ASSESSMENT OF WATER QUALITY IN AQUACULTURE PONDS IN TIGONI, KIAMBU COUNTY, KENYA

BY

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DECLARATION

This thesis report is my original work and has not been presented for degree in any other university or any other award.

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DEDICATION

I dedicate this work to my family and friends who always supported me and gave me steadfast encouragement and financial support in my studies.

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ACRONYMS AND ABBREVIATIONS

AMC: Annual Mean Conductivity

FAO: Food and Agriculture Organization of the United Nations

GOK: Government of Kenya

mg/l: Milligram Per Liter

uS/cm: Micro Siemens Per Centimeter

ppm: Parts Per Million

SPSS: Statistical Package for Social Science

TDS: Total Dissolved Solids

UNEP: United Nation Environmental Programme

UNESCO: United Nation Education Scientific and Cultural Organization

WHO: World Health Organization

DEFINITION OF TERMS

Aquaculture:

Aquaculture is also known as fish farming. It involves cultivating freshwater populations through some management interventions to enhance production.

Management:

Management includes interventions like; fish stocking, feeding and protection from diseases, infections and predators and regular harvesting with the aim of enhancing productivity.

Freshwater:

Fresh water is naturally occurring water on the earth's surface characterized by having low concentrations of dissolved salts and other total dissolved solids.

Populations:

All the fish inhabiting a pond, the species can reproduce sexually; the members of a population interbreed with members of their own population.

Stocking:

Introduction/reintroduction of fish fry or fingerlings into a fish pond for rearing

Enhanced production:

Is the increase in production in quality and quantity of fish in a pond.

Physicochemical parameters:

These are parameters measured they include temperature, pH, DO, light penetration and Conductivity, Biochemical oxygen demand, phosphate and nitrates.

Biological parameters:

The biological parameter in this study is algae whose identification will be done in the laboratory.

Pond:

A pond is a pool of water used to rare fish in Tigoni. They are either earthen or liner pond. Earthen ponds are fish pond constructed from soil material while liner ponds are ponds with polyvinyl chloride(PVC) used for water retention.

Warm water culture:

It is the culture of catfish, tilapine fishes and common carp, it requires a temperature range of 20-30^{0}C

ABSTRACT

Fisheries and aquaculture is an important source of food, income and livelihoods for hundreds of millions of people around the world. Aquaculture production has increased from 29.5million tonnes in 2010 to 37.5 million tonnes in 2014 in the world and 1.3 million tons in 2010 to 3.8 million tonnes in Africa. There is no sufficient information suitability of water quality in aquaculture ponds in Tigoni. The aim of the study was to determine the suitability of aquaculture ponds for fish farming based on their water quality. The specific objectives of the study were; to find out quality of water in aquaculture ponds, to identify the type of algae in aquaculture ponds and to evaluate the relationships between water quality and algae in the aquaculture ponds. The study area was Tigoni in Kiambu County. Stratified random sampling design was used to select 8 sample ponds which water samples were collected twice a month for four months. Parameters were temperatures, pH, conductivity, dissolved Oxygen (DO), secchi depth, Biochemical oxygen demand (BOD), nitrates, phosphate and algae identification was also done. The mean values for the physical parameters ranged from 19.69±0.48^{0}C to 22.54±0.57^{0}C (water temperature), 7.57±0.52 (pH), 190.25±127.86 to 416.50±168.93 µS/cm (conductivity), 14.13±3.36 to 28.38±7.13cm (transparency) and 4.03±1.39 to 6.63±1.37mg/l. Chemical parameter 1.99±0.52 to 2.82±0.48 mg/l (BOD), 5.06±1.05 to 57.57±15.84mg/l (phosphate) and 0.38±0.10 to 8.86±1.20 (nitrates). One-Way ANOVA indicated significant difference between pond F and H (P=0.001) (temperature), pond A and G (P=0.001) (pH), pond A and C (p=002) (conductivity). Pond D from G (p=0.000) (Secchi depth), pond C and G (P=0.001) (DO). Pond D and G (p=0.001) (BOD) Pond F and H (p=0.001) (phosphates) and pond A and H (0.000) (nitrates). Mean temperature were in the lower range with pond D and H being below optimum range. DO t-test, pond G had a significant difference (t=7.500, α=0.05, p=0.00) and there was no significant difference in BOD in all ponds. A total of 12 genera of algae were identified. Composition per pond was; pond A, B, C, D, E, F, G and H recorded 6, 10, 7, 6, 6, 7, 10 and 11 genera respectively. Temperature, lowest Pond H 6 genera identified, highest mean pond 7 genera were identified. Phosphate, Pond H highest mean 11 genera pond F 7 genera. Nitrates highest in pond H 11 genera while lowest was in pond A 6 genera were identified. In conclusion, water quality in most aquaculture ponds did not vary significantly from one pond to another and the quality in most aquaculture ponds met quality for fish farming. Ponds high in phosphates and nitrates had more genera of algae. The study recommends water management intervention be practced to manage water quality and control algae growth also water and soil conservation to control nutrient load in water sources. Research on suitability of water used for aquaculture in the area, a comparative study for water quality in liner and earthen ponds and the algae composition and abundance in the aquaculture ponds.

CHAPTER ONE: INTRODUCTION

1.1 Background Information

In recent decades, aquaculture has become an increasingly important part of the world economy (Piasecki *et al.,* 2004). According to FAO (2012), fisheries and aquaculture are income source for 55 million people in the world, where 12% of livelihoods in the world's population rely on aquaculture, the sectors contributes to food security and nutrition, providing more than 4.3 billion people with about 15% source of animal protein. In Africa aquaculture production is above 40300metric tonnes. Aquaculture production in Kenya showed an upward trend since year 2000 with production increasing from 1000 tonnes which is less than 1% of total fish production in year 2006 to 24,000 tonnes in 2017 (Obiero et al., 2019). In addition, 37% of production that enters international trade, the sub-sector contributed more than 0.5% to GDP of the country (Mbugua, 2008). Aquaculture also produces fingerlings for stocking natural waters, by this means, it is possible to support or even enhance the populations (Steffens, 2008).

Water quality is important for aquaculture production as it is the main factor controlling the production of the aquaculture in ponds. In addition, it affects the production in the ponds which in turn affects the productivity of food and the health of the people (FAO, 2012). According to Arain *et al.,* (2015), the different forms of high density, intensive aquaculture is similar worldwide because they obey the same set of physical, biological and chemical principles. They add that, these principles compose the subject of water chemistry and its net result, that is, the water quality among others. The reactions of water with the environment and the natural chemistry also have an important bearing on fish (FAO, 2012).

Water pollution has become a global problem to human health due to increased pathogen and also the increased sediment into water bodies (Obasohan and Agbonlahor, 2010). Agricultural runoff (containing pesticides and fertilizers), effluents of industrial activities, and sewage effluents, supply the water bodies and sediment with huge quantities of inorganic anions and heavy metals that greatly affect water quality depending on the source (Arain *et al.,* 2015). Pollution of the aquatic environment by inorganic and organic chemicals poses serious threats to the fish (Saeed and Shaker, 2008) for example; in February 2010 there was massive death of fish in Lake Naivasha, Kenya due to insufficient dissolved oxygen level (Ndungu *et al.,* 2015). The presence of a healthy level of microscopic algae in a pond is important for maintaining water quality so as to take care of fish and other aquatic organisms in the pond (Ojo *et al.*, 2004). Algae also undergo a continual succession of dominant genera due to dynamic changes of growth factors such as light, temperature and nutrient concentration in aquatic environment due to changes in water quality which in turn affects production (Obasohan and Agbonlahor, 2010). Moderate levels of algae in aquaculture ponds are beneficial; they serve as the base of the food chain and also take up ammonia, a waste product of fish (Goodwin *et al*., 2004). However, algae also change the appearance of water bodies, and the filamentous forms can interfere with fish harvesting (Obasohan and Agbonlahor, 2010). Most types of algae are rarely directly harmful although, in rare cases some types can produce toxins which at times cause fish mortality (Odino, 2013).

Water quality is also affected by management practices of ponds, these practices varies from one farmer to another and they include interventions such as stocking (Moogouei *et al.,* 2009), population control especially in carps and tilapia, pond water fertilization and feeding. These interventions impact on water quality which in turn affects fish ponds productivity (Mbugua, 2008). For healthy fish and high production to be enhanced, good water quality must be maintained and currently there is no sufficient information on aquaculture in the area.

In Central Kenya aquaculture is on the rise and information on the suitability of water quality in the aquaculture remains limited to water quality without documenting the suitability of aquaculture ponds in fish farming. Hence the documentation of the suitability of aquaculture ponds in fish farming based on their water quality in Tigoni is important to provide a vital baseline for detecting changes water quality and formation of management interventions.

1.2 Problem Statement

In Kenya there has been an increase in aquaculture in the country since the introduction of ESP in 2009, currently intensive and semi-intensive aquaculture is practiced it involves enhancement of rapid growth of fish is through pond fertilization and supplementary feeding. In aquaculture pond water fertilization stimulates natural pond productivity, large amounts of nutrients being accumulated (Musyoki., 2015). Inmost cases, feeds are rarely fully consumed by the fish, these causes accumulation of substances in the ponds during the culture period. Which affects the water quality and enhance algae growth (Gautier et al., 2009 and Iwama, 2009).

Since the ESP no studies have been done to assess the water quality since the implementation of the project in Tigoni. The need to understand the dynamics of aquaculture in relation to appropriate fish production is paramount. In addition, in Tigoni area, most of the area is cropland (Fig 3.1) this may have contributed to various impacts on the quality of water resource including rivers/streams which in turn have brought about impact on water quality in aquaculture production.

The current status has directly and indirectly contributed to low aquaculture production in the area as the poor water quality causes stress to fish affecting their growth and at times fish mortality. The objectives of the study are to determine the quality of water in fish ponds in Tigoni, to identify the type of algae in aquaculture ponds in Tigoni and to find out the relationship between water quality and algae type in Tigoni. It will fill the current information gap in aquaculture water quality in Tigoni and also inform farmers on s in ponds and suggest areas of further studies.

1.3 Research Questions

The study was guided by the following questions:

1. How suitable is the quality of water in fish ponds in Tigoni?

2. Which type of algae is found in the aquaculture ponds in Tigoni?

3. What is the relationship between water quality and algae type in aquaculture ponds in Tigoni?

1.4 Objectives

The broad objective of the study was to assess the quality of the water in aquaculture ponds in Tigoni.

Specific Objectives

1. To find out quality of water in aquaculture ponds in Tigoni.
2. To identify the type of algae in aquaculture ponds in Tigoni.
3. To evaluate the relationships between water quality and algae in the aquaculture ponds.

1.5 Hypotheses

1. There is no significant difference in water quality in fish ponds in Tigoni.
2. There is no difference in the type of algae in the aquaculture ponds.
3. There is no relationship between water quality and algae in the fish ponds in Tigoni

1.6 Significance of the Study

The study will provide information on suitability of water quality in aquaculture ponds in Tigoni. It will identify the algae genera in aquaculture ponds and find out the relationship between water quality and algae genera in aquaculture ponds. The information from the research would be used in similar studies. It would be used in aquaculture sector that is extensional services to raise awareness on water quality in the area, as well as availing information to policy makers in order to ensure good water quality for aquaculture activities and mitigation measures to be put in. The information would be of use for providing guidelines in water quality management in aquaculture sector.

1.7 Conceptual Framework

Water quality being the main factor determining type of fish culture and aquaculture production, is affected by different environments it flows through, for example, natural processes (weathering and soil erosion), anthropogenic inputs (municipal, industrial wastewater discharge) and agricultural farm runoff. The source of water also determines the water quality in aquaculture ponds. Aquaculture with the application of animal manure and fertilizers, affects the quality of the water. Water in the open environment, natural chemistry and pond management can have impacts on water quality which affects fish culture and fish production. water quality influence algal growth, green algae produce oxygen and acts as a food source for fish however, some algae species are toxic to fish and can cause fish kill. In addition excessive phytoplankton grow depletes oxygen at night and also during decomposition.

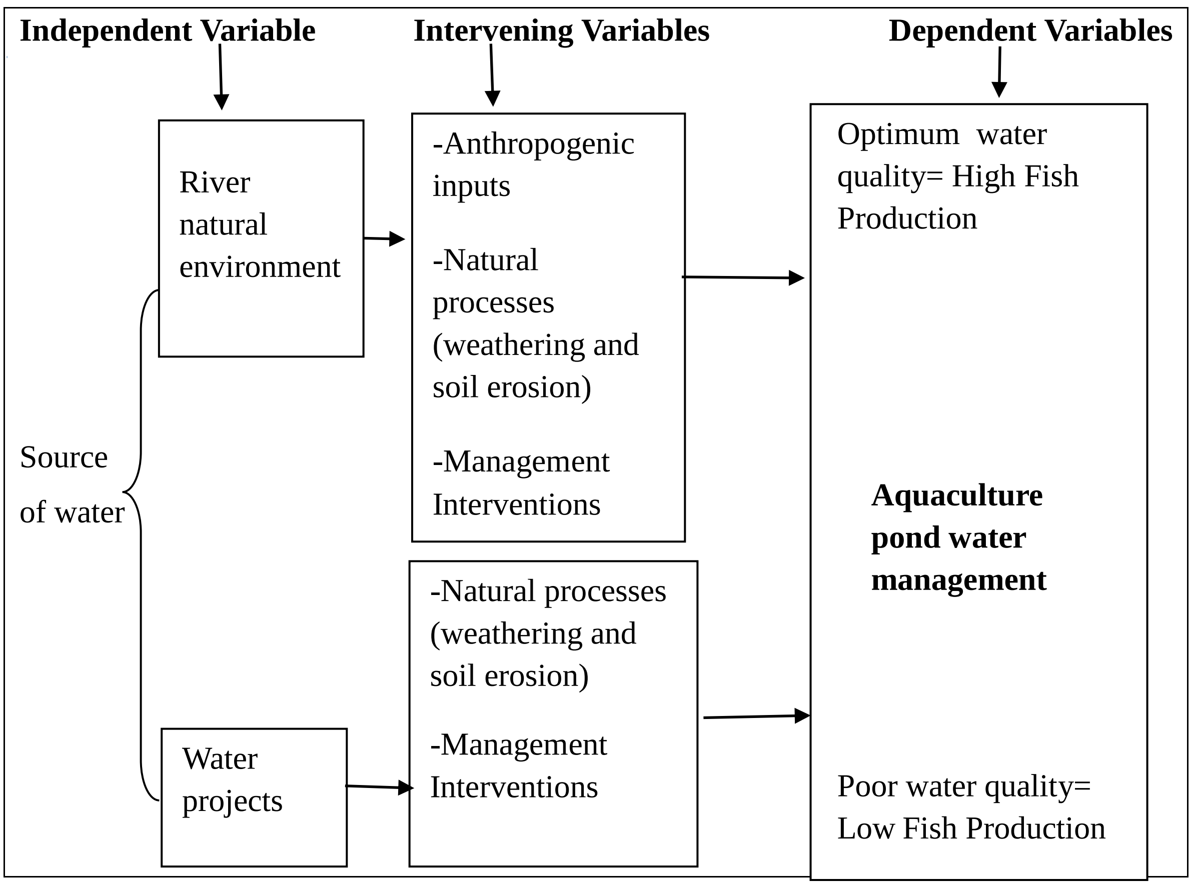


Figure 1.1: Conceptual Framework (*Modified from: Obasohan and Agbonlahor, 2010)*

CHAPTER TWO: LITERATURE REVIEW

2.1 Aquaculture

Aquaculture sector is among the fastest growing in food production sector in the world (FAO, 2012), first practice was in China where the cultured species was the carp (*Cyprinus carpio*). In Africa, it was first practiced by ancient Egyptians adjacent to the Nile River where they farmed the tilapia (Water Research Commission, 2010). According to Piasecki *et al.*, (2004), it has become important to world economy in the last decades, through employment creation, foreign exchange earnings, production of fingerlings suited for stocking natural waters for example, lakes. By this means, it has supported or even enhanced the populations (Steffens, 2008), poverty reduction and food security support. According to FAO (2012), hunger and malnutrition is one of the problems facing the worlds poor and needy persons. In addition, about 80 to 90 million people have to be fed yearly of whom most of them are from the developing countries.

The most reliable source of protein for people are fish, yet millions of people who depend on fish are faced daily with the fear of food shortage because of inability to rear them (Akinrotimi *et al.,* 2009). Aquaculture contributed 43% of aquatic animal food for human consumption in 2007 (for instance, fish, crustaceans and molluscs). This is expected to grow further to meet the future demand (Bostock *et al.,* 2010). Aquaculture in sub-Saharan Africa has immense potential as a means of increasing food security. According to Mjoun *et al.*, (2010) fish such as tilapia have got very high nutritional value. It has been found out that, Americans are consumers of fish because of its high nutritional value and mild taste. Aquaculture also promotes other auxiliary industries such as net making, packaging material industries and boat building (Ojo *et al.,* 2004).

In Kenya like other African countries aquaculture is characterised by low level of pond production (FAO, 2012). It dates back 1910 to 1921 it involved culture of trout which was for sport fishing, in static ponds it was introduced in 1920s when it was started with tilapia later, common carp and African catfish were introduced (Opiyo *et al.,* 2017). In 1960s the goverement stimulated fish farming when the Fisheries department was created. Since 1999 through on-farm research, training and programmes like the

Economic Stimulus Programme aquaculture production has increased and currently likely to be almost 1500 tonnes (FAO, 2012).

2.2 Water quality in Aquaculture Ponds

Water is the most important compounds of the ecosystem and to all forms of life (Mjoun *et al.,* 2010). The social, economic, and political development of the society are affected by water resources and water quality (Saeed and Shaker, 2008). It is the environment for fish and other aquatic organisms; it is the physical support where they carry out their life functions such as feeding, swimming, breeding among others (Arain *et al.,* (2015). According to Lamtane *et al.,* (2008), water quality determines growth and survival in the ponds. And it is a varied entity with respect to physical, microbiological and chemical quality. They add that, water composition changes from the time it falls from space, during infiltration into the subsurface through different geologic materials and in the saturation zones. According to Arain *et al.,* (2015), its reactions with the environment, natural processes and anthropogenic inputs and the natural chemistry have an important bearing on living things. All stages of healthy fish development require good water quality however, requirement in water quality in aquaculture differ between species of fish and between fish development stages (Obasohan and Agbonlahor, 2010).

Many of the water-quality parameters are interlinked and a change in one feature can have an effect on another (Water Research Commission, 2010). In aquaculture ponds, it is not constant but varies with the time of the day, season, weather conditions, water source, soil type, temperature, stocking density, and feeding rate and culture systems (Simpi *et al.,* 2011). For a successful aquaculture venture, it is essential to maintain suitable water quality for both survival and optimum growth of cultured fish (Odino, 2013), moreover, levels of metabolites in pond water that can have an adverse effect on growth are generally an order of magnitude lower than those tolerated by fish for survival.

Physical and chemical factors like dissolved gases, temperature, and nutrients affect the quality of water both directly and indirectly, which directly affects survival and health of fish and other aquatic organism in aquatic bodies (Obasohan and Agbonlahor, 2010).

Environmental factors govern growth, survival and feed consumption of tilapia and aquaculture almost depends on the water quality, that is; quality of aquatic environment (Arain *et al.*, 2015). It is essential to maintain good water quality for both survival and optimum growth of cultured fish, levels of metabolites in pond water that can have an adverse effect on growth. These are generally an order of magnitude lower than those tolerated by fish for survival (Ekhator, 2010). According to Ballace and Batrram (1996), environmental factors governing growth, survival and feed consumption of tilapia and aquaculture almost depends on the water quality, that is; quality of aquatic environment. In regard to Obasohan and Agbonlahor (2010), dynamics and management of water quality in culture media must be taken into consideration and these parameters include: temperature, pH, DO, conductivity, BOD, light penetration, phosphate and nitrates.

2.2.1 Temperature

Temperature is a limiting factor for aquatic environment and all fish species have temperature maximum and minimum lethal limit. It is also a main factor affecting the rate of growth, conversion rate of feed and with each specific fish having a suitable temperature for their survival and growth (Arain *et al.*, 2015). Temperature also affects the metabolism (Water Research Commission, 2010) for every 1^0C rise in water temperature and the metabolic rate of fish increasing by 10%. In addition, Ballace and Batrram (1996) argue that fish can modify their body temperatures according to the environment as the feeding increases. Reproduction in tilapia and catfish is affected by temperatures below 12^0C and death occurs below 10^0C (Ngugi *et al*., 2007).

In regards to aquaculture the temperature tolerance of fish is categorized as cold water and warm water (Arain *et al.*, 2015). According to Ngugi *et al.*, (2007) most tropical fish, such as tilapia, die when temperatures are less than 10°C, and most salmonids (trout and salmon) die when temperatures exceed 25.7°C, while channel catfish, which are called warm water fish, survive from near freezing to about 32.2°C (Mjoun *et al.*, 2010).

According to Kitur (2009), the temperature of surface water is influenced by the time of the day, cloud cover and flow of the water body and these factors also affect water temperatures in aquaculture ponds. In addition, water temperatures affects various factors such as solubility of dissolved oxygen that is more gas can be dissolved in cold water than warm. Therefore, fish species requiring a high level of dissolved oxygen will only thrive in cold water. In regard to rate of plant growth; increased water temperature can cause an increase in the photosynthetic rate of aquatic plants and algae (Simpi *et al.*, 2011), which can lead to increased plant growth and algal blooms and harm the local ecosystems. Notably, if water temperatures are extremely beyond the optimal range, fish become stressed, lowering their resistance to pollutants, diseases and parasites. Many organic solids discharged into the fish pond facilities settle rapidly and decompose at the sediment-water interface (Schueler and Holland, 2000). Moreover, solids may also lead to increased water temperatures ultimately decreasing oxygen because warmer water has lower oxygen saturation levels.

According to Yadav *et al*., (2013) the magnitudes of variation in atmospheric and water temperature was less during summer and the surface temperature closely reflected to ambient air temperature. Shallow lakes and ponds quickly react to the changes in the atmospheric temperature (Joshi and Singh, 2001). Fish are exothermic, their body temperature are controlled by that of the surrounding environment; and affects all metabolic processes.

Cold water slows metabolism and warm water increases metabolic rate (Ekhator, 2010). According to studies done by (Ndungu *et al.,* 2015), in Lake Naivasha, water temperature ranges from 18.1 to 29.6^0C while the mean water temperature ranges from 23.97-24.35°C which is suitable for warm water fish production. Notably, warm-water fish survived in 37.8^0C water however, a sudden change from a water temperature of 18.3^0C to 23.9^0C may shock and kill the fish (Obasohan and Agbonlahor, 2010).

2.2.2 pH

According to Tucker, (2000) alkalinity establishes the initial pH of water and therefore, adding or removing carbon dioxide causes changes in pH. Fertilization in aquaculture ponds increases pH due to phytoplankton blooms that rapidly take up carbon dioxide.

According to Ekhator (2010), pH variation exerts heavy stress on the inhabitant organisms in the aquatic media. In fish ponds, pH varies during different times of day because of variations in the carbon dioxide (CO_2) concentration (Tessema *et al.,* (2014). As aquatic plants in the water remove carbon dioxide for photosynthesis, the pH will increase and at night, the pH will decrease as carbon dioxide accumulates (Helmond and Fechmer, 1994). Unfortunately, the early life stages of fish and crustaceans are particularly susceptible to pH toxicity and juveniles are less able than older animals to "environment regulate" by moving to areas of lower pH in the pond (such as deeper waters) (Ngugi *et al.,* 2007). Other factors affecting pH levels are acidic rainfall, level of water hardness, algal blooms, release originating from industrial processes, detergents release into water, carbonic acid from decomposition or respiration and oxidation of sulphides in sediments (Water research commission, 2010). Increasing the total alkalinity concentration in water helps buffer against pH changes, most fish species do well within the pH range of 6.5 to 9.5 (Hulyal and Kaliwal, 2011).

Chronic pH levels below 6.5 may reduce fish reproduction and are associated with fish die-offs that sometimes occur (Ngugi *et al.,* 2007). A low pH increases toxicity of dissolved metals and may cause phosphate, sulphate, calcium and potassium to exceed acceptable levels (Helmond and Fechmer, 1994). However, ionized form of ammonia is also more prevalent which is less toxic.

According to Tessema *et al.,* (2014), in assessment of water quality, pH is an important variable as it influences many biological and chemical processes within a water body and all processes associated with water treatment and supply. In unpolluted water bodies, pH principally controlled by the balance between the carbon dioxide, carbonate and bicarbonate ions as well as other natural compounds such as humic and fluvic acids and changes in pH can indicate the presence of certain effluents, particularly when continuously measured and recorded, together with the conductivity of a water body (Simpi *et al.,* 2011). In addition, variations in pH can be caused by the photosynthesis and respiration cycles of algae in eutrophic waters.

The pH of most natural waters is between 6.0 and 8.5, although lower values can occur in dilute waters high in organic content, and higher values in eutrophic waters, groundwater brines and salt lakes (Hulyal and Kaliwal, 2011). According to Ekhator (2010), pH variation exerts heavy stress on the inhabitant organisms in the aquatic media. During his study the pH ranged from 6.9 to 8.2 in aquaculture ponds. The optimum pH range for fish is between 6.5- 9. Long term exposure to pH values beyond these limits slows fish growth and reduces health (Obasohan and Agbonlahor, 2010). According to Ngugi *et al*., (2007) exceedingly alkaline water (greater than pH 9) is dangerous as ammonia toxicity increases rapidly.

2.2.3 Dissolved Oxygen

According to Torrans (2008), fluctuations of dissolved oxygen affect the survival of fish, most of which survive at minimum dissolved oxygen level of 5 mg/l. Nevertheless; species like catfish, have ability of breathing air directly and are able to survive short periods at levels of low oxygen (Water research commission, 2010). Although some fish species have adaptations to low levels of dissolved oxygen (of up to 3mg/l), species like trout require at least 5mg/l (Ngugi *et al.,* 2007), growth rate is slow than usual because they require more oxygen for converting their food into body tissue.

Fish and other aquatic organisms take up the oxygen and the amount saturated is depleted as the oxygen in the water is taken up more rapidly than it enters from the air (Water Research Commission, 2010). When the water temperature increases beyond the optimal temperatures for the fish species, fish require more energy and more waste is created (Ngugi *et al.*, 2007). Aquatic plants and algae in aquatic ponds produce oxygen during the day but during the night both the plants and the fish, take up oxygen lowering the oxygen levels in the pond (Water research commission, 2010).

During cloudy weather algae and plants production of oxygen is low due to less sunlight falling on water (Odino, 2013). On windy days, oxygen levels increase as mixing of the water with air is more at the water surface (Lamtane *et al.*, 2008). Growth of bacteria also increases in the water, waste is used making the condition worse because bacteria also use up oxygen from the water (Water Research Commission, 2010).

The level of dissolved oxygen in water is affected by the effluents which get into the water body (Odino, 2013). A waste discharge high in organic matter and nutrients decreases DO, as a result of the increased microbial activity during the degradation of the organic matter (Helmond and Fechmer, 1994). Solids in aquaculture ponds as suspended and settleable forms come primarily from fish waste and unconsumed feed. Solids in effluents from ponds contains a high percentage of organic content. These solids can contribute to eutrophication and dissolved oxygen depletion where, microorganisms decompose the organic matter and consume dissolved oxygen (lamtane *et al.*, 2008).

Oxygen increase in aquaculture ponds includes natural atmospheric aeration and photosynthesis while oxygen sinks include respiration, BOD and COD (Hulyal and Kaliwal, 2011), however according to Ekhator (2010) over application of feed and other input cause rapid changes in water quality parameters. Earlier studies indicate that in some cases, organic manure also leads to severe depletion of dissolved oxygen. In addition, increased growth of green fodders in the fish ponds, can result to oxygen depletion since green manures is usually oxidised after 5 days (lamtane *et al.*, 2008).

DO is governed by the water turbulence, surface diffusion, rate of photosynthesis, BOD, water temperature and carbon dioxide concentration (Joshi and Singh, 2001). According to a study done by Lang'at (2009), DO in what ranged between 2.0 mg/l, and 8.6 mg/l, DO in water samples depend on water temperature, partial pressure of the gas in contact with water, the concentration of the dissolved salts, biological activities and geology of river basin. Further, concentration of DO is inversely proportional to temperature at a given time and the present investigation resembles their observations indicating that the higher temperature of water decreased the solubility of oxygen at all the ponds (Ojo *et al.*, 2004).

2.2.4 Secchi Depth

Suspended solids from planktons; fish waste, unconsumed feeds and suspended clay particles in aquaculture ponds affect light penetration (Joshi and Singh, 2001). Suspended solids are usually particles that settle out of static water throughout the time

(Ekhator, 2010). However, clay particles remain suspended because of their negative electrical charge associated with clay soils; they restrict light penetration and limit photosynthesis (Simpi *et al.*, 2011). Most planktons are not directly harmful to fish, phytoplankton produce oxygen and food for zooplanktons, act as food source for filter feeding fish and shellfish and use ammonia produced (Moogouei *et al.*, 2009).

A plankton density allowing one to see a depth of 30-45 cm into water is maintained (Ngugi *et al.,* 2007). According to Mbugua (2008), when light penetration is low it is an indicator of high phytoplankton density or other forms of turbidity. If not monitored it result to low amount of dissolved oxygen and death of algae. High light penetration means that there is low phytoplankton density hence less food for fish (Ojo *et al.,* 2004). Suspended solids degrades aquaculture ponds by increasing turbidity and reducing light penetration depth, which decreases photosynthesis and growth of aquatic vascular plants and algae which are source of food to the fish (Fagbenro and Adebayo, 2005).

Suspended particles increase the temperature of surface water by absorbing heat from sunlight (Obasohan and Agbonlahor, 2010). These suspended particles carry nutrients and metals, bring about a shift toward more sediment-tolerant species, and affect aquatic insects forming the base of food chain (Schueler and Holland, 2000). Transparency in water is a vital factor controlling the relationship of energy at different trophic levels, according to studies done by Yadav *et al., (*2013), transparency ranged between 25 cm. to 60 cm at the study period and it was low during the summer and higher during the winter season. The transparency decreases in summer due to high planktonic density and in the rainy season because of increase in the suspended substances brought in through run off (Obasohan and Agbonlahor, 2010). The maximum transparency is usually recorded in wintertime which is attributed to the suspended particle sedimentation (Kadam *et al.*, 2007; Shah and Pandit, 2012).

2.2.5 Electrical Conductivity

According to Moogouei *et al., (*2009), freshwater fish thrive over a wide range of electrical conductivity. Some minimum salt content is optimum to help fish maintain their osmotic balance (Water Research Commission, 2010). Most fish do well within the range of 100-2,000 µS/cm the upper range varies with fish species, catfish, for example, can withstand salinities up to 1/2-strength seawater (Stone and Thormforde, 2004). In addition, seawater has a conductivity of around 50,000 to 60,000 µS/cm.

Electrical conductivity (EC) also can be used to give a rough estimate of the total amount of dissolved solids (TDS) in water (Moogouei *at el.,* 2009). Typically, he adds that, the TDS value in mg/l is about half of the EC (µS/cm). According to UNESCO (2002), electrical conductivity measure of total content of solids can be used to determine pollution zones, for instance, around an effluent discharge or the extent of effluence of runoff water (Lang'at, 2009).

Conductivity is related to the concentrations of total dissolved solids and major ions (Afolab *et al.,* 2000). The conductivity of most freshwaters ranges from 10 to 1000 µS/cm, but may exceed 1000 µS/cm, especially in polluted waters, or those receiving large quantities of land run-off (Obasohan and Agbonlahor, 2010). According to a study done by Tessema *et al.,* (2014) conductivity value measured in µS/cm was 1260-1569 in dams and reservoir. In addition, the higher conductivity might be due to their geological quality containing many cations.

Conductivity values ranged from 296.3±1.73 to 613.7±3.03 µS/cm values could be a pointer to the pollution status of these ponds probably caused by debris, excessive nutrients from excess feeds, run-off into the ponds from the adjacent farms during rains and waste products of fishes and other insects' population within the (Obasohan and Agbonlahor, 2010).

2.2.6 Biochemical Oxygen Demand

BOD is the measure of the amount of oxygen taken up by microorganisms as they decompose the readily degradable organic matter present (Lang'at, 2009) and is an indirect measure of organic content of freshwater, it's value changes with time (Torrans, 2008). According to Jha *et al,* (2008), high biochemical oxygen demand levels leads to stress in cultured fish and fish mortality.

According to Torrans (2008), BOD in fish ponds ranged from 0.8 mg/l to 6.6 mg/l also, it varied slightly among ponds in the study areas. In a study done by Stone and Thomforde (2004), a range of between 2.9 to 4.5 was recorded as the BOD values, higher levels may depend upon temperature, density of plankton, concentration of organic matter and related factors. Higher BOD reduces DO content in water and this could result in organisms being stressed, suffocated and eventual death, it also indicates the pollution status of waters (Torrans, 2008).

Phosphate

Phosphate is important for aquatic organisms to survive in most cases it is vital in the regulating algae growth and subsequenting food webs in the aquatic body (Ngugi *et al.*, 2007). Additionally, the amount of phosphate in aquaculture ponds is ordinarily around 0.05 mg/l. When higher levels of phosphate are introduced in the form of fertilizers, rapid algae and aquatic plant densities normally occur (Water Research Commission, 2010).

According to Lang'at (2009), in natural water and in waste water, it occurs mostly as dissolved ortho-phosphate and polyphosphate and originally bound phosphates, sources include domestic, industrial, agricultural runoff and storm runoff. High concentration of phosphorous compounds limits algae growth (Ballace and Batram, 1996). It is higher in soils with clay content than soils from higher sand content because phosphorous has lower infiltration capacities and is therefore more likely to be transported in runoff (Lang'at, 2009).

Phosphate in metabolic waste produced by fish is the origin of most dissolved phosphorous waste resulting from intensive aquaculture operations (Lazzari and Baldisserotto, 2008). The excess of this element in the effluents of aquaculture systems leads to eutrophication and a consequent change in the aquatic ecosystem (Watanabe *et al.*, 2003).

Phosphate as the key nutrient and causing eutrophication leads to extensive algal growth. According to Yadav *et al.*, (2013), maximum phosphate concentration was recorded in August that is; 0.061 mg/l and minimum in January that is; 0.020 mg/l. From the study it is evident from the data that seasonally phosphate concentration in the pond was more in summer followed by rainy, and followed by a decline in winter season. Highest seasonal values were reported during rainy season and lowest during winter as in the conformity with the findings of various studies (Hulyal and Kaliwal, 2011; Verma *et al.*, 2012).

The increase in the concentration of phosphate during rainy season is the result of incoming water from the catchment area of human settlements and the entry of domestic sewage (Fapohunda, 2005). The occurrence of less nutrients during winter may be due to their utilization in macrophytic growth (Ojo *et al.*, 2004). Increased nutrient load during hot season is connected to water level decrease affecting accumulation and the release of nutrients during breakdown, which rises with increase in temperature (Lawson, 2011).

According to Yadav *et al.*, (2013), high levels of phosphates result in eutrophication, increased algal blooms increased Biochemical Oxygen Demand (BOD), decreased Dissolved Oxygen (DO), while low levels of phosphate limit plant and algal growth. Moreover, plant growth can be stimulated by levels above 0.1mg/l PO4-P (i.e. phosphorous in the form of phosphates).

Nitrates

Nitrogen has various compounds and nitrates are the most highly oxidized form of nitrogen compounds which is commonly present in surface and ground waters, because it is the end product of the aerobic decomposition of organic nitrogenous matter (UNEP and WHO, 1996). Nitrate levels in freshwater are usually less than mg/l but man made sources of nitrate may elevate levels above 3mg/l (Saeed and Shaker, 2008).

A known sources of nitrate in aquaculture ponds are chemical fertilizers from cultivated land and drainage from livestock feedlots, as well as domestic and some industrial waters. Unpolluted natural waters usually contain only minute amounts of nitrate (UNEP and WHO, 1996). Nitrogen in metabolic waste produced by fish is the origin of most dissolved nitrogen waste resulting from intensive aquaculture operations (Lazzari and Baldisserotto, 2008).

The excess of these elements in the effluents of aquaculture systems leads to eutrophication and a consequent change in the aquatic ecosystem (Watanabe *et al.,* 2003). Sudden increase of fertilizer in ponds with low nitrate causes rapid aquatic plants growth and algae species that deplete levels of dissolved oxygen especially during the night (Water Research Commission, 2010). In addition, if supply of nitrates is not controlled the plants may die off which further depletes dissolved oxygen level due to bacteria activity in the aquatic body.

According to Obasohan and Agbonlahor (2010), nitrates are added to fresh water through discharge of sewage, industrial wastes and runoff from agricultural fields. Moreover, the concentration and rate of supply of nitrate depends on the land use practices of the surrounding watershed. In accordance to a study by Yadav *et al.,* (2013), value of NO^3-N varies from 0.69 mg/l to 3.08 mg/l. Lower values were recorded during rainy season and higher values were found during dry season. According to Saeed and Shaker (2008), nitrate is an essential nutrient and good indicator of contamination from natural and human activities where levels above 45 mg/l are considered harmful to aquatic organisms. The nitrates were ranging from 45.0 mg/l to 80.0 mg/l in the studies, the average from nitrates were extremely high as compared to the tolerable limits in all the pond, these were due to the fact that higher concentration may be due to influx nitrogen rich flood water which bring about large amount of sediments. The rainy season was the period with the highest nitrate-nitrogen concentration which is known to support the formation of blooms (Obasohan and Agbonlahor, 2010).

Algae

According to FAO (2012), algae are responsible, directly or indirectly associated tonutrient enrichment in lakes and other water bodies. Its abundance is determined by the supply of nutrients; lakes with higher nutrient levels support a greater abundance of algae. Nile tilapia obtains more than 50% of its nutritional requirements from feeding on algae and zooplankton, especially during the juvenile stage of growth (Verma *et al., (*2012). However, according to Watanabe *et al.,* (2003), algal toxins organic molecules produced by a variety of algae in marine, brackish and fresh waters cause problems in the

freshwater aquaculture of both vertebrates (fish) and invertebrates (shellfish). Problems include: off-flavor, indirect toxicity through changes in water quality, or direct toxicity (Rodgers, 2008). According to Obasohan and Agbonlahor (2010), some algae species are toxic only at high densities, while others are toxic at low densities (few cells per liter).
According to a study by Verma *et al., (*2012), 30 species of phytoplankton were identified in aquaculture ponds, the occurrence of plankton species showed that values for phytoplankton were significantly higher during the dry season than the wet for most of the species. According to the study blue-green algae and green algae dominate most tropical water bodies. Increased temperature, sunlight and tropholytic activities as a result of low water level coupled with frequent movement of water from the deep, nutrient-rich sediments into the tropholytic zone, increased the abundance of phytoplankton during dry season (Lang'at, 2009). Dominance of *Chlorophyceae* in the ponds in the dry season is attributed to the presence of sunshine and extensive catchment area draining phosphate from rich agriculture land (Uttah *et al.*, 2008), also flexibility in the physiology and behaviour of *Chlorophyceae* can tolerate environmental changes better than other genera (Silva, 2004).

2.3 Water quality Best Suitable for Specific Type of Fish Cultures

Water quality is the main factor affecting fish survival and growth fish servive at a specific range, if the water quality is below the range it affects fish growth. Most people practicing fish farming are not aware of the importance of water quality management, which is necessary to get maximum fish yield in their ponds to a greater extent through applying low input cost and getting high output of fish yield (Bhatnagar and Devi, 2014). The role of various factors like temperature, pH, DO, conductivity, transparency, nitrate, BOD and Phosphorous can't be overlooked for maintaining a healthy aquatic environment and for the production of sufficient fish food organisms in ponds for increasing fish production (Jha *et al.*, 2008).

According to Mbugua (2008), aquaculture in Kenya is categorized into three broad divisions; warm fresh water aquaculture, cold fresh water and marine water aquaculture. Warm water aquaculture involves rearing of African Catfish (Plate 2.1) and Nile tilapia

(Plate 2.2). The African catfish, *Clarias gariepinus* (family: Clariidae) is a warm water fish, an endemic species distributed in rivers, streams, dams and lakes in the country, because of its high growth rate, acceptability of artificial feed, hardiness and high market value (Ugwumba and Ugwumba, 2003; Akinrotimi *et al.*, 2009). The culture of African catfish is a rapidly emerging and has great potential in boosting the economic and food security in the country (Akinrotimi, 2010). It tolerates high concentrations in the water of ammonia (NH_3) and nitrite (NO_2). According to Okech (2004) it tolerates low oxygen concentrations, well developed air breathing organs; it can also be raised in higher densities than the other species.

Plate 2.1: The African Catfish (Tenge, 2015)

The Tilapine species are warm water fish indigenous to Africa, they make roughly 90% of aquaculture production in Kenya (Mbugua, 2008). According to Ngugi *et al.*, (2007) The tilapia species strains of Nile tilapia vary depending on their cold water tolerance, water temperature range for Nile tilapia is 20-30ºC, preferably about 28ºC. These is considered the best temperature for growth and good health. They live in levels of dissolved oxygen (DO) below 2.3 mg/l on condition that temperature and pH are favorable. In fertilized ponds, algae bloom can deplete oxygen levels to as low as 0.3 mg/l without mortality of tilapia, larger fish are less tolerant to low dissolved oxygen than fish fingerlings; because of their metabolic demand (Jha *et al.*, 2008).

Plate 2.2: Nile Tilapia (Tenge, 2015)

Cold fresh water aquaculture involves the production of rainbow trout (*Oncorynchus mykiss*). It is native to North America, its carnivorous strive well in cold fast flowing waters, 10-18^{0}C with high oxygen content, pH varies from 8.27 to 8.44 water flow rate 1L/min/kg without aeration (Mbugua, 2008). According to Fagbenro *et al.*, (2004) the Rainbow Trout is limited to highland regions in tropical areas with favorable conditions.

Bhatnagar and Devi (2014) note that, water in aquaculture pond vary in colour pale colour, light greenish or greenish waters suitable for fish culture and according to Bhatnagar and Davi (2014) dark brown colour is lethal for fish culture. Light green colour is good for fish culture, dark green colour is not ideal and clear water is unproductive for fish culture. Jha *et al.*, (2008) explain that, the abundance of phytoplankton and zooplankton is responsible for the determination of colour of an aquatic body and green, bluish green/ brown greenish colour of water indicates good plankton population hence, good for fish health.

2.4 Algae in Aquaculture Ponds

Productivity of water depends on plankton communities. They act as the main source of food for fish (Ekhator, 2010). The plankton has its place in the lower regions of the food chain and is the basic source of food for small aquatic animals like fish larvae Utah *et al.,* (2008). During the early stage of their life cycle fish rely on their yolk sac for nutrition.

Pond management practices like application of manure stimulate the growth of algae that are eaten by fish. The abundant growth of these algae gives water a turbid, greenish color "bloom" which prevent light penetration and reduce the growth of rooted aquatic weeds Utah *et al.,* (2008). In aquaculture farmers fertilize ponds to increase the available natural algae for fry or larval fish, or for species that are efficient filter feeders Rahman *et al*., (2013). Ponds may have very dense algae blooms dominated by one or two species caused by have a wider servival tolerance to extreme conditions (adequate space, moisture, light, nutrients, favorable pH, temperature and absence of toxic substances) than other (Ekhator, 2010). The blue green algae inhabits many habitats both marine and terestial habitas.

In studies done by Ekhator, 2010, identified Periphyton belonging to four divisions *Chlorophyta, Bacillariophyta, Cyanophyta* and *Euglenophyta* were the most common algae found in fresh water aquaculture ponds. According to Rahman *et al*., (2013) the planktonic algal community is largely influenced by the interaction of a number of physico-chemical and biological factors.

2.5 Water quality and Algae Type in Aquaculture

In accordance to Wirasith and Traichaiyaporn, (2012) certain water quality parameters influence algal dominance and succession, green algae produce oxygen and acts as a food source for zooplankton and fish and shell fish that feed through filter feeding. They add that, these green algae take up ammonia produced by fish as a source of nutrient, high amounts of algae can result to increased respiration during the night which consumes extra oxygen. Excessive phytoplankton accumulation or "blooms" die afterward die and consume extra oxygen during decomposition (Landsburg, 2002). Some blooms discolor the water (thus the terms “red tide” and “brown tide”), while others are almost undetectable with casual observation (Laibu, 2010).

Harmful algal blooms can affect public health when passed up the food chain; fish, shellfish, birds and even mammals are killed by eating organisms that have consumed algal toxins; they also affect light penetration, thus changing the function and structure of the aquatic ecosystem. The decaying biomass of a bloom depletes dissolved oxygen (especially critical in aquaculture) or blooms kill other important algae in the food web (Codd *et al.,* 2005; Landsburg, 2002).

Harmful algal blooms cause serious economic losses in aquaculture if they kill cultured organisms or causes consumers concern about food safety (Hudnell, 2008). For example, preliminary estimates show that the effect of harmful algal bloom outbreaks on the U.S. economy is more than $40 million per year, or $1 billion per decade (Landsburg, 2002; Hudnell, 2008), also several species found in the South and Southeast produce substances that cause taste and odor problems in water supplies and aquacultural products (Tucker, 2000).

In a certain correlation analysis, it was observed that algae genera density showed negative correlation with water temperature (Afolabi *et al.,* 2000). This result is consistent with the previous report that some euglenoids showed positive relation to low temperature and are abundant in winter. The present result is also agreed with the report that stated that the algae species proliferate its’ peak at low temperature. Rahman *et al*., (2013) observed that, thick bloom of algae specie in experimental fish ponds at relatively higher water temperature. This finding is contrasting to the present study which might be due to the variation in responses of algal genera to temperature changes or variation in geographical position or variation in other specific environmental factors (Lazzari and Baldisserotto, 2008).

According to Rahman *et al*., (2013), the density of algae genera have negative correlation with DO concentration and the maximum density recorded at lower DO concentration. This result is consistent with the previous reports that algae genera proliferate in the environment poor in DO concentration. Further, Watanabe *et al.,* (2003) observes that, algae species density negatively correlated to pH values and the density increased at acidic pH (less than 6.5) and showed a declining trend with increasing pH values. This finding is supported by the earlier report that algal abundance increased when the pH of water lowered from 6.6 to 5.0, the result showed that pH value <6.5 was conducive for increasing density of algae species.

According to Utah *et al.,* (2008), phytoplankton increase with increase in transparency, frequently associated with dry season, and it was also reported in ponds in Asia, where phytoplankton scarcity can be observed during the wet months (Silva, 2004). It was observed that most of the ponds in India where three plankton pulses occur within the dry season (Lazzari and Baldisserotto, 2008; Verma *et al.,* 2012). During the wet months flushing disturbs the standing crop of plankton. However, when the destabilizing effect reduces, the accumulated nutrient input favors an increased plankton production during the dry season (Watanabe *et al.,* 2003). According to Rahman *et al*., (2013), nitrate and phosphate concentrations are significantly abundant in the bloom ponds as compared to the non-bloom ponds. Algae species density increases with increase of nitrate and phosphate concentrations.

Globally, various studies have explored broadly on water quality in both the intensive and semi-intensive aquaculture ponds. In Kenya, just like the other countries studies have focused mainly on water quality in the aquaculture ponds since the introduction of Economic Stimulus Programme no studies have been done in Tigoni to assess if the water quality meets the optimum range for aquaculture and the relationship between water quality and algae genera in the ponds.

CHAPTER THREE: METHODOLOGY

3.1 Study Area

3.1.1 Study Area Location

Tigoni, a Sub County in Limuru of Kiambu County is located about 40 km North-west of Nairobi city center, at an altitude of 2131 masl, latitude of 1°15' S and longitude 23° 46' E (Jaetzold *et al.*, 2006).

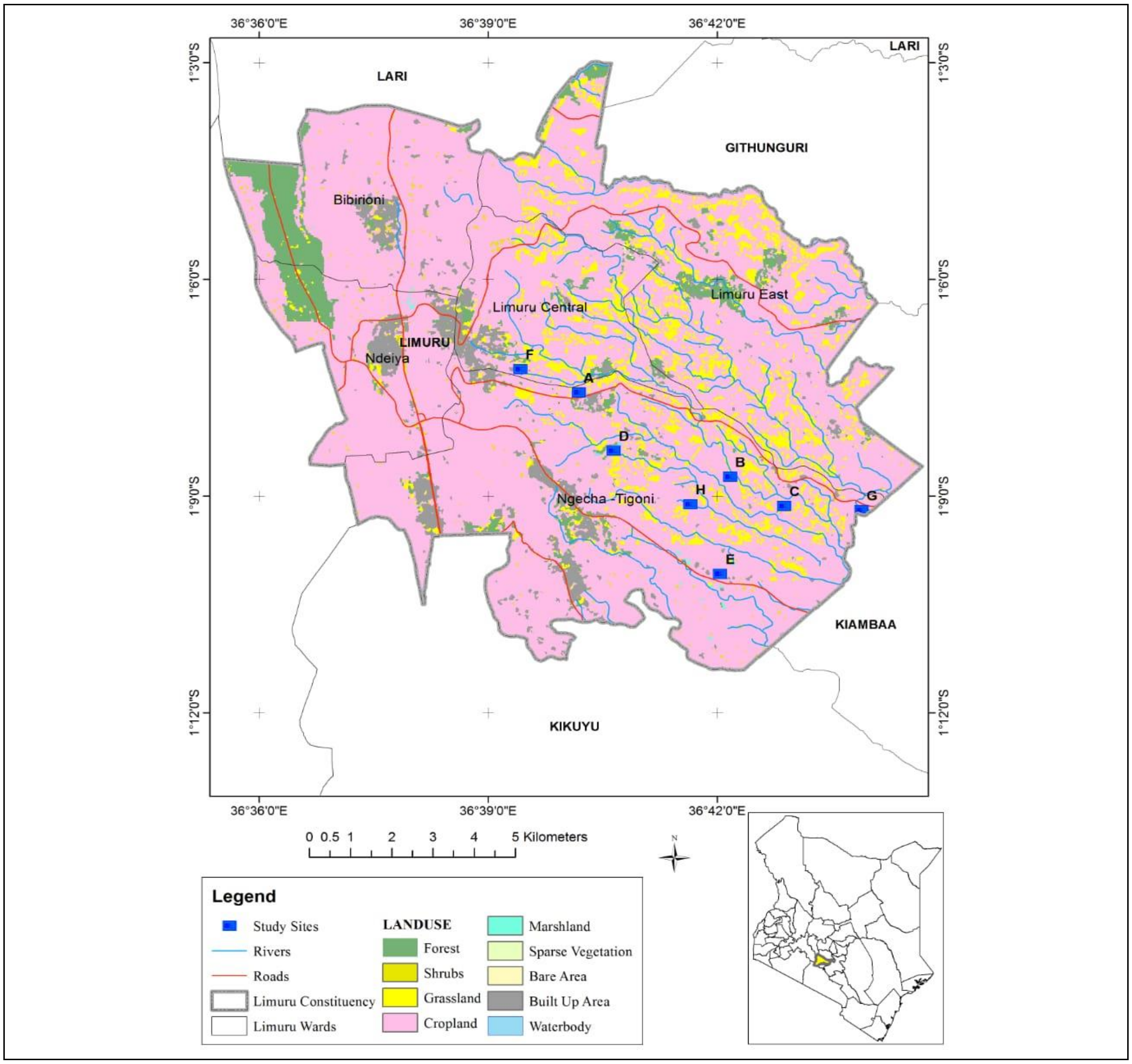


Figure 3.1: Map of Kiambu Showing Tigoni the Study Area (*source: google maps, 2015.Website: ww.googlemaps.com*).

It covers a total area of 41.4km^2. It bounders Limuru town to the west, Karambaini to the North, Kiambaa to the East, Ngecha to the south and Rironi to South West (Fig 3.1).

3.1.2 Climate/Relief

The mean annual air temperature is 18°C ranging between 12 and 24°C. The average annual rainfall is 1096mm with a bimodal distribution. Long rains occur between March and May while short rains are between October and December (Jaetzold *et al.*, 2006). The coldest months are July and August while the hottest month is March respectively. Humidity, evaporation and the wind direction is easterly and evaporation ranges from 100 to 150mm per month while, the humidity varies between 50% and 90%.

3.1.3 Drainage/Soils

Rivers Rwaka and Ithanji are main sources of water in the area. The soil type is humic nitosol (alfisol) derived from quartz trachyte. The soil is deep and well drained (Muthoni and Kabira, 2010; Jaetzold *et al.,* (2006).

3.1.4 Economic Activities/Land Use

The main economic activity in Tigoni is farming with most of the land being cropland (Figure 3.1), both subsistence and commercial farming, where crop farming and livestock keeping is practiced. Commercial farming includes tea farming mainly done in plantations and horticulture the main crop being flowers. Livestock keeping is also practiced the main activities being dairy farming and poutry keeping.

Aquaculture in the the region started in early 1920s the main species cultured were tilapine, later they were supplemententeded by common carp (FAO, 2012). It was mainly done in extensive systems but after the after the launch of the Economic Stimulus Programme in 2009, with time there is diversification of cultured species and systems, the systems changed from extensive to semi-intensive and the cultured of catfish is on the rise. Over the years, there has been an increased industrial activities Ombi Rubber factory, Kenchic, and ACME Containers Limited are found in the area. The activities have affected aquaculture in the area.

3.1.5 Target Population

Tigoni has a population of 11,511 people, where Ithanji has a population of 8,376 and Redhill 3,135 (GOK, 2009).

3.2 Research Design

3.2.1 Selection of Study Sites/Points

The preliminary study found there are 82 ponds of about 300m^2, the location was selected for the study because it was a good representaive of the area based on interest of the study, the information to be collected and also the area was easily accessible. It had both liner and liner ponds which were the main type of ponds used for aquaculture in the area, the pond had fish 5 to 6 months old since stocking. Out of the 82 ponds, 44 ponds are earthen ponds and 38 ponds are liner and were constructed under the Economic Stimulus Programme. In Tigoni 45 ponds while, 35 were in Ngecha location, Out of 45 ponds in Tigoni, 19 were found in Ithanji while 26 were found in Red hill.

Out of 45 ponds 8 ponds were selected from the ponds that were stocked, 4 of them were earthen (2 in Ithanji and 2 in Redhill) while the other 4 were liner ponds (2 in Ithanji and 2 in Redhill) the two type of ponds were selected to represent the two pond types in the study area. Stratified random sampling procedure was employed to select 8 ponds from which water samples were collected from (Figure 3.1). They were labelled as Pond A, B, C, D, E, F, G and H, Pond A, C,D and E were liner ponds while,pond B, F,G, and H were earthen ponds all the ponds were stocked with 1000 fish either catfish or Tilapia, 5-6 months old. Water samples were collected manually at each sampling ponds to represent the composition of the aquaculture pond. During the sampling seasonality was not considered.

3.3 Field Measurement

Temperature (^oC)

The temperature was measured using a thermometer model (Mrc.Scientific Instruments – RS232.). The thermometer probe was immersed in the pond water and left for at least 30 seconds to stabilize before taking the reading.

pH

A pH meter (Model; HI 99121) with a temperature compensation to 25^{0}C (Appendix 12) was used to measure pH. The meter probe was immersed into the water to10 cm depth let to stabilize, read and recorded.

Conductivity

The conductivity was measured using a conductivity meter type (CD-4303.Q572825) with temperature compensation to 25^{o}C. The conductivity probe was then immersed in water to a depth of 10cm. It was then allowed to stabilize and the readings were read and recorded in µS/cm^{-1}.

Dissolved Oxygen (DO)

Dissolved oxygen was measured with an Oxygen meter, type (MRC-RS.232). AC 79261 with temperature compensation to 25 ^{o}C. The DO probe was immersed in the water to 10cm depth, while stirring the water, the readings were let to be stable and the dissolved oxygen read in mg/l.

Secchi Depth

Secchi depth was measured using a Secchi disc, with a diameter of 20cm with a black and white pattern on the upper surface. The Secchi disc was lowered into the water, as it is lowered, the depth at which it just disappears was recorded, and then the disc was lowered a little further, then raised and the depth at which it reappeared was noted (Appendix 12). Average for the two depth readings were recorded as the Secchi depth in cm (APHA, 1998).

3.4 Sampling Procedure

Sampling points were identified in all the sample ponds away from inlet and outlets where samples were collected during the study. Water samples were collected at a depth 30cm from the water surface. Samples were collected twice a month for four months at the same point, one samples were collected from each of the sample pond in two weeks' intervals between July and November 2015. Altogether, sixty-four (64) samples were collected and used for analysis.

Water samples for laboratory analysis were collected using a scooper and transferred to cleaned 500ml plastic bottles which were rinsed twice with the wastewater sample before filling. Sampling bottles were labeled to indicate date of sampling, sampling pond and no preservatives added as the analysis was done within 4 hours of collection. Sampling was done according to standard sampling principles and guidelines outlined in American Public Health Association (APHA, 1998).

Algae

Samples for algae identification were collected using a phytoplankton net at a depth of 0.3m. Several volumes of water were passed through the phytoplankton net and the concentrate transferred into 15ml plastic tube and preserved with formalin (APHA, 1998) labeled and transported to the laboratory for identification.

3.4 Laboratory Analysis

Biochemical Oxygen Demand

Biochemical Oxygen Demand (BOD) was determined using the dilution method, 50ml water sample was diluted to 25% strength and the sample was placed in two 300 ml BOD bottles and incubated at 25^0C for 5 days. Dissolved Oxygen was measured before and at the end of the incubation period. BOD_5 in mg/l was calculated as the difference in DO content of the samples before and after incubation multiplied by the dilution factor.

The BOD was calculated as follows using the following formula:

$$BOD_5 \text{ (mg/l)} = \frac{D_1 - D_2}{P}$$

where D_1 = Initial DO of the sample,

D_2 = final DO of the sample after 5 days,

and P = decimal volumetric fraction of sample used.

Phosphate

Ascorbic acid reduction procedure (APHA, 1998) was used to determine the concentration of phosphates. Water sample (50 ml) was digested with 1:1 hydrochloric acid and filtered in a 100 ml volumetric flask and topped up using distilled water to the mark. Then, 10 ml of ammonium moly date was placed in a 50 ml volumetric flasks and 20 ml aliquot was added and filled up to the mark with distilled water. The absorbance of the sample was measured against a wave length 430nm, the readings of the calibration standards against the concentration were plotted (Appendix 9). Thereafter, the linear correlation coefficient of the graph (s) was determined to the linearity of the graph, the linearity should be between 0.99 to 1.0.

Nitrates

Nitrate concentration levels were determined using salicylate procedure (APHA, 1998). Nitrate nitrogen react with sodium salicylate in an acidic medium to form a complete nitrosalicylin acid, the salicylic acid turns yellow under alkaline condition. The color formed was then measured using UV-VIS Spectrophotometer at 420nm wavelength.

An amount of 2 ml Salicylate was added to the water sample (50 ml) solutions and evaporated to dryness in the oven at 100 ^{0}C ± 0.5 ^{0}C and the residue cooled in a desiccator. Once cooled 2 ml of sulphuric acid was added and the solution left to stand for 10 minutes after which 15 ml distilled water was added followed by 15 ml of sodium hydroxide solution. The solution was then put in a 100 ml one-mark volumetric flask and made up to the mark with distilled water. The absorbance was read in 1cm plastic curette at 420 nm. Standards of a known nitrates concentration were subjected to the treatment as the samples of water and the readings were used to determine the concentration of nitrate in the samples.

Algae Identification

The algae genera were identified microscopically using Leica Galen iii microscope, using preserved and fresh sample. Confirmation was done using standard keys for identification Entwisele *et al.,* (1997) and Vuuren *et al.,* (2006).

3.5 Data Analysis and Presentation

Data collected was entered in data sheet prior to analysis, data was then organized by coding and keying into a database in statistical package for social sciences. Data analysis was done using Statistical Package for Social Sciences (SPSS) Version 20. One-Way ANOVA was used to determine differences between pond means of the water parameters in aquaculture ponds significant differences accepted at $p \leq 0.05$ (Zar, 2001) and t-test to determine significant difference between means in water quality in ponds and the optimum range for aquaculture. Results were presented using graphs, tables and charts.

CHAPTER FOUR: RESULTS AND DISCUSSION

This chapter presents findings of quality of water in aquaculture ponds, the type of algae and the relationship between water quality and algae identified in aquaculture ponds in Tigoni.

4.1 Quality of Water in Fish Ponds in Tigoni

Physical parameters; temperatures, pH, conductivity, transparency and dissolved oxygen were analysed using One-Way ANOVA to determine the difference between mean in pond while, t-test was used to determine difference from the optimum quality in aquaculture and the water quality in aquaculture ponds in Tigoni (Table 4.1)

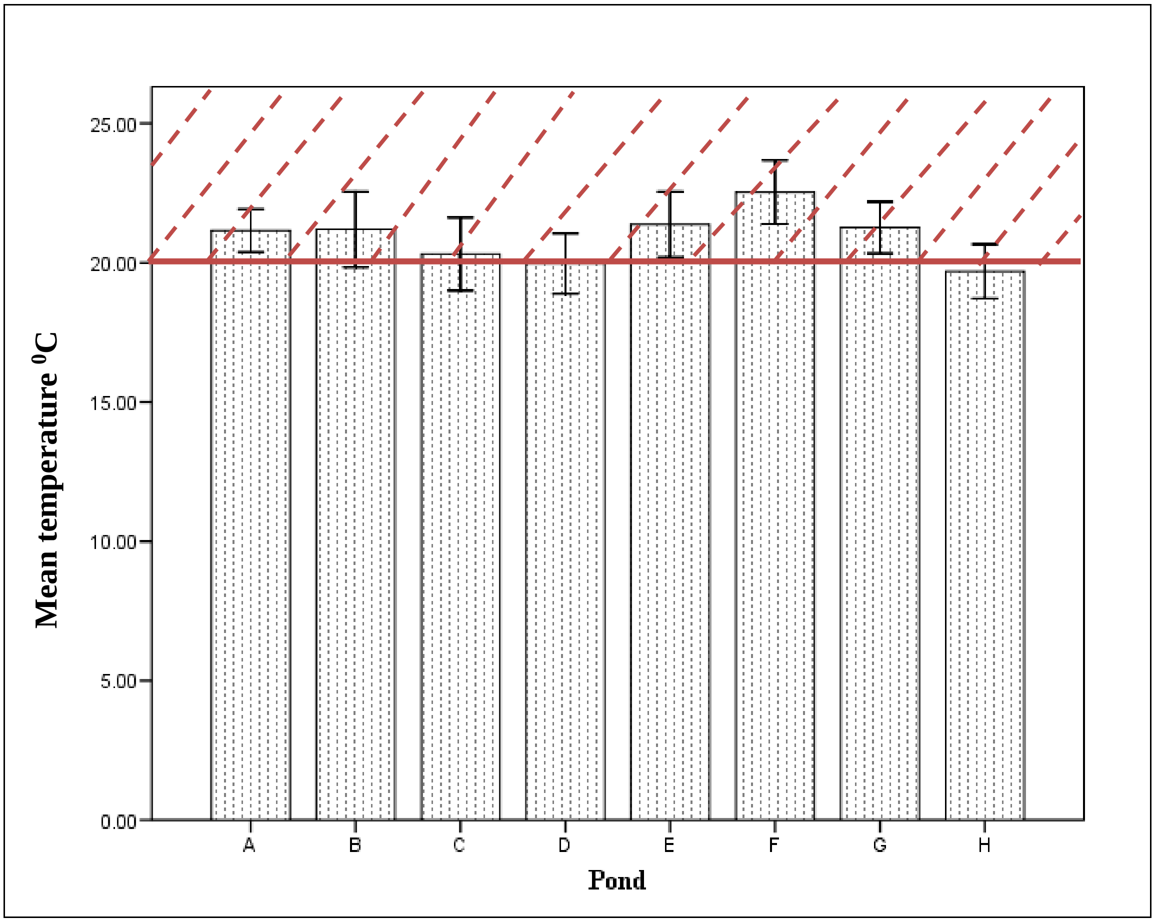
Table 4.1: Mean Value of the Physical Parameters measured during the study period ((July to November, 2015). ± = Standard Error)

Pond/ Optimum range	**Temperature (Mean±SE) ^{0}C**	**pH (Mean±SE)**	**Conductivity (Mean±SE)**	**Secchi depth (Mean±SE)cm**	**DO mg/l (mean±SE)**
	20-28	6.5-9.0	15-30	150-500	3mg/l (minimum)
A	21.15±1.08^{ab}	9.09±0.76^{b}	190.25±127.86^{a}	20.06±6.03 ^{abc}	4.72±1.26^{ab}
B	21.20±1.92^{ab}	8.63±0.25^{ab}	356.63±68.49 ^{ab}	17.00±3.70^{abc}	4.41±1.28^{ab}
C	20.31±1.86^{ab}	8.52±0.23^{ab}	416.50±168.93^{b}	20.66±6.03^{abc}	4.03±1.39^{a}
D	19.98±1.54^{a}	9.01±1.02^{b}	239.13±194.14^{ab}	14.13±3.36^{a}	5.24±1.61^{ab}
E	21.38±1.66^{ab}	8.12±0.76^{ab}	234.85±143.83^{ab}	24.10±8.25^{bc}	5.73±2.32^{ab}
F	22.54±1.62^{b}	7.66±0.83^{a}	243.63±154.6^{ab}	24.25±7.19^{bc}	4.60±1.17^{ab}
G	21.26±1.32^{ab}	7.57±0.52^{a}	203.94±98.22^{a}	28.38±7.13^{c}	6.63±1.37^{b}
H	19.69±1.38^{a}	8.65±1.03^{ab}	330.06±76.13^{ab}	24.67±7.21^{bc}	4.26±1.09^{ab}
p-value	0.001	0.000	0.013	0.001	0.016

(*) Mean values followed by the same small letter(s) within the same column do not differ significantly. ±SE means standard error.

4.1.1 Temperature

The mean temperatures measured during the study period showed variations, the temperature ranged from 19.69±1.380^{0}C to 22.54±1.62^{0}C (Figure 4.1 and Table 4.1). The lowest mean temperature was 19.69±1.38^{0}C in pond H and the highest was 22.54±1.62^{0}C recorded in pond F (Figure 4.1).



*The area highlighted in red indicates optimum range (20-28)

Figure 4.1: Mean temperature values recorded in the study ponds during the study period (July to November 2015) vertical bars indicating ±SE

In pond A water temperature in the sample ponds showed a narrow variation with a range from 19.6^{0}C to 22.6^{0}C with a mean of 21.15±1.08. Pond B, temperature ranged from 19.4 to 24.3 with a mean of 21.20±1.92^{0}C. Pond C, temperature showed a modest variation of 17.6^{0}C to 23^{0}C with mean of 20.31±1.86^{0}C. In pond D temperatures varied from 17.9^{0}C to 22^{0}C with a mean of 19.98±1.54^{0}C. Pond E, a range from 19.1^{0}C to 24.3 ^{0}C with a mean of 21.38±1.66^{0}C was recorded. Pond G, there was modest variation ranging from 20.5^{0}C to 24.8^{0}C with a mean of 22.54±1.62^{0}C. Pond H the temperature ranged from 17^{0}C to 21^{0}C, the pond had a mean of 19.69±1.38^{0}C (Table 4.1 and Appendix 1).

Using One-Way ANOVA, temperature in pond F differed significantly from pond D and H ($p=0.002$, $df=7$) and ($p=0.001$, $df=7$) respectively, (Table 4.1) the other ponds did not have a significant difference from each other.

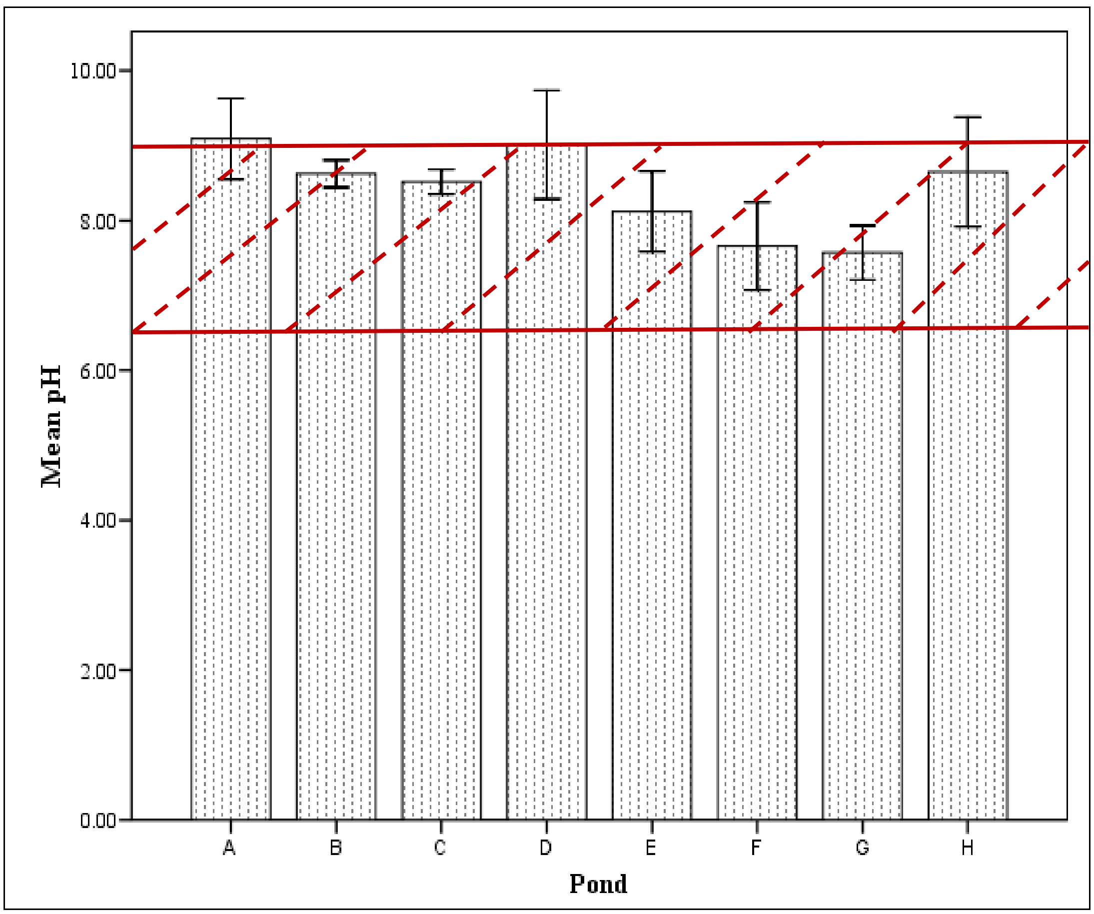
The temperature difference in water bodies is influenced by variation in weather conditions during sampling and ambient conditions, which ranged from clear sky to 100% cloud cover (Kitur, 2009). Suspended particles also increase the temperature of surface water by absorbing heat from sunlight (Musyoki., 2015).

The water temperatures were low in the study ponds due to the geographical zone of the study area which is highly influenced by the Aberdare Forest Ecosystem as it is located on the eastern side of the southern edge of Aberdare Escarpment. Pond H which was an earthen pond recorded the lowest temperature. Earthen pond provides a natural environment enabling the water to cool itself unlike liner ponds. The pond also had to water flowing in and out these lowered the water temperature in the ponds. In pond F which was also an earthen pond higher temperatures were recorded as the inlets were controlled which allowed water to stand for long allowing progressive increased of temperatures also the pond was shallow allowing heating up of the water. Pond D which also had low temperatures that differed significantly from pond F had stream diverted directly to the pond which contributed to the lowering of the pond water temperatures.

According to Zweig *et al.*, (1999), the acceptable ranges for optimal growth for warm water fish is 20-28^0 C, the mean water temperature recorded in all the ponds during the study period were within the range except pond D and H (Figure 4.1). The mean temperature recorded in all the ponds of 19-23^{0}C was within the same range as those of the ponds in Gatundu, Central Kenya, Musyoki (2015). The results were also comparable to studies by Laibu (2010), who recorded a mean range of 18 to 29 ^{0}C in a study done on fish pond in Abothuguchi Central, Meru County.

4.1.2 pH

The mean pH recorded in the ponds showed variations (Figure 4.2). The pH ranged from 7.57±0.52 in pond G to 9.09±0.76 in D (Table 4.1). In pond A, pH in the aquaculture pond ranged from 10.8 to 8.45, the mean was 9.09±0.76. Pond B, pH ranged from 8.3 to 9.1, with mean of 8.63±0.25. Pond C pH ranged from 8.2 to 8.9 with a mean of 8.52±0.23. Pond D it ranged from 7.4 to 10.5 with a mean of 9.01±1.02. Pond E there was a range of 7.2 to 9.2 with a mean of 8.12±0.76, pond F, pH ranged from 6.8 to 9.5 with a mean of 7.66±0.83. In pond G pH ranged from 6.98 to 8.5 with a mean of 7.57±0.52 and in pond H a range of 7.9 to 10.85 and a mean 8.65±1.03 was recorded (Table 4.1 and Appendix 2). One-Way ANOVA indicated pond A was significantly different from F and G (p=0.000, df=7) and (p=0.000, df=7) respectively also pond D had a significant difference from F and G and (p=0.001, df=7) and (p=0.000, df=7) respectively but all the other pond didn't differ significantly (Table 4.1).



*The area highlighted in red indicates optimum range (6.5-9)

Figure 4.2: Mean pH values recorded in the study ponds during the study period (July to November 2015) vertical bars indicating ±SE

pH in water body is dependent on the amount of carbonate and bicarbonate dissolved and carbon dioxide the variation is attributed to photosynthetic activities in aquaculture ponds. The difference in pH is also influenced by variation in weather conditions during the day and time of the day. pH is high between 12 noon to 4 pm. Cloud cover also affects pH during sunny days' photosynthesis increases rapidly after sunrise and remains high until almost sundown, cloudy skies causes decreases in photosynthesis rates (Kitur,.2009). The pH levels in the pond are also influenced by other parameters which include; carbon dioxide and ammonia concentrations (Ngwili 2014). Carbon dioxide concentration lowers the pond pH due to its reaction with water to form carbonic acid while ammonia increase the pH due to its alkaline ion. Other factors are when plants or algae are growing rapidly, a large amount of algae makes pH to strongly fluctuate during the day and too much algae also makes pH to increase (8.8 to 9.1) in the afternoon and at times may remain high throughout the night.

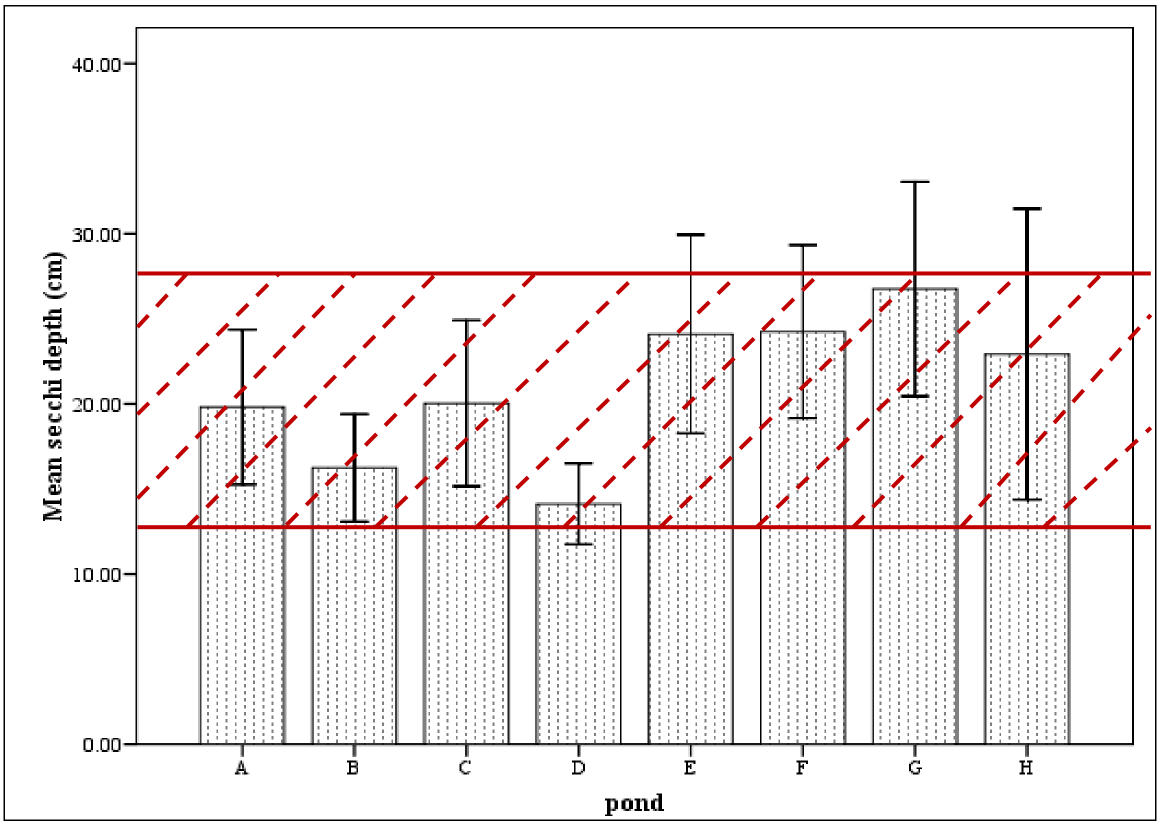
Pond G recorded the lowest mean which was a nuetral condition its atribited to the the natural environment of an earthen pond which is also influenced by the type of soil of the ponds. In pond A, the high pH may be as a result of high pH in water pumped into the pond that could have been influenced by the soils in the water source causing a rise in pH in water. It could also be attributed to high amount of nutrients which was evidence with low secchi depth in pond and increase of carbon dioxide due to photosynthesis activities of algae. In pond G the mean was optimal for fish culture since it was neither acidic nor alkaline. This was because of the water exchange practiced in the pond aquaculture ponds. The pond was an earthen pond the soil pH influenced the water pH.

According to *Zweig et al.,* (1999) the optimum range for fish production is 6.5-9.0. The mean value recorded in the sampled ponds were within optimal range except pond A and D (Figure 4.2). The mean pH recorded in all the ponds during the study were in the range of 5.9 and 9.4 recorded in fish ponds in Kiambu and Machakos (Ngwili, 2014). The mean recorded in earthen pond F and G which recorded the lowest mean was close to the mean value of 7.0 recorded in earthen ponds in studies done by Mwachiro *et al.,* (2012) on a comparative study of cage and earthen pond culture of oreochromis Jipe, in Lake

Jipe, Taita/Taveta District the results were also in the range studies done by Musyoki (2015) on aquaculture on water quality in Gatundu, Central Kenya, where a pH ranging between 6.7 and 7.8 was recorded and 7.51 - 7.88 recorded in studies done by Nzeve (2015), Masinga Reservoir, Kenya. The mean recorded in pond A was in the range 6.1-9.3 of studies by (Makori *et al.*, 2017) on tilapia growth in earthen ponds in Teso North, Busia County, Kenya.

4.1.3 Secchi Depth

The mean secchi depth values recorded during the study showed modest variations (Figure 4.3). The mean secchi depth ranged from 14.13±3.36 in the pond D to 28.38±7.13 in pond G (Table 4.1). The highest secchi depth was in pond G, 40 cm and the lowest was in pond B and H (Appendix 3).



*The area highlighted in red indicates optimum range (15-30cm)

Figure 4.3: Mean Secchi depth values recorded in the study ponds during the study period (July to November 2015) vertical bars indicating ±SE

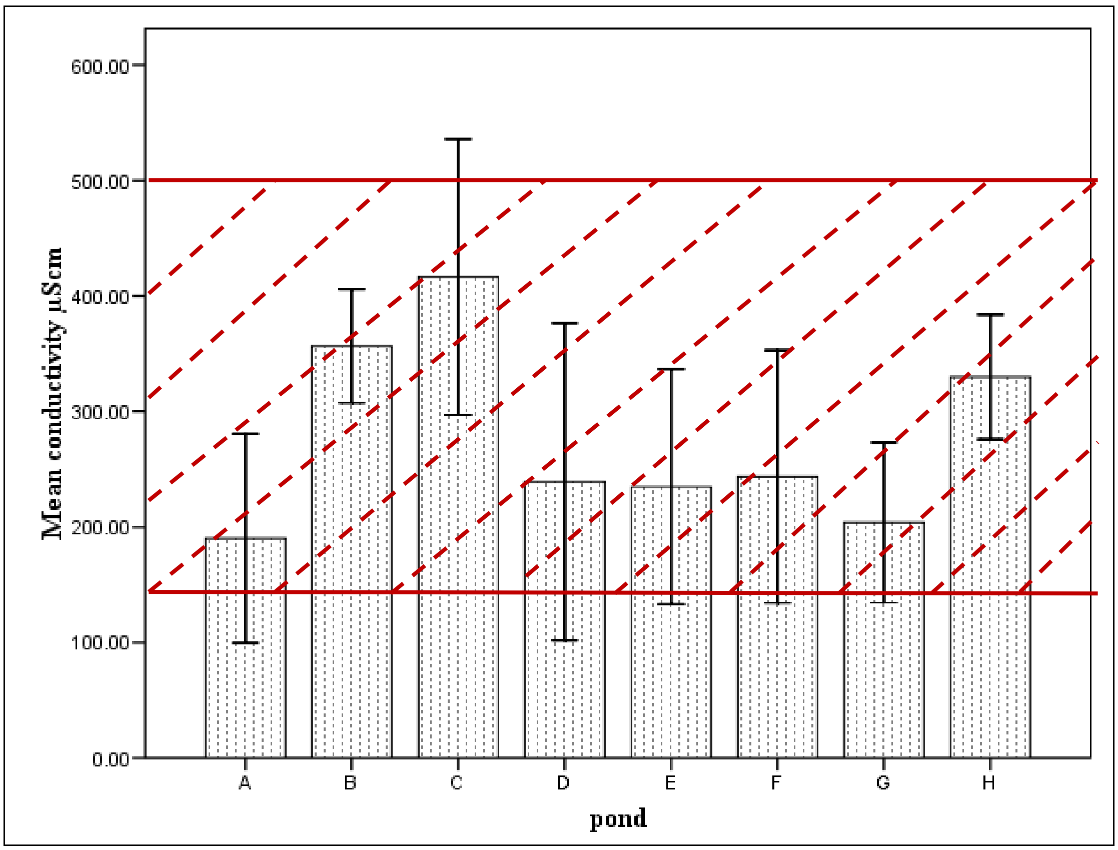
One-Way ANOVA showed a significant difference between sample pond B and G (p=0.001 df=7) also pond D differed significantly from pond E, F, G, and H (P=0.003 df=7), (p=0.002, df=7) (p=0.000 df=7) and (p=0.002 df=7) respectively.
Secchi depth provides an estimate of phonic zone where food for fish grow, it is influenced by the presence of suspended particles, the presence of plants, the time of sampling and depth of the water (Nzeve, 2015). Lack of plants and suspended particles allow light to penetrate to a depth in water bodies. Shallow depths of ponds lower secchi depth of the aquaculture ponds as slight breeze is enough to stir up the bottom sediments leading to an increased suspension which lowers the secchi depth.

The higher Secchi depth in pond G is an indication of low dissolved particles, suspended particles and also the natural breakdown of waste materials in the pond that occurs in earthen ponds these allowed light to penetrate to a higher depth in the pond. In addition Pond G, it was attributed to water flowing in and out with underground water source that had low dissolved particles (Figure 3.1). Pond D the low secchi depth recorded may be caused by accumulation of nutrients from left-over food material which increased primary production in the liner pond also due to the shallow depths of the aquaculture ponds as slight breeze is enough to stir up the bottom sediments leading to an increased suspension. The use of manure in the fish ponds to stimulate algal growth to serve as primary producers and subsequently increase fish yield could have increased nutrients load (Nweze *et al*., 2015) and this could have lowered the secchi depth. The pond was stocked with cat fish which are bottom dwellers, which extensively stir the benthic Sediments while searching for benthic invertebrates, which is their key food item (Koekemoer and Steyn, 2005).

According to Ngugi *et al.,* (2007) aquaculture ponds secchi depth optimum range 15-30cm, all the study ponds were in the optimum range except pond D were in the optimum range (Figure 4.3). The mean recorded in pond D was in the range 13.20 - 36.2 of studies by (*Nweze, et al.,* 2015) on water quality and algal diversity of fish ponds and dam reservoir in Gesedaddo farms, Adamawa State, Nigeria. The results of pond G were similar to studies done by Munni (2013), who recorded a mean range of 14.30 - 37.5 cm in fish ponds in Tangail, Angladesh. Bangladesh.

4.1.4 Conductivity

The mean values of conductivity recorded varied in the eight ponds. The highest mean was recorded in pond C with a mean of 416.5±68.93 µS/cm, while the lowest was recorded in pond A with a mean of 190.25±127.86 µS/cm (Figure 4.4 and Table 4.1). The highest conductivity of 696 was recorded in pond C and the lowest was in pond A 63 µScm (Appendix 4). According to One-Way ANOVA pond C showed a significant difference from A and G (p=0.002, df=7) and (p=0.003, df=7) respectively (Table 4.1).



*The area highlighted in red indicates optimum range (150-500µS/cm)

Figure 4.4: Mean conductivity values recorded in the study ponds during the study period (July to November 2015) vertical bars indicating ±SE

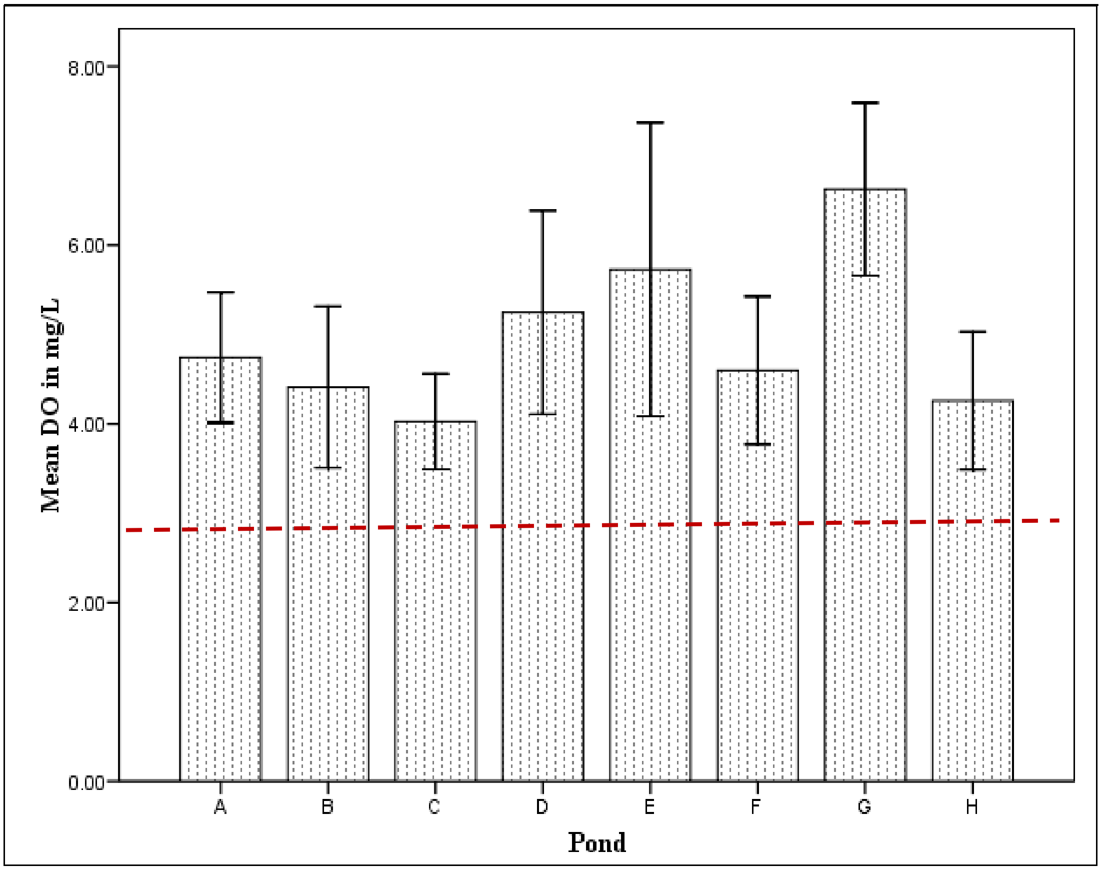
Variations in conductivity in water are influenced by amount and levels of dissolved particles in inflowing water and residence time in water body. The total dissolved solid load is determined by type of soil at the catchment, human activities and the nature of geological drainage (Kitur, 2009). Dams and reservoirs receiving large quantities of surface run-off have higher conductivity like in case of a study done by Tessema *et al.*, (2014).

In pond A, the high mean value of conductivity may be as a result of dissolved particles accumulation over time from left over feed, pond water fertilization practiced by farmers and other pumped in during water refill in the ponds. In pond C, the low conductivity could be attributed to low dissolved particles in the water pumped into the pond and water exchange practiced by the farmer these could also be related to the low turbidity which is evidence with high secchi depth.

The World Health Organization (WHO) limit for conductivity is 700 µS/cm (WHO, 2003) for drinking and potable water, based on the limit conductivity in all the ponds was in the limit (Figure 4.4). The results were in the range of studies by Lazzari and Baldisserotto (2008) who recorded a higher mean range of 190-416 on studies done on fish farms in Sau Paula also their results were close to studies done by Keremah *et al.*, (2014) in Bayelsa State, Nigeria where a range of 117.3+91.01 to 378.4+130.20 µS/cm was recorded. However, the results showed a wider range than studies on pond water quality in Santosh Tangait by Munni *et al*., (2013) who got a mean range of 138-274µS/cm and Dinesh *et al*., (2017) 290.30 to 405.10 µS/cm recorded in aquaculture ponds in Tamil Nadu, India was recorded.

4.1.5 Dissolved Oxygen

The values of dissolved oxygen recorded varied in the eight ponds, the highest mean was recorded in pond G with a mean of 6.63±1.37, while the lowest was recorded in pond C with a mean of 4.03±1.39 (Table 4.1 and Figure 4.5). The highest DO was recorded in pond E while the lowest was recorded in pond A (Appendix 5). One-Way ANOVA showed pond G differed significantly from pond B, C and H (p=0.004, df=7), (p=0.001 df=7) and (p=0.002 df=7) respectively (Table 4.1). According to t-test, only pond G had a significant difference from the optimum annual mean (t=7.500, df=7, P=0.000).



*The area highlighted in red indicates optimum range (3mg/l)

Figure 4.5: Mean dissolved oxygen values recorded in the study ponds during the study period (July to November 2015) vertical bars indicating ±SE

The variation in dissolved oxygen is caused by variation in weather conditions of the days of sampling and ambient conditions and the time of sampling (Kitur, 2009). During the day, there is a distinct diurnal fluctuation of oxygen, with lowest concentrations just after dawn, and increasing during daylight hours because of the photosynthetic production of oxygen to maximum in late afternoon and decreases again during the night (Makori *et al.*, 2017). Cloud cover also affects DO, it is high around midday when photosynthesis is high resulting in accumulation of DO in water. When cloud cover is below 10%, DO is low since ponds are shallow with a maximum depth of 1.5m which favor organic matter decomposition. The variation in dissolved oxygen is also caused by variation in weather conditions of the days and ambient conditions and the time of sampling (Kitur, 2009). DO in water is depleted by processes including respiration from fish, microbial life, and plants, and the degrading of organic matter by microorganisms (biological oxygen demand or BOD) also affects oxygen in aquaculture ponds.

All the ponds did not have significant difference from optimum mean except pond G which had a significant difference as flowing water has higher dissolved oxygen than static water, the difference was due to high amount of dissolved oxygen present in water flowing into the pond. In addition, in pond G the high levels of DO can be related to the continues flowing in and out of water in the pond which allow for continuous supply of dissolved oxygen and aeration of water in the ponds. In Pond C, the accumulation of nutrients as a result of feed left overs in the pond may have used up DO during decomposition affecting the dissolved oxygen negatively. The reduction in DO could be as result of increased uptake of DO by microorganisms during breakdown of accumulated organic matter in the pond.

According to Zwegi *et al.,* (1999) aquaculture ponds should have a minimum of 3mg/l. The results were comparable to the study done by Kiran (2010), who recorded DO ranging between 2.0 mg/l and 8.6 mg/l in a study done in fish ponds of Bhadra Karnataka. It is also comparable with study by Musyoki (2015), done in aquaculture ponds in Gatundu, Central Kenya where a mean of 3.2-10.0mg/l was recorded and Keremah *et al.,* (2014) who recorded mean range of 2.8+0.20- 6.6+0.18mg/l.

4.1.6 BOD

The values of BOD recorded varied in the eight ponds as shown in Figure 4.6. Pond D had the highest mean of 2.82±0.52 while pond G had the lowest mean of 1.99±0.52 (Table 4.2) The lowest BOD was 1.4 mg/l recorded in Pond G, while the highest was in pond A which recorded 3.81 mg/l.

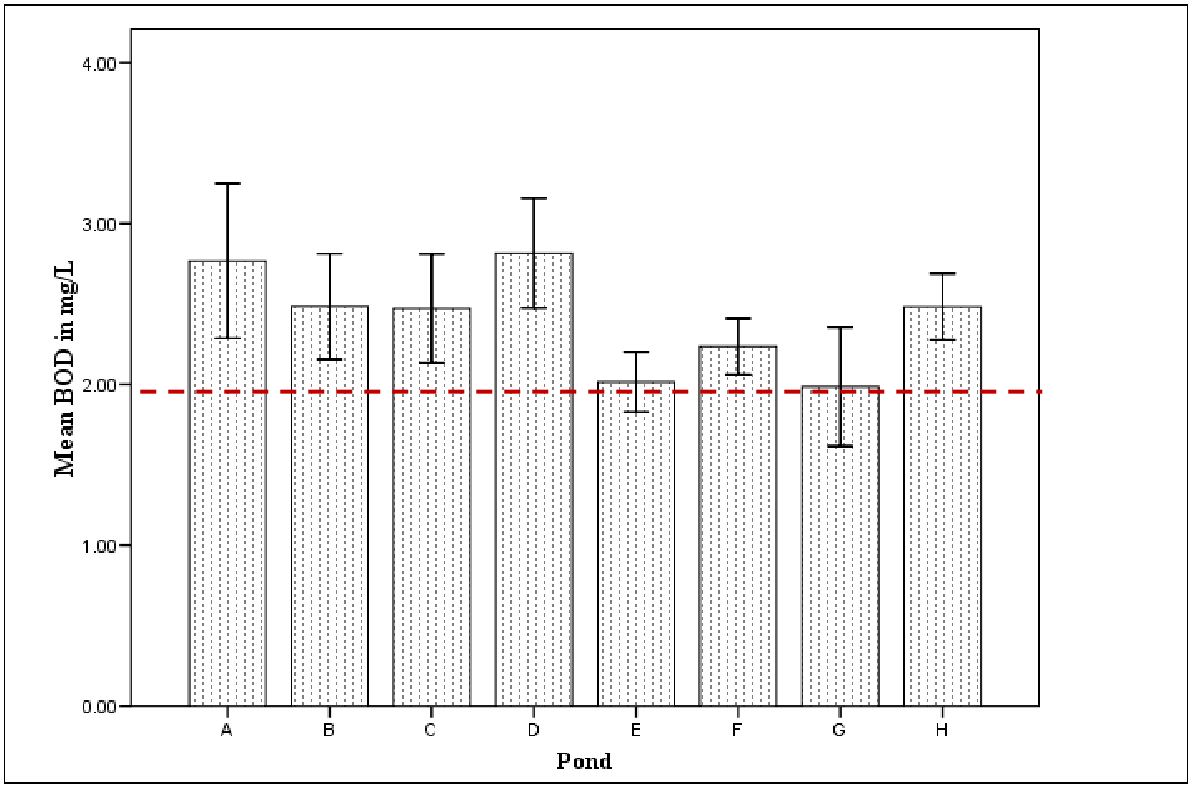
According to One-Way ANOVA pond A differed significantly from pond E and G, (p=0.002, df=7), (p=0.001, df=7) and also pond D differed significantly from E and G (p= 0.001, df=7) as shown in Table 4.2. According to t-test all the pond did not show significant difference from the optimum mean of 2mg/l.

Table 4.2: Mean Values of the Chemical Parameters measured during the study period ((July to November, 2015). ± = Standard Error)

Ponds/ Optimum range	**BOD (Mean±SE)mg/l**	**PO_4^- (Mean±SE)mg/l**	**Nitrates (Mean±SE)mg/l**
	2mg/l(minimum)	0.01-3mg/l	0.01-4.5mg/l
A	2.76 ± 0.68^{b}	4.82 ± 21.60^{ab}	0.38 ± 0.10^{a}
B	2.52 ± 0.53^{ab}	1.69 ± 3.31^{ab}	0.92 ± 0.47^{a}
C	2.48 ± 0.48^{ab}	0.57 ± 0.93^{a}	1.81 ± 0.61^{a}
D	2.82 ± 0.48^{b}	3.28 ± 9.74^{ab}	1.48 ± 0.17^{a}
E	2.01 ± 0.26^{a}	1.36 ± 2.63^{a}	2.12 ± 0.45^{a}
F	2.23 ± 0.25^{ab}	0.51 ± 1.05^{a}	2.65 ± 0.34^{a}
G	1.99 ± 0.52^{a}	0.82 ± 1.31^{a}	4.95 ± 1.46^{b}
H	2.48 ± 0.29^{ab}	5.76 ± 1.59^{b}	8.86 ± 1.20^{c}
P-value	0.001	0.001	<0.001

(*) Mean values followed by the same small letter(s) within the same column do not differ significantly.

In pond A, the lowest BOD recorded was 2.08 on sample day 1 and the highest was 3.81 recorded on day 6 with a mean of 2.77±0.42mg/l, the pond had a higher mean than the optimum mean (Table 4.2, Figure 4.6 and Appendix 6). The t-test results showed BOD level in A pond had no significant difference from the optimum annual mean BOD (t=3.187, df=7, P=0.015). In pond B, the lowest BOD was 2mg/l on day 1 and the highest 3.4 mg/l on day 7 with a mean of 2.77±0.24mg/l which was higher than the optimum mean (Table 4.2, Figure 4.6 and Appendix 6). The t-test showed BOD in pond B had no significant difference from the optimum annual mean of BOD (t=2.959, df=7, P=0.021). In pond C, BOD had a modest range from 2.08mg/l on day 1 to 3.52mg/l on day 8 and mean of 2.47±0.17mg/l which was higher than the optimum mean (Table 4.2, Figure 4.6 and Appendix 6). The t-test showed BOD had no significant difference from the optimum mean BOD (t=2.779, df=7, p=0.027). In pond D, BOD had modest variation of 2.05mg/l on day 1 to 3.5mg/l on day 5 a mean of 2.82±0.48 which was higher than the optimum mean. t-test indicated mean BOD had no significant difference from the optimum mean BOD (t=4.786, df=7,_P=0.002) (Table 4.2, Figure 4.6 and Appendix 6).



*The area highlighted in red indicates optimum range (2mg/l)

Figure 4.6: Mean BOD values recorded in the study ponds during the study period (July to November 2015) vertical bars indicating ±SE

In pond E, BOD lowest concentration was 1.7mg/l on day 2 while highest concentration was 2.58 on day 7 with a mean of 2.02±0.09mg/l, which was lower than the optimum mean (Table 4.2, Figure 4.6 and Appendix 6). The t-test showed BOD had no significant difference in relation to the optimum mean BOD (t=0.161, df=7, P=0.877). In pond F, levels of BOD ranged from 2 on day 2 to 2.64 on day 4 with a mean of 2.23±0.09mg/l which was lower than the optimum mean (Table 4.2, Figure 4.6 and Appendix 6). The t-test indicated BOD had no significant difference from the optimum mean BOD (t=2.697, df=7, P=0.031). In pond G, BOD levels in pond ranged from 1.4mg/l on day 1 to 2.85 on day 8, a mean of 1.99±0.18 was recorded which was higher than the optimum mean (Table 4.2, Figure 4.6 and Appendix 6). The t-test indicated no significant difference from the optimum mean (t=-0.081, df=7, P=0.937). In pond H, BOD levels ranged from 2.01mg/l on day 2 to 2.97mg/l on day 8 with a mean of 2.48±0.10 which was higher than the optimum mean. The t-test showed no significant difference from the optimum annual mean BOD (t=4.655, df=7, P=0.002) (Table 4.2, Figure 4.6 and Appendix 6).

BOD in aquaculture ponds is influenced by temperature, pH, the presence of certain kinds of microorganisms, and the type of organic and inorganic material in the water. BOD directly affects the amounts of DO in water, the higher the amount of BOD, the higher the depletion of DO in water. Hence, less oxygen is available for fish and other aquatic organisms this could result in organisms being stressed, suffocated and eventually die.

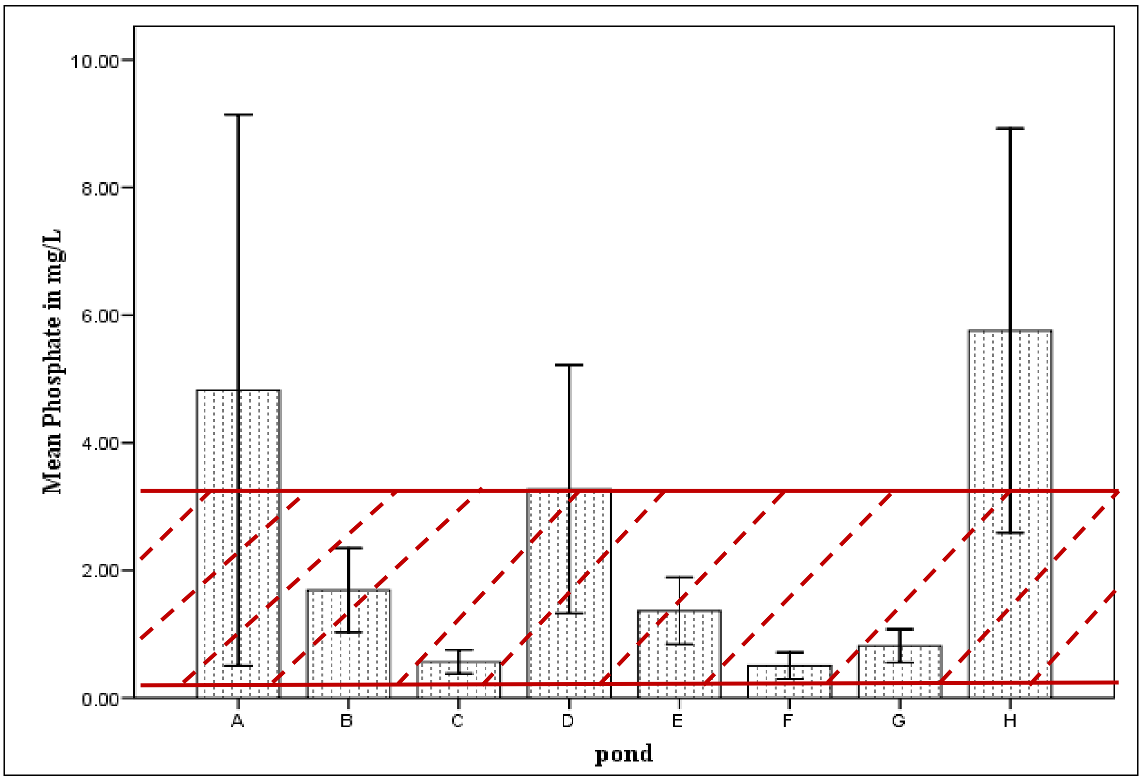
In pond D accumulation of waste feed and other nutrients in the aquaculture pond may have increased the BOD levels. this is evident by the low secchi depth of 14.13±3.36cm as dissoved oxygen is used up in the breakdown of organic matter in water raising the BOD in return. In pond G the flow in flow out system in the pond may have contributed to the low BOD as decomposition of organic matter and accumulation of nutrients in such ponds is low as standing time is low and the flowing water carried away organic matter cleaning the pond naturally. These lowered the amount of oxygen used by microorganisms in the decomposition of readily degradable organic matter in the pond

According to Bhatnagar and Devi (2014), aquaculture ponds should have a mean of 2mg/l, all the study ponds were within the optimum range. The results in all the ponds compared studies done by Deka (2015), where a comparative study of the seasonal trend in two fresh water aquaculture ponds of Assam a mean range of 1.34 to 3.02 mg/l was recorded. However, a wider range was recorded by Kiran (2010) on a study on fish ponds of Bhadra Project at Karnataka who recorded a mean range of 0.8mg/l to 6.6mg/l and a study by Olopade, (2013), on assessment of water quality for aquaculture uses in Abeokuta North, Nigeria who recorded mean range of 2.50 to 6.70mg/l. Finally, the mean was lower than that of studies by Onome and Ebinimi (2004), in aquaculture ponds in Port Harcourt, Nigeria recorded a mean of 6.66 ± 0.78mg/l.

4.2.7 Phosphate

The values of phosphate recorded varied in the eight ponds. Pond H recorded the highest mean of 5.76±1.59mg/l while, pond F recorded the lowest mean of 0.51±1.05mg/l (Figure 4.7). The highest value was recorded in pond A 16.14mg/l while the lowest was 0.26 recorded in pond F (Appendix 7).

In pond A, phosphate concentration had a wide variation ranging from 1.23 in day 1 to 16.14 on day 5, the mean concentration was of 4.82±2.16mg/l which was above the optimum range for aquaculture. In pond D, phosphates concentration ranged from 0.16mg/l on day 2 to 9.90mg/l on day 1 with a mean of 3.28±9.74mg/l. In pond H, phosphate concentration had a variation of 1.20 on day 8 and high 11.85 on day 4 with a mean of 5.76±1.59mg/l (Figure 4.7 and Appendix 7). According to One-Way ANOVA pond H differ significantly from pond C, E, F and G (p=0.001 df=7), (p=0.004 df=7), (p=0.001, df=7) and (p=0.001, df=7) also pond A and F had significant difference (p=0.004 df=7) (table 4.2).



*The area highlighted in red indicates optimum range (0.01-3mg/l)

Figure 4.7: Mean phosphate concentration recorded in the study ponds during the study period (July to November 2015) vertical bars indicating ±SE

Variation in level of phosphates in a water body is as a result of different water sources. In aquaculture ponds, different water sources and the different management interventions affects phosphates. Phosphate concentration also increases during rainy seasons due to incoming waters from the catchment area of human settlements. Storm runoff water loaded with phosphate from unutlized fertilizers getting into water reservoir from neighbouring farms also affects phosphate level in aquaculture ponds (Jafari and Gunale, 2006; Fikrat *et al.,* 2010).

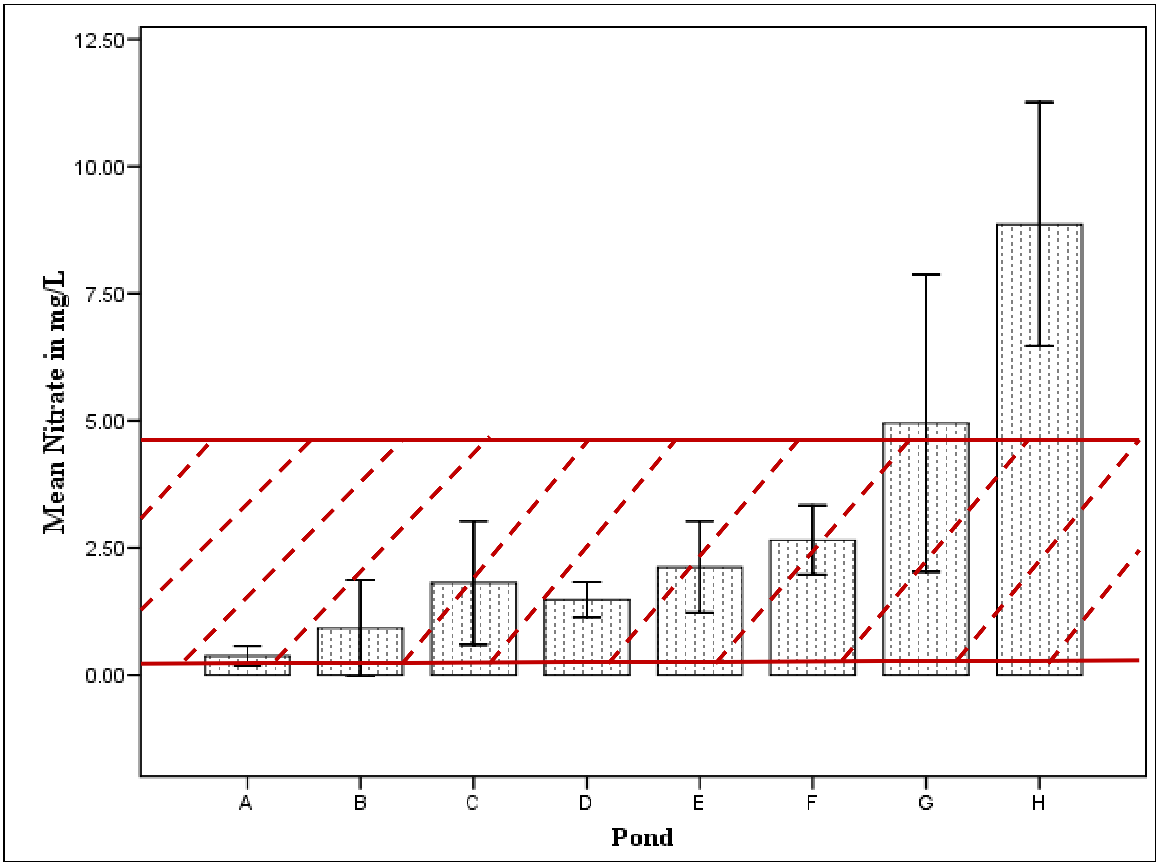
In pond F, Low phosphate may have resulted from ponds being supplied with water from source low in phosphates and the flow in flow out system which could have controlled accumulation of phosphates in the pond (Figure 3.1). In pond H, the high levels of phosphates in the aquaculture pond could be due to water from a source being containing with phosphates as a result of inflow of runoff rich in inorganic fertilizers from surface runoffs from neighbouring farms from tea farms that are dominant in the area (Figure 3.1). Although during the study, it was not possible to determine the exact amount of phosphates in the water pumped into the ponds hence subject to further research.

According to Bhatnagar and Devi (2014), aquaculture ponds are required to have an optimum range of 0.01-3mg/l, all the ponds apart from pond A, D and H recorded a concentration in the optimum range (Figure 4.7). The mean recorded in the study was in the range of 1.40 - 4.51 mg/l recorded by Ehiagbonare and Ogunrinde (2010), in their study of fish pond water in Okada and its environs, Nigeria.

4.1.8 Nitrates

The values of nitrates recorded varied in the eight ponds as shown in Figure 4.8. Pond H recorded the highest mean of 8.86±1.20 while pond A recorded the lowest mean of 0.38±0.10 (Figure 4.8). The highest value was recorded in pond H while the lowest was recorded in pond B (Appendix 8). In pond A, the lowest concentration was 0.03 recorded on day 1 and the highest was 0.75 recorded on day 5 the mean nitrate concentration was 0.38±0.10mg/l. In pond H, nitrate was as low as 4.68mg/l on day 8 and as high as 14.12mg/l on day 6 with mean of 8.87±1.20mg/l (Table 4.2 and Appendix 8).

According to One-Way ANOVA pond G differed significantly from pond A, B, D and H (p=0.000, df=7), (p=0.000, df=7), (p=0,002 df=7) and (p=0.001, df=7) while, pond H had significant difference from pond A, C, D, E, F (p=0.000, df=7) and G (p=0.001, df=7) (Table 4.2).



***The area highlighted in red indicates optimum range (0.01-4.5mg/l)**

Figure 4.8: Mean nitrate concentration in the ponds studied between July and November 2015 vertical bars indicating ±SE

Nitrates concentration differences in the water reservoir can be due to the inflow of inorganic fertilizers from surface runoffs from neighboring farms into the dam reservoir. This occurs whereby, the inorganic fertilizers are carried into standing water bodies in run off from farms around them (Jafari and Gunale, 2006; Fikrat *et al.*, 2010.

In pond A, low nitrates may be as results of low amounts of nitrates concentration in water being pumped into the pond and water exchanged done in liner ponds may have contributed to low nitrates in the ponds (Figure 3.1). In pond H, high nitrate on the other hand, is due to accumulation of uneaten feeds and feeds not utilized by fish effeciently and are excreated by fish to the environment as environmental pollutants (Okomoda., 2011). In addition, use of water from sources contaminated with inputs containing nitrogen (inorganic fertilizers) from sorrounding farms brought in by runoff from tea farms could have also have resulted to high nitrate in the pond (Figure 3.1). According to

(Ndiwa 2011) nitrate levels are significantly higher in reservoir which have been fertilized using farm manure which was also done in the ponds. In the study a wider range than 3.17 – 4.50 mg/l that of a study done by (Dinesh *et al.,* 2017) on pond water in Tamil Nadu, India.

According to Bhatnargar and Devi (2014), aquaculture ponds require to have a range of 0.01-4.5 mg/l, all the study ponds were within the optimum range. The results were similar to those of a study by Shafei (2016) who recorded a range of 0.01– 3.8mg/l which was recorded on a study in fish pond culture in Lake Manzala, Egypt and study by Kiran, (2010) who recorded 4.5 mg/l to 8.0 mg/l in fish ponds of Bhadra project at Karnataka.

4.2 The Type of Algae in Aquaculture Ponds in Tigoni.

A total of 12 genera belonging to four divisions, Chlorophyta was the richest taxonomic group with 6 genera, Euglenophyta had 3 genera, Bacillariophyta had 1 genus and Dinophyta had 2 genera as shown in Table 4.3.

Table 4.3: Algae genera in the sample ponds studied between July and November 2015

SITE	Pond A	Pond B	Pond C	Pond D	Pond E	Pond F	Pond G	Pond H	Total
TAXON									
Chlorophyceace									
Pediastrum	√	√	√	x	√	√	√	√	7
Cosmarium	x	√	x	x	x	x	√	√	3
Staurastrum	x	√	x	x	x	√	x	√	3
Ankistroemus	x	√	x	x	x	x	√	√	3
Closterium	x	√	x	x	x	x	x	√	2
Scenedesmus	√	√	√	√	x	√	√	x	6
Euglenophyceae									
Euglena	√	√	√	√	√	√	√	√	8
Phaccus	√	√	√	√	√	√	√	√	7
Trachelomonas	√	x	√	√	√	x	√	√	6
Dinophyceae									
Peridinium	x	√	√	√	√	√	√	√	7
Ceratium	x	x	x	x	x	x	√	√	2
Bacillariophyceae									
Pinnularia	√	√	√	√	√	√	√	√	8
	6	10	7	6	6	7	10	11	

Key √ Present x Absent

Generally, 12 genera of algae were identified namely; *Euglena, Trachelomonas, Pinnularia, Pediastrum, Scenedesmus, Phacus, Closterium, Peridinium, Cosmarium, Staurastrum, Ankistroemus* and *Ceratium*, *Euglena, Pinnularia* and *Peridinium* occurred more time with a percentage of 14.96 while, *Ceratium* was identified less time with a percentage of 0.25 (Figure 4.9). Higher algae genera occurrence was recorded in earthen ponds H, B, G and C (Appendix 11, Figures 4.10 and 4.11).

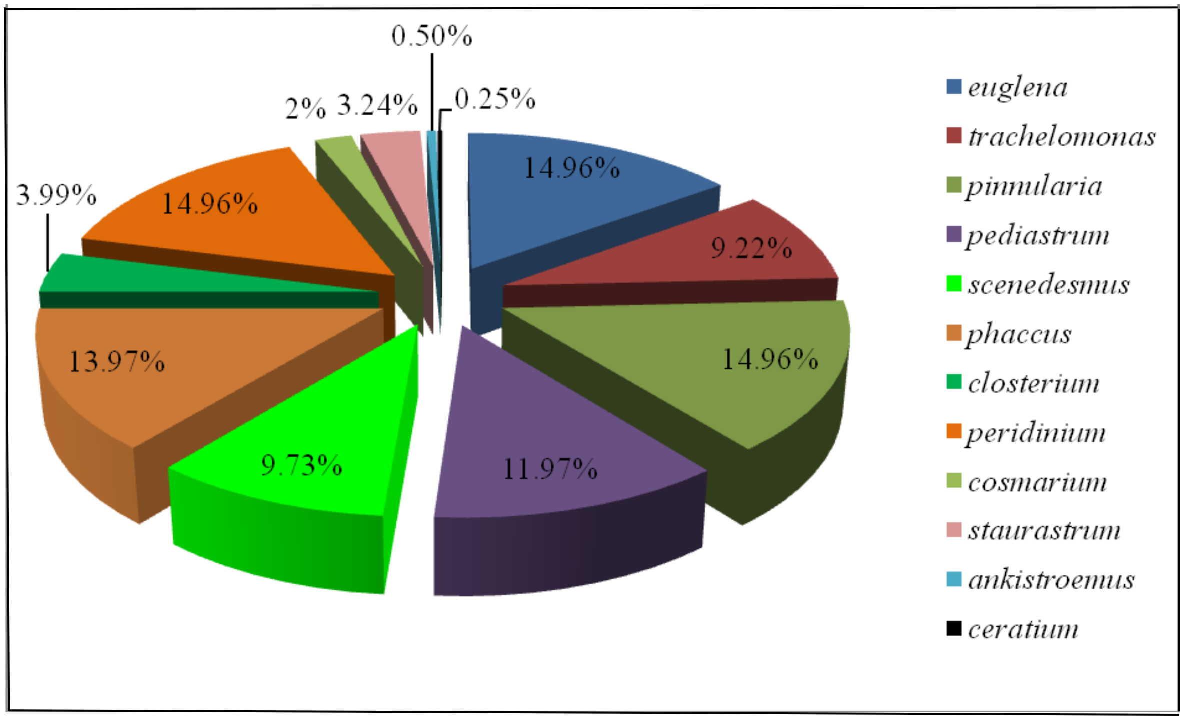


Figure 4.9: Algae occurrence in the aquaculture ponds during the study

In pond A *Pediastrum, Trachelomonas*, *phaccus* and *Pinnularia* recorded the highest percentage 18% while Euglena recorded the lowest percentage of 12% (Figure 4.10 i). In Pond B, 10 genera were identified *Peridinium*, *Closterium, Pinnularia* had a percentage of 14% while *Ankistroemus* had the lowest percentage 2% (Figure 4.10 ii). In pond C 7 algae genera were identified namely *Pediastrum*, *Euglena, phaccus, Trachelomonas* and *Peridinium* had the highest percentage of 15% while, *Scenedesmus* had the lowest percentage 12% (Figure 4.10 iii). In pond D, a total of 6 algae genera were identified *Euglena* and *Trachelomonas* had the lowest percentage of 18% while, *Pinnularia, Scenedesmus* and *Peridinium* had the highest percentage 18% (Figure 4.10 iv). A total of

6 algae genera were also identified in pond E *Peridinium* and *phaccus* had the highest percentage of 20% and had the lowest 10% (Figure 4.11 i).

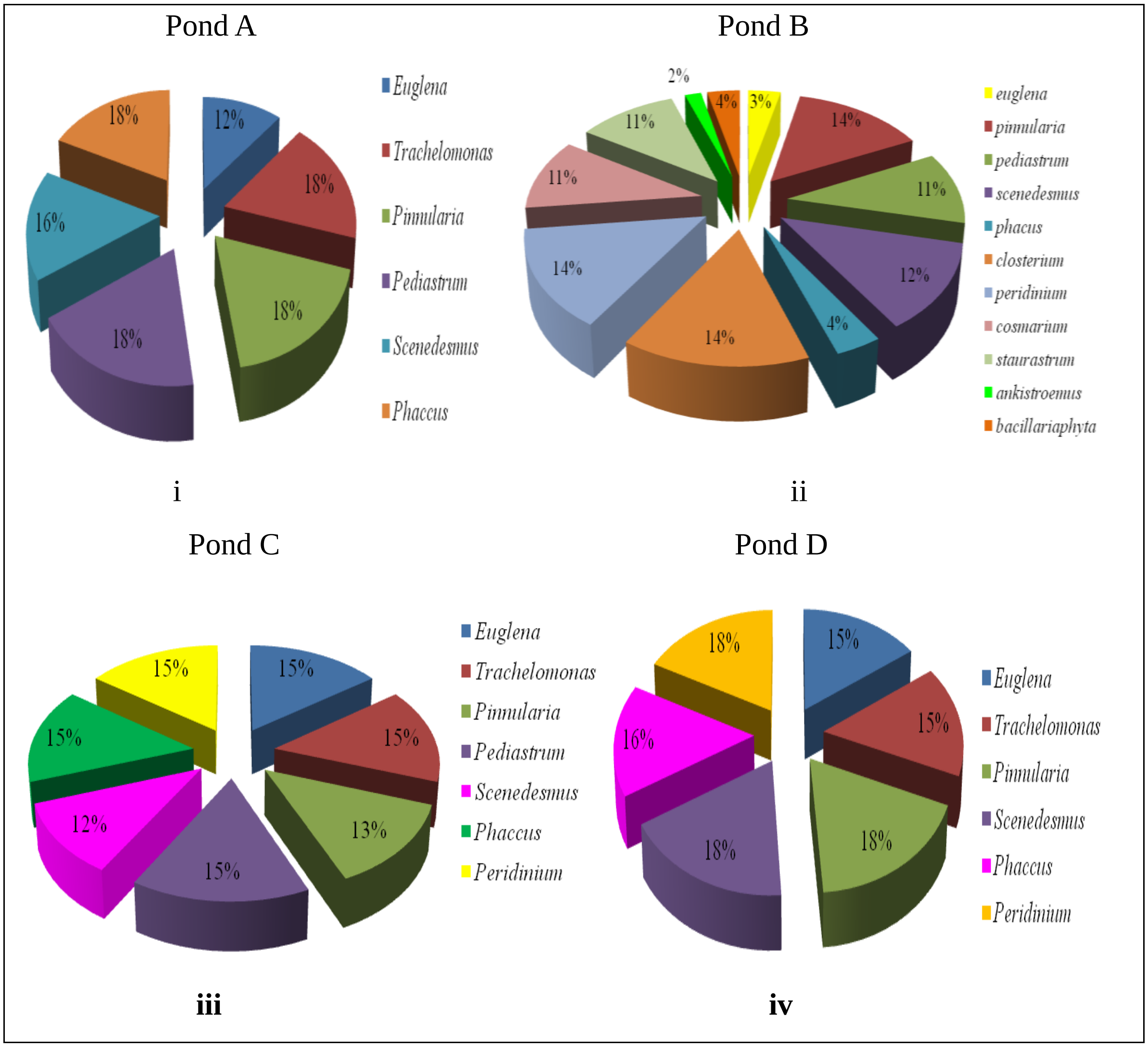


Figure 4. 10: Algae genera composition in (i) pond A, (ii) pond B, (iii) pond C and (iv) pond D

7 Genera of algae were identified in pond F namely; Euglena, *Pinnularia*, *Pediastrum*, *Scenedesmus*, *Phaccus*, *Peridinium and Staurastrum*, with *Phaccus*, *Pinnularia*, *Peridium*, *Euglena* having a higher percentage of 20% while *Staurastrum* had the lowest of 3%. In pond G, 10 algae genera were identified namely; *Euglena*, *Trachelomonas*, *Pinnularia*, *Pediastrum*, *Scenedesmus*, *Phaccus*, *Peridinium*, *Cosmarium*, *Ankistroemus* and *Ceratium* with *Pediastrum*, *Pinnularia*, *phaccus* and *Euglena* occurred more time

with an occurrence of 17% while, *Cosmarium*, *Ankistroemus*, *Ceratium* and *Trachelomonas* with 2%, while in pond H a total of 11 genera were identified in pond H namely; *Euglena*, *Trachelomonas*, *Pinnularia*, *Peridinium*, *Phaccus*, *Closterium*, *Pediastrum*, *Cosmarium*, *Staurastrum*, *Ankistroemus* and *Ceratium*, with *Pediastrum* having the highest percentage of 13% while, *Ceratium*, *Ankistroemus* and *Cosmarium* had the lowest of 2% (Figure 4.11 i, ii and iv) respectively.

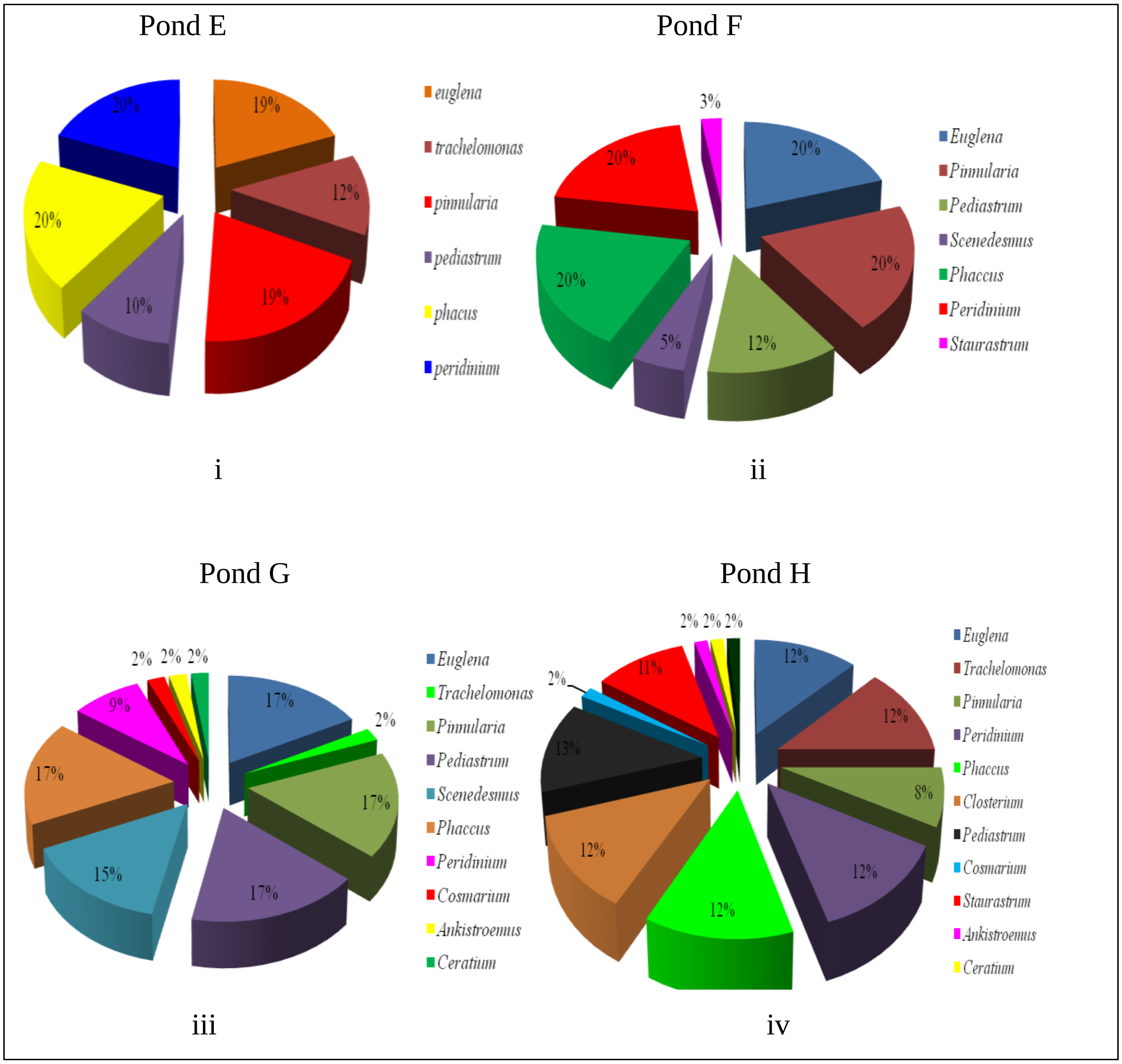


Figure 4. 11: Algae genera composition in pond (i) pond E, (ii) pond F, (iii) G and (iv) pond H

In aquaculture algae acts as source of food for fish species however some algae species like *Prymnesium parvum* are toxic to fish and cause fish kill. Ecologically algae comprise the major portion of primary producers in a aquatic bodies (Nweze,2015). . Chlorophyceace and euglenophyceae servives in a wide range of water habitats depending on several factors. Among the environmental factors, water temperature plays a significant role in affecting the growth and abundance of phytoplankton the other factors are pH, free CO_2, dissolved oxygen and nutrients of water like nitrogen and phosphate. The Euglenophyta (*Euglena, phacus* and *Trachelomonas* species) and chlophyta (*Pediastrum, cosmarium, Staurastrum, ankistroemus, Clossterium* and *Scenedesmus*) they are generally tolerant to organic condition and most of them are heterotrophic therefore, they are dominant in ponds with high organic matter

Euglena, Phaccus, Peridinium and *Pinnularia* genera were common in all ponds while *Ceratium* was only found in ponds G and H and *Closterium* which was also identified in 2 ponds was only present in pond B and H. Earthen pond (B, F and H) had more numbers of algae genera, this could be due to the higher nutrients level from the soils and nutrient loads coming from the rivers that feed them with water which enhance algae growth. Euglenophyceae is also known to survive a wide range of water.habitats hence, it was found in the ponds at higher percentage. In the study all the fish genera identified were non-toxic to fish.

The results are similar to studies done by (Mohamoud, 2015) in fish ponds in Gesedaddo farms, Yola, Nigeria whose studies indicated found *Euglena, Phaccus* and *Peridinium* to be a dominant species in fish ponds. The study is similar to studies by Ssanyu et al., (2011) who recorded Euglenophyta, Chlorophyta, Bacillariophyceae and Dinophya as the most common species in Fish trials ponds in Uganda.

4.3 Relationship between Water quality and Algae in the Aquaculture Ponds

4.3.1 Temperature

The mean temperatures measured during the study period showed modest variations. The temperature ranged from 19.69 ± 1.380^0C to 22.54 ± 1.62^0C. The lowest mean temperature was 19.69 ± 1.3^0C in pond H and the highest was 22.54 ± 1.6^0C in pond F (Figure 4.1). According to One-Way Anova, there was no significance difference in pond water temperatures in the pond. In pond H where the lowest temperature was recorded, 11 genera of algae were identified and pond F where the highest temperature was recorded, 10 genera were identified (Figure 4.11 iv) and (Figure 4.11 ii).

Temperature affect growth rate of microalgae in intensity and duration, in warmer temperature increases the algae growth. Algae increase at temperatures 20^0C to 24^0C, algae bloom usually absorb sunlight, increasing water temperatures (Nweze *et al.*, 2015). Algae optimal temperature generally between 20 and 24°C, although this vary depending on other environmental conditions. Most species of micro-algae can tolerate water temperatures between 16 and 27°C however, water temperature lower than 16°C lower growth of algae whereas those higher than 35°C is lethal to algae growth causing a death of algae.

In general, the two pond (pond F and H) didn't have a high difference in frequency of algae genera these could be due to the fact that they didn't have a significant difference in mean temperature. However, it was observed that in pond F *Pinnularia, Peridinium, Euglena, Staurastrum* and *Phaccus* had a percentage of 20% for each genus (Figure 4.11 ii). This could be that the high temperature recorded in pond F as 22.54 ± 1.62^0C favored their growth in that particular pond, unlike *Staurastrum, Pediastrum* and *Scenedesmus* which were observed to be in lower frequencies as 2%, 12% and 5% respectively in pond H which had lowest temperatures (Figure 4.11 iv).

Rahman *et al.,* (2013) noted that, the planktonic algal community is largely influenced by the interaction temperature. This closely conforms to findings of Rahman *et al.,* (2013) who observed thick bloom of algae genera in experimental fish ponds at relatively higher water temperature.

4.3.2 pH

The pH measured during the study period showed variations, it ranged from 7.57 to 9.09. The lowest was 7.57 in pond G and the highest was 9.09 in pond A. In Pond A which recorded the highest mean, 6 genera of algae were identified and Pond G the which recorded the lowest mean, 10 genera of algae were identified (Figure 4.10 i) and (4.11 ii), respectively.

Scenedesmus, *Trachelomonas*, *Pinnularia*, *Pediastrum* and *Phaccus* were identified in pond A in equal percentage at 18%. In this case, the algae genus such as *Scenedesmus*, *Pediastrum* and *Phaccus* were observed to be in more times in pond G with a percentage of 17%. Euglena was observed in the both ponds. These is due to the fact that *euglena* survives a wider range of pH.

The pH in water bodies favors the abundance and population of algae species, pH range for algae is usually 7 and 9 also decrease in pH decrease algae abundance (McKee, and Patel, 2015). Algae species don't survive the extremes (very low and very high) pH, each algae genus relate with pH differently *Closterium* and *Cosmarium* grows well in high pH.

According to the study by *Utah et al.,* (2013) *Euglena* was favored by both high and low pH levels in pond A and G as it was common in all ponds. The difference between the two ponds could be supported by difference between the frequencies of algae genera. Pond A which had low genera frequency recorded was more acidic while pond G which more alkaline had more algae genera frequencies.

Similar studies by Ikpi *et al.,* (2013) observed that algae genera density correlated to pH values and the density increased at acidic pH (less than 6.5) and showed a declining trend with neutral pH values. This finding is supported by the earlier report that algal abundance increased when the pH of water decreased from 6.6 to 5.0, the result showed that pH value <6.5 was conducive for increasing density of algae genera. The results are similar to studies by (Wirasith *et al*., 2011) which found out pH and alkalinity increases algae diversity in aquaculture pond in studies done on water quality and algae succession in integrated fish ponds.

4.3.3 Secchi Depth

The values of secchi depth recorded varied in the eight ponds as indicated in Figure 4.4. The highest mean was recorded in sample pond G with a mean of 28.38±7.13cm, while the lowest was recorded in pond D with a mean of 14.13±3.36 cm (Figure 4.3). In pond D, 6 genera were identified while in pond G 10 genera were identified (Figure 4.10 iv) and (Figure 4.11 iii) respectively. From the (Figure 4.11 iii), algae genera such as *Scenedesmus*, *Pediastrum* and *phaccus* were observed more times in pond G at 17% which had the highest mean of secchi depth. Pond D recorded the lowest mean of secchi depth genera such as *Euglena*, *Trachelomonas*, *Peridinium*, *Scenedesmus phaccus* and *Peridinium* were identified in nearly equal frequencies (Figure 4.10 iv) which had a frequency of 18%.

Secchi depth affects growth of algae genera, its variation affects distribution of algae. Light penetration affects productivity and survival of organisms such as algae in water bodies (Nweze *et al*., 2015).

High secchi depth favored growth of *Euglena*, *Trachelomonas, Peridinium, Scenedesmus phaccus* and *Peridinium.* These genera hence were found in large numbers compared to others. Pond G which had high secchi depth and 10 algae genera frequencies, indicating high secchi depth encouraged primary productivity.

Similar studies done by Utah *et al.,* (2008) indicates phytoplankton increase with increase in light penetration and frequently associated with dry season. It was also reported in ponds where phytoplankton scarcity can be observed during the wet months (Silva, 2004). During the wet months flushing disturbs the standing crop of plankton. However, when the destabilizing effect reduces, the accumulated nutrient input favors an increased plankton production during the dry season (Ikpi *et al.,* 2013). Lower algae diversity is probably a consequence of higher turbidity in the pond evident with low light penetration, Bruckner (2009) and high turbidity often results in reduced algae diversity.

4.3.4 Conductivity

The values of conductivity recorded varied in the eight ponds as shown in Figure 4.4. The highest mean was recorded in sample pond C with a mean of 416.5±168.93 µS/cm, while the lowest was recorded in pond A with a mean of 190.25±127.86 µS/cm (Figure 4.4). In pond C in which highest mean conductivity was recorded, 7 genera of algae were identified while in pond A, which recorded the lowest conductivity was recorded and 6 genera of algae were recorded (Figure 4.10 i and iii) respectively.

Conductivity in water bodies correlates positively with algae frequencies. High conductivity in water bodies can indicate high algae growth. Water high in conductivity also indicate high nutrient load which increases algae growth (Nweze *et al.,* 2015).

From the results, algae genera such as *Euglena, Trachelomonas, Scenedesmus, Pediastrum, Pinnularia, Peridinium* and *phaccus* were found to be present in equal percentages in pond C which had the highest conductivity. Pond A which recorded low mean conductivity the following algae genera were identified; *Scenedesmus, Trachelomonas, Pinnularia, Pediastrum* and *phaccus* appeared more frequently at 18%, of the two ponds (pond A and C) *Euglena* and *peridium* appeared only in pond C where the highest means of conductivity was recorded. The present results indicated that higher conductivity favored algae genera. *Closterium* genera was only present in pond B and H which had high conductivity, these would be indicator that high conductivity favored the growth of the genera.

The results are similar to studies by (Wirasith *et al*., 2011) which showed a positive correlation between algae genera and conductivity in studies done on water quality and algae succession in integrated fish ponds.

4.3.5 Dissolved Oxygen

The values of dissolved oxygen recorded varied in the eight ponds as shown in Figure 4.6. The highest mean was recorded in sample pond G with a mean of 6.63±1.37 mg/l, while the lowest was recorded in pond C with a mean of 4.03±1.39 mg/l (Figure 4.5). Pond G which recorded the highest mean, 10 genera were identified while in pond C had the lowest mean of 7 (Figure 4.11 iii) and (Figure 4.10 iii), respectively.

When algae species increase, at times they form algae bloom which deplete the DO level which may cause fish mortality. When there is low dissolved oxygen concentration in the water (anoxic), blue-green algae growth rate is higher than other group of algae. Dissolved oxygen in aquatic bodies is released during the day as a waste product of photosynthesis by aquatic plants and algae. When algae die bacterias break them down, during uthe process dissolved oxygen during decomposition making it diffcult for survival of fish and other aquatic organisms.

From the study, *Euglena, Trachelomonas, Scenedesmus, Pediastrum, Pinnularia, Peridinium* and *phaccus* were found in pond C, where the lowest dissolved oxygen was recorded while in pond G where highest DO was recorded, genera such as *Scenedesmus, Pediastrum* and *phaccus* were found more frequently.

The study agrees with studies by Kaggwa, (2006) who recorded a positive correlation between DO and algae genera during studies on managing nutrients and primary productivity for enhanced fish production in Lake Victoria's wetlands in Uganda. In regard to Rahman *et al.*, (2013) the density of algae genera have negative correlation with DO concentration and the maximum density was recorded at lower DO concentration. This result is consistent with the previous reports that algae genera proliferate in the environment of poor DO concentration.

4.3.6 BOD

The values of BOD recorded varied in the eight ponds as shown in Figure 4.6. Pond D had the highest mean of 2.82±0.48 mg/lwhile pond G had the lowest with mean of 1.99±0.52 mg/l (Figure 4.6). One-Way ANOVA showed no significant difference in BOD. In pond D which had the highest BOD, 6 genera were identified while pond H which had the lowest, 10 genera were recorded (Figure 4.10 iv) and (Figure 4.11 iv), respectively.

In aquaculture ponds algae grow but when the die they contribute to the organic waste in the water, during decomposition by bacteria BOD level increase as Dissolved oxygen is used up for decomposition of the algae. BOD and algae have a positive correlation when the algae species diversity and population increases the BOD levels also rises.

In pond G (where the lowest BOD was recorded) genus such as *Scenedesmus, Pediastrum* and *Phaccus* were found in higher frequency. While, *Pinnularia*, *Ceratium* and *Cosmarium* had 2% frequency. In the pond, the low BOD and high frequency of algae genera was attributed to the nature of the pond where water flowed in and out hence the pond was cleaned naturally. These resulted to less accumulation of decomposing matter resulting to low BOD levels. Pond D which had the highest mean BOD level *Pinnularia, Scenedesmus, and, Pediastrum* appeared more frequently at 18% and *Euglena* and *Trachelomonas* had the lowest frequency of 12%. The high mean BOD and also low frequency of algae genera was due to the fact that BOD and algae have a positive correlation, during decomposition of algae dissolved oxygen is taken up resulting to increase of BOD levels.

In aquaculture pond when BOD is high the DO is depleted faster. BOD is related to the amount of effluent degradability, when the biodegradable fraction is high the inert fraction is predominant therefore, the greater the biodegradable fraction the easier the biological decomposition. However the decomposition depends on several other factors which include temperature, dissolved oxygen and pH.

The results agree with studies by Rahman *et al.*, (2013), which showed that the density of algae genera have positive correlation with BOD concentration. Studies by Ikpi *et al.*, (2013), also showed that ponds with mean BOD between 2.5 and 4.05 have density phytoplankton community.

4.3.7 Phosphate

The values of phosphate recorded varied in the eight ponds as shown in Table 4.2 and Figure 4.7. Pond H recorded the highest mean of 5.76±1.58mg/l while, pond F recorded the lowest with a mean of 0.51±0.11mg/l (Figure 4.7). Pond H had the highest mean value where 11 genera were identified compared to 7 genera identified in pond F which had the lowest mean (Figure 4.11 iv and ii), respectively.

High phosphates favor the growth of algae genus, algae diversity is high in water with high in phospahtes. They promote dense growth of algae in aquatic ecosystems. Phosphates contribute to eutrophication this leads to an increase in aquaticmacrophytes and algae growth

Pond F which recorded the lowest mean of phosphate, *Pinnularia, Peridinium, Euglena, Staurastrum* and *Phaccus* were found to be present more frequently. This could be that the lowest phosphate recorded in pond F favored the environment for genera to live in. In this case, *Staurastrum, Pediastrum* and *Scenedesmus* were observed to be in lower percentage as 2%, 12% and 5%, respectively. Pond H which had the highest mean of phosphate also had highest genera of algae identified, the algae identified were; *Euglena, Trachelomonas, Pinnularia, Peridinium, Phaccus, Closterium, Pediastrum, Cosmarium, Staurastrum*, *Ankistroemus* and *Ceratium*, with *Pediastrum* having the highest percentage of 13% while, *microcystis, Ceratium, Ankistroemus* and *Cosmarium* had the lowest percentage as 2%. *Scenedesmus* genera was absent in pond H which recorded the highest mean concentration of phosphate these could be an indication that the phosphate levels didn't favor the growth of the genera.

This observation agrees with that of Kotut *et al.* (1999) found higher diversity of algae to be positively correlated to concentration of nutrients (phosphates). According to studies by Rahman *et al.,* (2007), the phosphate concentrations on algae blooms a correlation analysis indicated that algae genus density positively correlated to phosphate concentrations. The present results indicated that algae genus favored to a combination of higher concentrations of phosphates nutrients. However, these study contradicts studies by Melaku., (2017) who recorded a negative correlation between phosphates and algae genera in studies in the Southern Gulf of Lake Tana, Ethiopia.

4.3.8 Nitrates

The values of nitrates recorded varied in the eight ponds as shown in Table 4.2 and Figure 4.8. Pond H recorded the highest mean of 8.86±1.20 mg/l while, pond A recorded the lowest mean of_0.38±0.10 mg/l (Figure 4.8). In pond H that had the highest mean 11 genera were recorded while in pond A which had the lowest mean 6 genera were identified (Figure 4.11 iv) and (Figure 4.10 i), respectively. Pond H which recorded the highest mean of nitrate had 11 genus identified namely; *Euglena, Trachelomonas, Pinnularia, Peridinium, Phaccus, Closterium, Pediastrum, Cosmarium, Staurastrum, Ankistroemus* and *Ceratium*, with *Pediastrum* having the highest percentage of 13% as the main genus. While pond A which had the lowest mean of nitrates had 6 genera. The identification of low genus of algae was as a result of low nitrate levels.

According to studies by Rahman *et al.*, (2007), the nitrate concentrations were significantly abundant in the bloomed ponds as compared to the non-bloomed ponds. The present results indicated that algae genus favored the combination of higher concentrations of nitrate nutrients. According to Frimpong *et al.*, (2014) excess nitrates in the water source, with the additional fertilization and feeding allow high diversity of algae genus, which could explain the higher levels of algae observed in the study ponds. In pond H which had the highest mean nitrates *Scenedesmus* genera was absent while *Ceratium* was only present in the pond and other genera found are *Euglena, Trachelomonas, Pinnularia, Peridinium, Phaccus, Closterium, Pediastrum, Cosmarium, Staurastrum* and *Ankistroemus*. In pond A which had the lowest mean nitrates *Pediastrum, Scenedesmus, Euglena, Phaccus*, *Trachelomonas* and *Pinnularia* were present. From the study, the earthen pond recorded higher mean frequency of algae genera. This could be due to high nitrates level in the pond soil and runoff from agricultural fields in the area that stimulated the growth of algae as nitrates and algae have a positive correlation. *Ceratium* genera was present in pond G and H which recorded the highest mean nitrate. This was an indication that the *Ceratium* genera does well in high levels of nitrates.

The findings are in conformity with the previous studies which was reported by Ikpi *et al.*, (2013) that algae genus become abundant in higher concentrations of nitrates. This is similar to studies by Melaku, (2017) who recorded a positive correlation between nitrates and algae genera in his studies. According to studies by Rahman *et al.*, (2007), the nitrate concentrations were significantly abundant in the bloom ponds as compared to the non-bloom ponds. In correlation analysis, it was observed that algae genus density positively correlated to nitrate concentrations.

CHAPTER FIVE: SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary of Findings

From the results, water quality in aquaculture ponds met quality for warm water culture although the temperature was below the range. The quality was high above the quality for cold water culture hence, warm water genus was more suitable for the water quality. The studies revealed that, Chlorophyta was the most common taxon identified with 6 genera out of the 12 identified genus. There were similarities in the algae genus composition in the ponds although, some ponds had a higher variety of algae genus than others. Based on the findings, ponds with high amount of phosphates and nitrates had more genus of algae. These suggest high nutrients load contributing to wider variety of algae genus in aquaculture ponds and so there was a relationship between water quality and algae in the aquaculture ponds.

5.2 Conclusions

Mean temperature were in the optimum range but in the lower range but pond D and H were below the range (20-30^{0}C), pH all ponds within range except A and D which were above range (6-9.5), secchi depth all ponds within range except pond D which were above range (15-30cm), DO t-test, pond G had a significant difference ($t=7.500$, $\alpha=0.05$, $p=0.00$) from the optimum mean of 3mg/l, conductivity all ponds were within optimum range (100-2000µS/cm), BOD there was no significant difference in all ponds from the optimum mean of 2mg/l, nitrates all ponds were within optimum range (0.1-4.5mg/l) except pond G and H which were above range, and for phosphates Pond A, D and H were above range (0.01-3.00mg/l) although the exact concentration of phosphate and nitrates contained in the water getting in from the sources was not determine and thus a subject for research.

From the study, a total of 12 genera of algae were identified, composition per pond was; Chlorophyta was the most common taxon identified with 6 genera out of the 12 identified genus. There were similarities in the algae genus composition in the ponds although, some ponds had a higher variety of algae genera than others. *Euglena, Phaccus, Peridinium* and *Pinnularia* genera were common in all ponds while *Ceratium* was only found in ponds G and H and *Closterium* which was also identified in 2 ponds in pond B and H.

In pond H which had the highest mean nitrates *Scenedesmus* genera was absent while, *Ceratium* was only present in the pond H. Pond A which had the lowest mean nitrates *Pediastrum, Scenedesmus, Euglena, Phaccus, Trachelomonas* and *Pinnularia* were present. The results showed that, ponds with the high amount of phosphates and nitrates had more genus of algae and these suggested high nutrients load in the water which contributed to wider variety of algae genus in aquaculture ponds and therefore there existed a relationship between water quality and algae in the aquaculture ponds.

5.3 Recommendations

Management interventions at different levels should be practiced so as to ensure optimum water quality in ponds are met. These include; rearing of fish in green houses to raise temperatures and and Re-circulatory Aquaculture System (R.A.S) to treat and conserve water.

Farmers should be advised to practice water and soil conservation; this will help in reducing the amount of nutrients such as phosphate and nutrients getting into ponds during the run off.

Water management practices at farm level should encouraged to ensure algae growth is controlled excessiful growth may deplete oxygen levels in the ponds.

This study recommends the following areas for further research;

There is need for research on suitability analysis for water used for aquaculture in the area, to determine inflence human actities and land use on water quality in aquaculture.

There is need for a comparative study for water quality in liner and earthen ponds in aquaculture to determine the variation in waste and nutrient accumulation in aquculture.

More research is needed to establish the algae composition and abundance in the aquaculture ponds. This would mainly improve management strategies in aquaculture in Tigoni.

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APPENDICES

Appendix 1: Temporal variations in temperature (^{0}C) at different sampling sites during the study period

Sample (day)	Pond A	Pond B	Pond C	Pond D	Pond E	Pond F	Pond G	Pond H
1	20.4	20.7	17.6	18.7	19.1	20.5	20.6	20.9
2	21.9	19.5	18.7	17.9	19.3	20.6	20.9	21
3	20.4	19.4	19.4	20.9	21	22.7	23.1	19.5
4	22.4	20.4	19.8	20.4	24.3	23.2	23.6	20.9
5	19.6	19.9	20.1	18.6	21.3	21.3	20.3	17
6	20.5	21.5	21.5	19.5	21.9	22.9	20.4	18.6
7	22.6	24.3	23	21.8	22	24.8	20.3	19.7
8	21.4	23.9	22.4	22	22.1	24.3	20.9	19.9
Mean	21.15	21.20	20.31	19.98	21.38	22.54	21.26	19.69

Appendix 2: Temporal variations in pH at different sampling sites during the study period

Sample (day)	Pond A	Pond B	Pond C	Pond D	Pond E	Pond F	Pond G	Pond H
1	9.3	8.6	8.4	8.4	9.2	7.5	7.5	7.9
2	9.2	8.45	8.4	7.4	8.53	7.05	7.23	7.92
3	9.13	8.3	8.45	8.56	7.2	6.8	6.98	7.95
4	8.67	8.48	8.39	10.25	8.37	7.66	7.03	7.93
5	8.45	8.5	8.2	8.59	7.3	7.23	7.75	8.9
6	8.49	8.78	8.6	9.5	8.39	7.96	8	9.3
7	10.8	9.1	8.8	10.5	8.7	9.5	8.5	10.85
8	8.7	8.8	8.9	8.9	7.29	7.6	7.59	8.45
Mean	9.09	8.63	8.52	9.01	8.12	7.66	7.57	8.65

Appendix 3: Temporal variations in secchi depth (cm) at different sampling sites during the study period

Sample(day)	Pond A	Pond B	Pond C	Pond D	Pond E	Pond F	Pond G	Pond H
1	25.55	20.95	30	20	35	26	40	23.52
2	18.2	21	27.63	18	32	18	35.27	34.28
3	10.5	22	26.05	15	30	36	31.94	45
4	18.75	18.9	21.05	12	25	30	34.4	32.65
5	17.25	10	18.63	12	15	25	27.58	18.5
6	25.25	12.9	17.63	11	13	13	22.56	17.2
7	15.35	16.5	14.3	11	25.79	20	20.29	10
8	29.65	13.75	10	14	17	26	15	16.2
Mean	20.06	17.00	20.66	14.13	24.10	24.25	28.38	24.67

Appendix 4: Temporal variations in conductivity (µS/cm) at different sampling sites during the study period

Sample (day)	Pond A	Pond B	Pond C	Pond D	Pond E	Pond F	Pond G	Pond H
1	63	326	252	174	70	138	137	223
2	78	397	284	109	182	123	127	301
3	92	439	308	149	113.9	162	106	309
4	155	299	332	84	143.9	134	149.5	279.5
5	138	236	382	111	195	116	185	301
6	248	336	423	189	295	364	235	356
7	350	395	655	541	401	425	308	408
8	398	425	696	556	478	487	384	463
Mean	190.25	356.63	416.5	239.13	234.85	243.63	203.94	330.06

Appendix 5: Temporal variations in DO (mg/l) at different sampling sites during the study period

Sample (day)	Pond A	Pond B	Pond C	Pond D	Pond E	Pond F	Pond G	Pond H
1	5.95	5.3	5.45	4.5	4.9	4.3	8.72	6.3
2	5.91	6.06	5.97	6.7	5.7	3.32	7.8	3.4
3	1.17	2.9	1.19	4	3.2	4	5.9	3.55
4	6.25	4	2.77	7.24	10.54	5.72	6.72	5.24
5	5.25	4.3	4.75	2.9	6.8	6	7.8	4.9
6	3.57	2.9	3.19	4	3.2	4	5.9	3.55
7	5.91	6.07	5.95	6.8	5.7	3.32	5.3	3.36
8	3.74	3.76	2.99	5.74	5.77	6.12	4.86	3.77
Mean	4.72	4.41	4.03	5.24	5.73	4.60	6.63	4.26

Appendix 6: Temporal variations in BOD (mg/l) at different sampling sites during the study period

Sample	Pond A	Pond B	Pond C	Pond D	Pond E	Pond F	Pond G	Pond H
1	2.08	2	2.08	2.05	1.9	2.04	1.4	2.35
2	2.1	2.12	2.25	2.54	1.7	2	1.5	2.01
3	2.32	2.45	2.14	2.77	1.8	2.25	1.79	2.3
4	2.25	2.83	2.45	2.8	1.92	2.64	1.6	2.46
5	3.5	2.64	2.67	3.58	2	2.2	1.9	2.7
6	3.81	2.53	2.59	3.35	2.08	2.53	2.35	2.4
7	3.08	2.14	2.08	3.05	2.58	2.08	2.49	2.67
8	2.92	3.4	3.52	2.45	2.09	2.09	2.85	2.97
Mean	2.76	2.52	2.48	2.82	2.01	2.23	1.99	2.48

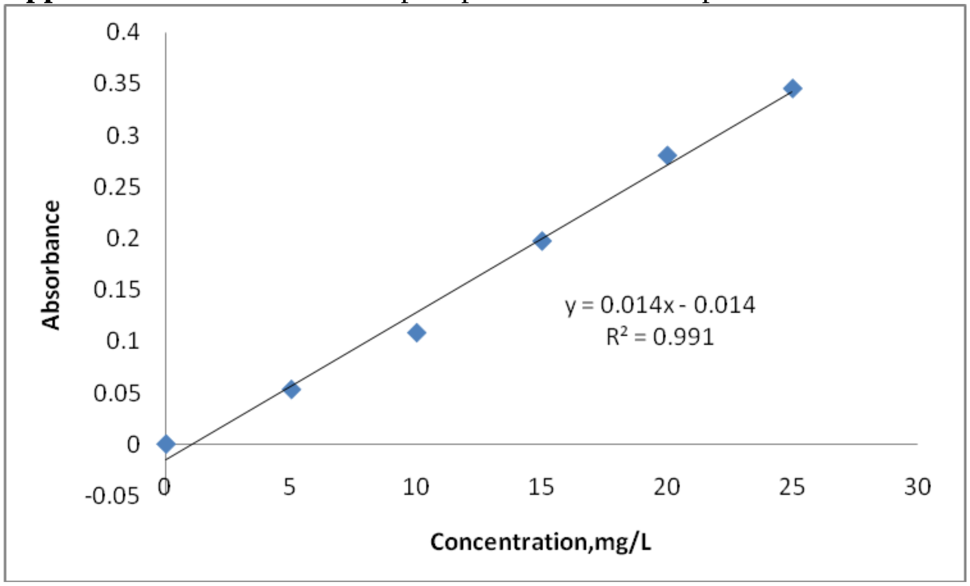
Appendix 7: Temporal variations in phosphates (mg/l) at different sampling sites during the study period

Sample (day)	Pond A	Pond B	Pond C	Pond D	Pond E	Pond F	Pond G	Pond H
1	1.23	0.84	0.33	9.89	0.46	0.26	0.39	8.64
2	1.73	0.88	0.35	1.61	0.61	0.26	0.41	9
3	1.86	1.02	0.37	2.04	0.86	0.26	0.63	9.89
4	13.11	1.59	0.41	2.52	1.2	0.27	0.82	11.86
5	16.14	1.86	0.48	1.86	1.93	0.46	0.86	1.63
6	1.86	2.64	0.7	2.89	2.52	0.77	0.89	2
7	1.27	3.46	0.88	3.59	2.09	0.79	0.98	1.84
8	1.39	1.23	1.02	1.8	1.2	0.98	1.55	1.2
Mean	4.82	1.69	0.57	3.28	1.36	0.51	0.82	5.76

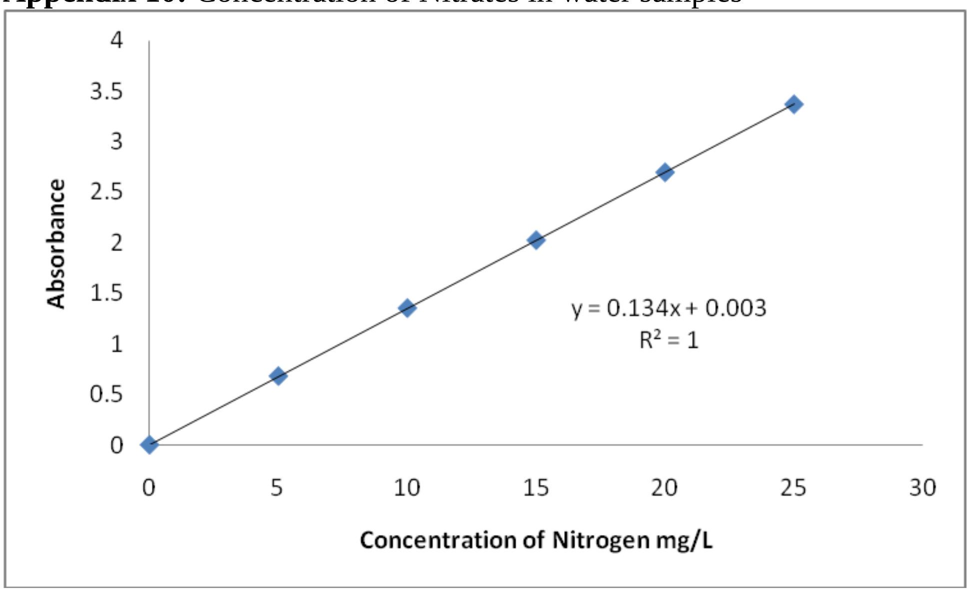
Appendix 8: Temporal variations in nitrates (mg/l) at different sampling sites during the study period

Sample (day)	Pond A	Pond B	Pond C	Pond D	Pond E	Pond F	Pond G	Pond H
1	0.03	0.01	0.09	0.78	0.73	1.36	1.62	5.54
2	0.13	0.02	0.11	0.97	1.19	1.53	2.18	5.91
3	0.13	0.01	1.25	1.32	1.64	1.83	3.68	8.34
4	0.49	0.11	3.49	1.19	3.23	3.15	8.71	10.02
5	0.63	1.42	3.69	1.62	3.69	3.36	10.58	12.44
6	0.75	3.81	4.24	2.13	3.77	3.26	10.02	14.12
7	0.58	1.57	1.03	1.94	1.98	3.97	0.3	9.83
8	0.3	0.43	0.58	1.87	0.75	2.74	2.48	4.68
Mean	0.38	0.92	1.81	1.48	2.12	2.65	4.95	8.86

Appendix 9: Concentration of phosphate in water samples



Appendix 10: Concentration of Nitrates in water samples



Appendix 11: Some of the algae genera identified

Euglena genus. Source (Vuuren *et al*., 2006)

Trachelomonas genus. Source (Vuuren *et al*., 2006)

Pinnularia genus. Source (Vuuren *et al*., 2006)

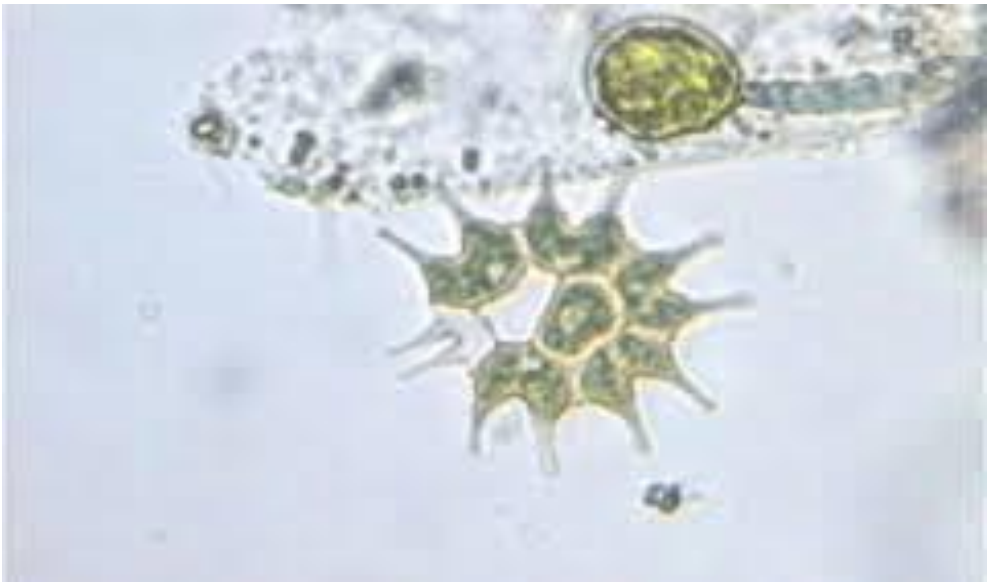
Cosmarium genus *(*Vuureen *et al.*, 2006)

Scenedesmus genus. Source (Vuuren *et al*., 2006)

Phaccus Genus. Source (Vuuren *et al*., 2006)

Peridium genus. Source (Vuuren *et al*., 2006)

Cosmarium Genus. Source (Vuuren *et al*., 2006)



Pediastrum genus. Source (Vuuren *et al*., 2006)

Appendix 12: Photos of field measurement

Measurement of pH

Field measurement of Secchi depth


Identification of algae