WATER QUALITY FOR FISH CULTURE

at

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Charles E Hicks

Pinnacle Aquatics LLC

chchicks82@gmail.com, 573-680-5047

Water Quality-Definition

Summation of all physical, chemical, biological, and aesthetic characteristics of water that influence beneficial use.

Characteristics of water in production systems that impacts survival, growth, and production of aquaculture species, influences system management decisions, and may cause environmental impact , or reduce product quality and safety.

Water Quality and Aquaculture Production

Goal = manage water quality maximizing aquaculture production

Inputs for increasing production impacting water quality

- Chemical fertilizers added to ponds/systems
- Organic materials added to ponds/systems
- Additions of manufactured feeds

Important water quality parameters in aquaculture

- Dissolved Oxygen/CO_2 – Dissolved gases of primary importance in aquaculture.
- Ammonia, Nitrite and Nitrate - resulting from respiration/degradation of protein; NH_3 and NO_2 potentially toxic
- Alkalinity- the sum of titratable bases in the water; bicarbonate (HCO_3) and carbonate (CO_3) predominate bases.
- Hardness- sum of calcium and magnesium expressed as mg/L $CaCO_3$; Important for building bones and shell.
- Conductivity = measure of total dissolved solids (freshwater), measure of salinity (saltwater)

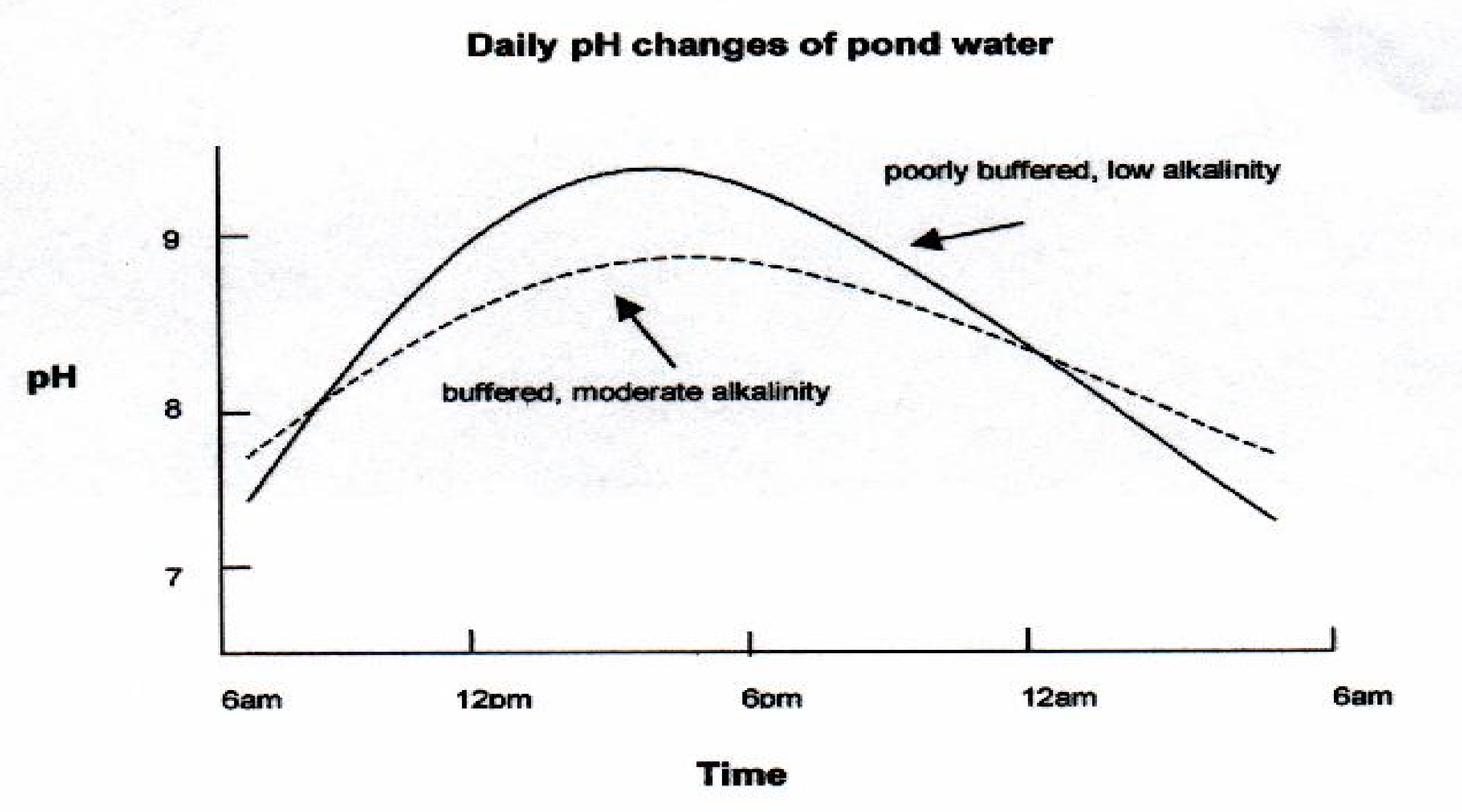
Alkalinity

- Alkalinity is a measure the substances in water that have "acid-neutralizing" ability.
- Alkalinity is a measure of solution's power to resist change in pH; pH = strength of an acid or base.
- Alkalinity = acid-neutralizing capacity of water , includes all bases down to pH 4.5.
- Alkalinity is typically expressed as as mg/l of $CaCO_3$

Industry Alkalinity Values

Industry and Process	Recommended Maximum Total Alkalinity (in mg/L $CaCO_3$)
Carbonated beverages	85
Food products (canning)	300
Fruit juice	100
Washing diapers	60
Pulp and paper making(ground-wood process)	150
Rayon manufacture	50
Tanning hides	135
Textile mill products	50-200
Petroleum refining	500

Daily Changes in pH



From: [Boyd and Tucker (1998)]

Alkalinity Summary

- Waters with low alkalinity have little capacity to resist changes in pH.
- Total alkalinities below 10 mg/L are highly sensitive to acidification.
- Aquaculture ponds should have alkalinity of at least 20 mg/L; 100 to 200 mg/l better. Alkalinity can be increased by adding lime or sodium bicarbonate to pond
- Buffering capacity (alkalinity) reduces effects of diurnal changes in carbon dioxide.
    1. Removal of CO2 at day (by photosynthesis) causes pH to increase
    2. Addition of CO2 at night (by respiration) causes pH to decrease

Dissolved Oxygen

- Dissolved oxygen concentration is major limiting factor in aquaculture production systems.
  1. Important in aerobic respiration.
  2. Relatively low levels of oxygen available in the water.
- Oxygen used by aquatic organisms is gaseous which is not very soluble in water.
  1. High rates of biological action deplete supply.
  2. Natural replenishment is relatively slow.

Oxygen(con't)

- Solubility of oxygen in water dependent upon water temperature, atmospheric pressure, and salinity.
  1. The higher the temperature the less the solubility.
  2. As pressure decreases (altitude) solubility declines.
- Increase in air-water interfacial area (turbulence) is used to transfer O_2.
  1. When the oxygen tension in water is less than air oxygen will diffuse into water.
  2. Oxygen tension greater, O_2 diffuses out of water

Factors Impacting O_2 Levels in Aquaculture Systems

1. O2 saturation level and air-water gas transfer rate
2. Sediment O_2 uptake rate
3. Animal respiration rate
4. Plankton respiration
5. Photosynthesis

Temperature °C	DO saturation value mg/L
0	14.6
1	14.2
2	13.8
3	13.4
4	13.1
5	12.7
6	12.4
7	12.1
8	11.8
9	11.5
10	11.3
11	11
12	10.8
13	10.5
14	10.3
15	10.1
16	9.8
17	9.6
18	9.4
19	9.3
20	9.1

Temperature °C	DO saturation value mg/L
20	9.1
21	8.9
22	8.7
23	8.6
24	8.4
25	8.2
26	8.1
27	7.9
28	7.8
29	7.7
30	7.5
31	7.4
32	7.3
33	7.2
34	7
35	6.9
36	6.8
37	6.7
38	6.6
39	6.5
40	6.4

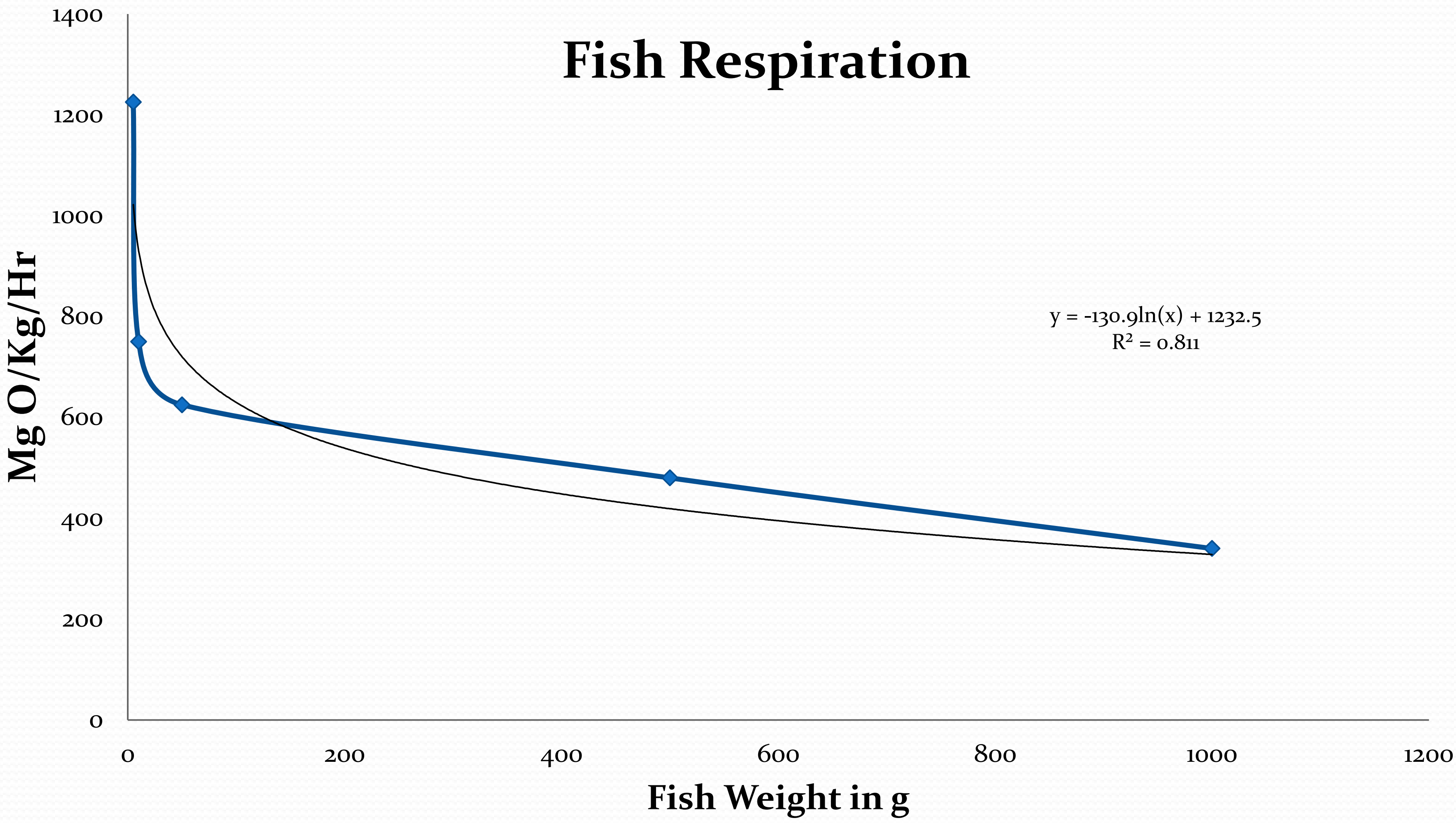
Aeration Devices; Typical O2 transfer rates = 1-2 lb O_2/hp-hr




Oxygen Uptake

- Sediment O2 demand = Aerobic decomposition of organic mater. Oxidation of reduced inorganic substances (oxidation of ammonia to nitrate).
- Animal respiration
  - Animal size, species, both important, smaller fish per body weight consume more because feeding rate is higher.
  - Higher consumption with greater activity.
  - Higher consumption with higher temperature.

Fish Oxygen Consumption

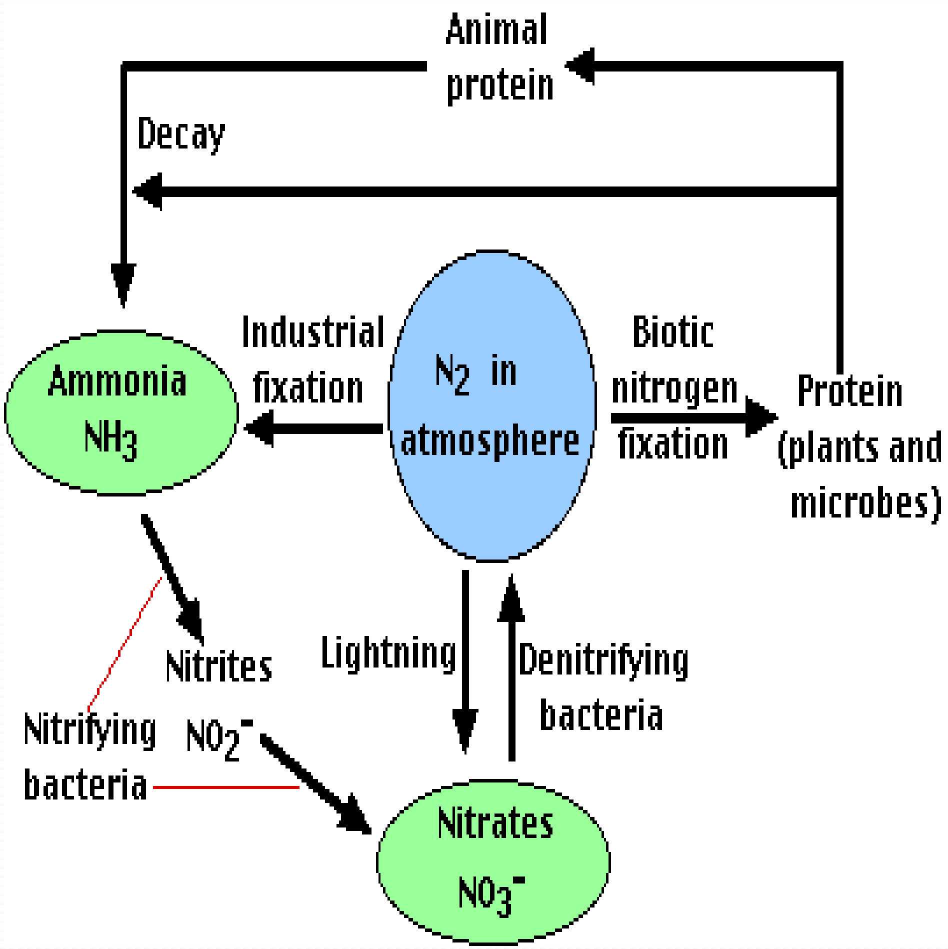


Cycling of Nitrogen

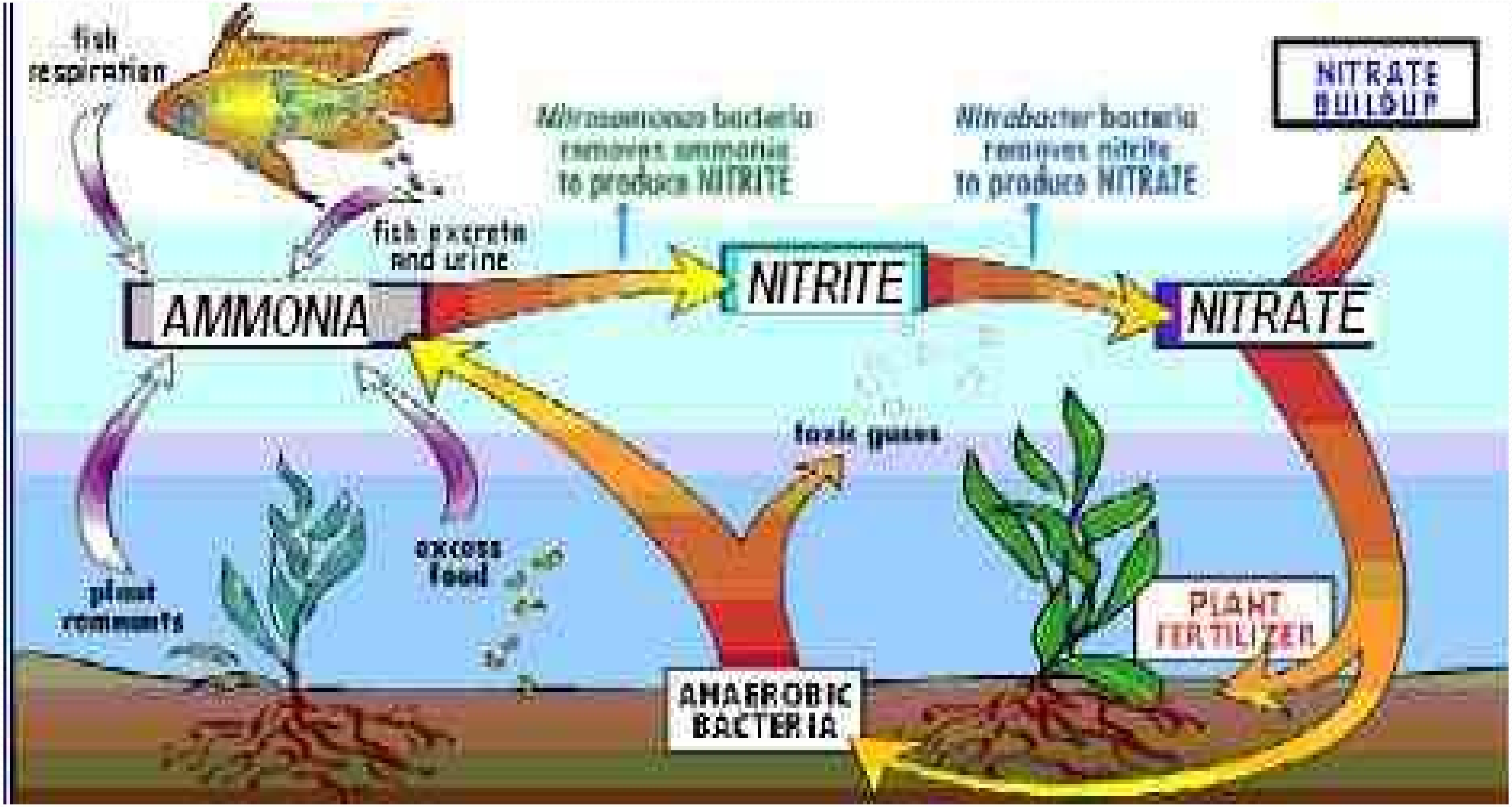
Four processes control cycling of nitrogen through biosphere:

1) Nitrogen fixation
2) Decay
3) Nitrification
4) Denitrification

Microorganisms dominate these processes

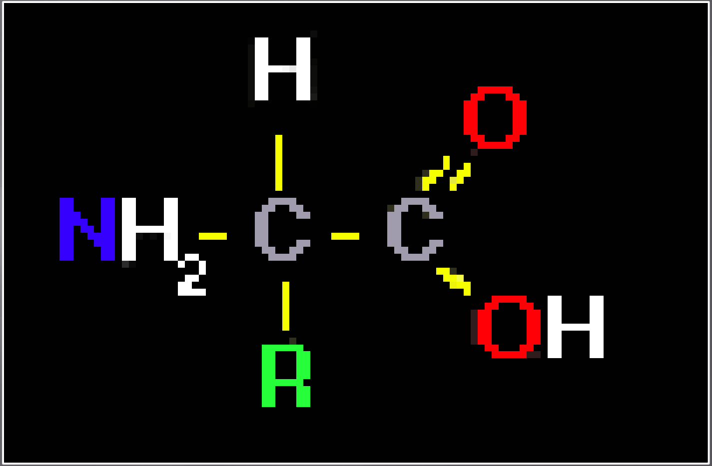


Nitrogen cycle in a saltwater aquaria



Nitrogen Cycling

- In aquaculture begins with the decomposition of organic matter
- Major source in aquaculture = feed
- Excreted as amino acids or in soluble form primarily as NH_3/NH_4^+, other compounds.

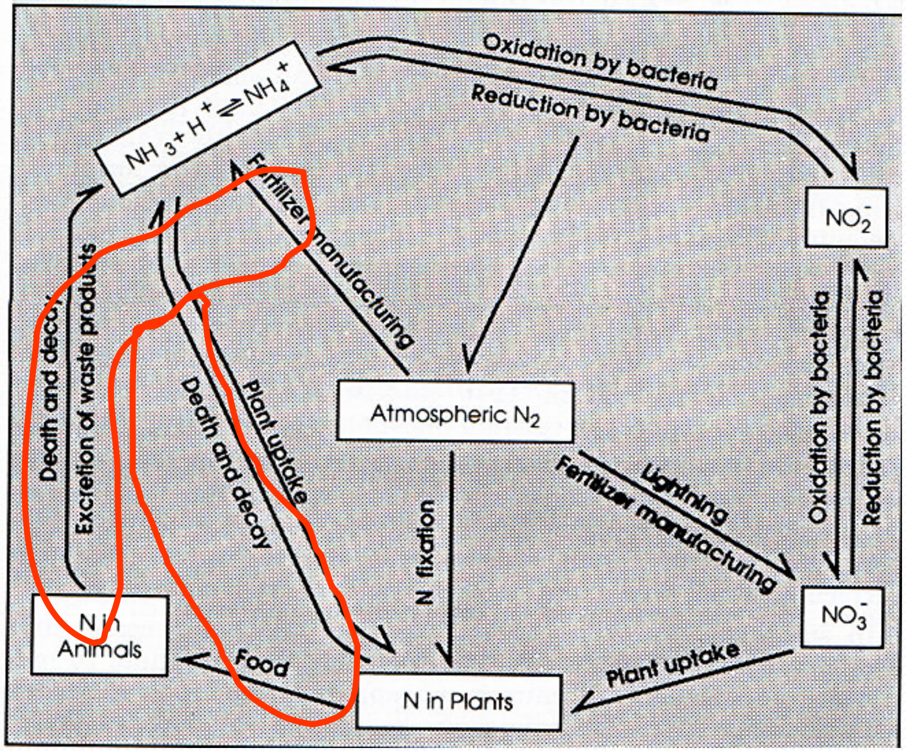


Respiration/Decompostion

- **Proteins pass through food webs, metabolism produces organic nitrogen compounds that return to the environment, chiefly in excretions.**
- **The final beneficiaries are microorganisms of decay.**
- **Microorganisms breakdown organic nitrogen into total ammonia nitrogen (TAN) = NH_4 +NH_3.**

Release of NH_3

- NH_3 released organic protein via microbial activity.
- Process referred to as **deaminification** or **ammonification.**
- NH_3 released to water (mineralization)
- ammonification is *heterotrophic*, under aerobic or anaerobic conditions.



Ammonia (NH_3) Toxicity

- Short-term (acute) toxicity ranges from 0.5-3.8 mg/L for most fish.
- Toxicity tolerance varies due to biological variability of different strains of species.
- Eggs are most tolerant (fish).
- Larvae least tolerant, older fish = more tolerant.
- Same probably holds true for invertebrates.

Nitrogen Equilibria; NH_3/NH_4

- Ammonia (NH_3) toxic to fish/invertebrates.
- pH affects proportion of NH_3/NH_4^+.
- As pH increases, NH_3 increases.
- Example TAN of 1.5 mg/L, 26°C, pH = 8.6
- NH_3/L = 1.5 x 0.1942 = 0.29 mg/l

TABLE 2.16. PERCENTAGE UN-IONIZED AMMONIA IN AQUEOUS SOLUTION AT DIFFERENT pH VALUES AND TEMPERATURES

pH	Temperature (°C)								
	16	18	20	22	24	26	28	30	32
7.0	0.30	0.34	0.40	0.46	0.52	0.60	0.70	0.81	0.95
7.2	0.47	0.54	0.63	0.72	0.82	0.95	1.10	1.27	1.50
7.4	0.74	0.86	0.99	1.14	1.30	1.50	1.73	2.00	2.36
7.6	1.17	1.35	1.56	1.79	2.05	2.35	2.72	3.13	3.69
7.8	1.84	2.12	2.45	2.80	3.21	3.68	4.24	4.88	5.72
8.0	2.88	3.32	3.83	4.37	4.99	5.71	6.55	7.52	8.77
8.2	4.49	5.16	5.94	6.76	7.68	8.75	10.00	11.41	13.22
8.4	6.93	7.94	9.09	10.30	11.65	13.20	14.98	16.96	19.46
8.6	10.56	12.03	13.68	15.40	17.28	19.42	21.83	24.45	27.68
8.8	15.76	17.82	20.08	22.38	24.88	27.64	30.68	33.90	37.76
9.0	22.87	25.57	28.47	31.37	34.42	37.71	41.23	44.84	49.02
9.2	31.97	35.25	38.69	42.01	45.41	48.96	52.65	56.30	60.38
9.4	42.68	46.32	50.00	53.45	56.86	60.33	63.79	67.12	70.72
9.6	54.14	57.77	61.31	64.54	67.63	70.67	73.63	76.39	79.29
9.8	65.17	68.43	71.53	74.25	76.81	79.25	81.57	83.68	85.85
10.0	74.78	77.46	79.92	82.05	84.00	85.82	87.52	89.05	90.58
10.2	82.45	84.48	86.32	87.87	89.27	90.56	91.75	92.80	93.84

Ammonia Toxicity

Species	96-hour LC_{50} (mg/L NH_3)
Pink salmon	0.08-0.1
Brown trout	0.50-0.70
Rainbow trout	0.16-1.10
Largemouth bass	0.9-1.4
Common carp	2.2
Channel catfish	0.50-3.8
Shrimp	5.71

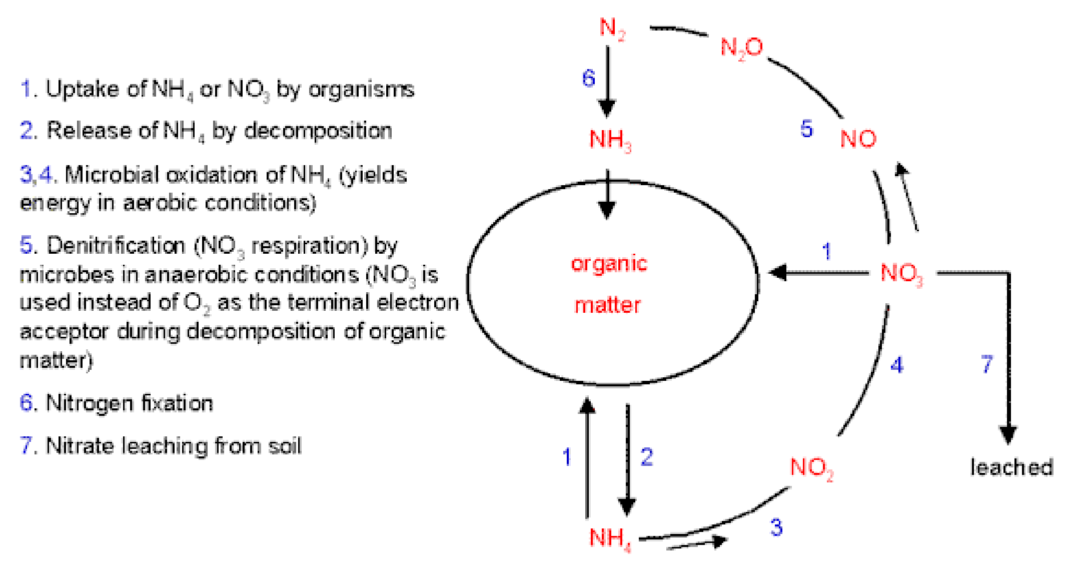
Safe long-term NH_3 (culture levels)
Typically ~ 1/10 of acute or short-term levels

Aquatic Nitrogen Cycling

- Conversion of ammonia (NH_3) to nitrate (NO_3^-) is via **chemoautotrophic** bacteria.
- First step by *Nitrosomonas* sp.
- second step by *Nitrobacter* sp.
- Both steps/reactions use NH_4^+ and NO_2^- as an energy source, CO_2 as a carbon source.
- This is a non-photosynthetic type of growth.

Nitrification

- The term **nitrification** refers to the conversion of ammonium to nitrite followed by conversion to nitrate
- Nitrifying bacteria = **chemoautotrophs.**
- Bacteria gain energy oxidizing NH_3, using CO_2 as source carbon source synthesizing organic compounds.
- Nitrification produces acid, decreasing alkalinity



Nitrite (NO_2^-) Toxicity

Species	48- or 96-hr LC_{50} (mg/L NO_2-N)
Rainbow trout	0.19-0.39
Chinook salmon	0.88
Common carp	2.6
Channel catfish	7.1-13
Largemouth bass	140
Guadeloupe bass	160
Shrimp, freshwater	8.5-15.4
Shrimp, saltwater	45-204 mg/L

Nitrate (NO_3) Toxicity

Species	96-hr LC_{50} (mg/L NO_3-N)
Guppy	180-200
Guadeloupe bass	1,260
Chinook salmon	1,310
Rainbow trout	1,360
Channel catfish	1,400
Bluegill	420-2,000
Shrimp	Who knows???

Denitrification

- NO_3 in soil or water is converted to N_2, nitric oxide or nitrous oxide.
- This occurs under *anaerobic conditions* (anaerobic respiration).
- Presence of O_2 can reverse the reaction.
- mediated by bacteria (*Pseudomonas* sp., *Alkaligenes* sp. and *Bacillus* sp.)
- Denitrification produces base increasing alkalinity