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1. INTRODUCTION

An ideal water condition is a necessity for the survival and good growth of fish since the entire life processes of the fish is wholly dependent on the quality of its environment. These water quality parameters become more critical in intensive culture systems where fish is raised in artificial ponds with reduced self purification capabilities as compared to natural systems. Furthermore, aquacultural manipulations such as fertilization and intensive feeding, if not properly carried out, have often compounded water quality problems in such ponds. Intensive artificial feeding for example, has been identified as a major source of water pollution in fish ponds as only about 25% of the nutrients in the feed is converted to fish flesh (Boyd, 1973). The remaining settle to the bottom of the pond as organic waste. This organic waste on decomposition use up dissolved oxygen (DO) and this process is capable of producing DO depletion in pond water. Indiscriminate pond fertilization with organic or inorganic fertilizers produce the same effect. There is therefore, the need to monitor these cultural practices and other water quality parameters to ensure an adequate water environment for the growing fish. This is important in order to optimize fish production per unit area of pond and to produce healthy fish, free of disease and parasites problems (Boyd and Lichtkoppler, 1979).

Literature on water quality studies and management in aquacultural systems are very few. Furthermore, most of the few available ones are restricted to academic environments and are therefore, not easily accessible to most fish farmers. This report is therefore, intended to redress this observed lapse. This report is as useful to fish farmers as it is to students and environmental scientists concerned with ensuring optimum water quality environment for all aquatic wildlife.

However, it should be pointed out that although this report is a combination of literature work and personal experience as a Fisheries Limnologist, it is by no means exhaustive. Thus, while this report serves its primary function as a simple Handbook on water quality management in fish ponds, it is hoped that it will also serve as a catalyst for a renewed investigation into the water quality needs of our local fish species.

2. DEFINITION AND SCOPE OF WATER QUALITY

Any physico-chemical and biological characteristics of water which affects the survival, growth and reproduction of fish is a water quality variable that demands the attention and management of the pond culturist. For ease of reference, these water quality variables could thus be grouped into three main headings viz:-

(i) Physical water quality variables

(ii) Chemical water quality variables, and

(iii) Biological water quality variables.

3. PHYSICAL WATER QUALITY VARIABLES (PWQV)

The two most important physical water quality v variables that affect fish production in ponds are temperature and turbidity, and these two parameters are discussed here.

3.1. Temperature

Water temperatures affects the activity, behaviour, feeding, growth and reproduction of all fishes (Dupree and Huner, 1984). Temperature is next to dissolved oxygen as the single most important factor affecting the welfare of cultured fish. A 5°C sudden change in temperature will stress or even kill fish, and this has formed the basis of acclimatization of fish especially when transporting them from one extreme weather condition to another (Boyd and Lichtkoppler, 1979).

Warm water fish grow best at temperatures between 25°C - 32°C (Boyd and Lichtkoppler, 1979; Dupree and Huner, 1984). In the fish hatchery complex of the National Institute for Freshwater Fisheries Research, the effect of the following temperature ranges have been observed on induced breeding of Clarias (Madu, unpublished):

30 - 32°C - eggs hatch within 24 hours

27 - 28°C - eggs hatch between 24 - 48 hours

0 - 25°C - No hatching - eggs rot.

Common carp (*Cyprinus carpio*) however, does better at lower temperatures (Madu, personal communication).

In general, temperature has a pronounced effect on the rate of chemical and biological processes in water (Boyd and Lichtkoppler, 1979). Fish and other aquatic animals require twice as much oxygen at 30°C than at 20°C (Santos, 1977). Aeration may, therefore, be necessary at higher temperatures. Furthermore, in warm water, fertilizers dissolve faster, herbicides act quicker and rotenone degrades faster.

In deep ponds (> 1.5m), temperature is capable of generating a situation called thermal stratification in which the water column is divided into an upper warm layer (epilimnion) and a lower cooler layer (hypolimnion) with a separating layer called the thermocline. The hypolimnion is often associated with low primary productivity and consequently low dissolved oxygen (Wetzel, 1983). Fish and other aquatic organisms therefore, tend to migrate from this lower portion of the water to the upper layer where water quality conditions are more suitable. To prevent this occurrence, fish ponds should not be too deep. The recommended depth is 1.5 m (Bard et al, 1976).

3.2. Turbidity

In general, water is turbid when it is not clear. It is therefore, a measure of water transparency. In pond culture, turbidity means that pond water contains suspended materials that interfere with the passage of light. Turbidity can be caused by plankton or by clay. While turbidity due to plankton is a desirable one (as it is an index of the amount of natural food present in the pond water), turbidity due to clay is bad and therefore, undesirable (Boyd and Lichtkoppler, 1979; Santos, 1979).

3.2.1. Effect of turbidity due to plankton:

When phytoplankton is the major source of turbidity, the Secchi disk reading is a measure of algal density. In the presence of excess phytoplankton, the oxygen produced is restricted to the top layer of the water because of the shading effect of the excess phytoplankton. Secchi disk readings of 10 - 20 cm in ponds where plankton is the primary source of turbidity is dangerous as night or early morning DO depletion is bound to occur. However, ponds having 30 - 60 cm Secchi disk reading are less likely to experience early morning DO deficiency.

3.2.2. Effects of turbidity due to clay particles

Clay turbidity in fish ponds has both direct and indirect effect on cultured fish. Some of these include:-

(i) Restriction of light penetration.

(ii) Reduction in the amount of photosynthesis.

(iii) Reduction in the amount of dissolved oxygen since the primary source of dissolved oxygen in water is through phytoplankton photosynthesis.

(iv) Clogging of fish fills. Many aquatic organisms especially filter feeders, cannot tolerate appreciable concentration of inorganic particulate matter (Wetzel and Likens, 1979).

3.2.3. Measurement of turbidity - Water transparency

Turbidity can be measured with spectrophotometers or with turbidimeters. However, in fish pond culture where turbidity is an index of water transparency, turbidity is usually measured with an instrument devised by an Italian oceanographer called the Secchi disk. This instrument can be fabricated locally from flat circular metal plates, plastic or ordinary plywood. Measurement is achieved by lowering the disk into the water gradually and a depth reading taken at the point the instrument just disappeared from sight. The instrument is then gently raised, and another reading taken at the point the disk just reappears. The average of the two readings is the correct Secchi disk reading for the pond. A Secchi disk reading of 30 - 60 cm is good for fish culture.

Note: Whenever Secchi disk measurement is taken from a boat or canoe, it is usually taken from the shaded side of the boat or canoe.

3.2.4. Constructing a Secchi disk

(i) Cut the relevant material into a circular plate of 20 cm diameter. This is the standard diameter but it can be slightly smaller or larger.

(ii) Rule circular plate into triangular quadrats.

(iii) Paint quadrats alternately with white and black oil paints.

(iv) Attach a calibrated twine to the centre top and a little weight to the bottom centre if disk cannot sink independently. After this, the Secchi disk is ready for use.

3.2.5. Causes and prevention of Clay turbidity in ponds

Soil erosion and runoffs due to rains generally account for clay turbidity in pond waters. To prevent high turbidity, pond margins or shores should be planted with creeping grass species. Construction of drainage channels outside the pond margin serve to divert products of runoffs and erosion from emptying into the pond. Alternatively, flocculation and sedimentation of the particles can be achieved by application of alum. This latter method is however not recommended for the local fish farmer.

4. CHEMICAL WATER QUALITY VARIABLES (CWQV)

The chemical water quality variables discussed here include dissolved oxygen (DO), pH, total alkalinity and hardness, Ammonia (NH_3), hydrogen sulphide (H_2S) and agricultural pollutants. Fertilization and liming are also discussed under this section.

4.1. Dissolved Oxygen (DO)

In the absence of deliberate poisoning, dissolved oxygen (DO) is the single most important and critical water quality parameter for fish in pond culture systems (Andrews et al, 1973; Boyd and Lichtkoppler, 1979). Fish and other aquatic animals therefore, require oxygen just like man and other terrestrial animals. The sensitivity of fish to low concentrations of DO differs between species, between the various life stages (eggs, larvae and adults) and between the different life processes such as feeding, growth and reproduction (EIFAC/T19). In general, however, a minimum constant value of 5 mg/l is satisfactory for most species and stages of cultured fish (EIFAC/T19). Furthermore, the amount of DO in the water determines how much organic matter such aquatic system can receive before pollution problems arise. The pond manager is therefore, required to be familiar with the dynamics of DO concentrations in ponds.

4.1.1. Effects of low DO on fish

Inadequate DO in ponds has the following effect on fish:

(i) Fish stop feeding

(ii) Growth and reproduction is impaired at DO below 4 - 5 mg/l

(iii) Fish become more susceptible to diseases and parasites attack.

(iv) At prolonged exposure to low DO, fish become stressed and eventually die.

A general guide for DO requirement for warm water culturable fish is shown in Figure 3. As mentioned earlier, a minimum DO of 5 mg/l is required for most species of fish. Below this value, the fish enters tolerable range where growth and reproduction are impaired, and finally into the lethal range when DO falls below 1 mg/l.

4.1.2. Sources of DO in ponds

There are two major sources of DO in fish ponds. These are:-

(i) Dissolved oxygen resulting from photosynthetic activities of indigenous phytoplankton and other submerged aquatic plants, and

(ii) Dissolved oxygen resulting from atmospheric reaeration by wind and waves. The first method is however, the principal source of natural DO in any aquatic system as atmospheric DO diffusion is a very slow process (Boyd and Lichtkoppler, 1979).

One major factor that influences the rate of phytoplankton photosynthesis and consequently the amount of DO in water is light and its level or depth of penetration. Photosynthesis decreases with depth as a result of decreasing light intensity. Thus, in deep ponds, photosynthesis is limited to only the top 1 m depth of water. It is therefore, recommended that ponds should not be too deep (1.5 m is ideal) to ensure adequate concentration of DO in the entire water column.

4.1.3. Sources of DO loss from ponds

As DO is being put into pond water by photosynthesis and atmospheric re-aeration, so also are various activities in the pond water that utilize DO and therefore, form major sources of DO loss from the pond. Some of these include:

(i) Respiration by plankton phyto and zooplankton

(ii) Respiration by fishes and other pelagic organisms.

(iii) Respiration by benthic organisms.

(iv) Decomposition of organic matter.

(v) Diffusion into the atmosphere from the pond water surface.

In pond culture systems, the volume of oxygen entering or produced in the pond must outweigh the volume of oxygen leaving the pond, otherwise oxygen depletion will occur and this is most critical in the mornings (Doudoroff and Shuway, 1970; Dupree and Huner, 1984). When DO depletion occurs as a result of overfertilization, intensive feeding and heavy stocking in limited volume of water, massive or entire fish kill could occur in a single night (Dupree and Huner, 1984).

4.1.4. Diurnal DO fluctuation

Dissolved oxygen in ponds fluctuate diurnally (daily) and this fluctuation is more pronounced in highly productive ponds with high ph toplankton densities as a result of intensive feeding and fertilization. Daily variations are less pronounced in less productive ponds with sparse population of phytoplankton.

This phenomenon is shown in Figure 1. In general DO concentrations are lowest in the early morning and this increase during day-light hours to a maximum in late afternoon and decrease again during the night (Boyd and Lichtkoppler, 1979).

4.1.5. Measurement of DO

There are two methods commonly used in measuring DO in water. These are the Winkler's method and the use of DO meters.

(i) Winkler's method:

This is a titration method which involves fixing the DO in a known volume of water with manganous sulphate or chloride and alkaline iodide azide solutions. If oxygen is present in the water, a brownish precipitate is formed, and if DO is absent, a white precipitate is formed. Addition of concentrated sulphuric acid to the brown precipitate releases iodine which is equivalent to the amount of oxygen trapped in the sample bottle. The released iodine is estimated by titration with a standard 0.025N sodium thiosulphate solution to give the value of oxygen in the pond water (A.P.H.A., 1980).

If 200 ml of the original fixed sample was titrated, the volume of sodium thisulpahte used is numerically equal to the concentration in mg/l of dissolved oxygen. However, to save reagents, lesser volumes of fixed sample could be titrated and the thiosulphate volume multiplied by an appropriate correction factor. For example, if 10 mls of sample is used, DO concentration is calculated using the relationship below:

$$\text{mg/l DO} = \frac{200}{10} \times X$$

where X = volume of thisulphate used in titration.

(ii) Use of DO meters:

These are most rapid and suitable for field work but are less reliable as the electrodes are fragile and could thus be easily damaged if not properly handled. They also need pre-standardization and frequent re-standardization for any accurate readings to be obtained.

4.1.6. Detection of low DO in pond water

The level of DO in water can be measured by the methods outlined previously. However, for the fish culturist who has not got the equipment and reagents for these scientific tests, the following are some pointers or indicators of low DO in fish ponds.

(i) Sudden change in the colour of the phyto-plankton (Algae) from green to brown or grey. This indicates that the phytoplankton which are the primary source of DO in water are either dying or dead.

(ii) Snails crawl up grass stems on the shore and on side of dikes in early morning when DO is least.

(iii) Reduction or complete stopping of feeding by fish.

(iv) Increase in the rate of popping up of tadpoles and some easily stressed fish in the water.

(v) Appearance of black oily streaks in water.

(vi) Rotten egg smell of hydrogen sulphide (H_2S) at an advanced stage of DO depletion.

4.1.7. Predicting low DO

DO is least during the early morning hours because of cessation of photosynthesis at dusk and this period represents the most critical period for the fish and the fish farmer. Consequently, low DO predictions have focused on estimating what the DO level will be during the early morning hours of the day. The simplest method commonly used is the projection method (Shroeder, 1974; Boyd et al, 1978). This procedure is outlined below:-

(i) Measure DO at dusk say 8.00 p.m.

(ii) Measure DO again after 2 - 3 hours

(iii) Plot DO concentrations against time

(iv) Project a straight line through the two points as shown in Figure 2.

An early morning DO of 2 mg/l is the minimum permissible, below which it becomes critical for the fish and therefore, demands the attention of the pond manager (Shroeder, 1974; EIFAC/T19, 1973; Boyd et al, 1978; Boyd and Lichtkoppler, 1979).

4.1.8. How to improve low DO in ponds

This could be done by a number of methods which are dependent on the size and resources of the fish farmer. Some of the methods commonly used include:

(i) Driving an outboard engine round the pond to stir the pond water therby aerating it but making sure that the bottom mud is not disturbed.

(ii) Pumping in highly oxygenated water from a nearby water source and if possible pump out the deoxygenated bottom water.

(iii) Use of paddlewheel aeration system and

(iv) In the absence of the three mechanical devices mentioned above, canoe paddles can be used to stir the pond water vigorously while on a boat or canoe. This is quite appropriate for the local fish pond owner having small ponds.

4.2. pH

This is a measure of hydrogen ion concentration and it ranges from 0 - 14. The pH of the water tells us whether the pond water is acidic <7 or alkaline >7 or neutral 7. The pH of natural water is principally influenced by the concentration of carbon dioxide and acidic substance. Like DO, pH fluctuates diurnally. In the day, when phytoplankton utilizes CO_2 for phytosynthesis pH readily rises but drops at night when respiration becomes more active.

4.2.1. Effect of pH on fish

To maintain a good fish population in water, it is necessary to keep the pH between 6.7 - 8.6 (Swingle, 1961; Boyd and Lichtkoppler, 1979). A medium with extremely high pH >10 or low pH <4 cannot support fish at all. In addition, high pH is known to increase the toxicity of ammonia while low pH is known to increase the toxicity of sulphides and cyanides (Dupree and Huner, 1984). A general guide for pH requirements in fish ponds is shown on Figure 4.

4.2.2. How to increase pH to acceptable levels

When pond water pH is low, it can be brought to acceptable levels by:

(i) Application of agricultural lime preferably calcium carbonate ($CaCo_3$) in powder form.

(ii) Application of calcium hydroxide (slaked lime). Calcium oxide (quick lime) can also serve to increase pH but their use is discouraged as they are both caustic and can raise alkalinity to lethal points.

4.2.3. How to decrease pH to acceptable levels

When pH is above 9, calcium sulphate (gypsum) or aluminium sulphate (Alum) can be applied to the pond to bring down the pH to an acceptable level.

4.3. Total Alkalinity and Hardness

Total alkalinity is expressed in terms of milligrams per litre of carbonate and bicarbonate of calcium, while total hardness is the concentration of divalent ions mainly calcium (Ca) and magnesium (Mg) expressed in terms of milligrams per litre of calcium. Alkalinity and hardness contribute to the buffering capacity of water i.e. the ability of the water to resist change in pH when small amounts of acid or alkali are added to the water. Desirable levels of alkalinity and hardness for fish culture fall within the range of 20 - 300 mg/l (Boyd and Lichtkoppler, 1979). If pond water has too low total alkalinity and hardness, these parameters can be raised as discussed under liming.

4.3.1. Measurement of total Alkalinity and Hardness

This is done by titrating a known volume of the pond water to which a mixed indicator has been added, with a 0.02N sulphuric acid (H_2SO_4).

4.4. Liming

Liming increases pH of bottom muds and makes phosphorus and carbon more available to photosynthesizing plankton. Liming is only beneficial if total alkalinity is below 20 mg/l.

4.4.1. Types of liming materials

There are two principal types of liming agent. These are:

(i) Calcium carbonate ($CaCO_3$). This is the best liming agent especially for ponds that are already stocked with fish.

(ii) Calcium hydroxide or Calcium oxide. These are liming agents but are not recommended for liming already stocked ponds as they are capable of raising pH to lethal levels.

They are however, good to lime ponds that are not stocked or ponds that have been drained. These two liming agents are capable of killing disease carrying organisms in ponds.

4.4.2. Quantity and time of application

Usually, 2 tonnes/ha applied at least one month before fertilization in powdered or finely ground form. After the initial application, total alkalinity is determined after 1 - 2 months and application is repeated until concentration is above 20 mg/l.

4.5. Ammonia (NH_3)

There are two forms of ammonia - the un-ionized (NH_3) is non toxic and the ionized (NH_4^+) which is non-toxic except at high concentrations. High concentration of the toxic form is known to produce a lethal effect, while lower concentration inhibit growth rate. Lethal and sub-lethal concentrations have been put at .6 mg/l and 0.3 mg/l respectively (Santos, 1979).

4.5.1. Sources of Ammonia in ponds

There are three major sources of ammonia in fish pond waters. These are:

(i) Principally from uneaten fish feed which are proteinous in nature.

(ii) From excretory products of fish and other aquatic organisms.

(iii) From rapid die-off and decomposition of dense bloom of blue-green algae.

4.5.2. Prevention of Ammonia accumulation

(i) Intensive feeding should be highly regulated and minitored to avoid the accumulation of uneaten feed.

(ii) Maintaining moderate concentration of algal population especially of blue greens to prevent ammonia production during rapid die-off and decomposition.

(iii) For small sized ponds, aeration could help in accelerating the nitrification process i.e. oxidation of ammonia to nitrite and to nitrate.

4.6. Hydrogen Sulphide (H_2S)

This is formed from the putrefaction of organic waste in the absence of oxygen. It is most common in feeding areas where uneaten feed accumulates. Hydrogen sulphide may be endemic to coal mining areas with sulphide deposits. Such areas should be avoided during site selection for pond construction. Un-ionized hydrogen sulphide at concentrations less than 1 mg/l may be rapidly fatal to fish (Smith et al, 1976).

4.6.1. Detection of Hydrogen Sulphide

Hydrogen sulphide can be detected by the presence of:

(i) Black bottom sediment coupled with

(ii) Rotten egg smell.

4.6.2. Effect of Hydrogen sulphide

Hydrogen sulphide on oxidation forms sulphuric acid which is highly acidic, thus depressing the pH of the pond water to lower acidic levels. It is the ability of hydrogen sulphide to depress pond pH to a sub-lethal and lethal levels that makes it a major problem in ponds, as this situation could result into a fatal blood disease called blood acidocis which is the accumulation of acid in the fish blood. To raise pH, liming as earlier discussed, is recommended.

4.6.3. Prevention of H_2S accumulation

(i) Avoid siting ponds in coal mining areas where H_2S is endemic.

(ii) Supplementary feeding should be controlled and monitored to avoid too much accumulation of uneaten feed that could cause deoxygenation problems.

(iii) If feeding is done in a spot, uneaten accumulated feed should be removed periodically.

4.7. Fertilization

Fertilization is done essentially to provide basic nutrient components notably Nitrogen and Phosphorus primarily for the rapid development of phytoplankton. However, if the process is not carefully carried out and monitored, it becomes a major source of water in ponds. This is so because, excess fertilizer settle and accumulate at the bottom of the pond and on decomposition use up available dissolved oxygen in the pond. This process often leads to DO depletion and consequently has adverse effect on the various life processes of the cultured fish. It is therefore, essential for the pond manager to have a good knowledge of the type and rate of application of any fertilizer employed in fish pond culture in order to avoid the consequences of over-fertilization.

4.7.1. Before Fertilization

The pond manager should bear the following in mind when making plans to fertilize:

(i) If secchi disc visibility is less than 30 cm and turbidity is caused by clay prrticles, pond water will not respond to fertilization because of inadequate light penetration for plankton growth.

(ii) If total alkalinity is less than 20 mg/l, liming should be done first, before fertilization in a month's time.

(iii) If there are rooted aquatic plants, these should be removed before fertilizer application otherwise, fertilization will only encourage further luxuriant growth of the macrophytes at the expense of the micro natural fish food.

(iv) Fertilization is not effective in flowing waters, because the nutrients are easily washed away by the flowing water.

4.7.2. Types of Fertilizers

There are two basic types - organic and inorganic.

4.7.3. Organic fertilizers

These include:-

(i) Cow dung
(ii) Chicken droppings
(iii) Swine manure
(iv) Duck droppings
(v) Horse manure
(vi) Human waste
(vii) Vegetable manure etc.

All these are rich in Nitrogen and Phosphorus, the two basic nutrient components necessary for plankton growth. Chicken manure for example, has been found in our laboratory to contain 72 mg/l and 7.35 mg/l of NO_3 and PO_4 respectively.

4.7.4. How to Apply organic fertilizer

Two methods are commonly used. These are the fermentation and sac methods.

Fermentation method:

This involves fermenting a known weight of the manure in water for 2 - 3 days and filtering through a white clean nylon cloth to obtain the extract. The residue is discarded and the extract is used to fertilize the pond. This extract obtained from chicken manure has been used to grow micro-algal in our laboratory and a quick response is always achieved in this way.

Sac method:

This involves putting the manure in a porous bag e.g. fertilizer bag and placing it on stationary platforms just below the surface or in floating devices that permit slow seepage of nutrients into the water.

4.7.5. Quantity of organic manure to apply

This depends on prevailing pond fertility but in general, 200 - 500 lb (90.9 - 227 kg) per acre of the manure is sufficient (Dupree and Huner, 1984; Rappaport et al, 1977). Secchi disc transparency should be consistently taken during fertilization periods to ensure the level of plankton development. Plankton turbidity of 30 - 60 cm is adequate for a fertilized pond.

4.7.6. Inorganic fertilizer

In general, these are fertilizers with known concentration of their inorganic components and are usually rich in Nitrogen and phosphorus. Examples include:

(i) N.P.K 15.15.15 or 12.12.12 or other combinations

(ii) D.A.P - Diammonium phosphate

(iii) C.A.N - Calcium Ammonium Nitrate

(iv) Super Phosphate etc.

These various grade fertilizers can be obtained from State and Federal Agricultural Ministries and other private agricultural companies and stores.

4.7.7. How to apply inorganic fertilizer

(i) Generally by broadcasting on the surface of the pond. For small ponds, application can be done from the pond shoreline while a boat or canoe is needed for large ponds.

(ii) The sac method is also used or the fertilizer is placed on stationary platforms just below the water surface. Some fish farmers use liquid formulations for quick response of phytoplankton growth.

4.7.8. Quantity to apply

Again, this depends on prevailing pond fertility but in general, 60 kg/ha applied at a bi-weekly interval is good, especially for tilapia (Hepher, 1958; 1962; 1963).

In general, most ponds require phosphate fertilizers since phosphorus is the major limiting nutrient in aquatic systems (Hepher, 1958; Boyd and Lichtkoppler, 1979).

4.8. Agricultural Pollutants - Types

The two commonly implicated agricultural pollutants are herbicides (used to kill weeds) and pesticides (used to kill pest e.g. insects). The advancement of agricultural mechanization in recnnt times in developing countries like Nigeria has resulted in the massive use of these agricultural inputs. These chemicals which often get into the ponds by surface runoff are usually used at sublethal quantities to treat farms but bioaccumulate to lethal levels if used frequently. It is therefore, important that the use of these chemicals near fish ponds should be discouraged and if used at all, it should be done with caution and close monitoring to avoid concentrations reaching lethal levels in fish ponds. In view of the fact that monitoring and estimating these agricultural pollutants in water needs special and expensive equipments, it is recommended that fish farmers should employ preventive measures to avoid such chemicals getting into the fish ponds at all.

4.8.1. How to prevent Agricultural pollutants from fish ponds

(i) Avoid siting fish ponds in areas with residual pesticides or herbicides in the soil.

(ii) Avoid locating fish farms in agricultural farms where these chemicals are routinely and intensively used.

(iii) In situations where these chemicals have to be used, direct drainage of runoff into the farms must be avoided by rechannelization of the runoff water.

(iv) Crops planted on embarkment of fish ponds must not be sprayed.

(v) Application of these chemicals in the vicinity of fish ponds must be delayed until the wind is blowing away from the fish pond.

(vi) Wherever practicable, insect resistant crops should be planted in the vicinity of fish ponds e.g. soybean and rice.

5. BIOLOGICAL WATER QUALITY VARIABLES (BWQV)

Three major biological water quality parameters are discussed here. These include plankton, Aquatic vegetation and predators.

5.1. Plankton

This group of organisms form the most valuable natural food resource in any aquatic system. It consist of all suspended microscopic plants phytoplanton) and animals (zooplankton) which are very important for the good growth and development of the the fish especially at the fry and fingerling stages. Smith and Swingle (1938) have shown a positive relationship between plankton abundance and fish production in ponds. A highly simplified relationship which exists between the phytoplankton, zooplankton and fish is shown below:

Phytoplankton - Zooplankton - fish.

The phytoplankton act as food for the zooplankton while the zooplankton in turn is fed upon by fish. The abundance and quality of one to a large extent determines the abundance of the other. It is therefore, essential that the pond manager should ensure an adequate development of plankton population, as this indicates an ideal water environment for the growing fish.

5.1.1. How to generate plankton population

This is usually done by fertilzing pond water with either organic or inorganic fertilizers as previously described under "fertilization". However, it should be noted that initial fertilization should be done before introduction of fish to the pond. This is to ensure that the stocked fish has adequate plankton available for feeding right from the time of stocking.

5.1.2. Measurement of plankton abundance.

Quantitatively there are standard methods for measuring plankton abundance in ponds e.g. sedimentation or centrifugation of algal cells in ponds water and estimating density under a microscope using a Sedgewick-Rafter counting chamber or a Haemacytometer (Wetzel and Likens, 1979). These methods are not only too advanced for the local fish farmer, they also require expensive equipments.

A simpler and most practical method of estimating plankton abundance is by the Secchi disk visibility. When phytoplankton is the major source of turbidity, Secchi disk visibility of 30 - 60 cm is considered adequate for good fish production and for shading underwater weeds (Boyd and Lichtkoppler, 1979). When visibility is less than 30 cm, DO depletion problems may arise and at above 60 cm, light penetration to greater depth encourages development of water weeds. By taking Secchi disk readings regularly and by observing the appearance of the water, the fish culturist can determine the condition of the pond water and know when to fertilize and when not to fertilize.

In general, there is enough oxygen to support fish at 2 - 3 times the Secchi disk depth. Figure 5 shows the range of Secchi disk visibility good for fish culture.

5.1.3. Control of phytoplankton Bloom in ponds

Blooms of phytoplankton often occur in over-fertilized ponds and are capable of forming scums covering the entire pond surface. When the algal bloom dies, it settles to the bottom of the pond where it decomposes, leading to dissolved oxygen depletion in ponds. To prevent D.O. depletion arising from mass mortality and decomposition of algal scum, control measures should be initiated not only to prevent the bloom but also to control it at an early stage before the bloom becomes massive.

Chemicals used to control or kill algae are called algicides. The most commonly used is copper sulphate applied at a rate of 0.1 to 0.5 mg/l in waters with total alkalinities below 40 or 50 mg/l (Toth and Riemer, 1968; Phillipose, 1968). When total alkalinities are higher than above, copper sulphate concentration of 1 mg/l or more may be required to kill phytoplankton.

5.1.4. Application of Copper Sulphate

This may be done by:

(i) Dissolving it in water and distributing it over the pond.

(ii) Placing the crystals in porous bags and bags towed behind a boat until the copper sulphate dissolves or

(iii) Positioning bags in ponds so that chemical gradually dissolves and mix with the water (Crance, 1963).

5.2. Aquatic Vegetation

The presence of rooted aquatic vegetation should be discouraged in fish ponds as they have the tendency to reduce the production of fish in ponds.

5.2.1. Effects of aquatic vegetation on fish pond culture

Generally, aquatic vegetation have the following effects on fish ponds culture.

(i) Compete with plankton for soil nutrients

(ii) Limits the access of the cultured fish for food organisms produced on and in the pond bottom soil.

(iii) Interfers with feeding of prepared rations as most feeds are obscured by the vegetation.

(iv) Increased quantity of uneaten food results in lowered water quality.

(v) The vegetation competes with fish for oxygen at night.

(vi) Fish harvesting by seining is hampered by vegetation and may interfere with pond draining by clogging screens and drains.

5.2.2. <u>Control of aquatic weeds in ponds</u>

Although some methods of fish pond weed control are discussed here, the effort of the fish pond culturist should be directed towards the prevention of pond weeds. rather than the control as most control measures are not only expensive but also ineffective and sometimes dangerous. Some common control measures however, includes:

(i) <u>Mechanical removal</u>:

This method involves cutting, pulling, raking etc by mechanical or manual devices. The method is not only time-consuming, but also expensive and not very effective except when the vegetation is confined to small area of the fish pond. It is however, the best option for the local and unscientific fish farmer.

(ii) <u>Chemical treatment</u>:

This involves the use of registered herbicides for the control of the weed. To avoid or minimize the problem of D.O. depletion due to decaying vegetation, pre-emergent herbicides are usually recommended. However, whether pre- or post-emergent herbicides are used, great caution should be exercised as these herbicides are toxic to fish. Preferably, application should be done several weeks before stocking.

(iii) <u>Biological control</u>

This method involves introducing a non-predatory plant-eating species of fish into the pond to feed on the aquatic vegetation, thus enhancing overall fish production. This method is currently being used in a number of places such as Asia, the United States and Israel and some species commonly employed include, the grass carp stocked at a density of 10 - 40 per acre and the Israeli carp (Dupree and Huner, 1984). Stocked at high densities, these biological control species tend to compete with cultured species, thus interfering with their overall production.

5.2.3. Prevention of aquatic weeds

As earlier mentioned, prevention is the best answer to aquatic weed control in fish ponds and this is best done at the initial stage of pond construction. Usually, vegetation starts growing from the shoreline into the shallow water areas. To prevent the establishment or growth of these aquatic weeds, pond should be constructed in such a way that the shoreline is not less than 90 - 100 cm deep. In this way, rooting by aquatic weed is inhibited.

5.3. Predators and their adverse effects

This is one important potential problem in pond culture that does not often receive much attantion from the fish culturist but could adversely affect overall fish productivity in ponds. Predation occurs when one species kills and consumes another species in the population (Pianka, 1983).

5.3.1. Types of predators

The common ones include:-

(i) Wild predatory fishes. The presence or entry of wild predatory fish into a fish pond constitute one of the most serious predatory problems in fish ponds as this is difficult to detect by the manager. These predatory fish are capable of reducing substantially, fry and fingerling population of the pond.

(ii) Reptiles: These include water turtles, alligators, crocodiles and water snakes. These eat both juvenile and adult fish and they are serious problems in ponds situated on wetland areas. They are not as obscure as the wild predatory fishes as they can easily be detected or spotted by the pond manager on regular visits to the pond.

(iii) The third group are the awater birds and the common ones include egrets, kingfishers, herons, ducks, pelicans etc. These are the most easily detected predators as they are always hovering above the pond. They prey mainly on schools of young fish.

(iv) Finally, giant frogs are also potential predators in fish ponds and they can easily be spotted on close examination of pond.

5.3.2. Control of predators

(i) Wild fish predators can be controlled by filtering and screening the source of water supply to eliminate both adult and eggs of wild fish. On the other hand, once wild fish has successfully entered the pond, the only remedy is to drain the pond to eliminate it. Careful inspection of the fish to be stocked is highly recommended to avoid introducing unwanted fish.

(ii) The reptiles e.g. the turtle can be trapped or shot, while the snakes can be controlled by keeping the pond banks and margins free of tall grasses and debris. Gill nets drawn round the podns are capable of eliminating turtles and snakes by entanglement.

(iii) Birds are usually reduced but not eliminated by shooting and noise/light inducing devices installed on the pond site.

6. CONCLUSION

Water quality investigations and management in fish ponds, and indeed in intensive aquaculture systems are still at their infancy in Nigeria as these studies have not received any or much attention from fish farmers and fisheries research scientists nation-wide. It would appear that most fish farmers do not see the quality of pond water as a major factor influencing the overall productivity of cultured fish and therefore, a component that needs to be taken into account when planning any intensive aquaculture business.

Although this report is a combination of literature work and personal experiences as fisheries limnologists on the subject matter, it is by no means exhaustive. Thus the content of this report is intended to serve two major purposes:-

(i) To awaken in all intensive fish farmers especially fish pond manager, the desired need to see water quality management as an integral and important part of any aquacultural business that demands adequate attention so as to enhance overall fish production in aquacultural systems; and

(ii) To stimulate research scientists and fisheries students into investigating very critically, the water quality needs of specific species of fish under different environmental conditions in order to accumulate relevant data on which future recommendations on water quality needs and management of our cultured fish will be based.

7. REFERENCES

Andrew, J.W.; T. Murai and G. Gibbons (1973) The influence of dissolved oxygen on the growth of channel catfish. Trans. Amer. Fish. Soc. 102: 835 - 838

Bard, J.; De Kimpe, P, J. Lazard, J. Lemasson, P. Lessent (1976) Handbook of tropical fish culture. Centre Technique Forestier Tropical: 45 bis, A venue de la Belle Gabrielle 94130 - Nogent Sur-Marne, France.

Bonn, E.W. and B.J. Follis (1967) Effects of hydrogen sulphide on Channel Catfish, Ictalurus puntatus. Trans. Amer. Fish. Soc. 96: 31 - 36

Boyd, C.E. (1973) The chemical oxygen of waters and biological materials from ponds. Trans. Amer. Fish. Soc. 105: 634 - 636

Boyd, C.E. and Lichtkoppler, F. (1979) Water quality management in pond fish culture. Research and Development Series No.22. Internatonal Centre for Aquaculture Agricultural Experiment Station, Auburn University, Auburn, Alabama.

Boyd, C.E.; R.P. Romaire and E. Johnston (1978) Predicting early morning dissolved oxygen concentrations in channel catfish ponds. Trans. Amer. Fish. Soc. 107: 484 - 492

Crance, J.H. (1963) The effects of copper sulphate on Microcystis and zooplankton in ponds. Prog. Fish. Culture 25: 198 - 202

Dupree, K.H. and J.V. Huner (1984) The status of warmwater fish farming and progress in fish farming research. U.S. Fish and Wildlife Service, Washington, D.C., U.S.A.

Doudoroff, P. and D.L. Shuway (1970) Dissolved oxygen requirements of freshwater fishes. FAO Fish Tech. Pap. (86): 291 pp

EIFACT/T19 (1973) European Inland Fisheries Advisory Commission on Water Quality Criteria for European Freshwater Fish. Report on dissolved oxygen and inland fisheries. EIFAC Tech. Pap. 19: 10 pp

Hepher, B. (1958) On the dynamics of phosphorus added to fish ponds in Israel. Limn. Oceanogr. 3: 84 - 100

Hepher, B. (1963) Ten years of research in fish pond fertilization in Israel. II: Fertilizer dose and frequency of fertilization. Bamidgeh 15: 78 - 92

Phillipose, M.T. (1968) Present trends in the control of weeds in fish cultural waters of Asia and the Far East. FAO Fish. Rep. 44: Vol.5 26 - 52

Pianka, E.R. (1983) Evolutionary Ecology. Harper and Row Publishers, New York. 416 pp

Rappaport, U.; S. Sarig and Y. Benjerano (1977) Observations on the use of organic fertilizers in intensive fish farming at the Genosar Station in 1976. Bamidgeh 29: 57 - 70

Shroeder, G.L. (1975) Night time material balance for oxygen in fish ponds receiving organic wastes. Bamidgeh. 27: 65 - 74

Smith, L.L.Jr.; D.M. Osied, G.L. Kimball, and S.M. El-Kandelgy (1976) Toxicity of hydrogen sulphide to varous life history stages of Bluegill (Lepomis macrochirus). Trans. Amer. Fish Soc. 105: 442 - 449

Smith, E.V. and H.S. Swingle, (1938) The relationship between plankton production and fish production in ponds. Trans. Amer. Fish. Soc. 68: 309 - 315

Swingle, H.S. (1947) Experiments on pond fertilization. A.P.I. (Ala.) Agr. Exp. Sta. Bull. 264: 34 pp

Swingle, H.S. and E.V. Smith (1938) Fertilizer for increasing the natural food for fish in ponds. Trans Amer. Fish. Soc. 68: 126 - 135

Toth, S.J. and D.N. Riemer, (1968) Precise chemical control of algae in ponds. J. Amer. Wat. Works Assoc. 60: 367 - 371

Wetzel, R.G. (1983) Limnology. 2nd Edition. Sauders Philadelphia. Philadelphia. 767 pp

Wetzel, R.G. and G.E. Likens (1979) Limnological analyses. Sauders, Philadelphia. 357 pp

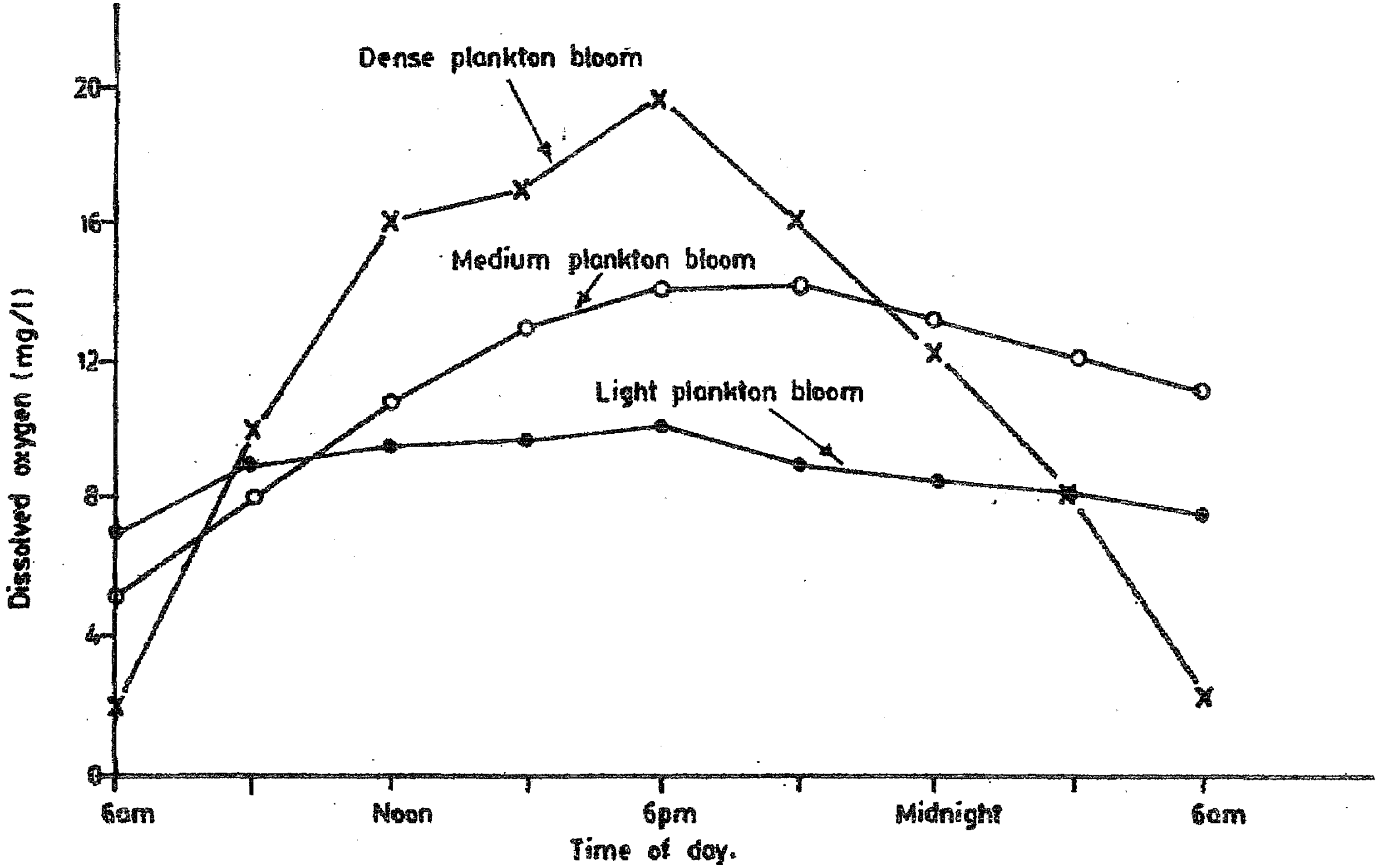

Fig. 1. Diurnal DO fluctuations in the surface waters of fish ponds with different phytoplankton densities (after Boyd and Lichtkoppler 1979)

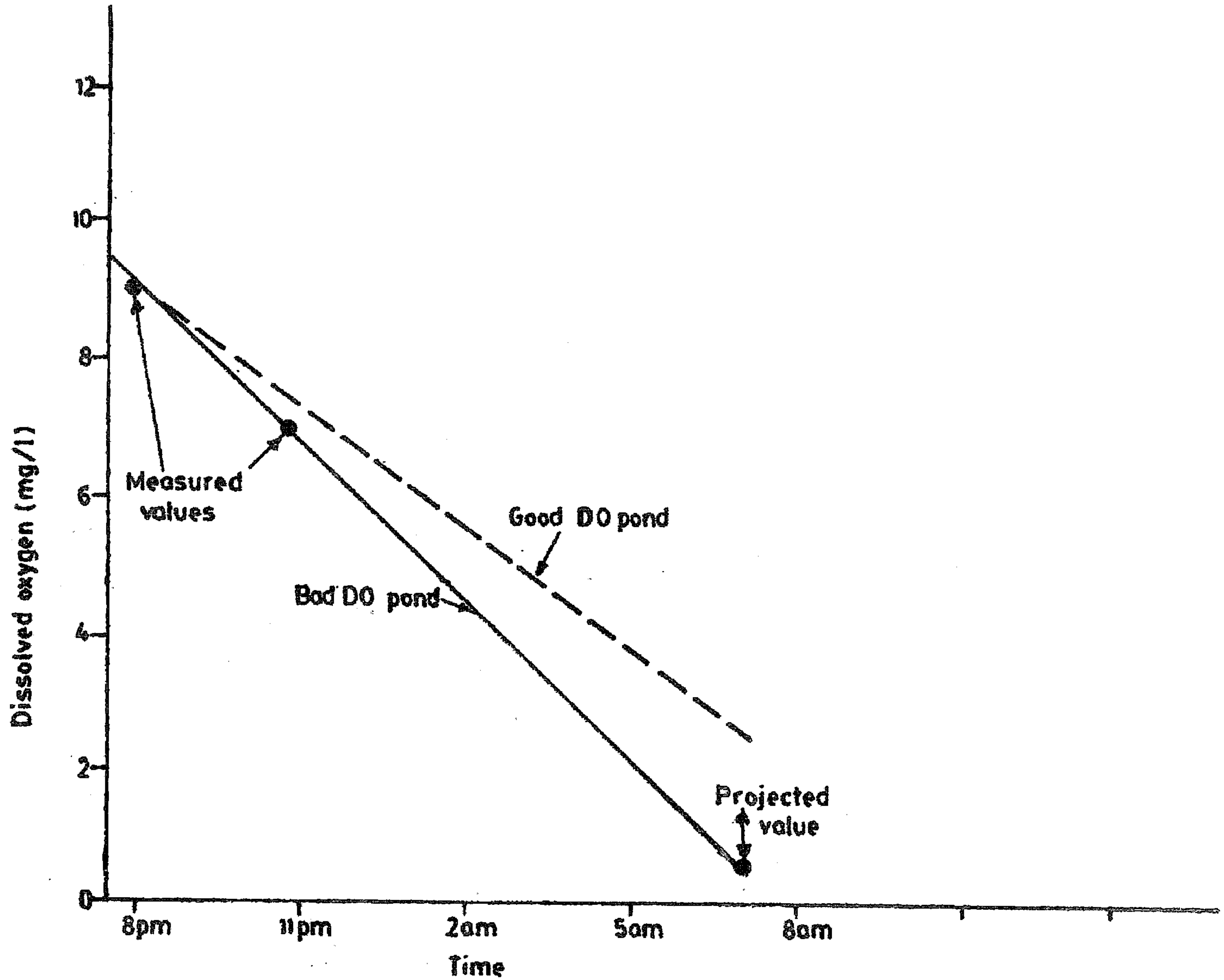

Fig. 2. Graphical technique for predicting night time decline in DO

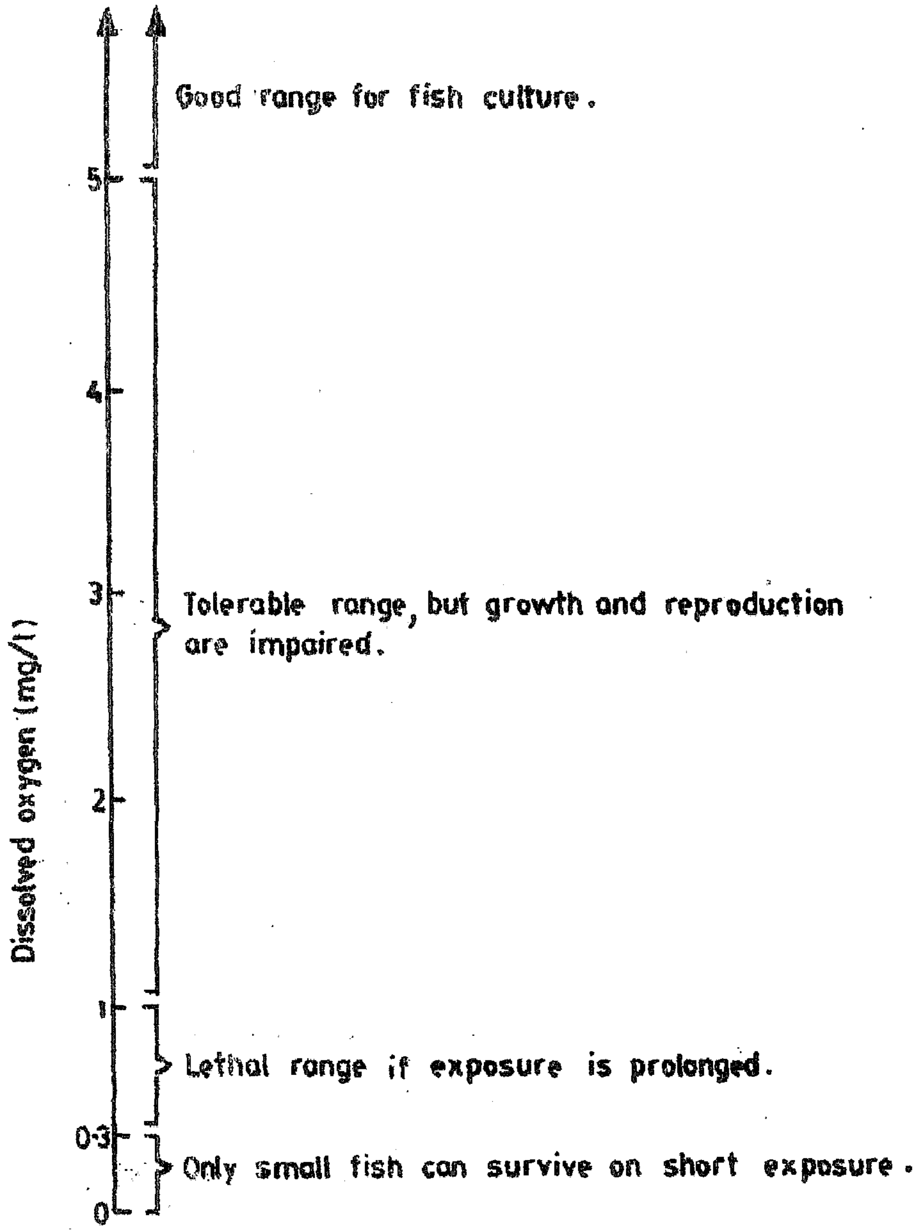

Fig. 3. A general guide for DO requirements for warm water culturable fish.

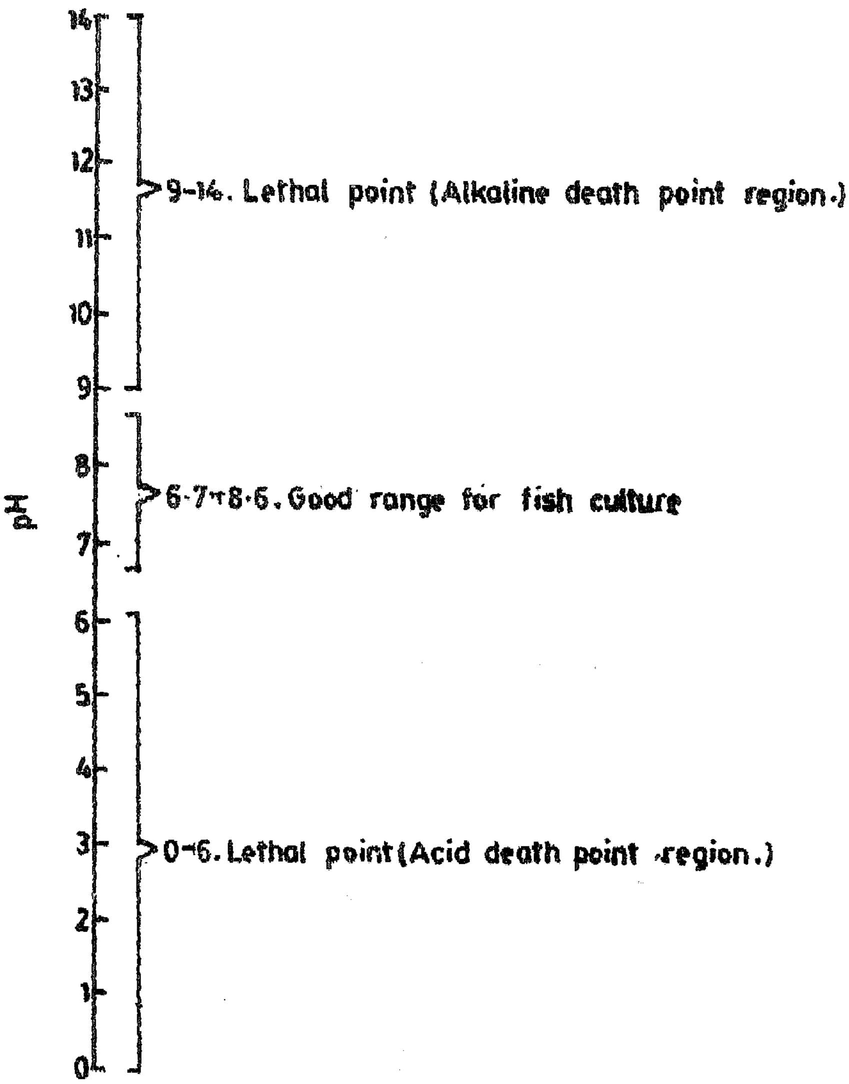

Fig. 4. A general guide for pH requirement in fish ponds.

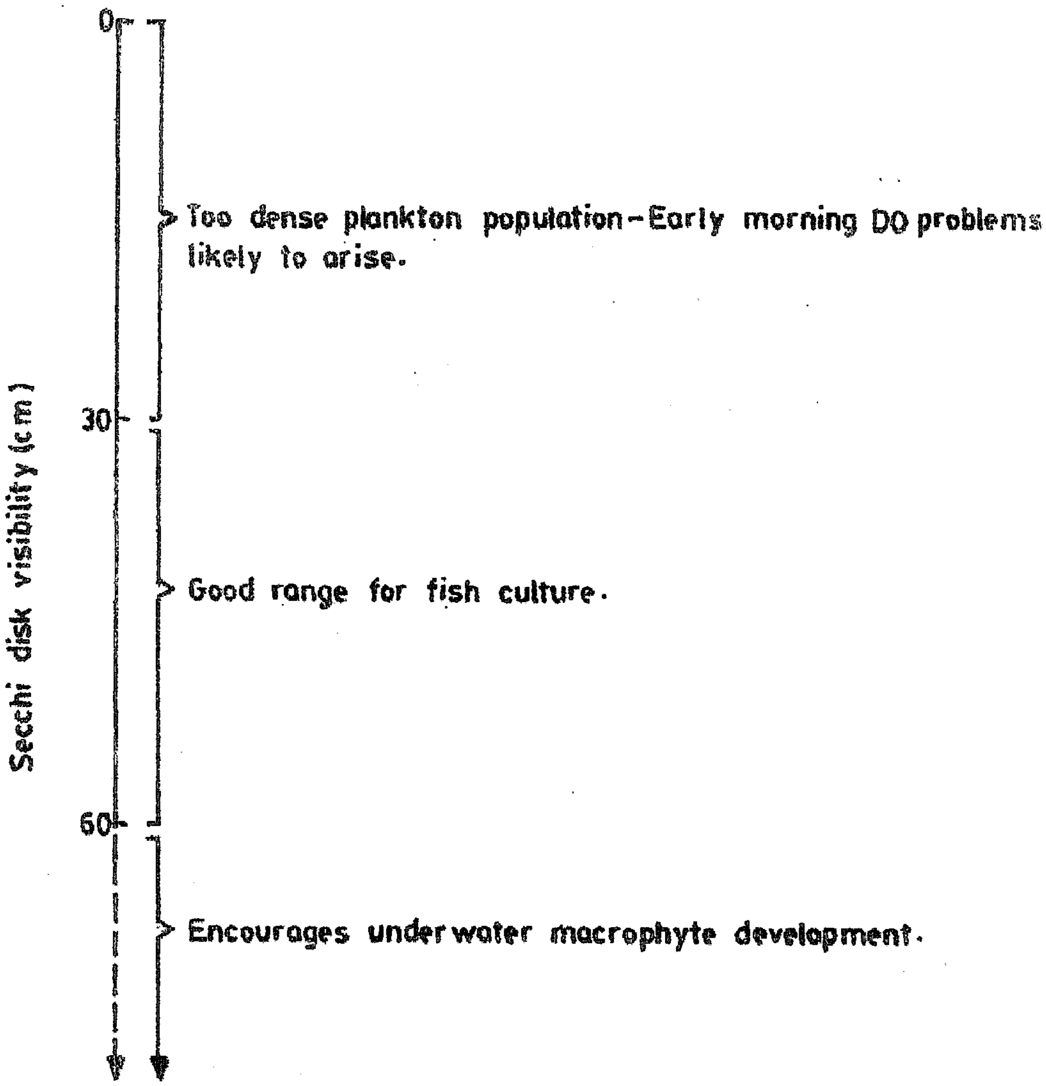

Fig. 5. Secchi disk visibility range for fish culture.

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