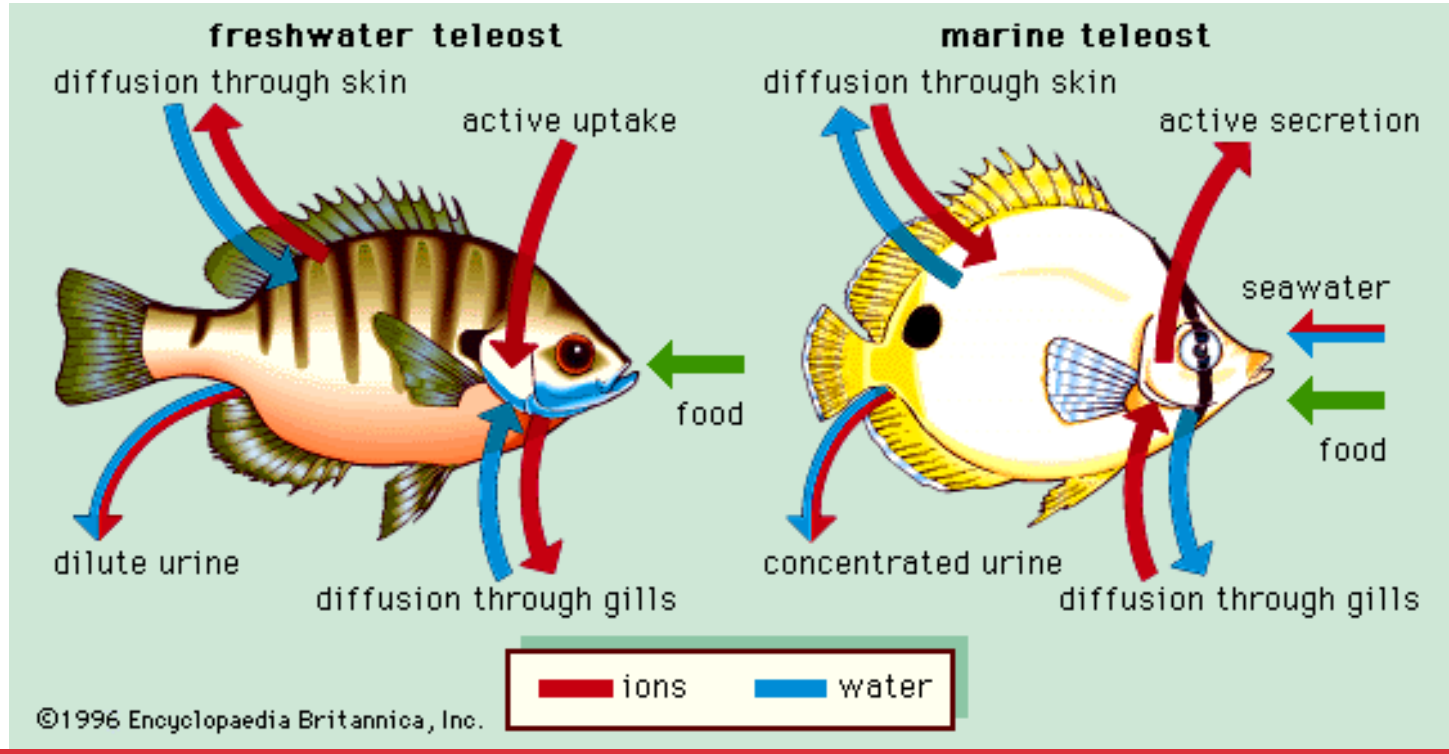
Salinity

A measure of the salt concentration of the water

- Important for osmoregulation

  * NaCl salt to relieve stress and nitrite poisoning.

  – Freshwater
    - fish lose salts through gills
  – Saltwater
    - fish lose water through gills



Dissolved Oxygen

The amount of oxygen available for respiration in water

- Used in the breakdown of energy-storing molecules
- Has a natural saturation equilibrium in water
  - Temperature ↑ DO level at saturation ↓
  - Salinity ↑ DO level at saturation ↓
- Minimum DO requirements
  - Warmwater 2-3 mg/L
  - Coldwater 5 mg/L

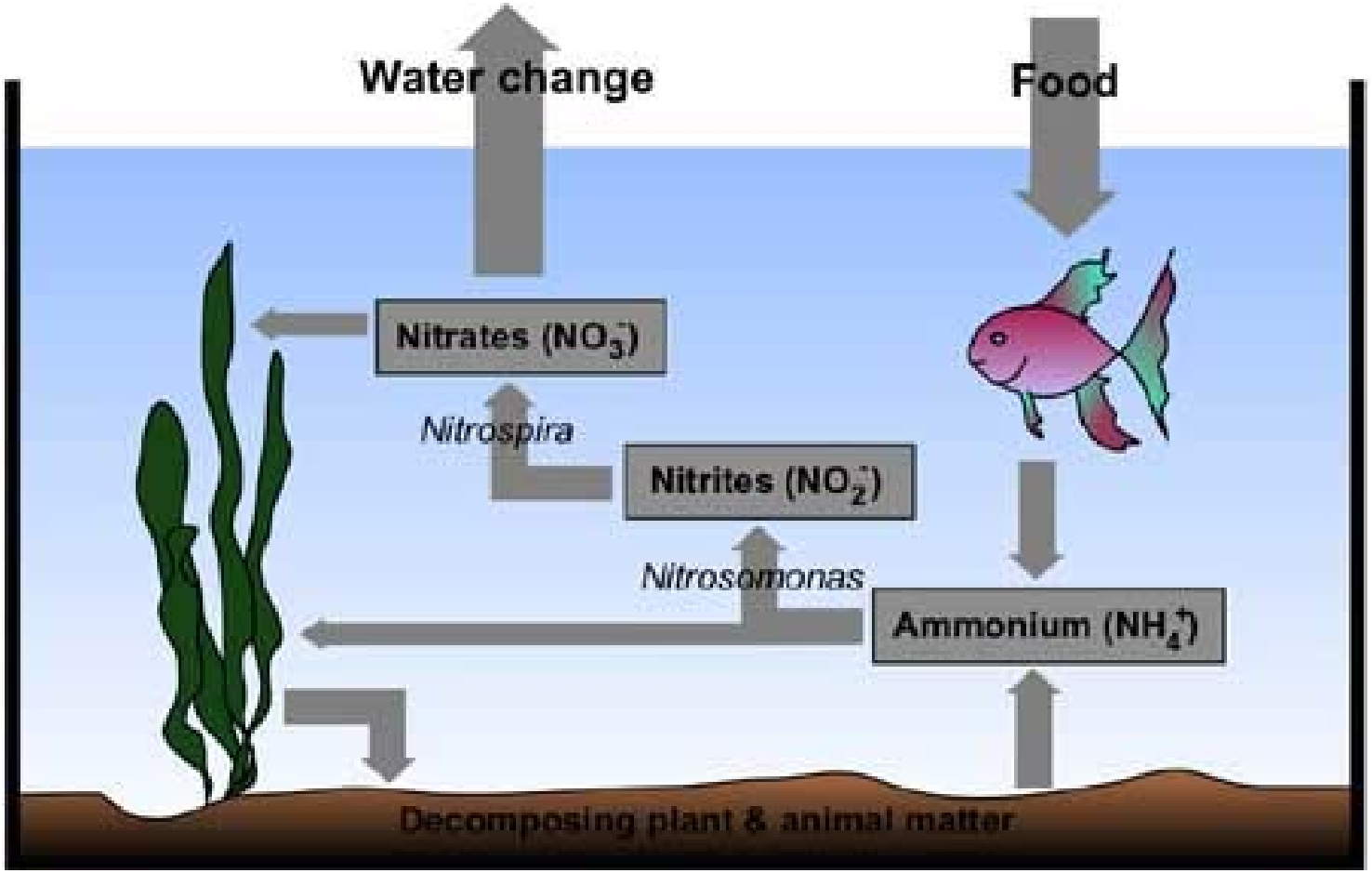
- Supersaturation (>100%)
  - gas bubble disease

Chlorine

A toxic gas typically used in water treatment and wastewater treatment plants to disinfect water before and after human use

- Biosecurity - disinfect aquaculture equipment
  - Bleach – Sodium hypochlorite (NaOCl)
  - Oxidizing agent
  - Chloramines
  - Crayfish and shrimp less susceptible
- Removed by
  - Carbon filtration
  - Sodium sulfite
  - Heavy aeration

Nitrogen Cycle

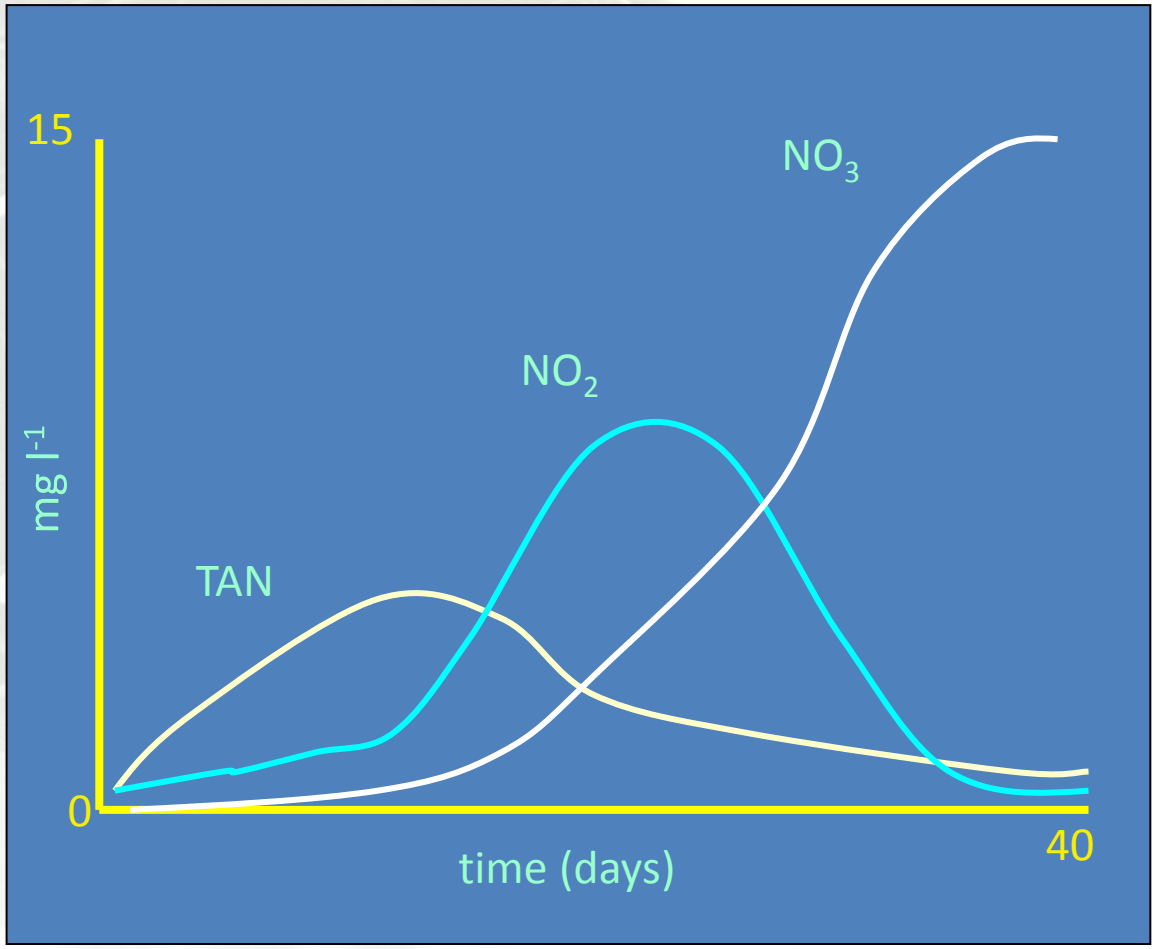


N_2 gas is also created through denitrification under anoxic conditions
Volatilized from water by aeration

Bio-Filters

Live bacteria need time and resources to establish

- ~ 1 month
- Ammonia
- Nitrite
- Alkalinity
- Easy to kill



Ammonia Nitrogen

- Primary metabolite of protein
  - Used in household cleaners – very toxic
  - Ammonia (NH_3) - toxic
  - Ammonium (NH_4^+) – non-toxic

High pH and temperature make the proportion as NH_3 higher, and more toxic

	Temperature													
pH	42.0 (°F)	46.4	50.0	53.6	57.2	60.8	64.4	68.0	71.6	75.2	78.8	82.4	86.0	89.6
	6 (°C)	8	10	12	14	16	18	20	22	24	26	28	30	32
7.0	.0013	.0016	.0018	.0022	.0025	.0029	.0034	.0039	.0046	.0052	.0060	.0069	.0080	.0093
7.2	.0021	.0025	.0029	.0034	.0040	.0046	.0054	.0062	.0072	.0083	.0096	.0110	.0126	.0150
7.4	.0034	.0040	.0046	.0054	.0063	.0073	.0085	.0098	.0114	.0131	.0150	.0173	.0198	.0236
7.6	.0053	.0063	.0073	.0086	.0100	.0116	.0134	.0155	.0179	.0206	.0236	.0271	.0310	.0369
7.8	.0084	.0099	.0116	.0135	.0157	.0182	.0211	.0244	.0281	.0322	.0370	.0423	.0482	.0572
8.0	.0133	.0156	.0182	.0212	.0247	.0286	.0330	.0381	.0438	.0502	.0574	.0654	.0743	.0877
8.2	.0210	.0245	.0286	.0332	.0385	.0445	.0514	.0590	.0676	.0772	.0880	.0998	.1129	.1322
8.4	.0328	.0383	.0445	.0517	.0597	.0688	.0790	.0904	.1031	.1171	.1326	.1495	.1678	.1948
8.6	.0510	.0593	.0688	.0795	.0914	.1048	.1197	.1361	.1541	.1737	.1950	.2178	.2422	.2768
8.8	.0785	.0909	.1048	.1204	.1376	.1566	.1773	.1998	.2241	.2500	.2774	.3062	.3362	.3776
9.0	.1190	.1368	.1565	.1782	.2018	.2273	.2546	.2836	.3140	.3456	.3783	.4116	.4453	.4902
9.2	.1763	.2008	.2273	.2558	.2861	.3180	.3512	.3855	.4204	.4557	.4909	.5258	.5599	.6038
9.4	.2533	.2847	.3180	.3526	.3884	.4249	.4618	.4985	.5348	.5702	.6045	.6373	.6685	.7072
9.6	.3496	.3868	.4249	.4633	.5016	.5394	.5762	.6117	.6456	.6777	.7078	.7358	.7617	.7929
9.8	.4600	.5000	.5394	.5778	.6147	.6499	.6831	.7140	.7428	.7692	.7933	.8153	.8351	.8585
10.0	.5745	.6131	.6498	.6844	.7166	.7463	.7735	.7983	.8207	.8408	.8588	.8749	.8892	.9058
10.2	.6815	.7152	.7463	.7746	.8003	.8234	.8441	.8625	.8788	.8933	.9060	.9173	.9271	.9389

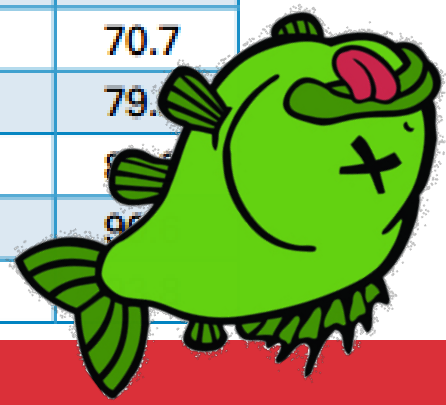
pH & Temp. Ammonia Toxicity

NH_4^+

NH_3

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

	Temperature (°C)						
pH	**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.
9.8	50.5	58.1	65.2	71.5	76.8	81.6	
10.0	61.7	68.5	74.8	79.9	84.0	87.5	
10.2	71.9	77.5	82.4	86.3	89.3	91.8	



Nitrite Nitrogen (NO_2^-)

- Secondary metabolite of protein
  - Causes brown-blood disease
    - Alters hemoglobin
    - Less oxygen transfer
    - Effects weakened by addition of chloride ions
      - NaCl salt
      - 10 Cl^- to 1 NO_2^- ratio
      - 4.5 lbs of NaCl = 1 ppm Cl^- per acrefoot of water

Nitrate Nitrogen (NO_3^-)

- Major Nitrogen fertilizer
  - Algal blooms
- Least harmful nitrogen ion
  - Can be toxic at extremely high concentrations
- Readily taken up by plants
  - Wetland mitigation
  - Aquaponics

Alkalinity

- **Measure of pH buffering capacity of the water**
  - Quantitative measure of carbonates in the water
  - Minimum requirement of 40 mg/L (ppm) to stimulate a phytoplankton bloom
    - Provides CO_2 for plant growth

Hardness

- **Surrogate measure of calcium concentration in water**
  - Measures cations (positive ions) in water
  - Limestone may contain both Ca and Mg

Agricultural Limestone $CaCO_3$

Sodium Bicarbonate $NaHCO_3$

Suppliers

- HACH
  - http://www.hach.com/
- LaMotte
  - http://www.lamotte.com/
- Yellow Springs Instruments (YSI)
  - http://www.ysi.com/index.php
- Aquatic Eco-Systems, Inc.
  - http://www.aquaticeco.com/
- Southern Aquaculture Supply
  - http://southernaquaculturesupply.com/

Effluent Management

Discharge is regulated by the Ohio Department of Natural Resources (OH DNR)

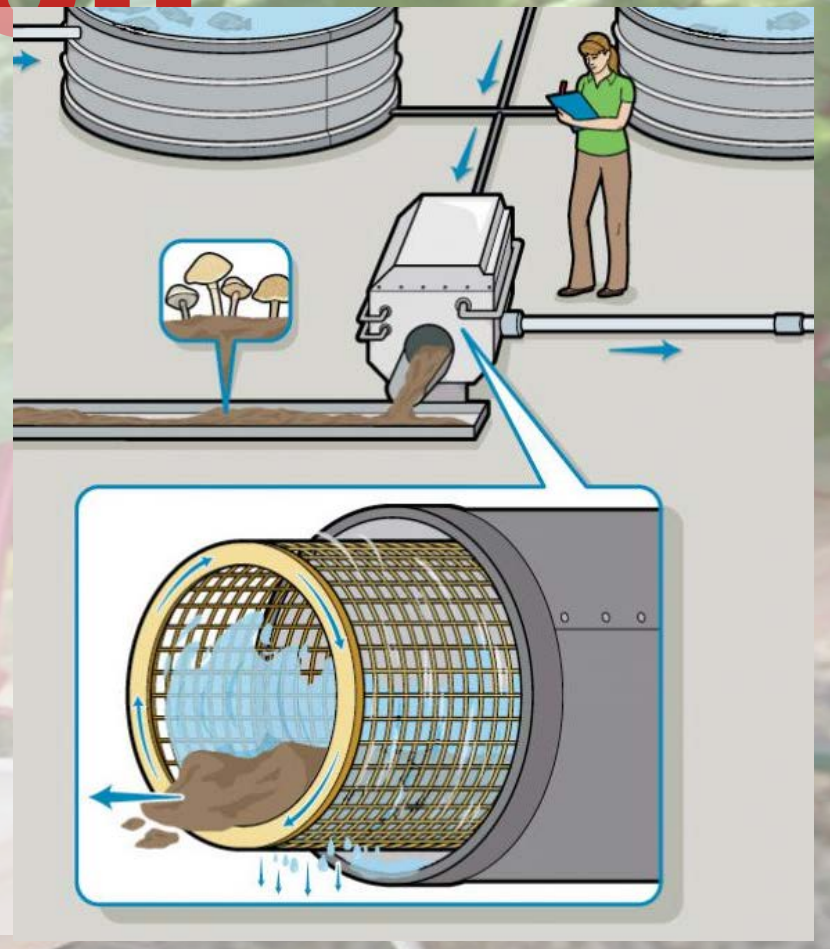
Check with your state natural resource agency or extension service for details

Nutrient Management

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

Reduced Water Consumption

- Recirculating Aquaculture Systems
  - 5-15% daily exchange
- Aquaponics
  - 1.4% daily exchange
  - Water lost in waste purging
  - Potential co-products



ISU System

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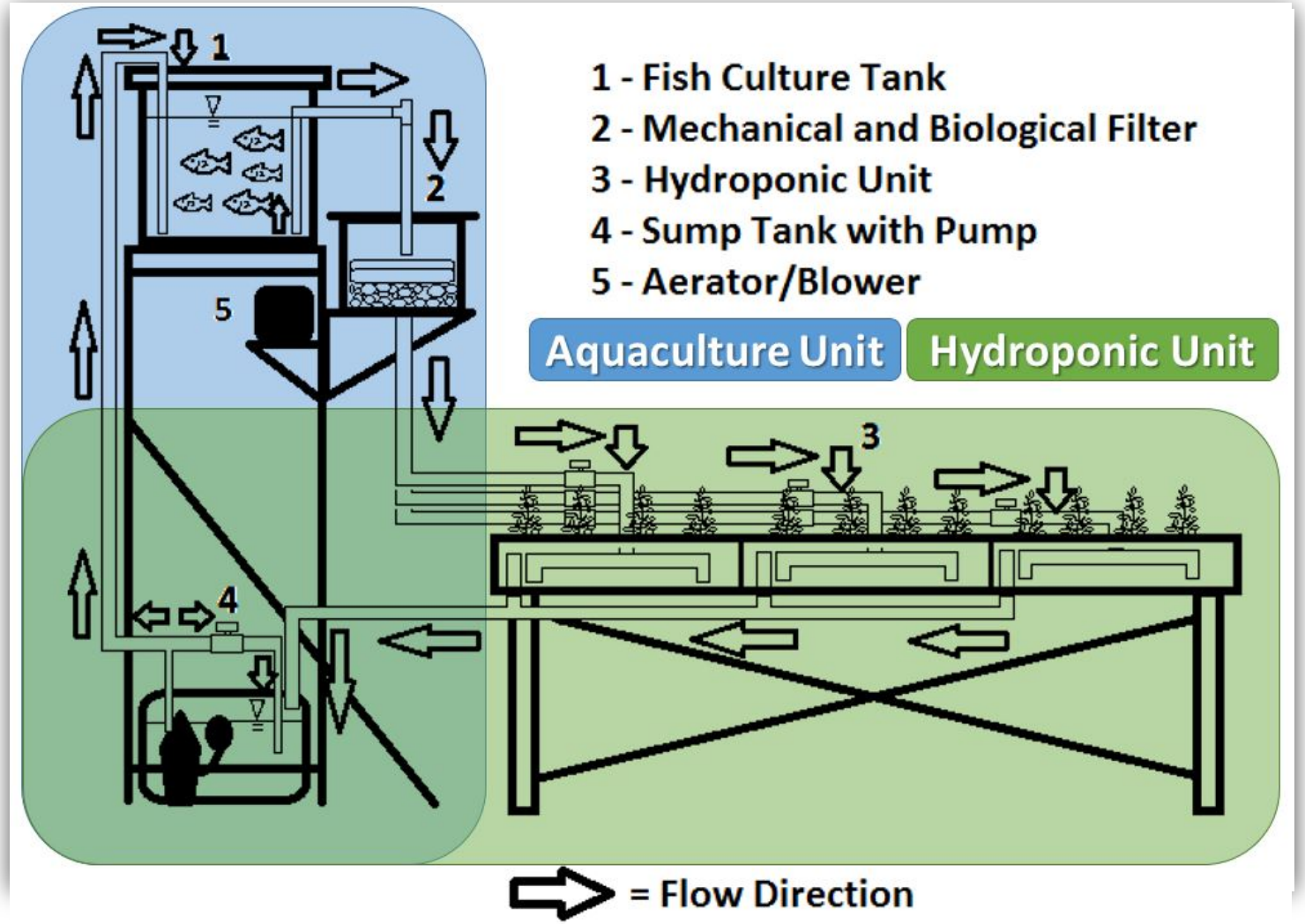
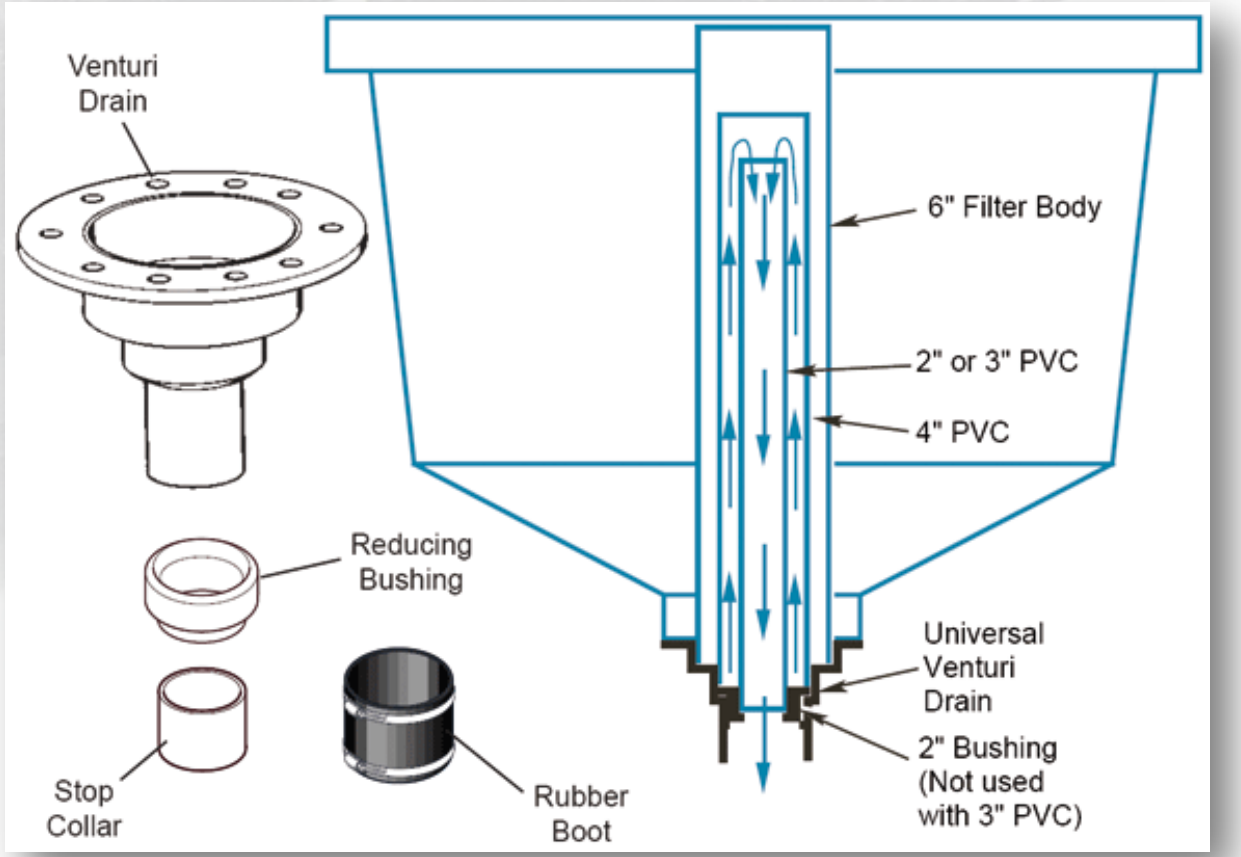
How does it work?



Fish Tanks

Solid Waste Removal

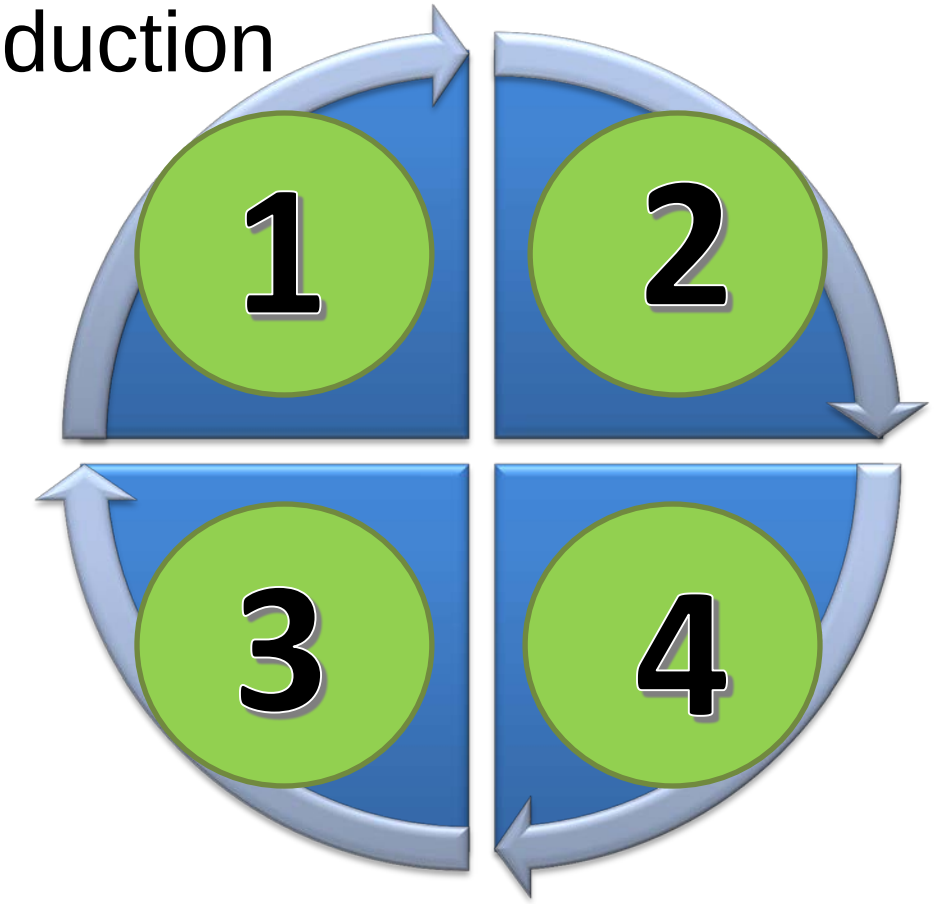
- Solids must be removed quickly for optimal water quality
  - Tank design is critical
  - Double stand-pipe design helps remove waste in round tanks



Feed Consistently

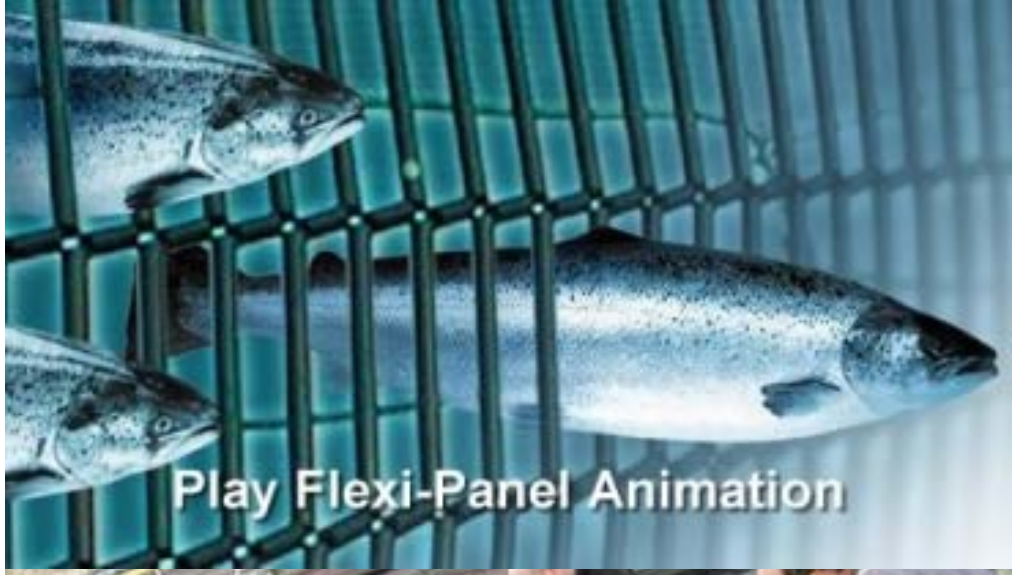
Feed = Fertilizer

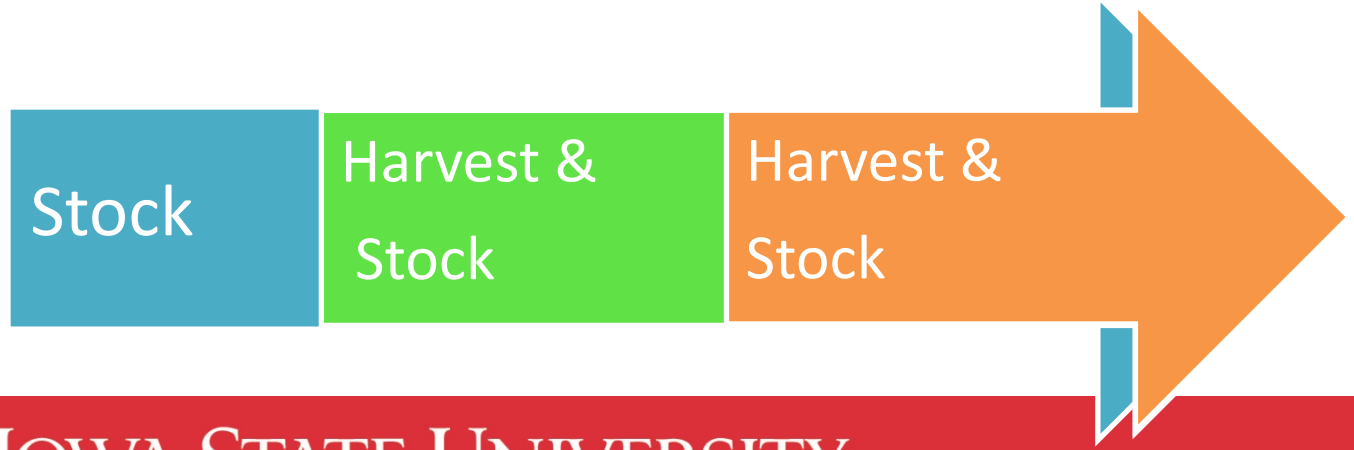
- Multiple rearing tanks, staggered production
  - four tilapia rearing tanks
  - Stock & Harvest every 6 weeks
  - All-in/all-out production (per tank)



Feed Consistently

- 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





Filter Tanks

- Biofilter Material Vol. = 0.063 m^3
  - Bio-Fill™
  - 800 m^2/m^3
  - Total filtration surface area ~ 51.6 m^2
- Solids filter pads

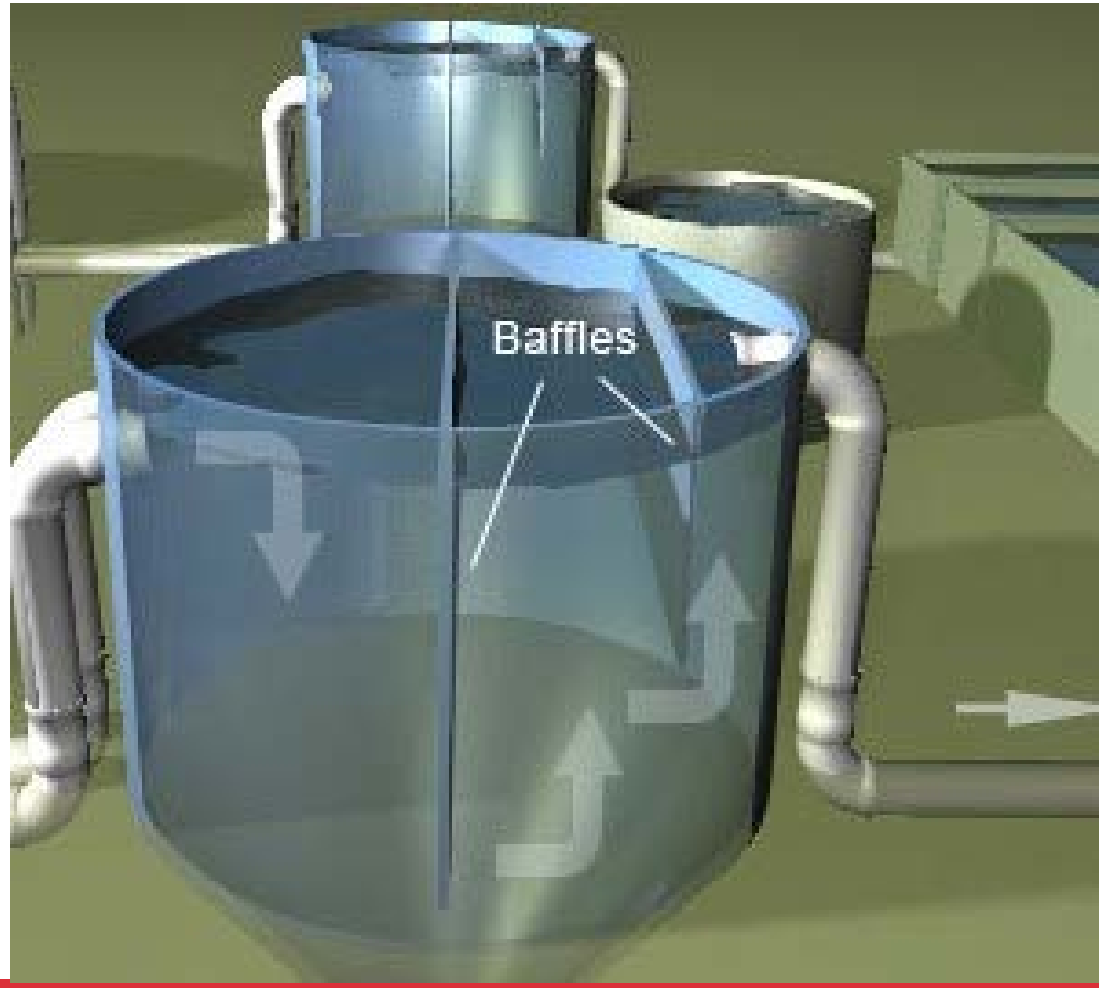
Mechanical Filtration

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

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

Solids Removal

- 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

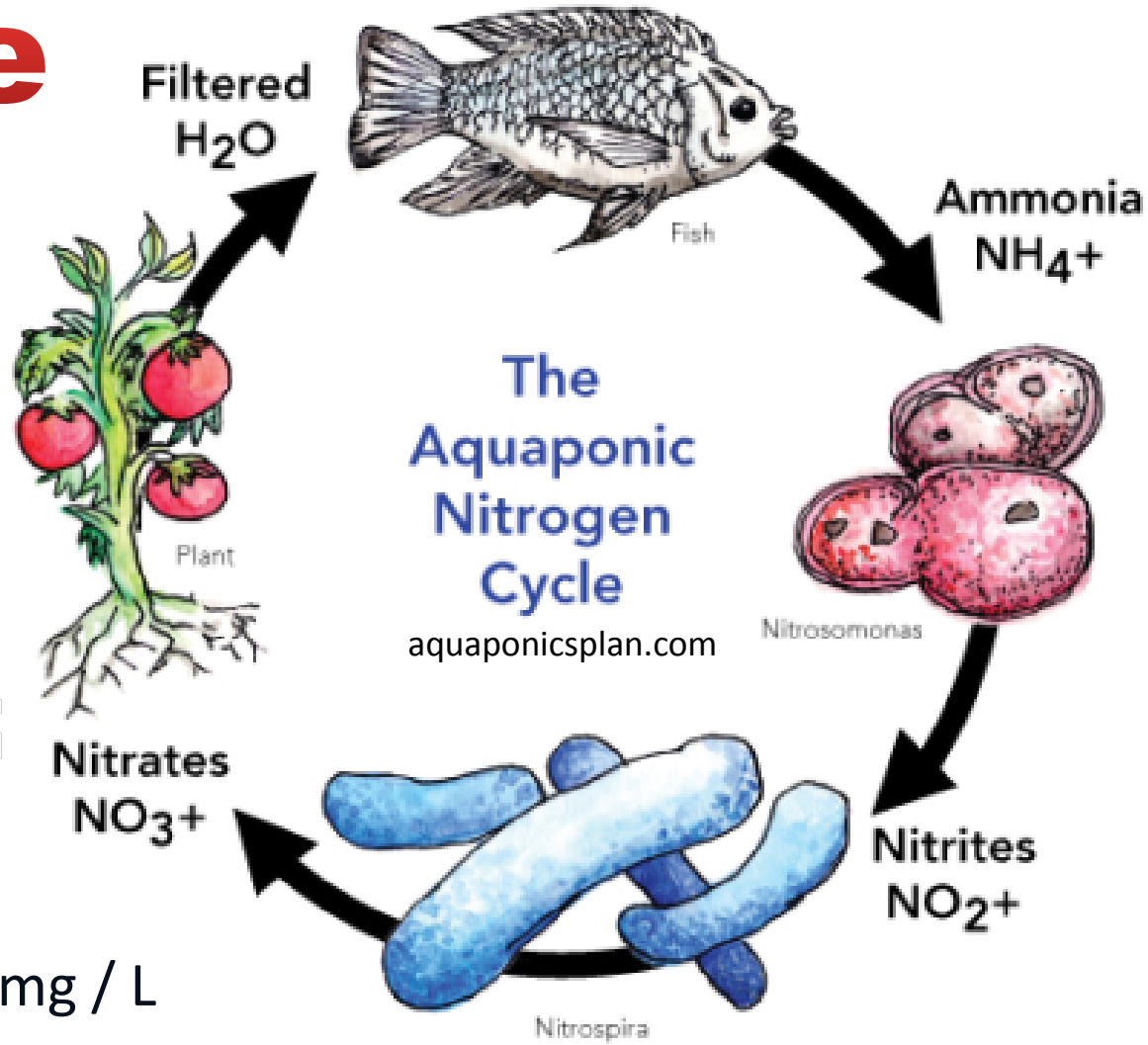


Prevent Biofouling

- Use **oversized pipes** to reduce the effects of biofouling
  - dissolved organic matter promote the growth of filamentous bacteria restricts flow within pipes

Ensure adequate biofiltration

- **Surface Area**
  - Living Space for the Nitrifying Bacteria
  - Competition for that Space
- **Food**
  - ammonia or nitrite
  - > 0.07 mg / L
- **Good Living Conditions**
  - Dissolved Oxygen going into the biofilter > 4 mg / L
  - pH 7.2 – 8.8
  - Alkalinity > 200 mg / L as $CaCO_3$



Aeration

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

Plant Trays

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Plant Trays

Keep Plant Density Consistent

Plants provide critical filtration!!

Single rearing tank with multiple size groups of plants

- 6-week growout time for plants will require
- Harvest plants weekly or bi-weekly
- restock equal number of seedlings

SOW SEEDS

Week 1

Week 2

TRANSPLANT

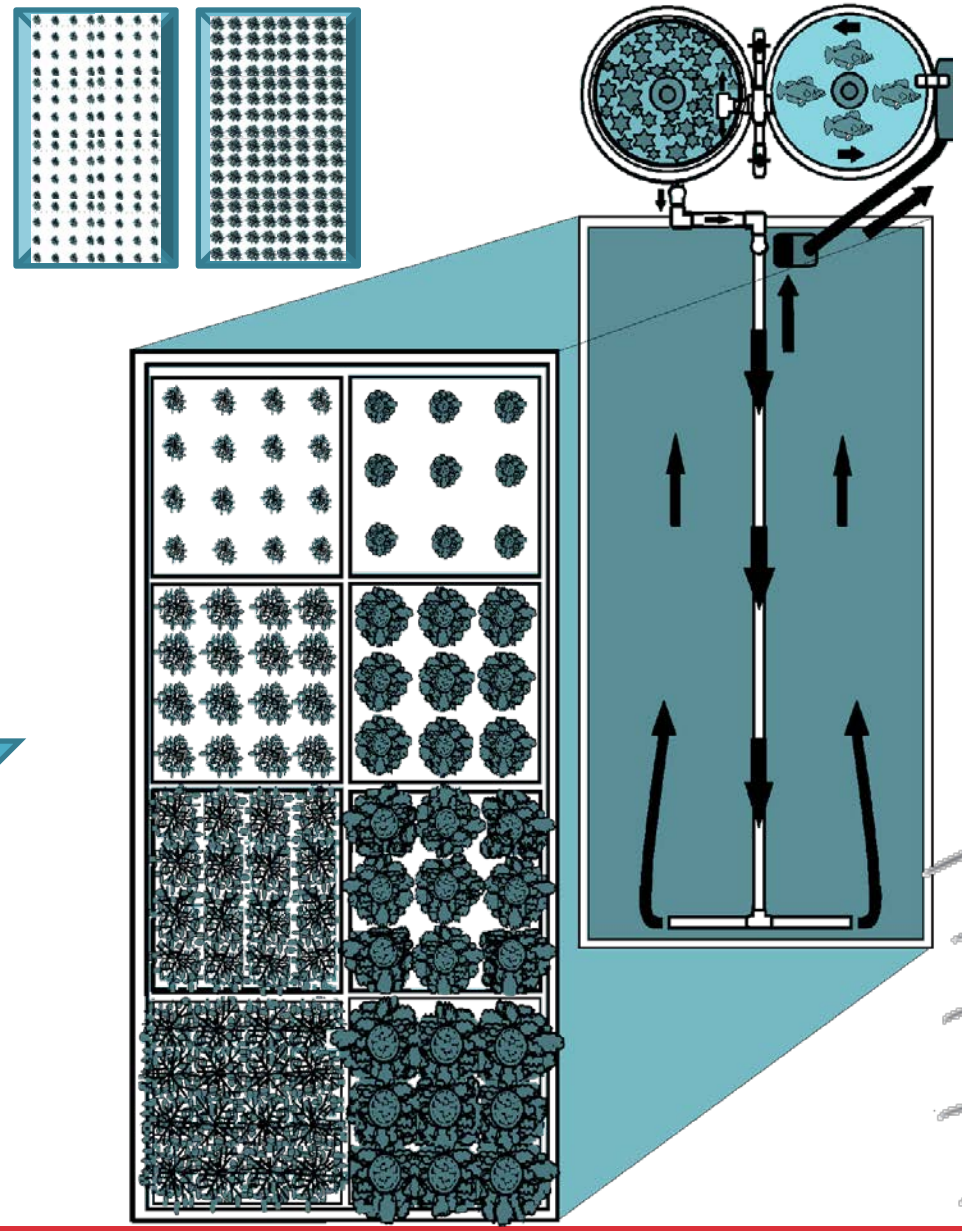
Week 3

Week 4

Week 5

Week 6

HARVEST

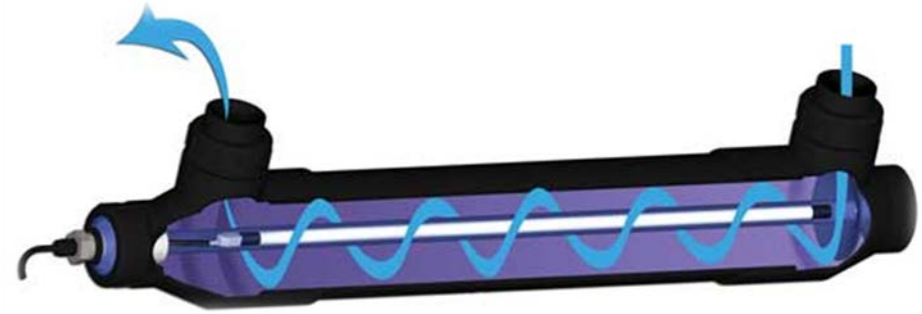


Sumps

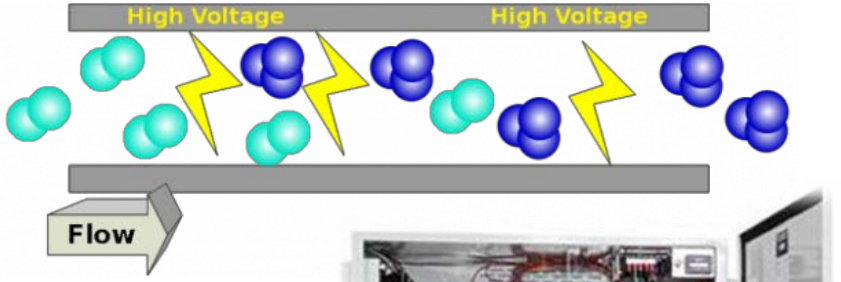
- Water Collection
- Pumping
- Nutrient supplementation
  - Iron
  - Calcium
  - Alkalinity

Disinfection Tools

Ultraviolet Irradiation



Ozone



Species Grown

Nile Tilapia

Oreochromis niloticus

Barramundi

Lates calcarifer

Money-Maker Tomato

Buttercrunch Bibb Lettuce

Italian Large leaf Basil

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- www.NCRAC.org
- http://www.nrem.iastate.edu/fisheries/