WATER MANAGEMENT (SUPPLY AND QUALITY)

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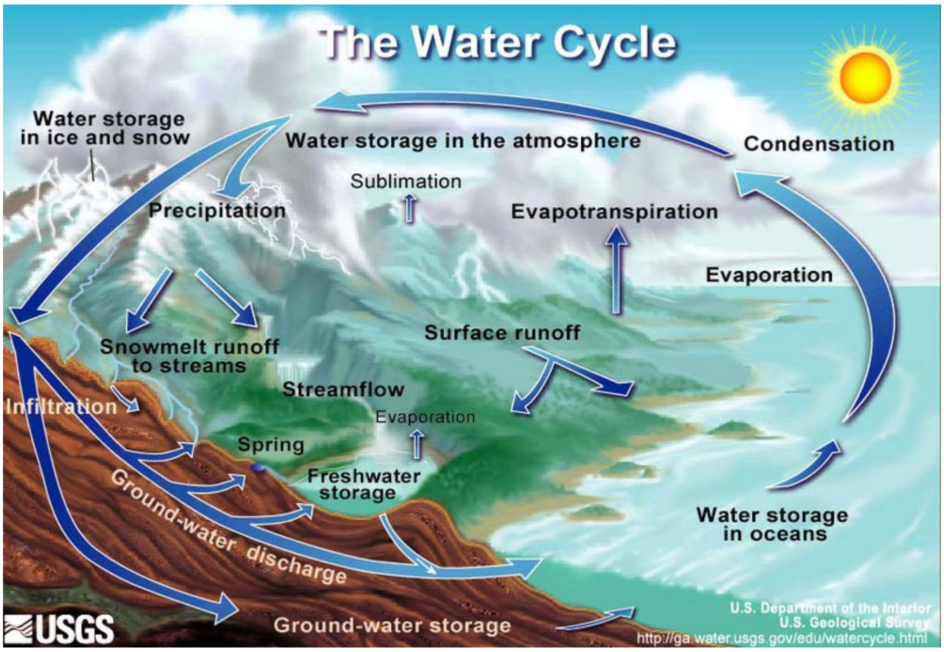
1. INTRODUCTION

Water is vital for sustaining life and well being of people. It is also essential for the production of goods and services. People's quality of life, therefore depend on the availability of water.

1.1 Water: Water (H_2O, HOH) is the most abundant molecule on Earth's surface, composing 70-75% of the Earth's surface as liquid and solid state in addition to being found in the atmosphere as a vapor. It is in dynamic equilibrium between the liquid and vapor states at standard temperature and pressure. At room temperature, it is a nearly colorless, tasteless, and odorless liquid.

Many substances dissolve in water and it is commonly referred to as *the universal solvent*. Because of this, water in nature and in use is rarely clean, and may have some properties different than those in the laboratory. However, there are many compounds that are essentially, if not completely, insoluble in water. Water is the only common, pure substance found naturally in all three state of matter.

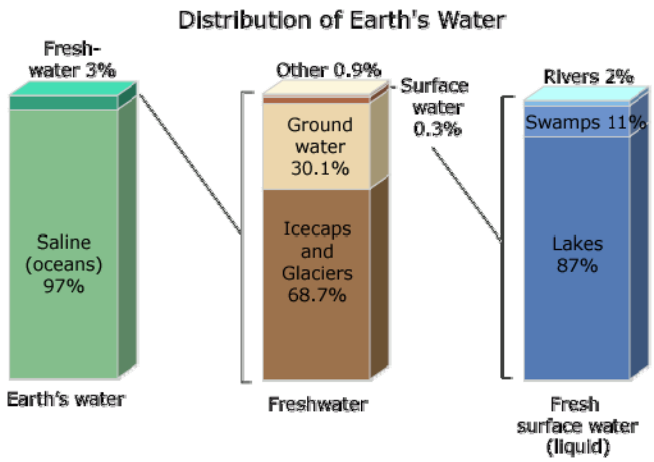


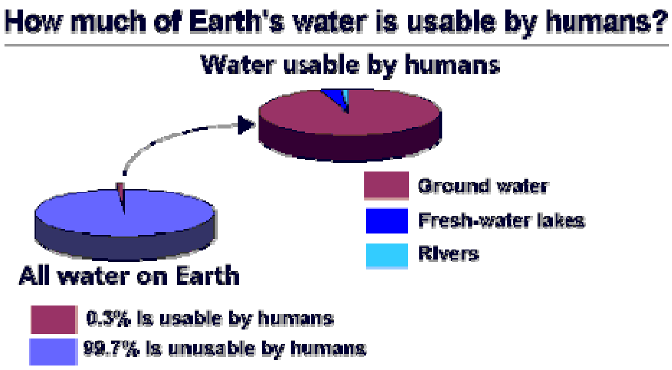
1.2 Water cycle: The water cycle has no starting point. But, we'll begin in the oceans, since that is where most of Earth's water exists. The sun, which drives the water cycle, heats water in the oceans. Some of it evaporates as vapor into the air. Ice and snow can sublimate directly into water vapor. Rising air currents take the vapor up into the atmosphere, along with water from evapo-transpiration, which is water transpired from plants and evaporated from the soil. The vapor rises into the air where cooler temperatures cause it to condense into clouds. Air currents move clouds around the globe; cloud particles collide, grow, and fall out of the sky as precipitation. Some precipitation falls as snow and can accumulate as ice caps and glaciers, which can store frozen water for thousands of years. Snow packs in warmer climates often thaw and melt when spring arrives, and the melted water flows overland as snowmelt. Most precipitation falls back into the oceans or onto land, where, due to gravity, the precipitation flows over the ground as surface runoff. A portion of runoff enters rivers in valleys in the landscape, with stream flow moving water towards the oceans. Runoff, and ground-water seepage, accumulate and are stored as freshwater in lakes. Not all runoff flows into rivers, though. Much of it soaks into the ground as infiltration. Some water infiltrates deep into the ground and replenishes aquifers (saturated subsurface rock), which store huge amounts of freshwater for long periods of time. Some infiltration stays close to the land surface and can seep back into surface-water bodies (and the ocean) as ground-water discharge, and some ground water finds openings in the land surface and emerges as freshwater springs. Over time, though, all of this water keeps moving, some to reenter the ocean, where the water cycle ends

1.3 Water on Earth: The water cycle (known scientifically as the hydrologic cycle) refers to the continuous exchange of water within the hydrosphere, between the atmosphere, soil water, surface water, groundwater, and plants.

Earth's approximate water volume (the total water supply of the world) is 1,360 million km^3. Of this volume:

- 1,320 million km^3 (97.2%) is in the oceans.
- 25 million km^3 (1.8%) is in glaciers, ice caps and ice sheets.
- 13 million km^3 (0.9%) is groundwater.
- 0.250 million km^3 (0.02%) is fresh water in lakes, inland seas, and rivers.
- 0.013 million km^3 (0.001%) is atmospheric water vapor at any given time.





Where is Earth's water located and in what forms does it exist? You can see how water is distributed by viewing these bar charts. The left-side bar shows where the water on Earth exists; about 97 percent of all water is in the oceans. The middle bar shows the distribution of that three percent of all Earth's water that is freshwater. The majority, about 69 percent, is locked up in glaciers and icecaps, mainly in Greenland and Antarctica. You might be surprised that of the remaining freshwater, almost all of it is below your feet, as ground water. No matter where on Earth you are standing, chances are that, at some depth, the ground below you is saturated with water. Of all the freshwater on Earth, only about 0.3 percent is contained in rivers and lakes—yet rivers and lakes are not only the water we are most familiar with, it is also where most of the water we use in our everyday lives exists.

2. AQUACULTURE

2.1 Definition: Aquaculture is the farming of aquatic organisms, including fish, molluscs, crustaceans and aquatic plants. Farming implies some form of intervention in the rearing process to enhance production, such as regular stocking, feeding, protection from predators, etc (Pullin, 1993).

The decline of fish communities in inland water due to pollution was particularly marked during the phase of industrialization in the temperate zone and resulted in the disappearance of many species. This tendency has continued into newly industrialize nations, and many of the river countries by a combination of falling water quality and environmental modification.

It has been suggested that aquaculture will expand to compensate for shortfalls from catches. Certainly, the present trend, with aquaculture as the only fishery sector to be increasing, would appear to support this contention. The continuing rise in production from aquaculture is paralleled by a diversification of the sector, with more and more species entering culture systems.

Aquaculture, like all food production by farming, has large effects on the environment, many of which can be negative: occupation and fragmentation of former natural habitats; reduction of the abundance and diversity of wildlife and changes in soil, water and landscape quality. Because farming will remain the mainstay of most developing country economies for the foreseeable future and will cause much environmental change, it is essential that the potential negative effects of further development of aquaculture be thoroughly appraised. Environmental protection and nature conservation now have much higher profiles in the political arena, mass media and public awareness than before. Environmental impacts at the relatively new frontier of aquaculture need very careful attention (Pullin, 1993).

Intensive aquaculture (in effect, using the feedlot principle) usually poses much greater threats to the environment than does extensive or semi-intensive aquaculture. Intensive fish farms are often heavy users of antibiotics and disinfectants and their operators need to be aware of the dangers of release of such chemicals to the natural environment including the possibilities of producing drug-resistant. Pollution by intensive aquaculture is well known. Fish fecal wastes and uneaten food in effluents from fish farms and in settlement from cages have high biological oxygen demands (BODs) and contain large quantities of particulate matter and nutrients (Pullin, 1993).

2.2 Intensity of Farming Systems (Selected from Edwards, 1993)
a). Extensive Systems rely on natural feed produced without intentional inputs. By definition they are excluded from integrated farming systems except for integrated rice fish farming in which fish may derive benefits from inputs added solely for rice.

b). Semi-intensive systems depend on fertilization to produce natural feed in situ and/or on feed given to the fish, supplementary feed, to complement the natural feed which develops. A significant amount of the fish nutrition is derived from natural feed. Integrated crop-livestock-fish farms and wastewater-fed fishponds have semi-intensive pond systems.

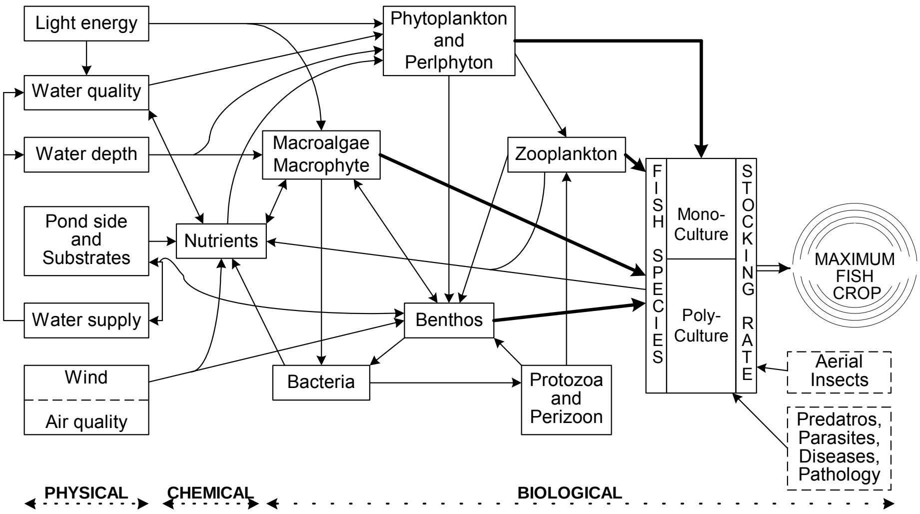
c). Intensive systems depend on nutritionally complete feeds, either in moist formulations or in dried pelleted form, with fish deriving little to no nutrition from natural feed produced in situ.

The degree of intensification is defined according to feeding practice but intensification may be accompanied by increasing amounts of capital, labor and mechanization. Intensive aquaculture has the highest nutrient conversion efficiencies because feed is ideally formulated according to the nutritional needs of the target species. Nutrient conversion efficiencies in term of nutrient inputs and nutrients in fish range of 21-53% for N and 11-28% for P with food conversion ratios (FCR) of 1.0-2.5, respectively. Nitrogen and phosphorus conversion efficiencies of semi-intensive systems are 5-25% and 5-11%, respectively (Edwards, 1993).

The estimated volume of water need for extensive, semi-intensive and intensive culture system assume mean pond depth of 1 m

System	Production(t/ha/year)	Water (m3/t)
Extensive	0.3-0.8	44,000-233,000
Semi-intensive	1.0-5.0	7,000-70,000
Intensive	3.0-8.0	4,000-23,000

3. FISH POND DYNAMICS



ue, violet.

3.1 Light energy

Spectral distribution: Ultraviolet, visible and infrared
Visible region: 400 - 700 nm, including red, orange, yellow, green, blue, violet.
Photosynthetic active radiation (PAR)

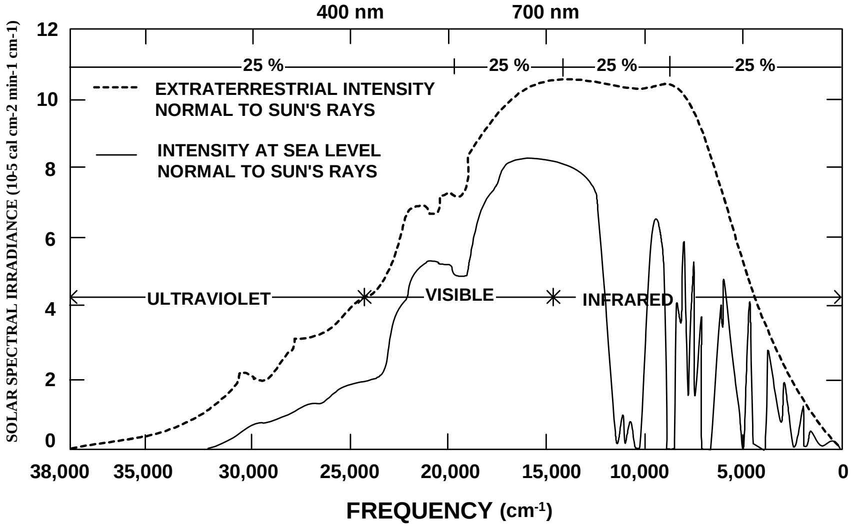
Light penetration = Incident light - (reflection + absorption + scatter)

Reflection: Direct solar radiation reaching the water surface varies with the angular height of the radiation and, therefore, with time of day, season, and latitude. A significant portion of the light is reflected by the surface of the water.

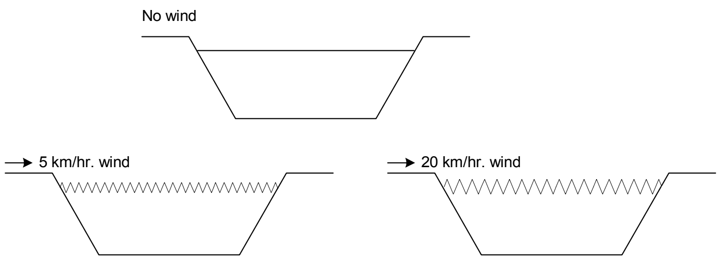
Absorption: Diminution of light energy with increasing depth by transformation to heat Influenced by the molecular structure of water itself, by particles suspended in the water, and especially by dissolved organic compounds. Over half of the solar radiation that penetrates into water is absorbed and dissipated as heat.

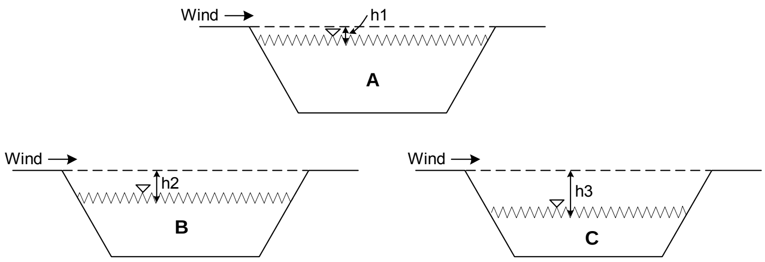
Scatter: Composite of reflection from a massive array of angles existing internally within a water. The extent of scattering in a specific volume of water varies greatly with the distribution of inorganic and organic suspended matter and proximity to sediments.

Measurement is done by using visibility or transparency with a Secchi disc or by using underwater photometer.



3.2 Wind and air quality





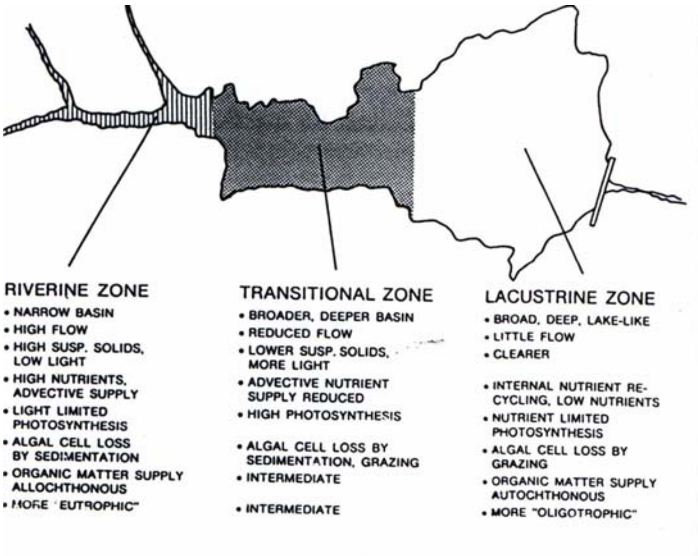
Wind effect A>B>C

Pure water has a pH of 7, and, generally, rainfall is somewhat on the acidic side (a bit less than 6). But, acid rain can have a pH of about 5.0-5.5, and can even be in the 4 range in the northeastern United States, where there are a lot of industries and cars.

Acid rain is a uniquely human-related phenomenon. The burning of fossil fuels (coal and oil) by power-production companies and industries releases sulfur into the air that combines with oxygen to form sulfur dioxide (SO2). Exhausts from cars cause the formation of nitrogen oxides in the air. From these gases, airborne sulfuric acid (H2SO4) and nitric acid (HNO3) can be formed and be dissolved in the water vapor in the air. Although acid-rain gases may originate in urban areas, they are often carried for hundreds of miles in the atmosphere by winds into rural areas. That is why forests and lakes in the countryside can be harmed by acid rain that originates in cities.

3.3 Water supply

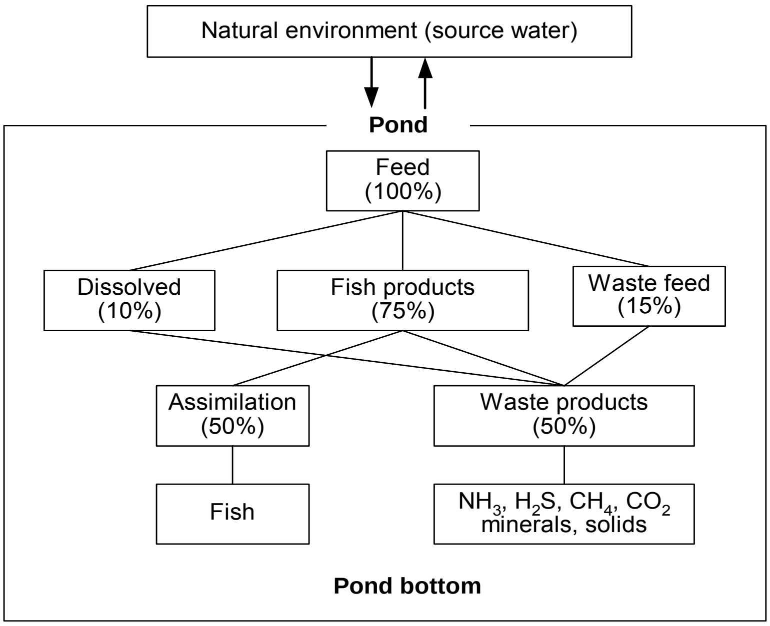
Source: http://www.archives.gov

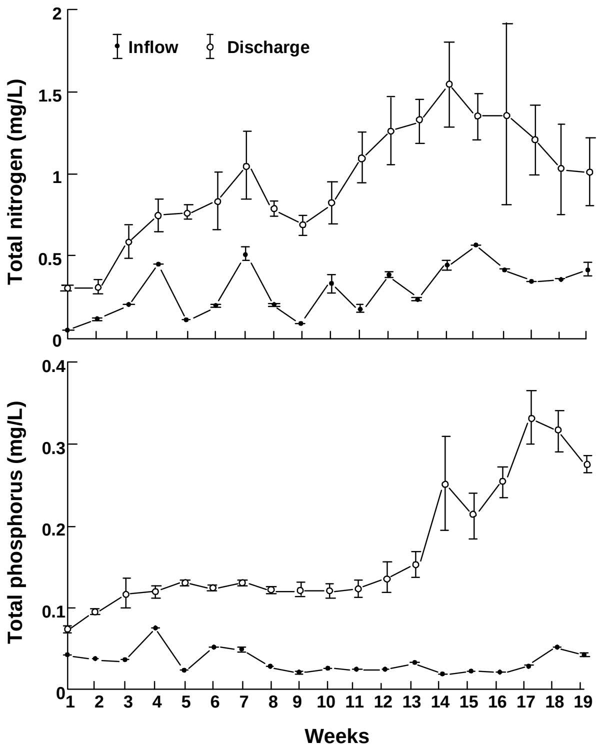


3.3.1 Pond side and substrate

Source of nutrients

- Source water: waters with high alkalinity normally possess, greater concentrations of dissolved minerals.
- Sedimentary regeneration
- Artificial fertilization





Change in P and N concentrations in intensive shrimp ponds.

Uneaten Foods: In both semi-intensive and intensive aquaculture, food is provides. A proportion remain uneaten because of quantities and quality are often inappropriate and because aquaculture systems and their management tend to confound optimization of ingestion. Study indicates that the proportion of uneaten food varies from around 1% to as much as 30% and confirm that system, type of feed and management are important determinants of wastage. Available data suggest that feed losses associated with pelleted feed are less than for trash fish (although if the dry matter content of feeds is taken into account, the significance of these differences is negligible) and that the proportion of uneaten food in cages is considerably greater than those from tanks or ponds.

Excreta: The undigested fraction of feed, together with mucus, sloughed intestinal cells and bacteria, is voided as feces whilst the digested portion is absorbed and metabolized. Nutrients absorbed in excess to requirements may be excreted together with end-products (ammonia and urea) derived from the catabolic breakdown of protein for energy purposes.

It is possible to estimate the fecal production associated with a diet from digestibility data on the principal constituents. Although this approach necessarily ignores the effects of variables such as temperature, body size, health, feeding rate and the synergistic/antagonistic effect of one dietary component on the digestibility of another, such estimates have been found to approximate those obtained by direct measurement.

Artificial fertilization

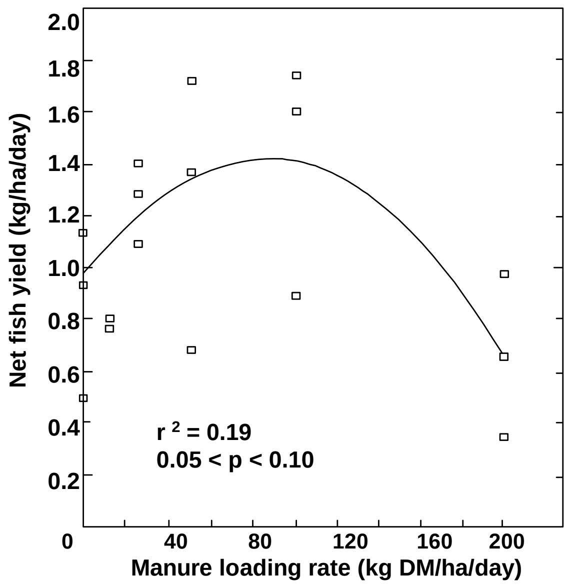
Fertilization: To stimulate phytoplankton production, thereby increase fish food organisms and fish yield.

Fertilizers:

- Inorganic fertilizer stimulate primarily autotrophs and related food chain organisms
- Organic fertilizers act on heterotrophs and autotrophs

Inorganic fertilizers supplement to organic fertilizers: As animal wastes often contain nitrogen and phosphorus concentrations that are not in balance as required for optimal phytoplankton production, it is necessary to supplement the manures with inorganic fertilizer source (N/P) to make the more desirable ingredients.

Fertilizer application rate and frequency:
As the complication relating to the effectiveness of fertilization discussed above, it is difficult to offer a set of quantitative formula for fertilization rate applicable to all situations. In general, to maintain a level of phytoplankton production at 20-40 cm. Secchi disc depth (@80-300 mg chl a / m^3), the total P and N concentrations in the water column should be kept at a range of 0.2-0.5 mg P/L and 1-3 mg N/L, with a N:P ration of 5-10:1. In principle, greater frequency of fertilization gives greater stability of nutrient concentration level in water thus maintain even stable biological productivity. In practice, twice per week to weekly application is adequate frequency.



Off-Flavor

Off-flavor fish make taste muddy, weedy, or rancid, making fish product unmarketable or offered at low price.

Chemical compounds cause off-flavor:

- Geosmin ($C_{12}H_{22}O$),
- Methyhsobomeol (MIB, $C_{11}H_{20}O$),
- Mucidone ($C_{16}H_{18}O_2$)
- Threshold concentration for off-flavor is <1 µg/kg fish

The compounds may occur in the water, mud, microorganisms, and fish; can be extracted by distillation and separated by methylene and analyzed by gas-liquid chromatography. Fish take up the off-flavor compounds from gills and transferred to blood throughout the body, or from food ingestion.

Organisms produce off -flavor substances:

- Blue-green algae: *Anabacna scheremetievi, Lyngbya best, Oscillatoria agardhii, O. bornetii fa.* Tenuis, O. *cortiana, O. prolifica, O. simplicissima, O. spiendida, O. tenuis, O. variabilis, Schizothrix muelleri, Symplow muscorum, Lyngbya cryptovaginata, Oscillatoria curviceps, O.* tenuis var. levis
- Fungi: (Actinomycetes - *Streptomyces* spp.)

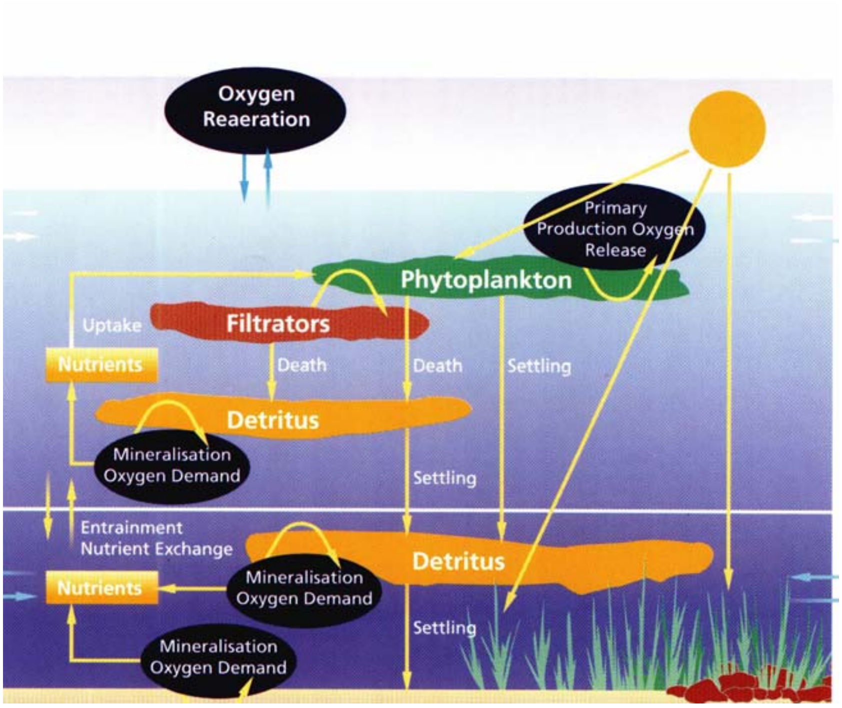
Environmental conditions influence off-flavor organism growth

- High organic matter in the ponds that provide substrate for fungal growth.
- *Streptomycete* spp. can be inhibited by low D.O. content in the ponds
- The walking catfish and snakehead grown in low D.O. with little phytoplankton growth seldom have off-flavor problem.
- The optimal temperature for off-flavor causing organisms ranged from 25-30°C
- Alkaline water and soil favor growth of off-flavor organisms.

Preventive measures for off-flavor problems

- Avoid accumulation of organic in the pond bottom.
- Prepare pond bottom by removing excessive organic matter and through sun dry.
- Chemical compounds to control off-flavor organisms - $CuSO_4$, Simazine.
- NaCl (10 mg/L) inhibits Streptomycete growth.
- Sea fish have few off-flavor incidence.

3.3.2 Water depth



3.3.3 Water quality

a) Temperature

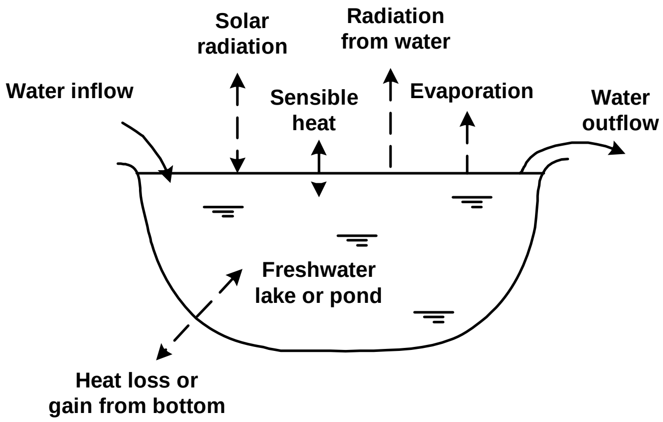
Temperature affects on feeding, reproduction, immunity, and the metabolism of aquatic animals. Drastic temperature changes can be fatal to aquatic animals. Not only do different species have different requirements, but optimum temperatures can change or have a narrower range for each stage of life.

All species tolerate slow seasonal changes better than rapid changes. Thermal stress or shock can occur when temperatures change more than 1-2 .C in 24 hours. The heat capacity of water is very high, making it resistant to changes in temperature. This moderates the daily and seasonal climatic changes in temperature. But cooling is often impractical and heating is possible but costly. Water temperature is an important variable in many chemical tests and electronic measures for water quality. Many determinations require adjustment for the temperature or noting the temperature at the time of sampling.

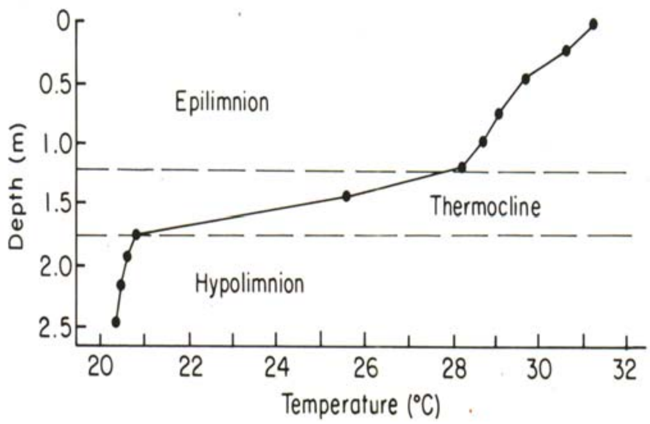
Water temperature affects many biological chemical processes. Spawning is triggered by temperature. Temperature differences between the surface and bottom waters help produce vertical current moving nutrients and oxygen throughout the water column. Temperature influences the solubility of oxygen and the percentage of unionized ammonia in water.

Gains: solar radiation + water inflow + geoheat

Losses: reflection + evaporation + water outflow + substrate



Thermal energy flow in aquatic environment



b) Transparency

Although the measurement of extinction coefficients and spectral characteristics of underwater irradiance is commonly done with photometer, an proximate evaluation of transparency of water can be made with a Secchi disc. The Secchi disc is a weighted white disc, 20 cm in diameter.

Transparency, estimated in this way, is the mean of the depths at which the Secchi disc disappears when viewed from the shaded side of the boat and at which it reappears upon rising after it has been lowered beyond visibility.
Secchi disc transparency is basically a function of reflection of light from the surface of the disc and is therefore affected by the absorption characteristics of the water and of dissolved and particulate matter contained in the water.

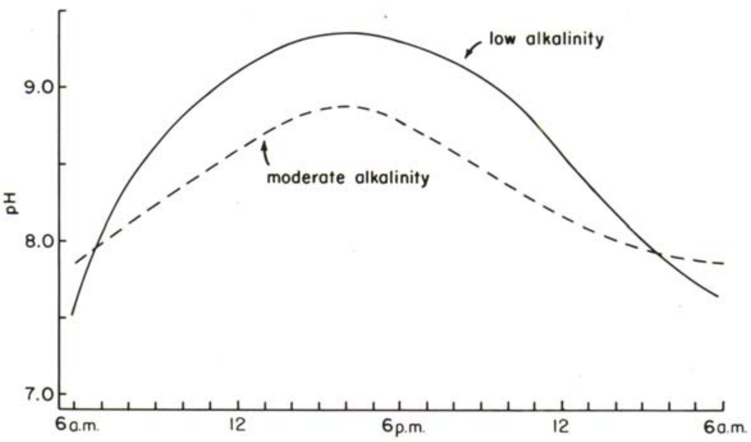
High concentrations of organic matter decrease transparency in a nonlinear way as measured with Secchi disc, reduction in light transmission as evaluated by the disc is influenced strongly by increased scattering of light by suspended particulate matter.

c) Alkalinity and Hardness (Selected from Parker, 1995)
This is a measure of the basic substances of water. Because in natural water these substances are usually carbonate and bicarbonate the measurement is expressed as mg/L of equivalent calcium carbonate. In some cases, such as many groundwater and western ponds, sodium carbonate is the predominant basic substance. These basic substances resist change in pH (buffering) and where an abundance of calcium and magnesium bicarbonate is dissolved the pH will stabilize between 8 and 9. Some laboratory forms report carbonate (CO_3^{2-}) and bicarbonate (HCO_3^-) in addition to total alkalinity. These are typically derived from alkalinity measurement by multiplication by standard conversion factors.

Total hardness is the measure of the total concentration of primarily calcium and magnesium expressed in milligram per liter (mg/L) of equivalent calcium carbonate (CaCO3). Calcium and magnesium are usually present in association with carbonate as calcium carbonate or magnesium carbonate. Total hardness relates to total alkalinity and indicates the water's potential for stabilizing pH. Water can be high in alkalinity and low in hardness if sodium and potassium are dominant. Table below lists water hardness classifications as mg/L of $CaCO_3$.

Water Hardness Levels (Parker, 1995)

Water hardness	**mg/L $CaCO_3$**
Soft	0-20
Moderately soft	20-60
Moderately hard	61-120
Hard	121-180
Very hard	>180

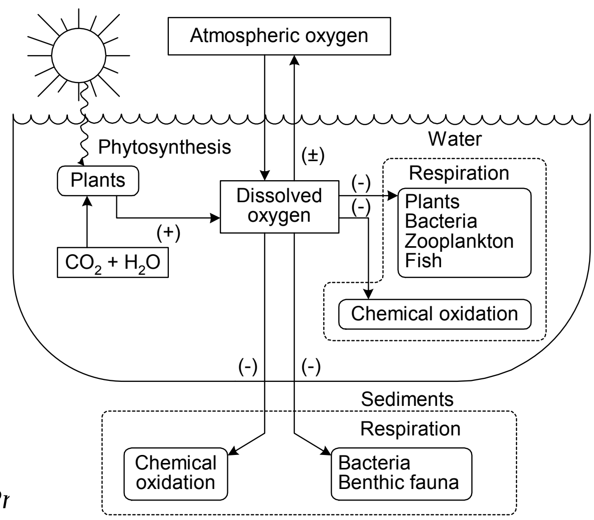


d) pH
The pH is one of the most common water tests-is a measure of hydrogen ions in the water. The pH scale spans a number of ranges of 0-14 with the number 7 being neutral. The pH scale is logarithmic, so every one-unit change in pH represents a ten-fold change in acidity. Measurement above 7 is basic and below 7 is acidic. The farther a measurement is from 7, the more basic or acidic is the water. Acid and alkaline (basic) death points for fish are approximately pH 4 and 11. Growth and reproduction can be affected between pH 4-6 and 9-10 for some fishes. Also, pH affects the toxicity of other substances, such as ammonia and nitrite.

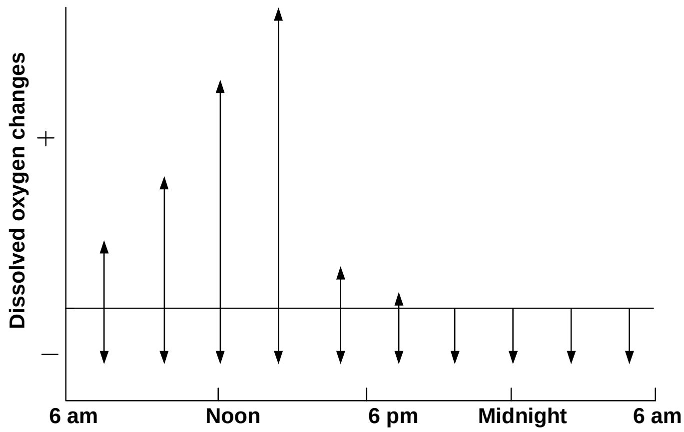
The pH of some ponds may change during the course of a day and is often between 9 and 10 for short periods of afternoons. Fish can usually tolerate such rises that result when carbon dioxide, and acidic substance, is used up by plants in photosynthesis. The most common pH problem for pond fish is when water is constantly acidic. The nature of the bottom and watershed soil is usually responsible. Water with a stable and low pH is only correctable with liming.

e) Dissolved Oxygen (D.O.) (Selected from Parker, 1995)
Aquatic life requires D.O. It varies greatly in natural surface water and is characteristically absent in ground waters. Most aquatic animals need more than a 1 mg/L concentration for survival. Depending on culture circumstances, aquatic animals need 4-5 mg/L to avoid stress. Concentrations considered typical for surface water are influenced by temperature but usually exceed 7 to 8 mg/L. In ponds, dissolved oxygen fluctuates greatly due to photosynthetic oxygen production by algae during the day and the continuous consumption of oxygen due to respiration. D.O. typically reach a maximum during the late afternoon and a minimum around sunrise. Cloudy weather, rain, plankton die-off, and heavy stocking and feeding rates result in low levels of dissolved oxygen, which can stress or kill fish.

Oxygen is only slightly soluble in water. Water may be frequently supersaturated with oxygen in ponds with algae blooms. For example, at sea level at temperature of 77.F (25.C), pure water contain about 8 mg/L of oxygen when 100 percent saturated, but during the afternoon hours, levels of 10 to 14 mg/L in ponds with healthy algae blooms are not uncommon.



Pr *h pond*



As water warms, is raised to higher altitudes, become more saline, its oxygen holding capacity declines. Water saturated with oxygen at 59.F (15.C) contains about 9.8 mg/L, while water at 86.F (30.C) is saturated at about 7.5 mg/L.

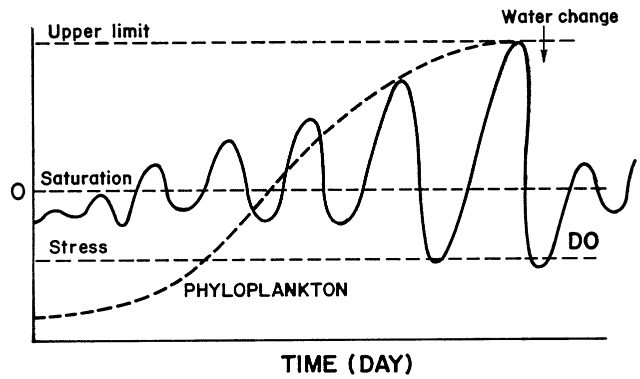
Guidelines for oxygen management usually report that oxygen levels should be maintained above 4 mg/L to avoid stress. Most warmwater fish experience significant oxygen stress at levels of 2 mg/L, and that levels of less than 1 mg/L may result in fish kills. While these guidelines are accurate, fish actually respond to the percent saturation of oxygen rather than the oxygen content in water. A reading of 1 mg/L at 30.C (13.3 percent saturated) is a higher concentration than 1 mg/L at 15.C (10.2 percent saturated) and represents more available oxygen.

If dissolved oxygen reaches low levels, fish will show signs including;

- Not eating and acting sluggish
- Gasping for air at the surface
- Grouped near water inflow pipe
- Slow growth
- Outbreaks of disease and parasites.

Proper water management prevents the problems from depletion of dissolved oxygen. Management techniques include;

- Monitoring dissolved oxygen at critical times
- Avoiding overfeeding
- Proper stocking level
- Avoiding over-fertilization
- Controlled plant growth
- Some form of aeration
- Keeping water circulation



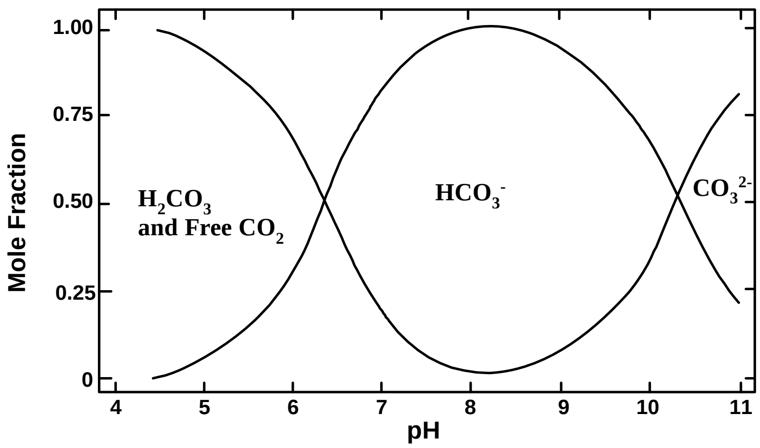
f) Carbon dioxide (CO_2) (Selected from Parker, 1995)

Carbon dioxide (CO_2), a minor component of the atmosphere, is slightly soluble in water. Most carbon dioxide in pond water occurs as a result of respiration. Levels usually fluctuate inversely to dissolved oxygen, being low during the day and increasing at night, or whenever respiration occurs at a greater rate than photosynthesis.

Carbon dioxide is present in surface water at less than 5 mg/L concentrations but may exceed 60 mg/L in many well waters and 10 mg/L where fish are maintained in large numbers. Some aquatic animals, including fish can endure stress and survive at up to 60 mg/L. If oxygen is lowered into its stress-causing range, carbon dioxide limitation is reduced to 20 mg/L.

Carbon dioxide interferes with the ability of the aquatic animals to extract oxygen from water, contributing to stress of fish during periods of low oxygen. Aerating water to improve its oxygen content drives off excess carbon dioxide.

Adding quick lime, $Ca(OH_2)$ to water rapidly removes carbon dioxide without affecting oxygen content. This improves the ability of fish to use the available oxygen. Carbon dioxide acts as an acid in water, lowering pH as it increases in concentration. Carbonate buffers in water neutralize carbon dioxide and stabilize pH fluctuations within the range tolerated by fish. Water low in alkalinity and hardness may experience extremes of pH due to its poor buffering against changes in carbon dioxide concentrations.



Effect of pH on the relative proportion of H_2CO_3 and free CO_2 (total CO_2), HCO_3^-, and CO_3^{-2} (Boyd, 1988).

g) Hydrogen Sulfide (H_2S) (Selected from Parker, 1995)
Hydrogen Sulfide, rotten-eggs gas, is present in some well waters but is so easily oxidizable that exposure to oxygen rapidly converts it to harmless form. Its toxicity depends on temperature, pH, and dissolved oxygen. Any measurable amount after providing reasonable aeration could be considered to have potential to harm fish life.

Hydrogen sulfide occurs in ponds as a result of the anaerobic decomposition of organic matter by bacteria in mud. Hydrogen sulfide is toxic to fish and interferes with normal respiration. Toxicity is increased at higher temperatures and a pH less than 8 when the largest percentage of hydrogen sulfide is in the toxic unionized form. Vigorous aeration or splashing is usually sufficient to remove hydrogen sulfide from well water.

In ponds, hydrogen sulfide can be released from anaerobic mud when the bottom is disturbed by seining and harvest activities. Liming ponds raises mud pH and reduces the potential for the formation of H_2S. Potassium permanganate at 2 to 6 mg/L removed H_2S from water and reverses the effects of its toxicity to fish.

h) Ammonia (NH_3) (Selected from Parker, 1995)
Ammonia is present in slight amounts in some well and pond waters. As fishes become more intensively cultured or confined, ammonia can reach harmful levels. Any amount is considered undesirable, but stress and some death loss occurs at more than 2 mg/L, and at more than 7 mg/L fish loss increases sharply.

Ammonia is waste product of protein metabolism by aquatic animals. In water, ammonia occurs either in the ionized (NH_4^+) or unionized (NH_3) form, depending on pH. Unionized ammonia is considerable more toxic to fish and occurs in greater proportion at high pH and warmer temperatures. For example, at 82.4.F (28C) and pH 8,

6.55 percent of the total ammonia is present in ionized form. At pH 9, 41.23 percent of the ammonia is unionized. Unionized ammonia is stressful to warm water fish at concentrations greater than 0.1 mg/L and lethal at concentrations approaching 0.5 mg/L. Concentrations of 0.0125 mg/L cause reduces growth and gill damage in trout. Algae use ammonia as a nitrogen source for making proteins. Concentration usually remains low in ponds with phytoplankton blooms. The greatest concentration of ammonia often occurs after phytoplankton die-offs, at which time pH is low due to high levels of carbon dioxide, and the majority of ammonia is present in the relatively nontoxic ionized form.