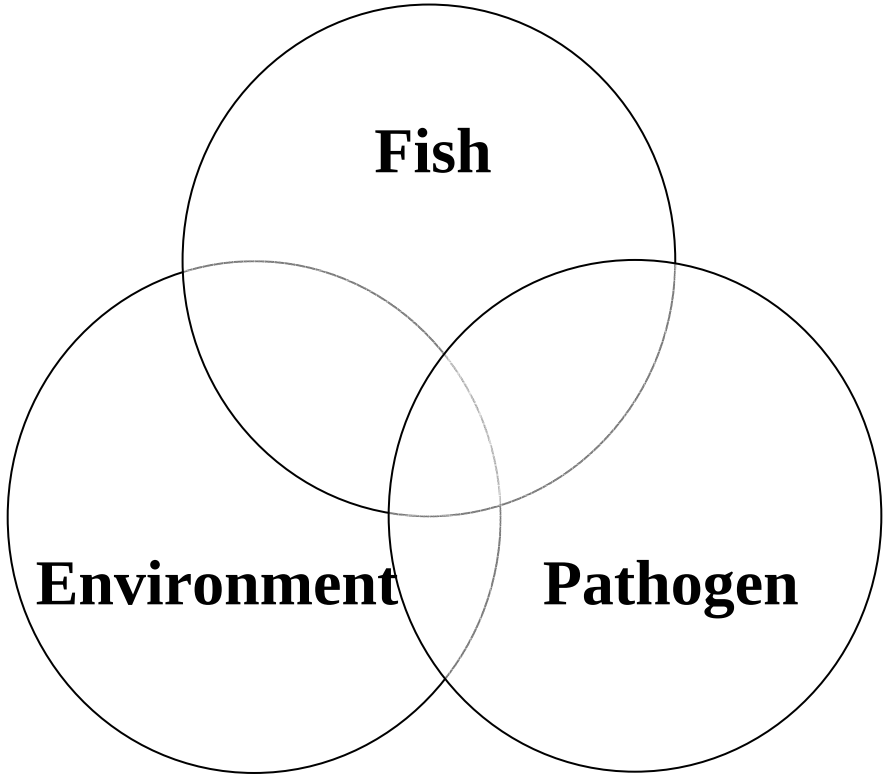
Water Quality Management

Fundamentals for optimal performance and on-farm disease prevention and control

- Good husbandry
- Good nutrition
- Good genetic stock
- Good management
- Good environment
- Good bio-security



Importance of Water quality

Fish perform all bodily functions in water which include

- eating,
- breathing,
- Excreting wastes,
- reproducing
- taking in or removing salts.

- Water quality within aquaculture ponds can affect these functions and therefore will determine the health of the fish and consequently the success or failure of a fish farming operation.

- Water quality is divided up into different characteristics
- physical,
- biological
- chemical.

Physical parameters

Parameter	Recommended Limits
Temperature	Varies among species
Turbidity	<20 Natelson turbidity units (NTU), in hatchery
Total Dissolved Solids	<200 mg/L
Total Suspended Solids	<80 mg/L
Colour	Varies

Chemical Parameters

- Salinity (ppt)
- pH
- Alkalinity (ppm)
- Dissolved oxygen (DO, ppm)
- Ammonia (ppm)
- Nitrite (ppm)
- Nitrate (ppm)
- Chlorine (ppm)
- Hydrogen sulfide (ppm)

Water chemistry (criteria) limits recommended (for fish)

Oxygen

- 6 mg/L, coldwater fish
- 4 mg/L, warm water fish

Nitrite <0.1 mg/L

Nitrate <1.0 mg/L

Hydrogen sulfide <0.003 mg/L

Chlorine <0.003 mg/L

Ammonia (un-ionized)

- <0.02 mg/L (long term)
- 0.2-0.5 ppm (acute)

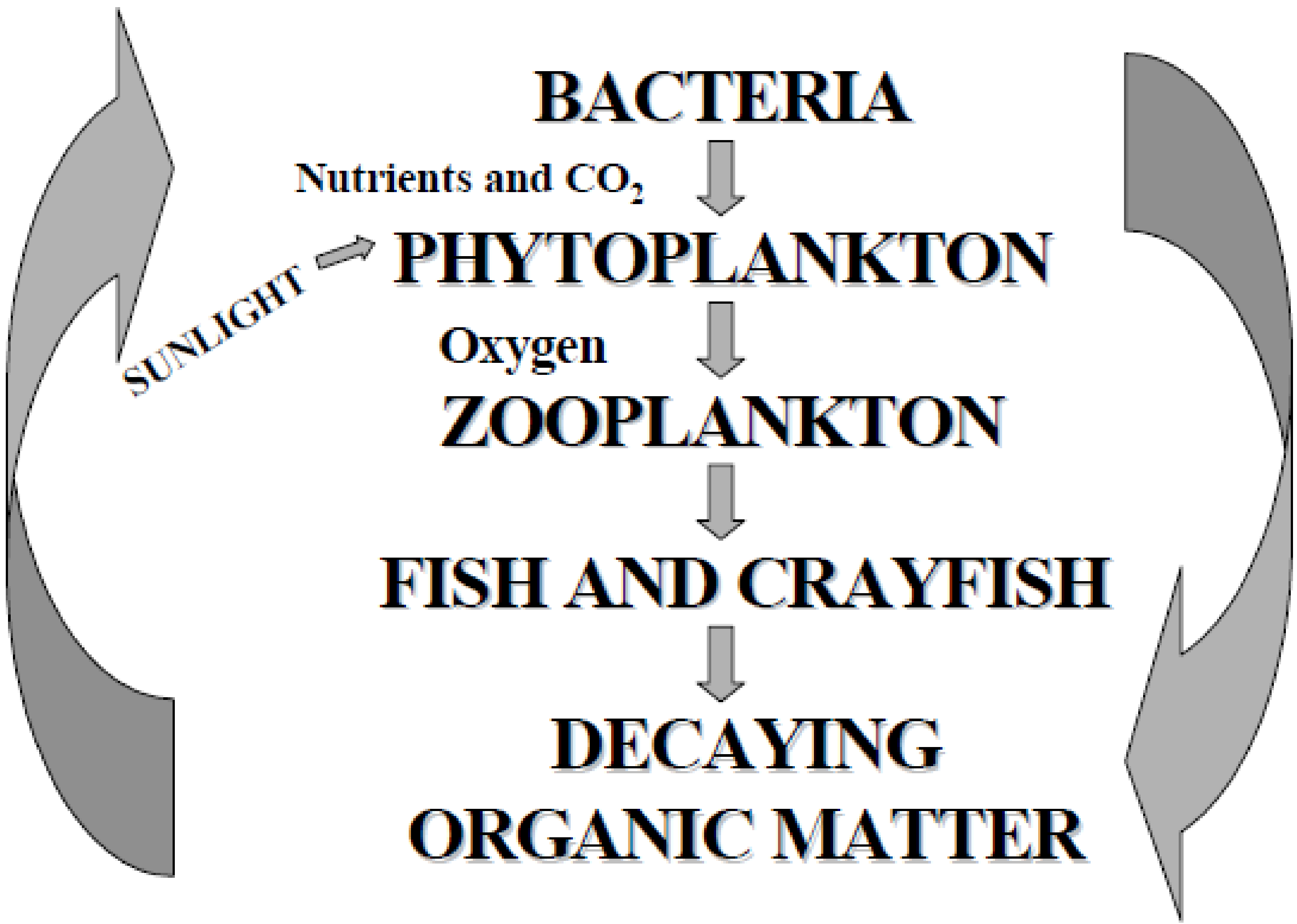
- Alkalinity >20 mg/L (as CaCO3)
- Acidity pH 6-9

Biological Parameters

- Phytoplankton, diatom, dynoflagellate,
- Zooplankton
- Benthos
- Water plant
- Water Insect
- Protozoa
- Bacteria (e.g. nitrifying bacteria)
- Fungi

Nutrient cycle

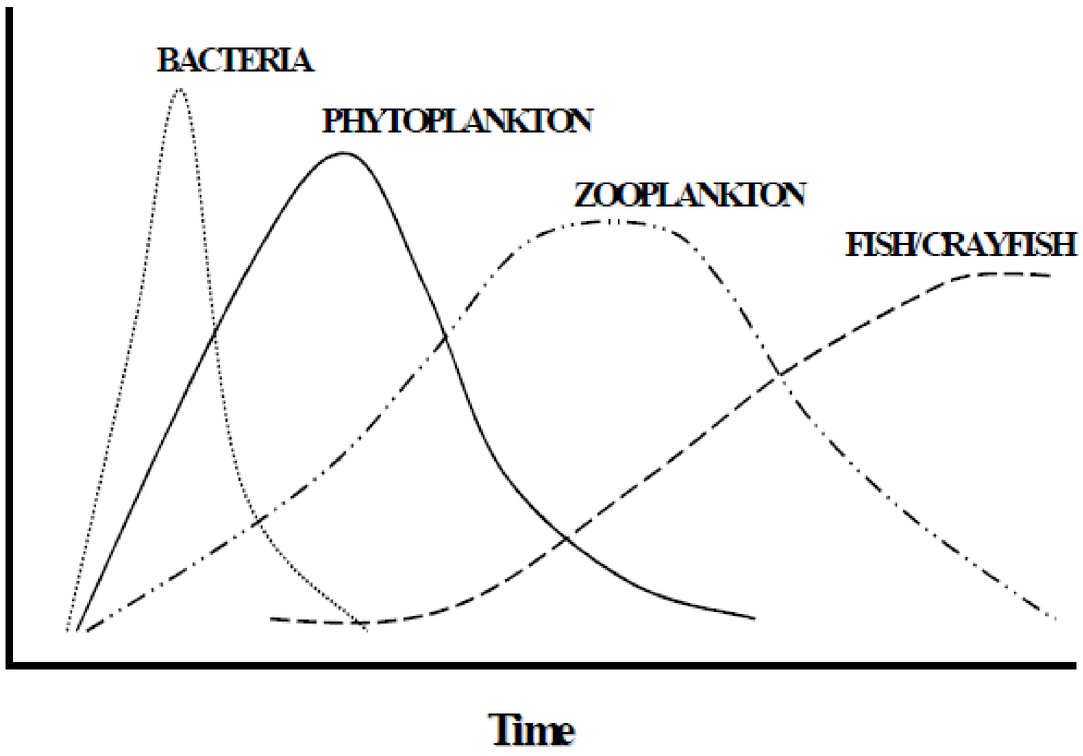
- Bacteria form the base of the food chain within an aquaculture pond.
- Bacteria break down organic matter to produce nutrients such as phosphorus and nitrogen, and carbon dioxide (CO2).
- These products are then utilised by phytoplankton, microscopic algae, to produce oxygen via photosynthesis.
- Oxygen and phytoplankton are then consumed by zooplankton which are tiny aquatic organisms.
- Fish feed on zooplankton as well as larger aquatic plants and supplementary feed that may be added to the aquaculture ponds.
- Uneaten supplementary feed, dead aquatic organisms (including planktonic organisms and aquaculture species) and animal wastes will settle on the pond floor.
- Bacteria will feed on this decaying organic matter and the cycle will commence again.



BACTERIA
Nutrients and CO_2
SUNLIGHT
PHYTOPLANKTON
Oxygen
ZOOPLANKTON
FISH AND CRAYFISH
DECAYING
ORGANIC MATTER

Succession

- The aquatic organisms within an aquaculture pond will vary over time
- It is therefore important to have a good understanding of the population dynamics within your pond to stabilise population numbers of aquatic organisms and to ensure that the system will not crash.



Chemical Characteristics

- Chemical characteristics refer to the water quality parameters that are measured within an aquaculture pond.
- Water quality in ponds change continuously and are affected by each other along with the physical and biological characteristics that have been mentioned previously.
- With this in mind water quality should be monitored regularly.
- This can be achieved by recording simple visible water characteristics such as water colour, clarity, plant and animal life.
- Alternatively relatively inexpensive testing kits and recording probes (more expensive) can be purchased from analytical supply stores.

Dissolved Oxygen

- Dissolved oxygen is probably the most critical water quality variable in freshwater aquaculture ponds.
- Oxygen levels in ponds systems depend on water temperatures, stocking rates of aquaculture species, salinity, and the amount of aquatic vegetation and number of aquatic animals in the ponds.
- Dissolved oxygen concentrations will vary throughout the day. Dissolved oxygen in the water is obtained through diffusion from air into water, mechanical aeration by wind or aeration systems, and via photosynthesis by aquatic plants

$$6CO_2 + 6H_20 + \text{Sunlight} \rightarrow C_6H_{12}O_6 + 6O_2$$

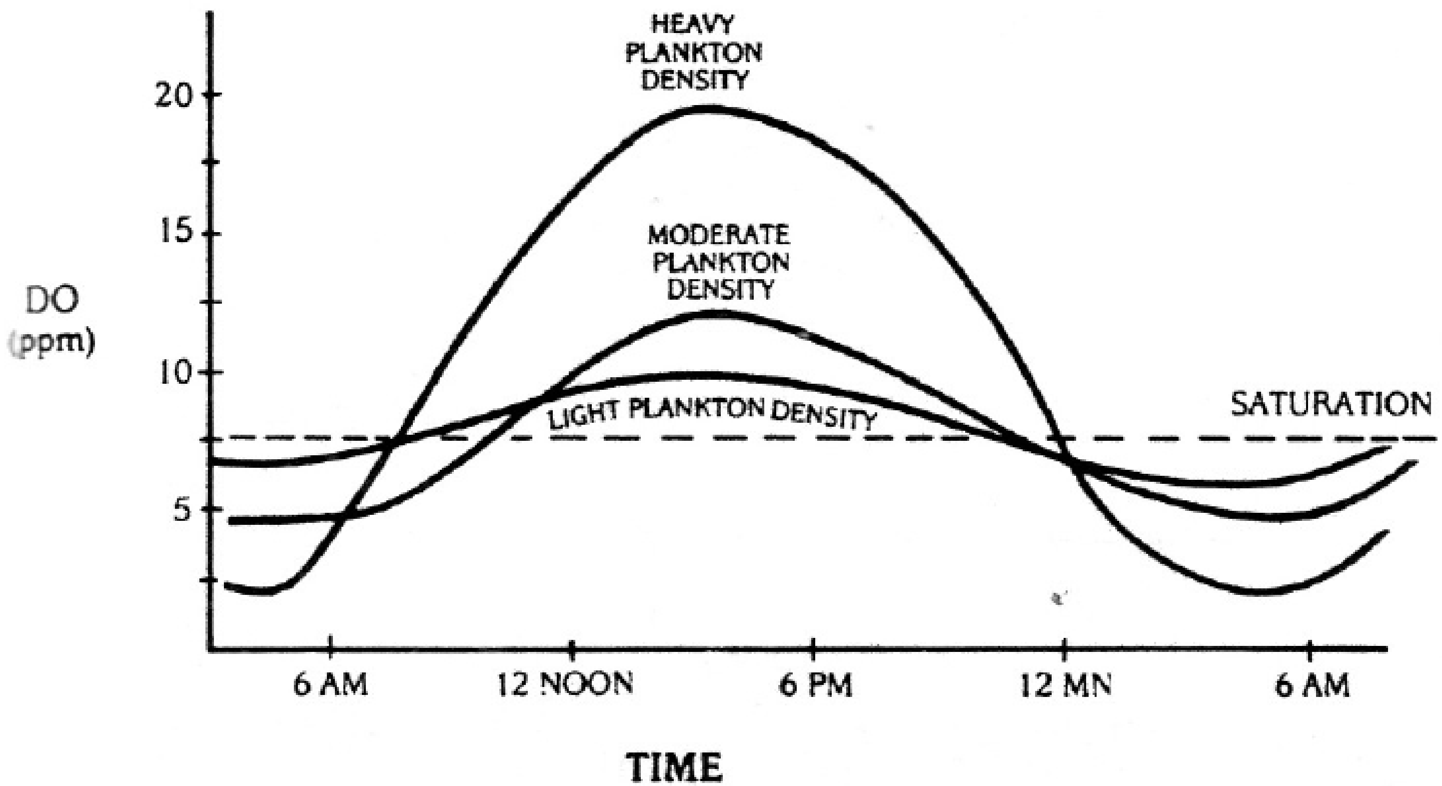
Carbon Dioxide — *Water* — *Sugar* — *Oxygen*

Photosynthesis

Oxygen

- Oxygen is also lost from the system via respiration where oxygen is consumed by aquatic organisms (both plants and animals), and by decaying organic matter on the pond floor.
- Declining oxygen levels can be caused by a number of factors. This includes large blooms of phytoplankton and zooplankton, high stocking rates, excessive turbidity that will limit the amount of photosynthesis occurring and high water temperatures.
- Levels of dissolved oxygen will also decrease after a series of warm, cloudy, windless days.
- Low dissolved oxygen can be lethal to our aquaculture species. Some effects include stress, increased susceptibility to disease, poor feed conversion efficiency, poor growth and even death.

Changes in Oxygen level due to different algae density



Oxygen

- A number of ways to improve low oxygen levels.
- There are different types of aeration systems that help circulate and oxygenate the water.
  - Airlift pumps
  - Paddle wheels,
  - Aspirator pumps
  - Diffused air systems.
- Flushing ponds with fresh water and reducing feeding rates will also help increase oxygen levels within the ponds.

Oxygen

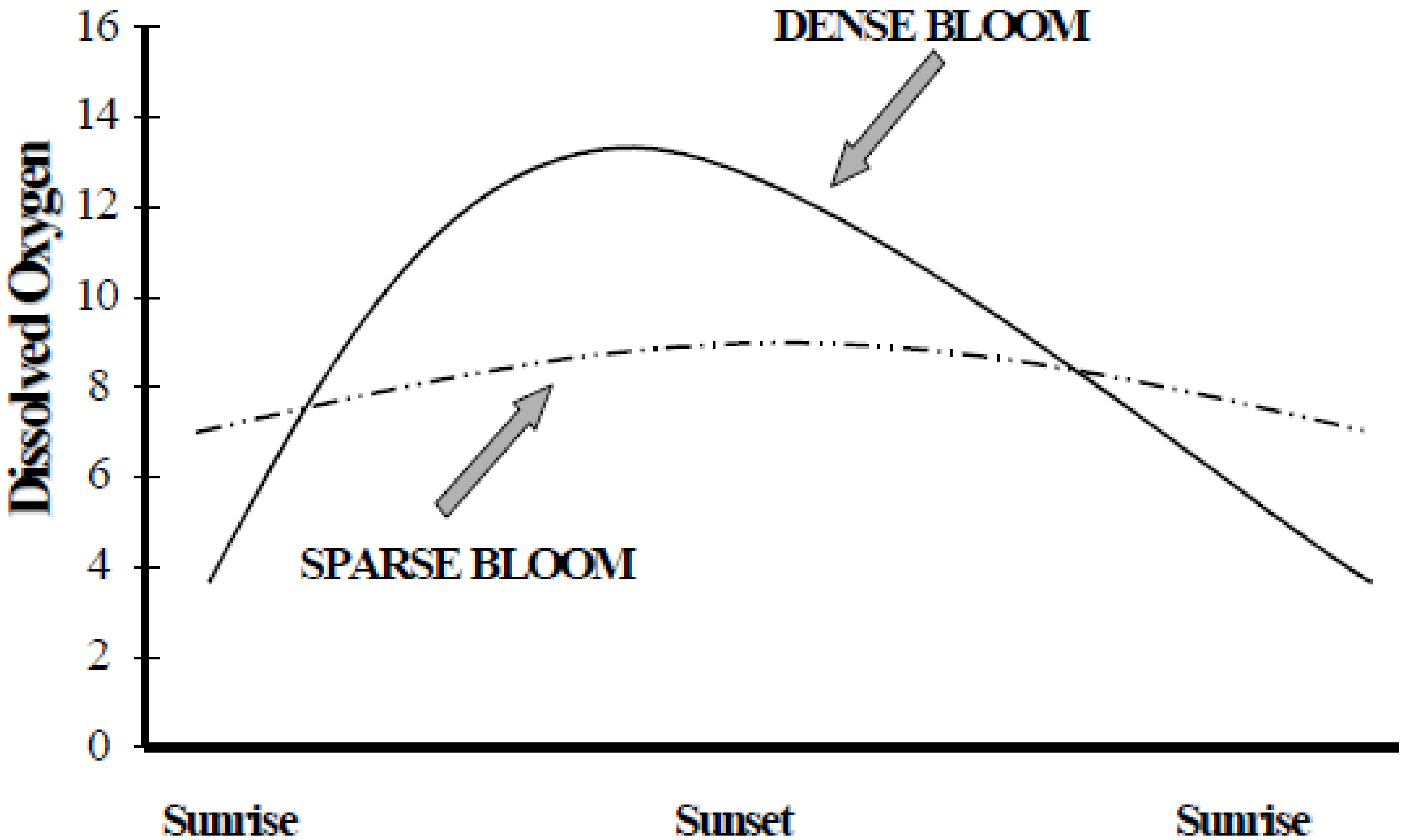
When taking measurements of dissolved oxygen within an aquaculture ponds it is important to note that readings will alter depending on

- the time of day,
- the amount of plant growth within in the pond,
- the position in the pond from where the measurement was taken.

This is due to the following reasons.

- Aquatic plants, algae or phytoplankton are present in large numbers will produce high oxygen levels during the day due to photosynthesis.
- However at night these organisms consume oxygen rather than producing it via photosynthesis which may result in dangerously low oxygen levels
- Therefore if the pond has extremely high oxygen levels during the day there may be a good chance they will drop considerably at night.

Oxygen dynamics



pH

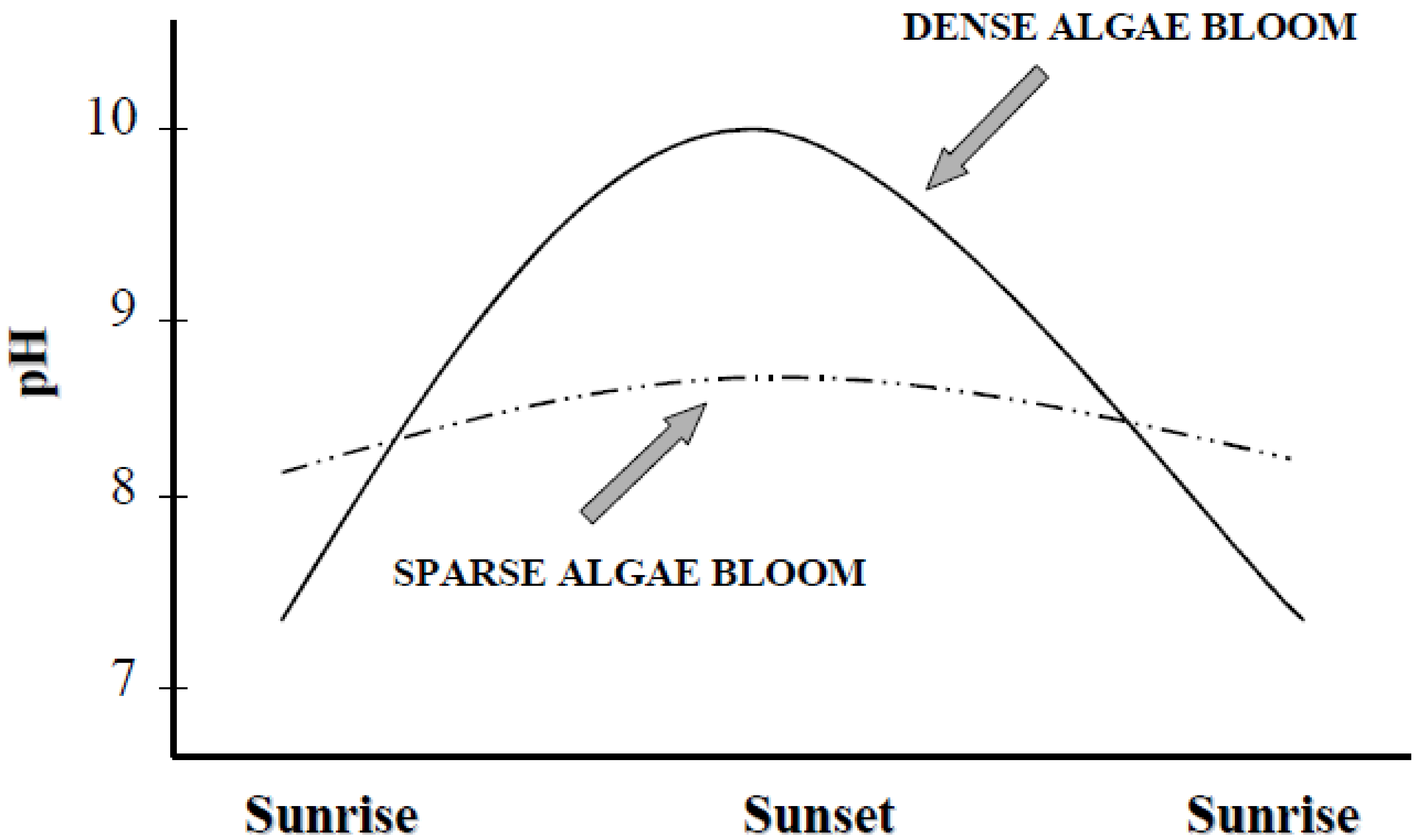
- The pH is the measure of the hydrogen ion (H+) concentration in soil or water. The pH scale ranges from 0 – 14 with a pH of 7 being neutral. A pH below 7 is acidic and an pH of above 7 is basic.
- An optimal pH range is between 6.5 and 9 however this will alter slightly depending on the culture species.
- The pH is not dependent on other water quality parameters, such as carbon dioxide, alkalinity, and hardness.
- It can be toxic in itself at a certain level, and also known to influence the toxicity as well of hydrogen sulfide, cyanides, heavy metals, and ammonia

pH

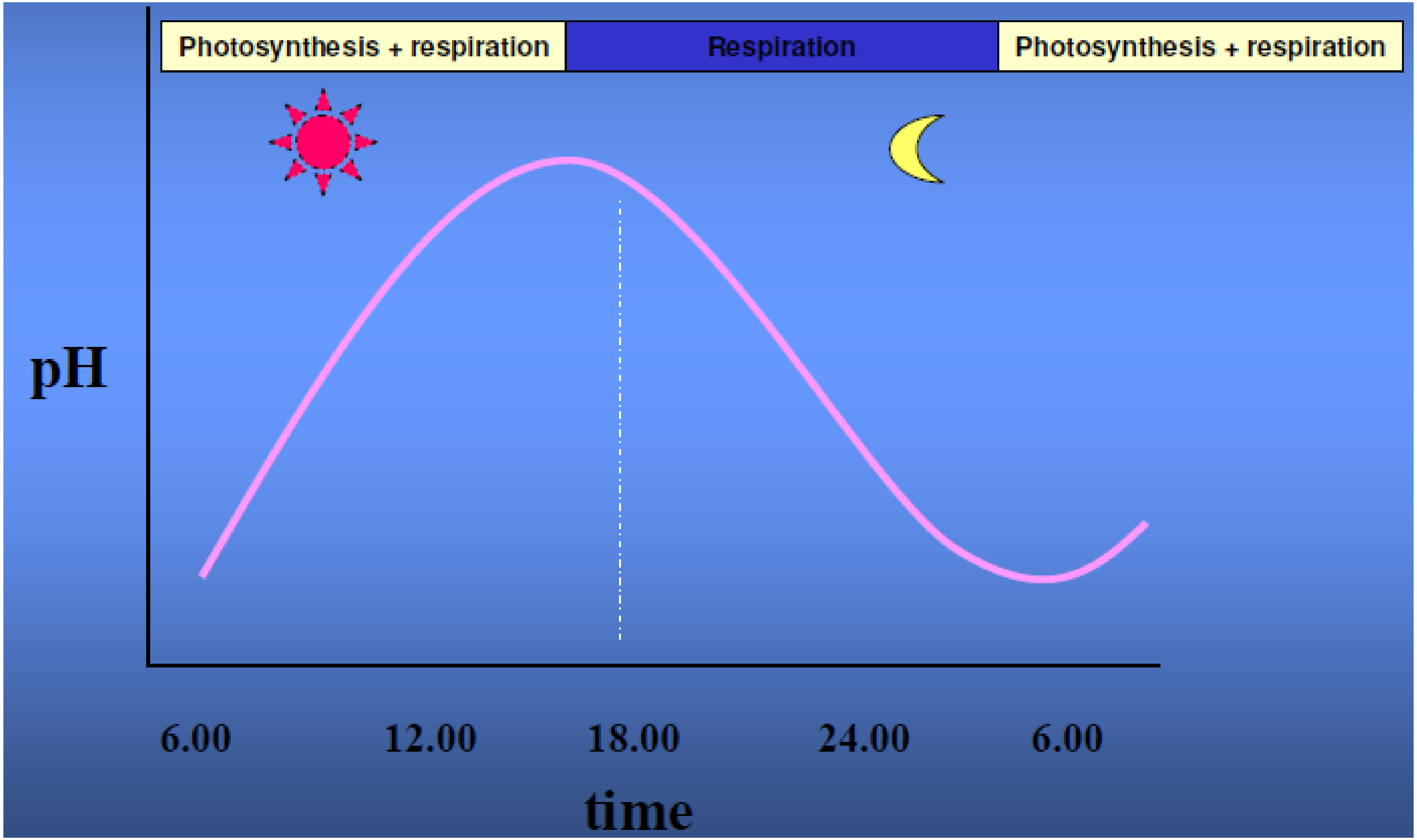
pH will vary depending on a number of factors.

- pH levels of the pond water will change depending on the aquatic life within the pond.
- Carbon dioxide produced by aquatic organisms when they respire has an acidic reaction in the water. The pH in ponds will rise during the day as phytoplankton and other aquatic plants remove CO_2 from the water during photosynthesis.
- The pH decreases at night because of respiration and production of CO_2 by all organisms.
- The fluctuation of pH levels will depend on algae levels within the pond

pH daily fluctuations



pH changes due to different CO2 concentrations



Problems with pH

- Sub-optimal pH has a number of negative affects on fish and macrobrachium.
- It can cause
  - stress,
  - increase susceptibility to disease,
  - low production levels
  - poor growth.
- Signs of sub-optimal pH include
  - increase mucus on the gill surfaces of fish,
  - damage to the eye lens,
  - abnormal swimming behaviour,
  - fin damage,
  - poor phytoplankton and zooplankton growth
  - can even cause death.
- In the case of macrobrachium, low pH levels will cause the shell to become soft. This is due to the shell of the crayfish being composed of calcium carbonate which reacts with acid.

Control of pH

- Treatment methods will depend on whether there is a high pH problem or a low pH problem.
- To treat a pond with low pH, a pond can be
  - limed with agricultural lime
  - fertilised to promote plant growth.
- To decrease a high pH,
  - the pond can be flushed with fresh water,
  - feeding rates can be reduced to decrease nutrient input into the pond,
  - gypsum (CaSO4) can be added to increase the calcium concentration,
  - alum (AlSO4) can be added in extreme cases.

Salinity

- The term salinity refers to the total concentration of all dissolved ions in the water (not just the concentration of sodium chloride in the water).
- Measurements of salinity is referred to as parts per thousand (ppt). For a point of reference, seawater is approximately 35 g/liter or 35 ppt.
- Each species has an optimal salinity range. This range allows the fish to efficiently regulate their internal body fluid composition of ions and water.

	Fresh water	Brackish water	Saline water	Brine
percentile	< 0.05	0.05 - 3	3 - 5	> 5
Part per thousand (ppt)	< 0.5	0.5 - 30	30 - 50	50

Osmoregulation

- A freshwater fish will gain water via osmosis.
- Excess water is excreted in the urine and ion uptake is through the gills
- If salinity is too high, the fish will start to lose water to the environment. As freshwater fish are not physiologically adapted to osmoregulate within a saline water source, decreased growth and survival can occur under these conditions

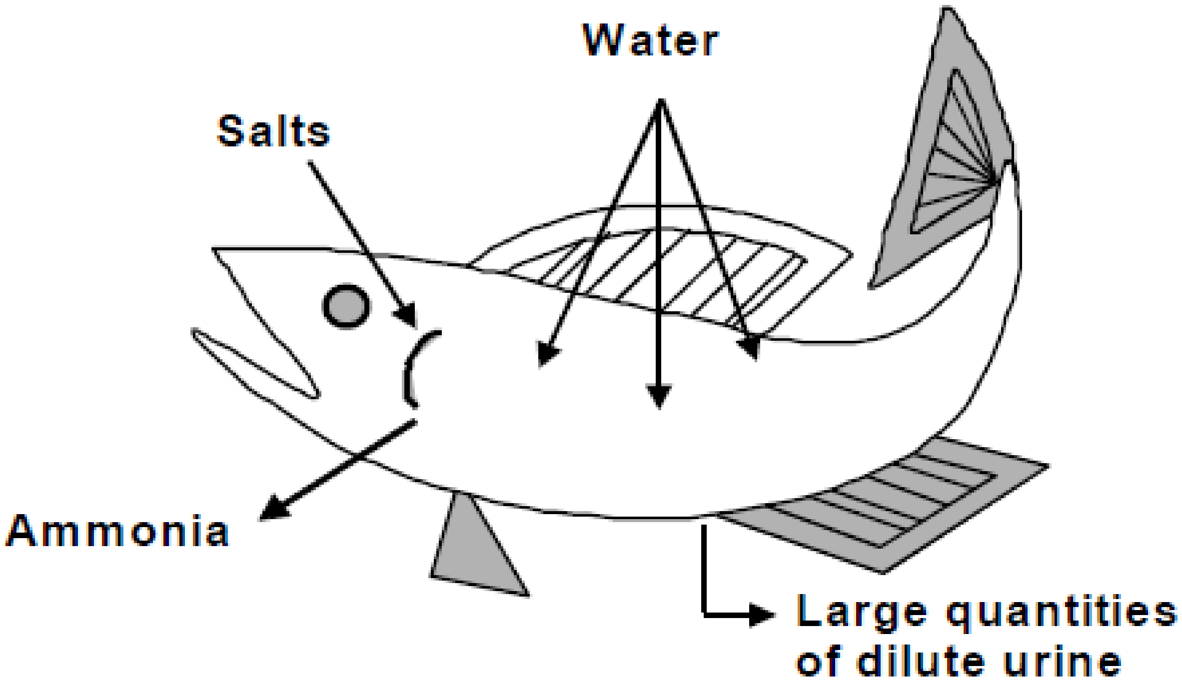


Table 3.2 Salt composition of sea water.

Salt	Salinity PPT	Composition (%)
Sodium chloride (NaCl)	27.21	77.7
Magnesium chloride ($MgCl_2$)	3.8	10.8
Magnesium sulphate ($MgSO_4$)	1.6	4.7
Calcium sulphate ($CaSO_4$)	1.2	3.6
Potassium sulphate (K_2SO_4)	0.8	2.4
Calcium carbonate ($CaCO_3$)	0.1	0.3
Magnesium bromide ($MgBr_2$)	0.07	0.2
	35.0	**100**

Concentration of Major ions (mg./l)

Ion	Seawater	Brackishwater	Freshwater
chloride	19,000	12,090	6
Sodium	10,500	7,745	8
Sulfate	2,700	995	16
Magnesium	1,350	125	11
Calcium	400	308	42
Potassium	380	75	2
Bicarbonate	142	156	174
Other	86	35	4
Total	34,558	21,529	263

Phosphorous (P)

- Phosphorus (P) is found in the form of inorganic and organic phosphates (PO4) in natural waters.
- Inorganic phosphates include orthophosphate and polyphosphate while organic forms are those organically-bound phosphates.
- Phosphorous is a limiting nutrient needed for the growth of all plants- aquatic plants and algae alike.
- However, excess concentrations especially in rivers and lakes can result to algal blooms.
- Phosphates are not toxic to people or animals, unless they are present in very high levels. Digestive problems could occur from extremely high levels of phosphates.

Phosphorous (P)

- Among the common sources of phosphorous are wastewater and septic effluents, detergents, fertilizers, soil run-off (as phosphorous bound in the soil will be released), phosphate mining, industrial discharges, and synthetic materials which contain organophosphates, such as insecticides.
- Phosphorous concentration is measured either by using Total phosphorus (TP), which is a measure of all the various forms of phosphorus that are found in a water sample or by Soluble Reactive Phosphorous (SRP), which measures organophosphate, the soluble, and inorganic form of phosphorous which is directly taken up by the plants.

Phosphate (PO4) limits

Country	Freshwater (mg/L)	Marine (mg/L)	Reference
Australia	< 0.10 (PO_4)	< 0.05 (PO_4)	ANZECC, 2000
ASEAN		0.015 (dissolved P)	AMEQC, 1999
Malaysia	0.10 – 0.20 (P)		
New Zealand	< 0.10 (PO_4)	< 0.05 (PO_4)	ANZECC, 2000
Norway	$\leq$ 0.025 (P)	$\leq$ 0.025 (P)	SFT
Philippines	0.05 - 0.10 (P) (lakes and reservoir) 0.20 (all others) (P)	Nil (as organophosphate)	DAO 1993-34
United States	0.05 (point source) 0.10 (non-point source)		EPA

Total Solids

- Total solids refer to any matter either suspended or dissolved in water.
- Everything that retained by a filter is considered a suspended solid, while those that passed through are classified as dissolved solids, i.e. usually 0.45 µ in size (American Public Health Association, 1998).
- Concentrations in water are both measured as Total Suspended Solids (TSS) and Total Dissolved Solid (TDS), respectively.
- Suspended solid (SS) can come from silt, decaying plant and animals, industrial wastes, sewage, etc.

Total Solids

- They have particular relevance for organisms that are dependent on solar radiation and those whose life forms are sensitive to deposition.
- High concentrations have several negative effects,
  - decreasing the amount of light that can penetrate the water, thereby slowing photosynthesis which in turn can lower the production of dissolved oxygen;
  - high absorption of heat from sunlight, thus increasing the temperature which can result to lower oxygen level;
  - low visibility which will affect the fish's ability to hunt for food;
  - clog fish's gills;
  - prevent development of egg and larva.
- It can also be an indicator of higher concentration of bacteria, nutrients and pollutants in the water.

Dissolved solids

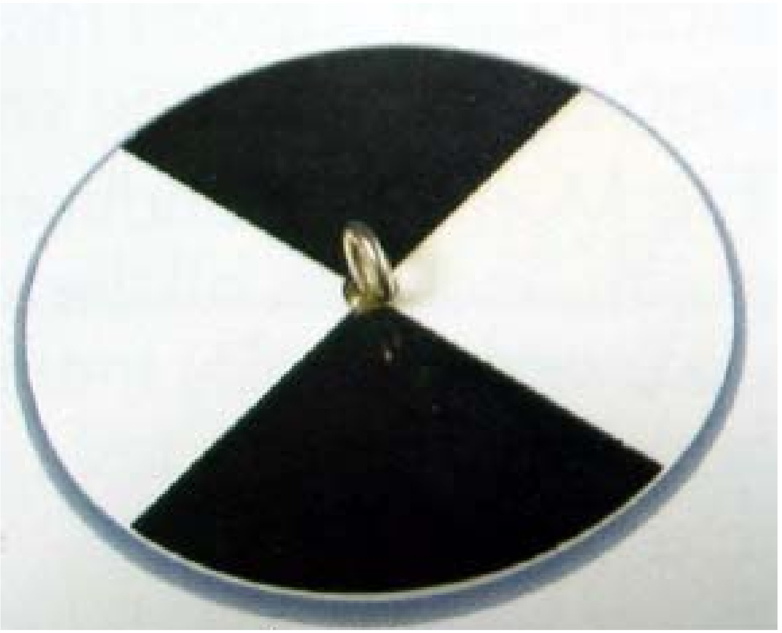
- Dissolved solid (DS) includes those materials dissolved in the water, such as, bicarbonate, sulphate, phosphate, nitrate, calcium, magnesium, sodium, organic ions, and other ions.
- These ions are important in sustaining aquatic life.
- However, high concentrations can result in
  - damage in organism’s cell,
  - water turbidity,
  - reduce photosynthetic activity
  - increase the water temperature.
- Factors affecting the level of dissolved solid in water body are urban and fertilizer run-off, wastewater and septic effluent, soil erosion, decaying plants and animals, and geological features in the area.

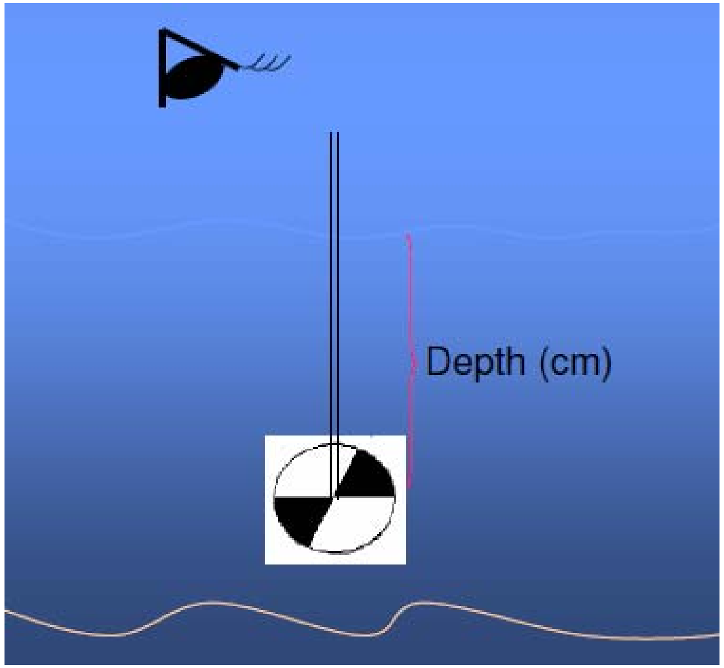
Turbidity

- Water turbidity in freshwater ponds is caused by phytoplankton and zooplankton (microscopic plants and animals) and suspended solids such as clay and silt particles in the water column.
- Water turbidity is important as it determines the amount of light penetration that occurs in the water column of a pond.
- This in turn will have an affect on the temperature of the water and the amount of vegetation and algae that will grow in the pond itself. For example a highly turbid pond will allow less light penetration therefore the temperature of the water will be lower.
- A combination of less sunlight and lower temperatures will result in a decreased amount of vegetation present with in the ponds which depend on sunlight and warmth to grow. A low turbid pond will of course have the opposite affect.

Measuring turbidity

Turbidity is measured in centimetres using a sechii disk which consists of a round plate divided into alternate black and white “pie” sections.
This disk is attached to a graduated rope or a metal handle divided into measuring units (usually at 2 cm intervals). The disk is lowered into the water until it can not be seen and then raised until it re-appears.
Sechii depths between 20cm and 60cm are recommended for optimal management of freshwater ponds.

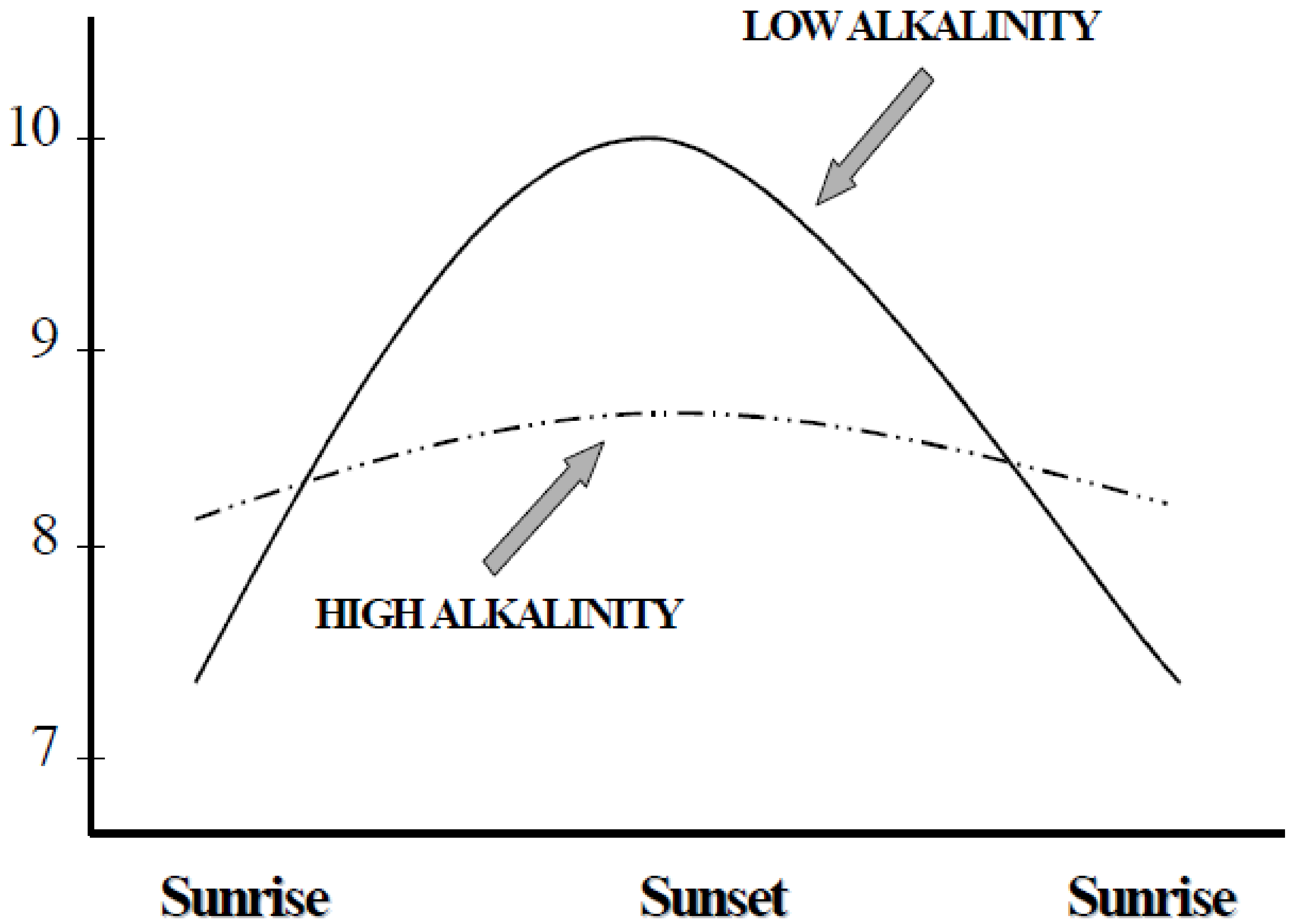




Water Alkalinity and Hardness

- Alkalinity refers to amount of carbonates and bicarbonates in the water
- Water hardness refers to the concentration of calcium and magnesium.
- As calcium and magnesium bond with carbonates and bicarbonates, alkalinity and water hardness are closely interrelated and produce similar measured levels.
- Waters are often categorised according to degrees of hardness as follows:
  - 0 – 75 mg/l soft
  - 75 – 150 mg/l moderately hard
  - 150 – 300 mg/l hard
  - over 300 mg/l very hard

Alkalinity changes in different types of pond



Alkalinity

- Alkalinity and hardness levels should be maintained around 50 to 300 mg/l which provides a good buffering (stabilising) effect to pH swings that occur in ponds
- A lack of calcium in the water will also result in soft shelled macrobrachium as they rely on the intake of calcium from the water column to harden their shells after moulting.
- Water alkalinity and hardness can be increased by liming ponds which involves adding a measured amount of lime to the pond.
- However there is no practical way of decreasing alkalinity and hardness when they are above desirable levels.

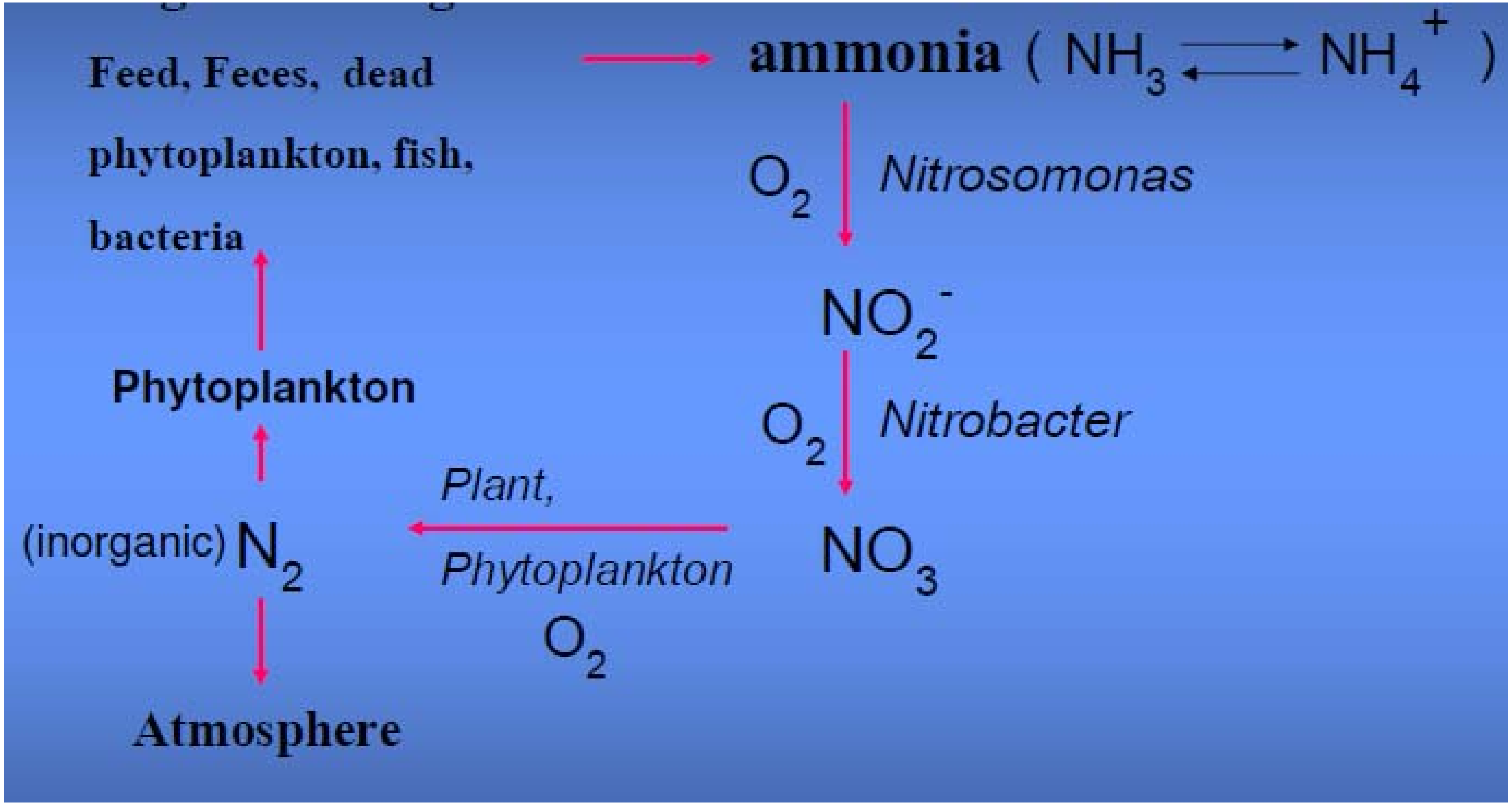
Ammonia

- Ammonia in ponds is produced from the decomposition of organic wastes resulting in the breakdown of decaying organic matter such as algae, plants, animals and uneaten food.
- Ammonia is also produced by fish and macrobrachium as an excretory product.
- Ammonia is present in two forms in water – as a gas NH3 or as the ammonium ion (NH4 +).
- Ammonia is toxic to culture animals in the gaseous form and can cause gill irritation and respiratory problems.
- Ammonia levels will depend on the temperature of the pond's water and its pH.
- For example at a higher temperature and pH, a greater number of ammonium ions are converted into ammonia gas thus causes an increase in toxic ammonia levels within the freshwater pond.

Ammonia

- Primary nitrogen waste
- By-product of bacterial degradation
- New tank syndrome
- Two form of ammonia in water depend on: pH, temp and salinity
  - Un-ionized ammonia (NH_3); toxic form
  - ionized ammonia ; NH_4^+; less toxic form
- Acute toxic level in freshwater aquarium 0.2-0.5 ppm of unionized ammonia
- Chronic toxic begin at 0.002 ppm of un-ionized ammonia

Nitrification



Percentage of the toxic unionised form NH3 at different temperature and pH levels

pH	Temperature (^{0}C)						
	8	***12***	***16***	***20***	***24***	***28***	***32***
7.0	0.2	0.2	0.3	0.4	0.5	0.7	1.0
8.0	1.6	2.1	29.	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	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	85.8
10	61.7	68.5	74.8	79.9	84.0	87.5	90.6
10.2	71.9	77.5	82.4	86.3	89.3	91.8	93.8

Ammonia (NH_3)

Prevention; good husbandry, regular monitoring of water quality, limit overcrowding and overfeeding

If high levels are ammonia are present within the pond's water, a number of measures can be taken.

These include:

- reduce or stop feeding
- flush the pond with fresh water
- reduce the stocking density
- aerate the pond
- in emergencies – reduce the pH level
- Control plant and algal growth
- Add nitrifying bacteria

Nitrite (NO2)

- Chronic effect if compare to ammonia
- More toxic than nitrate
- Actively transported across the gill epithelium
- Toxic effects of nitrite: gill hypertrophy, hyperplasia, hemorrhages and necrotic lesions in the thymus, increasing susceptibility to infectious diseases, short life of RBC
  - Toxic level > 0.1 ppm,
  - Lethal level 10-20 ppm, 96-hLC50: 13 ppm (channel catfish)

Nitrite solutions

Action:

- Treatment success depends on the severity and duration of toxicity
- Chlorine ions competition – inhibit nitrite absorption over the gill (3 ppm (salt) : 1 ppm (nitrite))
- Partial water changes every 2-3 days
- Clinical sign will often resolve in 24 hr
- Increase aeration
- Checking the biological filter

Nitrate (NO3)

- Non toxic to fish
- Substrate for protein synthesis of plant and phytoplankton
- Absence of regular partial water change
- High level of nitrite will inhibit bacteria oxidation of nitrite to nitrate
- nitrite level start to increase
- Nitrobacter: low activity in low temp water
- Eggs and fry are more sensitive than adult
- Should be maintained below 50-100 ppm
- High levels may encourage algal boom
- Eradicate: a vegetable filter (Outdoor), water exchange (indoor)

Nutrient Levels

- Nutrient levels refer to the amount of phosphorus and nitrogen that is present in the water column.
- Nutrients are important as they promote healthy plankton blooms which are necessary to maintain turbidity levels and provide feed for fish. Nutrient levels can be increased in the ponds by adding inorganic or organic fertilisers in measured doses.

Nutrient Levels

- Increased levels of nutrients can be harmful. It can cause excessive plankton growth, potential blue-green algae blooms and oxygen depletion.
- High levels of nutrients can be caused by high stocking densities, over feeding, high productivity, and dead plant and animal matter.
- To decrease high nutrient levels, feeding rates should be decreased (or stopped) and the pond may need to be flushed with clean water.

Water quality limits

Element	Form in Water	Desired Concentration
Oxygen	Molecular Oxygen (O_2)	5 – 15 mg/l
Hydrogen	H^+ [-log(H^+) = pH]	PH 7 – 9
Nitrogen	Molecular Nitrogen (N_2) Ammonium (NH_4^+) Ammonia (NH_3) Nitrate (NO_3^-) Nitrite (NO_2^-)	Saturation or less 0.2 – 2 mg/l < 0.1 mg/l 0.2 – 10 mg/l < 0.3 mg/l
Sulfur	Hydrogen Sulfide (H_2S) - rotten egg gas Sulfate (SO_4^-)	Not detectable 5 – 100mg/l
Carbon	Carbon Dioxide (CO_2)	1 – 10 mg/l
Calcium	Calcium Ion (Ca^{2+})	5 – 100 mg/l Can be higher in crustacean ponds
Magnesium	Magnesium ion (Mg^{2+})	5 – 100 mg/l
Sodium	Sodium ion (Na^+)	2 – 100 mg/l
Potassium	Potassium ion (K^+)	1 – 10 mg/l
Bicarbonate	Bicarbonate ion (HCO_3^-)	50 – 300 mg/l

Boyd (1998) "Water Quality for Pond Aquaculture"

Water quality limits

Element	Form in Water	Desired Concentration
Carbonate	Carbonate ion (CO_3^{2-})	0 – 20 mg/l
Chloride	Chloride ion (Cl^-)	1 – 100 mg/l
Phosphorus	Phosphate ion (HPO_4^{2-} , $H_2PO_4^-$)	0.005 – 0.2 mg/l
Silicon	Silicate ion (H_2SiO_3 , $HSiO_3^-$)	2 – 20 mg/l
Iron	Ferrous iron (Fe^{2+})	0 mg/l
	Ferric iron (Fe^{3+})	Trace
	Total iron	0.05 – 0.5 mg/l
Manganese	Manganese ion (Mn^{2+})	0 mg/l
	Manganese dioxide (MnO_2)	Trace
	Total manganese	0.05 – 0.2 mg/l
Zinc	Zinc ion (Zn^{2+})	< 0.01 mg/l
	Total zinc	0.01 – 0.05 mg/l
Copper	Copper ion (Cu^{2+})	< 0.005 mg/l
	Total copper	0.005 – 0.01 mg/l
Boron	Borate (H_3BO_3 , $H_2BO_3^-$)	0.05 – 1 mg/l

Boyd (1998) “Water Quality for Pond Aquaculture”