**CHALLENGES IN FISH FARMING**

**1.0 INTRODUCTION**

Farming of aquatic organisms, including fish, molluscs, crustaceans, and aquatic plants, is aquaculture. Farming requires some form of interference in the breeding process to increase yield, such as daily storage, feeding, protection from predators, etc. Farming also implies individual or corporate ownership of the stock being cultivated (Kaleem and Singou-Sabi, 2020). Fish farming is regarded as a key agricultural and food-producing sector throughout the world. The promoters argue, while depleted fish catches can be re-filled, that aquaculture can meet the food security needs of millions of people in developing countries who will benefit from relatively cheap protein (Hagar Dighiesh, 2014; Wally, 2016).

The aquaculture industry, which accounts for over 50 percent of global fish production, is the fastest-growing food-producing sector. About 424 aquatic species are cultivated globally, benefiting millions through the provision of nutrition, food security and sustainable livelihood, and poverty reduction (Galappaththi *et al.,* 2020). Over the past two decades, world aquaculture has developed tremendously to become an economically significant industry. The industry continues to grow at an average global annual growth level of 8.8 percent per year compared with all other animal food production industries (Onada & Ogunola, 2017).

Nigeria is the largest fish consumer in Africa and among the largest fish consumers in the world (Adelesi, 2019) with about 3.2 million metric tons of fish consumed annually. The aquaculture sub-sector is considered a very viable alternative to meeting the nation's need for self-sufficiency in fish production. This is based on its high reliability in return on investment and low capital intensity relative to capture fisheries. Yet, Nigeria imports over 900,000 metric tons of fish while its domestic catch is estimated at 450,000metric tons/year (Ozigbo, *et al.,* 2013).

1.1 OBJECTIVES OF FISH FARMING

Aquaculture is the farming of aquatic organisms and plants in fresh, brackish or salt water. A wide variety of aquatic organisms are produced through aquaculture. These include: fishes, crustaceans, molluscs, algae, and aquatic plants. Unlike capture fisheries, aquaculture requires deliberate human intervention in the organisms' productivity which results in yields that exceed those from the natural environment alone. Such interventions are stocking water with seed (fingerlings), fertilizing the water, feeding the organisms, and maintaining water quality (Green, 2009).

* Production of protein rich, nutritive, palatable and easily digestible human food benefiting the whole society through plentiful food supplies at low or reasonable cost;
* Providing new species and strengthening stocks of existing fish in natural and man-made water-bodies through artificial recruitment and transplantation;
* Production of sport-fish and support to recreational fishing; production of bait-fish for commercial and sport fishery;
* Production of ornamental fish for aesthetic appeal, recycling of organic waste of human and livestock origin, land and aquatic resource utilization:

This constitutes the macro-economic point of view benefiting the whole society. It involves:

(a) Maximum resource allocation to aquaculture and its optimal utilization

(b) Increasing standard of living by maximising profitability

(c) Creation of production surplus for export (earning foreign exchange especially important to most developing countries) (Jhingran, 2001).

Growth of fish is dependent on a wide range of positive or negative impacting factors. Studies show that growth of fish in aquaculture mainly depends on feed consumption and quality (Slawski *et al.,* [2011](https://fas.biomedcentral.com/articles/10.1186/s41240-017-0075-7#ref-CR35)); stocking density (Ma *et al.,* [2006](https://fas.biomedcentral.com/articles/10.1186/s41240-017-0075-7#ref-CR25)); biotic factors such as sex and age (Imsland and Jonassen, [2003](https://fas.biomedcentral.com/articles/10.1186/s41240-017-0075-7#ref-CR20)); genetic variance; and abiotic factors such as water chemistry, temperature (Imsland *et al.,* [2007](https://fas.biomedcentral.com/articles/10.1186/s41240-017-0075-7#ref-CR21)), photoperiod (Imsland and Jonassen, [2003](https://fas.biomedcentral.com/articles/10.1186/s41240-017-0075-7#ref-CR20)), and oxygen level (Bhatnagar and Devi, [2013](https://fas.biomedcentral.com/articles/10.1186/s41240-017-0075-7#ref-CR5)) to name a few.

As stated in the Sustainable Development Goals (SDGs), there is a global concern about erasing malnutrition, improving poverty alleviation, and achieving food security and planetary health. In particular, SDGs 1 and 8 are related to poverty and economic growth, respectively, and SDGs 2, 3, and 12 are about zero hunger, good health, and responsible consumption and production, respectively (UN, 2015).

The importance of fisheries as a source of food and nutrition cannot be overstated, especially in the face of population growth and increasing demand for animal protein (FAO, 2016; Thilsted *et al.,* 2016). Several studies have indicated that fish is an excellent source of animal proteins, micronutrients, and vitamins (Allison, 2011; Beveridge, *et al.,* 2013; Tacon and Metian, 2013; Rittenschober, *et al.,* 2016).

Globally, fisheries production peaked at about 171 million tons in 2016, of which aquaculture production represented 80 million tons (47%) and capture production represented 91 million tons

(53%) (FAO, 2018). During the recent decades, a large number of the world’s fish stocks have been depleted, and, therefore, global fisheries are no longer capable of producing their maximum sustainable yield (Agnew, *et al.,* 2009). Aquaculture has contributed to the impressive growth in the seafood supply for human consumption (Cressey, 2018).

Pollution is considered as one of the most serious problems that faces human societies in the whole world especially in the developing countries. Though produced by man himself and his activities, it has deleterious effects on human's environments and resources (Mendil & Uluözlu, 2007; Zaki, *et al.,* 2014). So, pollution and its effects are considered as one of man's greatest crimes against himself. Aquatic habitats, especially the freshwater ecosystems, are more subjected to pollution than other environments, because of water use in industrial processes as well as discharge of effluents from industry and urban developments (Demirak, *et al.,* 2006; Fernandesa, *et al.,* 2007; Zaki, *et al.,* 2014). Most aquatic ecosystems can cope with a certain degree of pollution, but severe pollution is reflected in a change in the fauna and flora of the community, which suffer such pollution. There are several categories of water pollutants, which include domestic sewage and oxygen demanding wastes, infectious agents, plant nutrients, chemicals such as insecticides, herbicides and detergents, and heavy metals.

Therefore, the measuring of physico-chemical characters of water; such as temperature, electrical conductivity, total solids pH, nutrient salts, etc. is important to investigate the water quality and the ecological variations in the fauna and flora of water body (Zaki *et al.,* 2014).

The growing production of freshwater and marine aquaculture has tremendous potential to help sustainably feed the growing human population (Froehlich, *et al.,* 2018). However, fish farming may also lead to a decrease in biodiversity and nutrition diversity, as it usually focuses on a few selected species (Lutaladio, 2010; Golden, *et al.,* 2016; Thilsted, *et al.,* 2016; Lachat, *et al.,* 2018). However, several studies have pointed towards the challenges facing aquaculture production and, in particular, its environmental and ecological impacts.

**CHAPTER TWO**

**2.0 BIOLOGICAL SUBSTANCES**

Natural and synthetic substances such as antibiotics, disinfectants, water and soil treatment compounds, pesticides, fertilizers, probiotics, and other feed additives have become crucial inputs to treat and prevent bacterial and parasitic diseases, to improve water quality, to increase pond natural productivity and/or as growth promoters (Subasinghe, *et al.,* 1996; Bondad-Reantaso, *et al.,* 2005; Rico, *et al.,* 2013). Residues of potentially toxic substances such as pesticides or antimicrobials can accumulate in the treated animals, resulting in a potential hazard for consumers and for the marketing and export of aquaculture produce (Sapkota, *et al.,* 2008; Heuer, *et al.,* 2009). The extensive use of antibiotics in aquaculture can contribute to the development of antimicrobial-resistant pathogenic bacteria both inside and outside the aquaculture facilities (Sørum, 1999; Inglis, 2000; Le, *et al.,* 2005). Moreover, some antibiotics are moderately to highly toxic to non-target bacteria and primary producers (Wollenberger, *et al.,* 2000; Flaherty and Dodson, 2005; Grinten, *et al.,* 2010; Rico, *et al.,* 2014; Yasser and Adli, 2015; Andrieu, *et al.,* 2015), thus possibly contributing to the degradation of aquatic ecosystems receiving aquaculture effluents (Rico *et al.,* 2012).

**2.1 CLASSIFICATION OF BIOLOGICAL SUBSTANCES**

These include

**2.1.1 Parasitic infestation**

In developing countries where human and animal wastes are used as inputs, nematode, cestode and other parasites are hazards, farm workers are exposed toit. Examples include leeches in ponds which attack individuals that the wade unprotected. ·

**2.1.2 Pathogenic infestation**

Risk of fungal and other pathogenic infections such as vibrio has a high likelihood in intensively manured ponds. Charmish (1996) observed that individuals pricked by spines of *Tilapia* sp infected by *Vibrio vulnificus* caused amputation of fingers.

**2.1.3 Diseases**

High productivity in aquaculture production only transpire when fish are healthy and free from diseases. Fish disease management is aimed at preventing the onset of disease and measures to reduce losses from disease when it occurs. Some common fish diseases, their causes and management control:

* *Streptococcosis* is a disease of freshwater pond fish cultures, particularly *Streptococcus*

*agalactiae* of tilapia (*Oreochromis spp*.). Clinical signs include cloudy eyes, exopthalmos and focal, ulcerative skin lesions along the caudal peduncle area. Control of streptococcosis relies on the administration of an antibiotic to which the isolate is sensitive together with control of any associated ectoparasites and appropriate risk reducing husbandry measures.

Preventative measures are dependent on an effective vaccine against the pathogenic strains of *Streptococcus* present in the fish environment or to which the susceptible fish stocks are likely to encounter (Roger *et al.,* 2011). Others diseases include Benediniasis, viral hemorrhagic septicemia, *Myxobolus cerebralis* (whirling disease), *Ichthyophthirius multifiliis*, *Epinephelus lanceolatus*, Viral Encephalopathy and Retinopathy (VER) Disease.

* *Vibriosis* is a bacterial disease causing significant losses of fish in marine fish farms.

Vibriosis accounts for an estimated two-thirds of disease reported in grouper species. Vibriosis results in severe skin, muscle, fin, eye and internal organ damage of fish. Stressors that trigger vibriosis outbreaks include high water temperatures, high stocking densities, poor handling of fish, and an organically polluted culture environment. Antibacterial medication, reducing stocking densities, careful handling of fish, improving the culture environment through the use of clean pelleted feeds, stocking of fish in cooler season of the year and vaccination are important control measures (Roger, *et al.,* 2011).

**2.1.4 Biological pollution**

The introduction of non-endemic species into natural water arising from their inadvertent release from aquaculture facilities is considered a serious environmental threat. The introduced species may carry diseases and parasites alien to the native with disastrous consequences (WHO, 1989). Instances abound where exotic fish species wiped out native stocks (Kutty, 1981). The Introduced species may have the tendency of out-competing the native stock partly because they do not have natural predators, parasites and pathogens in their new environment. This trend creates biodiversity loss in natural waters.

The introduction of genetically modified organisms such as transgenic fish is considered hazardous to the environment. Kapuscinski and Hallerman (1990) and Hallerman and Kapuscinski (1999) noted that such fish would pose ecological or genetic risks when they escape from production facilities. The authors further stated that the ecological hazards would include the possibility of the transgenic fish being a voracious predator or competitor thereby impacting negatively on key ecological processes. Inter breeding of introduced or transgenic fish with the native stock could cause dilution of the gene pool.

Transmission of diseases and parasites to native stocks from cage and pen facilities is a major problem. In many countries disease testing and certification programs for animals are not implemented with the result that native stocks are exposed to non-endemic parasites and diseases from aquaculture facilities.

In the recent past, more emphasis has been put into fish farming worldwide (Tidwell and Allan [2001](https://fas.biomedcentral.com/articles/10.1186/s41240-017-0080-x#ref-CR70)) and East-Africa in particular (Rutaisire, *et al.,* [2009](https://fas.biomedcentral.com/articles/10.1186/s41240-017-0080-x#ref-CR60)). This has resulted in a significant contribution from aquaculture to the overall fish production (Brander [2007](https://fas.biomedcentral.com/articles/10.1186/s41240-017-0080-x#ref-CR14)).

Unfortunately, intensive fish farming is associated with a number of challenges including diseases (Bondad-Reantaso, *et al.,* [2005](https://fas.biomedcentral.com/articles/10.1186/s41240-017-0080-x#ref-CR13); Walakira, *et al.,* [2014](https://fas.biomedcentral.com/articles/10.1186/s41240-017-0080-x#ref-CR76)), which demotivate farmers due to the increased economic loss.

**CHAPTER THREE**

**3.0 AQUATIC PLANTS**

Aquatic weeds are plants that have adapted to living in aquatic environment (salt water or fresh water). They are also referred to as hydrophytes or macrophytes. Weeds or macrophytes are critically important to many aquatic habitats:

* They provide spawning areas for adult fish, cover for smaller organisms, and they purify water in wetlands all over the world.
* Emergent weeds are also great stabilizers of shoreline areas and they provide a buffer zone, which helps clean the run-off entering the water body.

But some are also a nuisance, including invasive species. The diagnostic features of aquatic weed basically support its rate of proliferation and as such makes it a menace to the aquatic environment (Adekoya, 1997; (Adesina, *et al.,* 2015).

Aquatic plants infestation have a significantly adverse effect on the aquatic and terrestrial biodiversity of the affected location. Unmanaged population of this plant is capable of creating serious impacts that ripples through infested areas (Keddy, *et al.,* 2007).

Some popular species found in Nigeria aquatic environments include:

*Eichhornia crassipes* (water hyacinth),

*Pistia stratiotes* (water lettuce),

*Salvinia nymphellula* (water fern),

*Ceratophyllum demersum* (ceratophyllum),

*Tyha australis* (cattail),

*Nymphea lotus* (waterlily),

*Cyperus papyrus* (reed),

*Vossia cuspidata* (vossia)

*Phragmites karka* (reed) (Hutchinson, 1975; Adesina, *et al.,* 2015).

**3.1 Features of Aquatic weeds**

* Aquatic weed causes lot of problem for fishermen and this include access to fishing sites which is usually difficult whenever there is infestation of the water by the weeds. In most cases, loss of fishing equipment when nets or wires become tangled in the root system of the weed leading to reduction in catch and subsequent loss of livelihood (Adesina, *et al.,* 2015).
* In areas where fishermen get a meager living from their fishing occupation, this presents serious socio-economic problems. It was observed that about 45 million Kilograms of fish were annually lost due to aquatic weed infestation in the west Bengal of which the South-Western Nigeria is not left out (Charudattan, *et al.,* 1994; Adesina, *et al.,* 2015).
* Aquatic weeds increase the surface areas of the rivers or lakes and this increase the rate water bodies lose water to the atmosphere by 3-5 times the normal rate due to accelerated evapotranspiration. Incidentally, evapotranspiration reduces the water volume in rivers, lakes, reservoirs, canal and river basins and this means that aquatic weed can cause drying up of rivers and ponds (Charudattan, 2001; Adesina, *et al.,* 2015).
* Aquatic weeds impede transportation, irrigation and navigation by preventing free movement of fishes and other navigation vessels. Access to harbors and docking areas can be seriously hindered by mats of aquatic weeds. Ponds and rivers can become impassable as they clog up with densely intertwined carpets of the weed. It is also a serious hazard to lake transport as large floating mats of aquatic weeds clog up free waterways, sometimes leading to many of the Inland waterways being abandoned. This can have serious negative economic impact on the host communities (Davies, et al., 2009).
* Infestation by the weed produces an obnoxious smell that affect the color and taste of the water, thereby, impairing its quality and changing its chemistry; thus making it grossly unfit for human consumption, agricultural and industrial activities (Adesina, *et al.,* 2015).
* In addition to providing shelter for predator reptiles of fishes and other aquatic wild lives, the plant also harbors insect vectors of human and animal diseases. The diseases associated with the presence of the aquatic weed in tropical Countries are: Malaria, Schistosomiasis and lymphatic fillariasis. The Anophelis specie (female) of mosquito larvae thrive on the environment created by the aquatic weeds (Kitching, 2001).

This means that there is a high risk of malaria, schistosomiasis and lymphatic fillariasis because of rapid growth of aquatic weeds e.g (Water hyacinth) in rivers and streams in communities within the South-Western Nigeria. The continued inhabited infestation of water bodies by water hyacinth presents a long-term threat to the water bodies. The biodiversity (complex and mutual co-existence of other aquatic organisms for the balancing of the ecosystem), of an ecosystem can be lost entirely due to the invasion of the water body by aquatic weeds. It would spread over large areas and much of the water body could be eventually lost to land as other plants also begin to grow because of the new condition created by the presence of aquatic weeds (Adesina, *et al.,* 2015).

Also, aquatic weed blots out light, endangers oxygen supply (DO), slows down water flow and suppresses the growth of phytoplankton and algae with serious repercussions on biological productivity and diversity (Adesina *et al.,* 2015). Imbalance in the aquatic micro-ecosystem due to proliferation of water hyacinth also means that a range of flora and fauna that rely on a diversity of plants life for their existence will become extinct (Adesina *et al.,* 2015).

Based on the high degree of reduction in the biodiversity of water invaded by aquatic weeds, there is disruption of socio-economic structure, food supply and health of up to several millions of people in South-Western Nigeria. The impacts of aquatic weeds are numerous and their significance in the ecosystems, especially in large water bodies cannot be ignored. The weeds need to be managed prudently to allow sustainable exploitation and exploration of mitigating measures to minimize potential negative impact often associated with the massive proliferation. Aquatic weeds are highly susceptible to fast growth and their spread in water bodies is drastic (Adesina *et al.,* 2015). They are expected to be managed with high level of carefulness, due to the fact that their management must not lead to extinction of living organisms in the aquatic environment (Adesina *et al.,* 2015).

**CHAPTER FOUR**

**4.0 ZOOPLANKTONS**

One of the most difficult challenges facing commercial fish producers is the constant balancing act required to maintain a stable relationship among the water, fish, and microscopic flora and fauna in their pond systems. Information regarding the relative status of plankton (zooplankton and phytoplankton) communities gives insight into water quality parameters and the possible success or failure of the culture season. The dynamic characteristics of zooplankton populations have led researchers to use particular fertilization techniques and species specific zooplankton inoculations in culture ponds (Colura and Matlock 1983; Geiger et al. 1985; Morris and Mischke, 1999).

Zooplankton important to larval fish are classified as either rotifers, cladocerans (water fleas) or copepods. The ability of rotifers and cladocerans to reproduce asexually (parthenogenetically) enables them to react quickly to unfavorable and favorable environmental conditions (Pennak 1989; Morris and Mischke, 1999). Rotifers have the shortest life span (12 days) and can reach their peak reproductive level in about 3.5 days (Allan 1976; Morris and Mischke, 1999). At 20°C (68° F), the egg-to-egg span is 2-3 days and 1525 young are produced by an adult throughout its life span. Cladocerans and copepods have similar life spans of approximately 50 days, but with different peak reproductive periods. To reach this peak reproductive capacity, cladoceans require 14-15 days while copepods require 24 days (Allan 1976; Morris and Mischke, 1999). Copepods, which have only sexual reproduction, require longer periods to increase their population levels. Cladocerans are desirable fish prey since they have high energetic caloric value, assuming that they can be consumed by fry. However, cladoceran populations usually decline rapidly when subjected to predation by larval fish in culture ponds (Geiger 1983b; Geiger et al. 1985; Morris and Mischke, 1999). Conversly, copepods, because they are swift, powerful swimmers, are better able to maintain their populations during the later stages of a culture season (Geiger and Turner 1990; Morris and Mischke, 1999).

Zooplankton characteristics as environmental indicators namely cladocerans, which are colored a deep red are often indicators of low dissolved oxygen conditions (Pennak 1989; Morris and Mischke, 1999). This coloration is based on the increased amount of hemoglobin that these animals have to compensate for low oxygen levels in the environment; however, this increased amount of hemoglobin comes at an energetic cost. Landon and Stasiak (1983) found that D. pulex quickly become clear when placed into well-oxygenated waters. Another indication of poor environmental conditions is indicated by the increased number of eggs with delayed development (dispause eggs) in cladocerans. These diapause eggs are often quite large and dark and are produced when these animals are forced to undergo sexual reproduction in preparation of unfavorable environmental conditions (Pennak 1989; Morris and Mischke, 1999). When a cladoceran is food-limited, it matures at a smaller size and produces smaller offspring (total number being similar). The main response of D. pulex to low food levels is a reduction in size-specific food intake and egg size (Lynch 1989; Morris and Mischke, 1999). However, food concentration does not affect length/weight relationships, instar duration and weight-specific investment of energy in reproduction. Cladoceran populations consist of smaller individuals in water bodies with large populations of vertebrate predators. Large-bodied species, e.g., D. pulex, tend to be fewer in ponds with large predator bases (Zaret 1980; Morris and Mischke, 1999). In these situations, smaller species or smaller individuals within a species have better chances of escaping predation than larger individuals (based on prey visibility).

**CHAPTER FIVE**

**5.0 CHEMICAL AND PHYSICAL PARAMETERS**

The aquatic environment governs fish life; hence water quality should be suitable for fish culture. When environmental condition does not conform to optimal range for normal fish growth, then fish culture could be affected. The major concerns of the fish culturist should be to deal with the aspects of water quality that may cause poor growth or death of fish (Boyd, 1978; Pronob, *et al.,* 2021). Water quality management aims to regulate environmental conditions so that they are within a desirable range for growth and survival of fish. To a great extent water determines the success or failure of an aquaculture operation. The aquatic environment is composed of many aquatic variables. Fish culturist's must know the variables that are potential sources of stress for the fish. The variables may also explain the causes of fish culture problems.

Therefore, successful management of fish ponds requires an understanding of water quality, which is determined by abiotic factors such as temperature, dissolved oxygen (DO), transparency, turbidity, water color, carbon dioxide, pH, alkalinity, hardness, unionized ammonia, nitrite, nitrate, primary productivity, biological oxygen demand (BOD), plankton population among others (Bhatnagar and Devi, 2013)

**5.1 Water quality management**

Water quality is a dynamic web of the physical, biological and chemical factors, which constitute the water environment and influences the production of fish and other aquatic environment. There are many water quality variables in pond fish culture. All other things being equal, a pond with good water quality will produce more and healthier fish than a pond with poor quality. Water quality determines to a great extent the success or failure of a fish cultural operation (Piper *et al*., 1982; Pronob, *et al.,* 2021). Water quality parameters, which are of prime importance, are mainly temperature, turbidity, oxygen, CO2, nitrogen, ammonia, pH, alkalinity, hardness, etc.

**5.1.1 Temperature**

The water temperature is considered to be one of the most important factors in aquatic environment because it affects all metabolic, physiological activities and life processes of different trophic levels of pond ecosystem. In addition, it also affects the speed of chemical changes in soil and water (Dhirendra, 2002; Pronob, *et al.,* 2021). Water temperature plays an important role in influencing the periodicity, occurrence and abundance of phytoplankton as it had a direct relationship with total plankton (Tripathi and Pandey, 1990; Pronob, *et al.,* 2021). Fishes are cold-blooded animal and dependent upon the water temperature in which they live. Every fish species has an ideal temperature range within which it grows quickly. The optimum temperature range for 'cold water' and 'warm water' fishes are 14-18°C and 24-30°C respectively. Water temperature can be adjusted to optimum level in controlled system such as hatcheries. It is difficult to adjust temperature in large water bodies. Operation of aerator during calm and warm afternoon helps to break thermal stratification of pond by mixing warm surface water with cool subsurface water (Pronob, *et al.,* 2021).

**5.1.2 Turbidity**

The turbidity is a term that refers to the suspended solids particles, planktonic organism and humic substances produced through decomposition of organic matter. In aquaculture ponds, turbidity from planktonic organism is often desirable to an extent, whereas that caused by suspended particles is undesirable (McCombie, 1953; Pronob, *et al.,* 2021). However, heavy blooms limit heat and light penetration, then reducing the effective volume of productive zone. Optimum Secchi-disc visibility of fish ponds is considered to be 30-40 cm. In ponds with Secchi-disc visibility of 10-20 cm, dissolved oxygen concentration may fall so low at night that fish are stressed or even killed (Romaire and Boyd, 1978; Pronob, *et al.,* 2021). Turbidity due to suspended solids can be controlled by application of organic manure 500-1000 kg/ha or gypsum @ 250-500 kg/ha or alum @ 25-50 kg/ha (Pronob, *et al.,* 2021).

**5.1.3 Dissolved oxygen**

Dissolved oxygen is one of the most important chemical parameters in aquaculture. Low dissolved oxygen levels are responsible for fish kills, either directly or indirectly. The concentration of dissolved oxygen in natural water is influenced by the relative rates of diffusion to and from the atmosphere, photosynthesis by aquatic plants and respiration by aquatic biological community. Dissolved oxygen along with the turbidity could provide information about the nature of an ecosystem better than any other chemical parameters (Hutchinson, 1975; Pronob, *et al.,* 2021). It was also observed that dissolved oxygen content of pond water in the range of 5 mg/litre to saturation level favour good growth of flora and fauna. Aeration is proven technique for improving dissolved oxygen availability in ponds. Several form of mechanical aeration are available to the fish farm e.g. Paddle wheel aerator, airlift pumps, air diffuses, agitators etc (Pronob, *et al.,* 2021).

**5.1.4 pH**

pH is a measure of hydrogen ion concentration in water is acidic or basic. It has direct effects on fish growth and survival of food organisms. Hence, to achieve good fish production pH of the water should be monitored regularly to ensure its optimum range of 6.5-8.5 (Banerjea, 1967). It also exerts considerable influence on toxicity of ammonia and hydrogen sulphide as well as solubility of nutrients and thereby water fertility (Pronob, *et al.,* 2021). The generalised effects of pH on fish are presented in Table 1.

**Table 1. Effects of pH on fish**

|  |  |
| --- | --- |
| **pH** | **Effects** |
| 4.0 | Acid death point |
| 4.0-6.0 | Slow growth rate |
| 6.0-9.0 | Best for growth |
| 9.0-11.0 | Slow growth, lethal to fish over long period of time |
| 11+ | Alkaline death point |

The best way to counter water pH problem is application of lime for increasing soil pH to greater then pH 6 and total alkalinity and total hardness to greater than 40 mg/litre as calcium carbonate. Calcium carbonate (CaCO3), dolomite CaMg(CO3), calcium hydroxide (slaked lime)-Ca(OH)2 and calcium oxide (quick lime)-CaO are the different lime material used. Lime should be carried out a few weeks before addition of fertilizer and stocking of fish. Agricultural gypsum (CaSO4) is applied to correct the total hardness without affecting total alkalinity. It may be also applied to correct the alkaline pH (Pronob, *et al.,* 2021).

**5.1.5 Ammonia**

Ammonia is the first measurement to determine the health of biological converter. Fish are very sensitive to unionised ammonia and the optimum range is 0.02-0.05 mg/litre in the pond water. When ammonia accumulates to toxic levels, fish cannot extract energy from feed efficiently. If the ammonia concentration gets high enough, the fish will become lethargic and eventually fall into a coma and die. In properly managed fish ponds, ammonia seldom accumulates to lethal concentrations. However, ammonia can have so-called "sub-lethal" effects such as reduced growth, poor feed conversion, and reduced disease resistance at concentrations that are lower than lethal concentrations. The main source of ammonia in fish ponds is fish excretion. Protein in feed is the ultimate source of most ammonia in ponds where fish are fed. Another main source of ammonia in fish ponds is diffusion from the sediment. The decomposition of this organic matter produces ammonia, which diffuses from the sediment into the water.

There are two main processes that result in the loss or transformation of ammonia. The most important is the uptake of ammonia by algae and other plants. Plants use the nitrogen as a nutrient for growth. The other important process of ammonia transformation in fish ponds isâ 'nitrification'. Bacteria oxidize ammonia in a two-step process, first to nitrite (NO2) and then to nitrate (NO3).

Aeration can also reduce ammonia toxicity. Healthy phytoplankton removes ammonia from water. Formalin may also reduce the ammonia. Proper feeding management should be maintained in fish pond. Biological filters may be used to treat water for converting ammonia to nitrite and then to harmless nitrate through nitrification process (Cole and Boyd, 1986; Pronob, *et al.,* 2021).

**5.1.6 Nitrite**

Nitrite is the second chemical measurement made to determine the health of the biological converter. Nitrite should not be detectable in a pond with a properly functioning bio-converter. Nitrite is produced by the autotrophic Nitrosomonas bacteria combining oxygen and ammonia in the bio-converter and to a lesser degree on the walls of the ponds. Nitrite has been termed as the invisible killer. It can be deadly, particularly to the smaller fish, in concentration as low as 0.25 ppm. Effective removal of organic wastes, adequate aeration and correct application of fertilizers are the methods to prevent accumulation of nitrite to toxic levels in pond culture (Pronob, *et al.,* 2021).

**5.1.7 Hydrogen sulphide**

Freshwater fish pond should be free from hydrogen sulphide. Fish lose their equilibrium and subjected to sub-lethal stress at concentration of 0.01 mg/litre of hydrogen sulphide. Frequent exchange of water can prevent building up of hydrogen sulphide. Further increasing water pH through liming can also reduce the hydrogen sulphide toxicity. Potassium permanganate (6.2 mg/litre) is also used to remove hydrogen sulphide from the water (.

**5.1.8 Carbon dioxide (CO2)**

The primary sources of carbon dioxide in fish ponds are derived from respiration by fish and the microscopic plants and animals that comprise the fish pond biota. Decomposition of organic matter is also a major source of carbon dioxide in fish ponds. The fish producers are rightly concerned with maintaining adequate concentrations of dissolved oxygen. The problem with the potential toxicity of carbon dioxide can be related to the daily fluctuating pattern of dissolved oxygen and carbon dioxide concentrations. Carbon dioxide concentrations are highest when dissolved oxygen concentrations are lowest. Carbon dioxide concentrations are maximum during winter and minimum during summer. However, carbon dioxide is rarely a problem in winter because dissolved oxygen concentrations are usually well above saturation levels. Freshwater fish pond should contain a low concentration of free CO2(<3 mg/litre), although it can tolerate high concentrations of CO2(Boyd, 1978; Pronob, *et al.,* 2021). Aeration and increasing of pH can control the high concentration of CO2. Experiment have shown that 1.0 mg/litre of hydrated lime can remove 1.68 mg/litre of free CO2 (Adhikari, 2006; Pronob, *et al.,* 2021)

**5.1.9 Alkalinity**

Alkalinity is the capacity of water to neutralize acids without an increase in pH. Total alkalinity is the sum of the carbonate and bicarbonate alkalinities. Some water may contain only bicarbonate alkalinity and no carbonate alkalinity. The carbonate buffering system is important to the fish growth regardless of the production method used. In pond production, where photosynthesis is the primary natural source of oxygen, carbonate and bicarbonate are storage area for surplus carbon dioxide in the buffering system would never be limiting factor that could reduce photosynthesis, as in turn reduce oxygen production. On the other hand, by storing carbon dioxide the buffering system prevents wide daily fluctuations. Without a buffering system, free carbon dioxide will form large amount of weak acid (carbonic acid) that may potentially decrease the night time pH level to 4.5 (Pronob, *et al.,* 2021). During peak period of photosynthesis, most of the carbon dioxide will be consumed by the phytoplankton and as a result, drive the pH level above 10. Pond water with low alkalinity <20 mg /litre as CaCO3 and >300 mg/litre is unproductive. The ideal range of total alkalinity for freshwater fish pond is 50-300 mg/litre as CaCO3 (Pronob, *et al.,* 2021)

**5.1.10 Hardness**

Water hardness is similar to alkalinity but it represents several facts. It is important to fish culture and is commonly reported aspect of water quality. Hardness is the measure of calcium and magnesium, but other ions such as aluminium, iron, manganese, strontium, zinc and hydrogen ions are also covered. Calcium and magnesium are essential in the biological process of fish. Fish can absorb calcium and magnesium directly from the water or food. Hardness values are of at least 30 mg/litre should be maintained for optimum growth of aquatic organisms. Low hardness levels can be increased with the addition of agricultural lime (Pronob, *et al.,* 2021).

**5.1.11 Nutrients**

Nutrient a major constituent of protein occupies a predominant place in aquatic ecosystem. Though a relatively minor constituent, phosphorous is often considered to be the most critical single element in the maintenance of aquatic productivity (Moyle, 1946; Pronob, *et al.,* 2021). Dissolved inorganic nitrogen in the range of 0.2 to 0.5 mg/litre may be considered favourable for fish productivity and phosphorous fertility for aquatic productivity ranges from 0.05 to 2.0 mg/litre. In natural water, silicate remains in silicate form and is important structural constituent of diatoms. (Moyle, 1946; Pronob, *et al.,* 2021). The nutrient status of both water and soil play the most important role in governing the production of plankton organism in fish pond (Banerjea, 1967; Pronob, *et al.,* 2021). Nutrient can be increased in the ponds by adding inorganic and organic fertilizers in measured doses. However, increased levels of nutrient may be harmful; it can cause excessive plankton growth, algal bloom and oxygen depletion.

Concerns about pond water quality are directly related to its production and therefore water quality parameters of greatest concern to fish farming are important to consider in fish culture (Bryan et al., 2011). Therefore, when evaluating and selecting sites for earthen fish pond siting, the source of water and its quality are some of the main factors to consider while ensuring that the water source has a high concentration of dissolved oxygen and optimal temperatures which should be kept at the right levels throughout the culture period among other critical factors (Ngugi, *et al.,* 2007).

**CONCLUSION**

Proper aquaculture system design, good stocking and water quality management are essential to successful and quality fish production. Consequently, maintaining a good culture environment through use of proper management practices will reduce the risk of disease and increase production, fish quality, and marketability. Aquatic weed problems in cultures fish production is an important factor to consider in pond construction and management. Emergent aquatic weed species like sedges if not properly managed can in no small way affect the productivity of any pond and invariably reduce the profitability of fish production. Any changes to their environment add stress to the fish, and the larger and faster the changes, the greater the stress. It is therefore recommended that water of good quality as well as maintenance of all the other factors is very essential for ensuring maximum yield in a fish farming.

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