EFFECT OF STOCKING DENSITY AND DIET ON GROWTH AND SURVIVAL OF JIPE TILAPIA (*Oreochromis jipe*) CULTURED IN HAPAS AT SAGANA, KENYA

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DECLARATION AND RECOMMENDATION

Declaration

I declare that this work is original and has not been presented for the award of any other degree elsewhere.

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Recommendation

This work has been submitted for examination with our approval as the University's Supervisors.

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DEDICATION

This thesis is dedicated to my God the Lord Jesus Christ.

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ABSTRACT

With an ever-increasing global need for sustainable animal protein, agriculturists are turning to aquaculture for an alternative source of protein and revenue. Aquaculture is widely considered as an important component for enhancing food security, income and nutrition. Tilapias are considered as the best species for culture globally and in Kenya, *Oreochromis niloticus* has shown significant success. However, little is known about the aquaculture potential of *Oreochromis jipe*. This study sought to assess the culture potential of *O. jipe*. An 84 days experiment was conducted at Sagana Aquaculture Centre, Kenya, to assess the effect of stocking density and diet on performance of Jipe tilapia (*O. jipe*) reared in hapas in an earthen pond. It involved a completely randomized design (CRD) in a 3x2 factorial arrangement (3 diets x 2 stocking densities) in 18 (1m x1m) hapas mounted in an 800 m^2 earthen pond. The stocking densities were 30 fish/m^2 and 45 fish/ m^2 combined with 30% CP of both formulated feed (D_1) and Ranaan commercial feed (D_2) and 35% CP for Sigma commercial feed (D_3). Feeding was maintained at 10% of body weight (BW) adjusted after every 14 days of growth. The effects of stocking density and diet were compared on the basis of mean weight and length, weight gain percent, specific growth rate, survival, feed conversion ratio and average water quality parameters and the means of the variables were analyzed using two-way Analysis of Variance (ANOVA) at $p<0.05$ to test the effects of the two factors (stocking density and diet) on the various aspects of *O. jipe* growth and survival. Mean separation from ANOVA test was done using Tukey's HSD (Honestly significant difference) at $p<0.05$ to detail any difference among treatments. The best growth in terms of mean length and weight was achieved in D_3 irrespective of stocking density. It recorded mean length 7.50±0.19 cm and mean weight of 6.68±0.45 g respectively. Survival was highest on fish fed on D_2 (17.00±1.57 No.) whereas stocking density had no significant effect ($p>0.05$) on *O. jipe* survival. There was no significant interaction ($p>0.05$) of the two factors tested on calculated growth performance parameters (mean weight, SGR, percent weight gain, survival rate and FCR) except for mean length, survival and condition factor which were significantly affected ($p<0.05$). Stocking density and diet had no significant effect ($p>0.05$) on all the water quality parameters measured. Furthermore, all the water quality parameters were within the recommended ranges for tilapia culture. The results suggest that diet has a marked effect on *O. jipe* growth and survival. I therefore recommend that the fish should be fed on a high CP diet in the culture systems.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS AND ACRONYMS

°C	Degrees Celsius
D	Diet
µS	Micro-Siemens
BW	Body weight
CF	Condition factor
CP	Crude protein
CRD	Completely Randomized Design
DO	Dissolved oxygen
EOO	Extent of Occurrence
ESP	Economic Stimulus Program
ESP-FFEPP	Economic Stimulus Program-Fish Farming Enterprise Productivity Program
FAO	Food and Agriculture Organization of United Nations
FCR	Feed conversion ratio
FJB	Fig jam by-product
GDP	Gross Domestic Product
GoK	Government of Kenya
IUCN	International Union for Conservation of Nature
KMFRI	Kenya Marine and Fisheries Research Institute
mg/L	Milligrams per Litre
OECD	Organization for Economic Co-operation and Development
ppm	Parts per million
SDGs	Sustainable Development Goals
SE	Standard error
SGR	Specific growth rate
SMEs	Small and Medium Enterprises
SSA	Sub-Saharan Africa
TDS	Total dissolved solid
TISA	The Institute of Social Accountability
WHO	World Health Organization

CHAPTER ONE
INTRODUCTION

1.1 Background Information

The global human societies are experiencing the enormous challenge of having to provide food and livelihoods to a population of over 9 billion people as well as addressing the disproportionate impacts of climate change and environmental degradation on the resource base (FAO, 2018). However, growth in the global supply of fish for human consumption has outpaced population growth in the past five decades thus resulting in increasing average per capita availability (FAO, 2016). In per capita terms, food fish consumption has increased from 9.0 kg in 1961 to 20.2 kg in 2015, at an average rate of about 1.5% per year (FAO, 2018).

The preliminary estimates recorded for 2016 and 2017 indicate further growth to about 20.3 kg and 20.5 kg respectively (FAO, 2018). This expansion in consumption has not only been driven by increased production, but also by a combination of many other factors, including; reduced wastage, better utilization, improved distribution channels and growing demand, linked with population growth, rising incomes and urbanization (FAO, 2018). Furthermore, the significant growth in fisheries and aquaculture production since the middle of the twentieth century has increased the world's capacity to consume diverse and nutritious food (FAO, 2018).

However, in the African continent, only Nigeria and Egypt have been dominant countries in aquaculture production surpassing over 50% of total African production of farmed fish (Yongo *et al*., 2012). The situation is critical in Sub-Saharan Africa (SSA) where prevalence of chronic undernourishment appears to have risen from 20.8% to 22.7% between 2015 and 2016 (FAO, 2017). Many countries in SSA have the potential to develop aquaculture but they continue to produce negligible quantities of fish. In 2006, for example, SSA contributed an insignificant 0.03% of the world's aquaculture production (Yongo *et al*., 2012).

Many African countries depend on food fish obtained from natural water bodies (Opiyo *et al*., 2010). In Africa, for instance, major lakes and rivers have been the source of food fish for many people for a long time (Opiyo *et al*., 2010). According to Tacon and Barg (2001), there has been a very high demand for food fish within most developing nations because of their greater affordability within poorer areas of the community compared to other

sources of animal proteins like beef and poultry. There is therefore an important need to develop alternative ways of food fish production that do not exert pressure on the natural water bodies so as to supplement the capture fisheries and to assure food security in developing countries in Africa (Opiyo *et al*., 2010).

Aquaculture, mainly the farming of fish, is often cited as one of the means of efficiently increasing food production hence promoting food security. A total of 842 million people in 2011-13, were estimated to be suffering from chronic hunger, regularly not getting enough food to conduct an active life (FAO, 2013). Despite overall progress, marked differences across regions persist; Sub-Saharan Africa remains the region with the highest prevalence of undernourishment (FAO, 2013). Fish provides a good source of protein and essential micronutrients and thus plays an important role in the prevention of many human diseases (Williams and Poh-Sze, 2003).

Aquaculture is one of the fastest growing food-producing sub-sectors (Subasinghe, 2003). According to Lehane (2013), it is recognized as a possible sustainable solution for food security and increased dietary nutrition in developing regions. The most cultured species worldwide are carp, tilapia, salmon and catfish. Globally tilapia has become the third most important fish in aquaculture after carp and salmon (Fessehaye, 2006). Though several species of tilapia are cultured commercially, Nile tilapia (*Oreochromis niloticus*) and its various hybrids are the predominant cultured species worldwide (Welker and Lim, 2011).

Tilapias are considered as the best species for culture because of their high tolerance to adverse environmental conditions, their relatively fast growth and easy breeding (El-Sayed, 1999). The *O. niloticus*, a member of the Cichlid family native to Africa (FAO, 2001), are among the easiest and most profitable fish to farm due to their omnivorous diet, prolific breeding, tolerance to high stocking density and rapid growth, hence completing their life cycle in captivity (El-Sayed, 2002 ; Tahoun *et al*., 2008). These characteristics make them ideal for aquaculture.

In Kenya, freshwater aquaculture activities mainly involve the production of *O. niloticus* and African catfish (*Clarias gariepinus*) under different culture systems. However, studies done in Kenya have shown that *O. niloticus* is the most readily cultured fish with significant success. It has an efficient feed conversion ratio, demonstrates fast growth rates, high tolerance to low water quality, ease of spawning and resistance to diseases (Opiyo *et al*., 2014). On the contrary little is known about Jipe tilapia (*Oreochromis jipe,* Lowe, 1955), a

commercially important tilapine endemic to Lake Jipe and Pangani River in Tanzania (Bayona, 2006). There is also lack of information on its culture potential, stocking density, growth and survival in relation to diet. Despite the great potential of tilapia culture, information on the effects of stocking density and diet on fish performance is limited, inconsistent and sometimes controversial (El-Sayed, 2002). Furthermore, determining an optimum stocking density that will ensure optimal growth performance and survival of the fish is a complex issue. It combines factors such as water quality, need for space in the rearing system and social behavior of the fish at any particular life stage of the fish being cultured (Karakatsouli *et al*., 2007). This study sought to assess the aquaculture potential of *O. jipe* based on stocking density and diet, reared in hapas in an earthen pond at KMFRI Sagana Aquaculture Centre.

1.2 Statement of the Problem

Currently, there has been exacerbation of food insecurity problems in Kenya, which is as a result of several factors including the frequent droughts in most parts of the country. Moreover, introduction of non-indigenous fish species to natural water bodies and aquaculture with the aim of improving the fisheries sector is not new in the world with *O. niloticus* being one of the most trans-located fish globally. Live fish movement has had both positive and negative effects with some introductions having far reaching effects to the aquatic ecological integrity. Aquaculture in Kenya is a fast growing food-producing subsector but is limited to two major warm water species (*O. niloticus* and *C. gariepinus*). Furthermore, *O. jipe*, a part of the commercially important fishery of Lake Jipe, is listed as an endangered fish (IUCN Red List). This species is faced with continued decline in population of mature individuals due to over-fishing, destruction of habitats, infestation by *Typha domingensis*, *Cyperus papyrus* and *Phragmites mauritianus*, high levels of siltation, competition for space with *O. esculentus* and increased salinity due to reduction in lake levels. There is also limited information on the culture potential of this species.

1.3 Objectives of the Study

1.3.1 Broad Objective

The broad objective of the study was to assess the effect of stocking density and diet on the growth and survival of *Oreochromis jipe* cultured in hapas as a contribution to food security.

1.3.2 Specific Objectives

To accomplish the aim of the study, the following specific objectives were used:

i. To determine the effect of stocking density on the growth of *O. jipe* cultured in hapas.
ii. To determine the effect of stocking density on the survival of *O. jipe* cultured in hapas.
iii. To determine the effect of diet on the growth of *O. jipe* cultured in hapas.
iv. To determine the effect of diet on the survival of *O. jipe* cultured in hapas.
v. To assess the effect of stocking density and diet on the water quality of culture facilities.

1.4 Null Hypotheses

i. H_o: Stocking density has no significant effect on the growth of *O. jipe* cultured in hapas.
ii. H_o: Stocking density has no significant effect on the survival of *O. jipe* cultured in hapas.
iii. H_o: Diet has no significant effect on the growth of *O. jipe* cultured in hapas.
iv. H_o: Diet has no significant effect on the survival of *O. jipe* cultured in hapas.
v. H_o: Stocking density and diet have no significant effect on the water quality of culture facilities.

1.5 Significance of the Study

This study is informed by the fact that aquaculture is widely considered as an important component for enhancing food security, income and nutrition. It forms part of the Blue Economy and thus makes significant contributions to economic growth, food and nutrition security and livelihoods for millions of people. However, little information is available concerning the direct and indirect impacts of aquaculture on food security and poverty alleviation in most developing countries. To provide food to a world population expected to surpass 9 billion in 2050, it has been estimated that agricultural output, originating primarily from crops, livestock and fisheries, including aquaculture must increase by 70%. Meeting this target is a formidable challenge for the international community considering that around one billion people presently suffer from hunger and poverty.

With an ever-increasing global need for sustainable animal protein, agriculturists are turning to aquaculture as an alternative source of protein and income. Currently, the fastest growing segment in the farming industry, inland aquaculture has taken off in a big way. This

calls for selection of fish species that have high growth rate, short food chain, climate and environmental adaptations, disease resistance, good breeding characteristics, compatibility with other fish species in cultivation and food conversion efficiency (FCR). In 2008, the government of Kenya (GoK) launched Kenya Vision 2030 as the new long-term development blueprint for the country whose focus is to create a "Globally competitive and prosperous country with a high quality of life by 2030." The vision is anchored on economic, social and political pillars.

The economic pillar aims at providing prosperity to all Kenyans through an economic development program aimed at achieving an average GDP growth rate of 10% per annum by deliberately prioritizing growth in areas that had hitherto not been fully exploited such as the fisheries sector particularly aquaculture. This study seeks to promote aquaculture which will in turn help in attaining two core Sustainable Development Goals (SDGs) as far as food security and the wider anti-poverty agenda is concerned. For instance, SDG number one- Ending Poverty-, which must be fought in rural areas where people depend directly or indirectly on farming, fisheries or forestry for incomes as well as food and will also help in attaining SDG number two on tackling food insecurity and malnutrition while promoting sustainable agriculture so as to achieve zero hunger.

The findings of the study will help determine the aquaculture potential of *O. jipe* which can help in enhancing commercialization, since tilapia fish has a huge demand among all the fish species available in Kenya. Furthermore, this indigenous species is traditionally a delicacy and improving its farming under captivity will lead to provision of quality seed to interested farmers as well as restocking of rivers and lakes. The findings will also be of use to the GoK and farmers by providing a clear understanding of the behavior of this fish species under captivity and in resource management. This study therefore assessed the effect of stocking density and diet on the growth and survival of *O. jipe* reared in hapas in an earthen pond with the aim of introducing it into aquaculture to supplement the existing tilapia fish species along the coastal parts of Kenya.

1.6 Scope of the Study

The study was conducted at Kenya Marine and Fisheries Research Institute, Sagana Aquaculture Research Centre within Kirinyaga County. The 84 days *O. jipe* experiment involved a 3x2 factorial arrangement (3 diets x 2 stocking densities) in 18 hapas mounted in an 800 m^2 earthen pond in a completely randomized design (CRD). *Oreochromis jipe*

brooders were sourced from Lake jipe in Taita Taveta County and transported in aerated live fish transportation tanks to Sagana where they have been stocked in a secured concrete pond for breeding. Fingerlings were later isolated and taken for culture trials. The study focused on the effect of stocking density and diet on growth performance parameters and survival of *O. jipe* as a preliminary way of assessing its culture potential along the Kenyan inland coastal fresh waters and parts of Tanzania. The water quality parameters that were measured during the experiment period included; pH, temperature, total dissolved solid (TDS), conductivity, ammonia, nitrites and phosphates.

1.7 Limitations of the Study

In the present study, the researcher had no control over the weather conditions at the study site. Furthermore, the experiment was conducted in one single pond due to biosecurity reasons hence increasing chances of feed interaction between hapas.

1.8 Assumptions of the Study

The observed changes in growth and survival was attributed to diet and stocking density and there was no feed interaction between hapas resulting from water turbulence in the earthen pond.

1.9 Definition of Terms

Aquaculture: Also known as aqua farming; is the farming of aquatic organisms such as fish, crustaceans, mollusks and aquatic plants. It involves cultivating freshwater and salt water populations under controlled conditions, and can be contrasted with commercial fishing, which is the harvesting of wild fish.

Aquaculture potential: This refers to ability and capacity to do well in captivity to enhance commercialization.

Condition factor (CF): A measurement of the general health condition of fish as calculated by the ratio of the body weight to body length; CF is used to compare growth conditions of fish and is indicative of environmental quality.

Diet: The food given or fed to fish and can either be commercial fish feed or locally formulated feed.

Earthen ponds: Natural earthen reservoirs, often created by excavation and/or damming up a natural soil-based basin, sometimes with the addition of a clay or artificial membrane liner.

Feed Conversion Ratio (FCR): Is an indicator that is commonly used in all types of farming, as well as in the field of research. FCR is the mathematical relationship between the input of the feed that has been fed and the weight gain of a population over a given period of time.

Food security: A situation in which all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets the dietary needs and food preferences for an active and healthy life (FAO, 2018).

Fry: Very young fish that is in its larval stage normally less than 21 days old.

Growth: The irreversible increase in the dry mass of an organism.

Hapas: Small (typically 1-5m^2), fixed, net enclosures sited in ponds. They are usually pegged by a number of sticks or posts with the net strung between them. Often, they are used in ponds in tropical areas for fry and brood stock because they offer cost effective method of control of brood stock and fry within large rearing ponds.

Spawning: This is an external method of reproduction where the female releases unfertilized eggs into the water. At the same time, a male or many males release a lot of sperm into the water which fertilizes some of these eggs.

Stocking density: Is the number of fish kept in a given volume of water.

Survival: Ability to exist or live in a new environment especially under adverse or unusual circumstances.

CHAPTER TWO
LITERATURE REVIEW

2.1 Overview of Fisheries and Aquaculture

Globally, fish and fish products provide an average of about 34 calories per capita per day (FAO, 2018). However, their daily contribution can exceed 130 calories per capita in regions where alternative protein foods are lacking and where a preference for fish has developed and endured, for example; Iceland, Japan, Norway, the Republic of Korea and several small Island States (FAO, 2018). More than being an energy source, the dietary contribution of fish is significant in terms of high quality and easily digested animal proteins. A proportion of 150 g of fish provides an average of about 50% to 60% of an adult's daily protein requirement (FAO, 2018).

In regard to this, fish and fish products have a crucial role in both the nutritional and global food security, as they represent a valuable source of nutrients and micro-nutrients of fundamental importance for diversified and healthy diets (FAO, 2018). Fisheries and aquaculture is a source not just for health but also of wealth. Moreover, it remains as an important source of food, nutrition, income and livelihoods for hundreds of millions of people around the world (FAO, 2016). It indirectly supports nearly half a billion people in ancillary occupations or as dependents (Richardson *et al*., 2011) albeit being an important, consistently affordable dietary component with large geographical variance (FAO, 2018).

According to Lynch *et al*. (2017), the vast majority of inland fisheries, are small-scale operations of poorer groups and are very essential for their food and economic security. Furthermore, fish contributes to nutritional security of poor households in developing countries through income generation and livelihood diversification (Thompson and Amoroso, 2014; Bènè *et al*., 2015). And therefore, fish is especially critically for rural populations, which have less diverse diets and lower food security rates (Thompson and Amoroso, 2014). Despite the increasing role of aquaculture in global fish supplies, the capture fisheries still remains dominant in the supply of a variety of species and is vital for domestic and international food security (OECD and FAO, 2017). With capture fishery production relatively static since the late 1980s, aquaculture has been responsible for the impressive growth for human consumption (Figure 2.1).

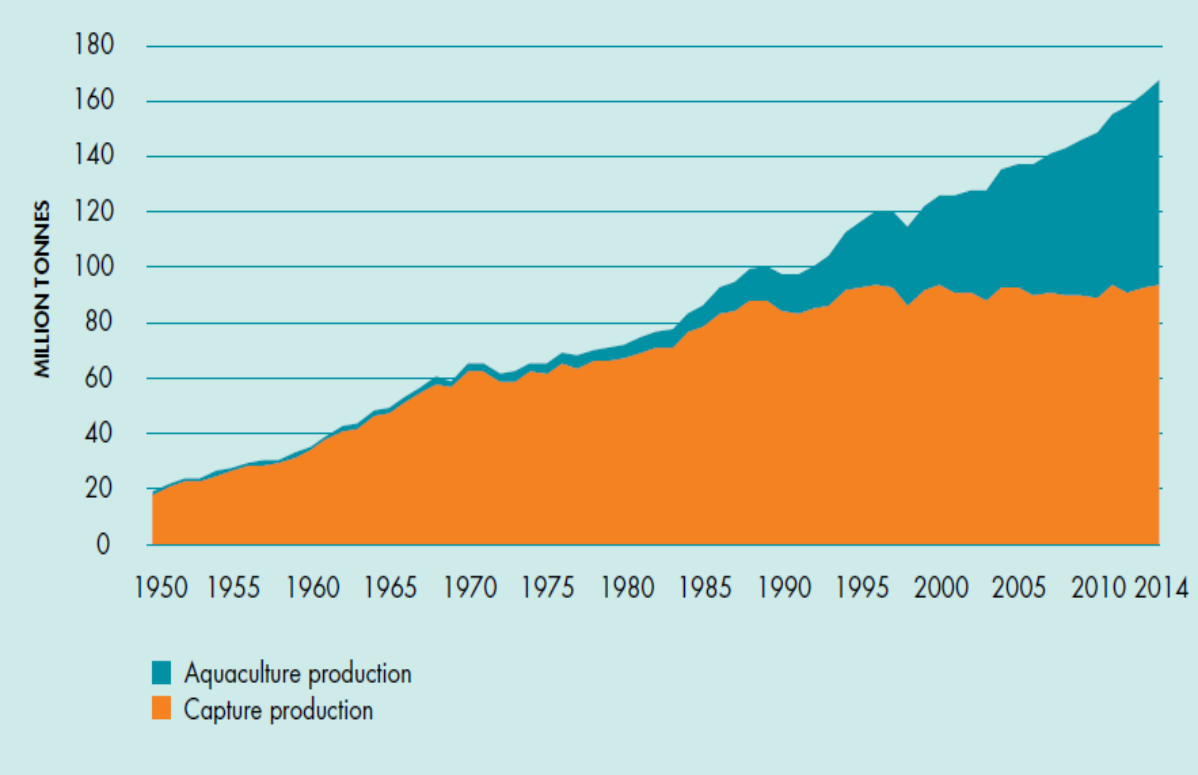

Figure 2.1: World capture fisheries and aquaculture production from 1950 to 2014. Source: Food and Agricultural Organization of the United Nations (2016).

Over time, fish has continued to be one of the most-traded food commodities. Global consumption of fish has doubled since 1973, and the developing world has been responsible for over 90% of this growth (Brummet and William, 2000; Bènè *et al.*, 2007). Generally, the global per capita fish consumption has increased from an average of 9.0 kg in the 1961 to 20.2 kg in 2015 with preliminary estimates for 2016 and 2017 as 20.5 kg (FAO, 2018) as seen previously. However, statistics indicate that capture fisheries will not meet the growing global demand for sea food in the future.

According to Bènè and Heck (2005), fish provides protein and micro-nutrition to about 200 million people in SSA. Though considered by many to be largely unrecognized and not utilized to their full potential, the fishery resources are of great social and economic value to Africa. Although the tilapia species most cultivated in the world originate from Africa (FAO, 2001), aquaculture in SSA is still at its infancy and until now the region continues to be mirror player providing less than 0.6% of global aquaculture. However, it has been advocated as an option to fulfill the increasing demand for fish products following the decline of wild marine and fresh water capture fisheries.

Currently, aquaculture is entering a very steady phase of expansion, with a three-fold increase in the past seven years in Africa and this growth has largely been attributed to the development of small and medium enterprises (SMEs). According to Brumett and Williams (2000), the industry earns and saves foreign exchange, provides jobs and creates wealth for the investors. The vast majority of farmed fish in Africa is freshwater, mainly *O. niloticus* and *C. gariepinus*. Culture preference of the omnivorous fish is due to their relative ease to raise, coupled with a growing consumer demand. In Egypt, a lot has been achieved in aquaculture through tilapia breeding programmes. New strains of the *O. niloticus* released in Egypt, Ghana and Malawi are up to 30% faster-growing than traditional strains, and have been heralded as a leap forward for African aquaculture (Ofori *et al*., 2010).

The Sub-Saharan Africa aquaculture industry has great potential to meet the increasing demand for aquatic food in most regions of the world. However, the sector stakeholders' face significant challenges due to lack of quality fingerlings and high prices (Maina *et al*., 2014; Munguti *et al*., 2014 and Orina *et al*., 2014). Lack of quality feed and seed availability, coupled together, are a major constraint to both commercial and non-commercial producers (Halwart and Moehl, 2005; Moehl *et al*., 2006; Blow and Leonard, 2007; Asmah, 2008).

According to FAO (2016), aquaculture in Kenya follows a pattern similar to many countries in Africa. It is characterized by low levels of pond production that have stagnated over the past decade. Fish farming was introduced by the colonialists for the purpose of sport fishing at the beginning of the 1900s and it evolved to static water pond culture of tilapias in the 1920s (Orina *et al*., 2014), later supplemented by carp and catfish. The colonialists set up two fish farms in 1948, the Sagana Fish Farm (for warm water species) and the Kiganjo Trout Farm (for cold water species). Although fish farming in rural Kenya has a relatively long history dating back to the 1920s, it was only made popular in the 1960s through the 'Eat More Fish' campaign and major strides achieved with the ESP-FFEPP government initiative which saw production rise from 4,895 tonnes in 2009 to 24,096 in 2014 (Orina *et al*., 2018).

2.2 Economic Stimulus on Income and Livelihoods

The Economic Stimulus Program (ESP) was introduced through the 2009/2010 budget as a GoK program coordinated by the Ministry of Finance. It was aimed at stimulating the growth of Kenya's economy through rapid creation of business opportunities and jobs (Musa *et al*., 2012). Key sectors of the economy, namely education, health and sanitation,

food production, environment, local government, industrialization and fisheries were large investments that were undertaken. According to TISA (2010), a sub-sector of aquaculture is identified as one of the key pillars in the agriculture production sector. Fisheries Department (2012) and Orina *et al*. 2014, highlight efforts put to promote aquaculture commercialization of *O. niloticus* and *C. gariepinus* in Western, Eastern, Central, Rift Valley and the Coastal regions of Kenya.

Although ESP subsidizes fish pond construction costs as well as the costs for feeds and fingerlings, Hino (2011) highlights that governmental infrastructure supporting the aquaculture sub-sector, for instance; training, research farms and extension officers are in place. Furthermore, his report reveals that Kenyan women predominate fish processing and marketing sectors. On the other hand, Jagger and Pender (2001) suggest that women should be more actively integrated into extension practices whereas Weeratunge *et al*., (2010), emphasize on the importance of women participation in aquaculture. Not only do the gender disparities affect the livelihoods of women themselves, but also livelihoods of the entire household and community.

2.3 Earthen Ponds Culture System

Pond culture is the most popular method of growing Tilapia in the world. They are grown in fertilized ponds where the fish utilize natural food from pond's natural productivity of phytoplankton and zooplankton. Development of cheap food resources in developing nations has been advocated through fish farming in earthen ponds (FAO, 2000). In Sub-Saharan Africa, over 90% of cultured fish come from earthen ponds of between 200 m^2 and 500 m^2 (Ngugi *et al.*, 2007; Mucai *et al.*, 2011), where fish are primarily fed with locally available low cost agricultural by-products. In less developed parts of the world today, the basic earthen pond design system is still the most important and affordable type of design. Despite considerable technological advances over the last decades that have transformed the aquaculture industry, earthen pond system remains mostly unchanged and still highly relevant in less developed countries. The size of earthen ponds built today can vary from 20 m^2 to 20 hectares (44 acres) or more. Pond size is determined by the type of species cultured, the intensity of the system, size and maturity of the species being farmed, access to capital, land availability, water availability, the harvesting method, and even the marketing and sales goals of the enterprise.

2.3.1 Earthen Ponds in Kenya

Fish ponds in Kenya range from small dug holes to designed ponds with inlets and outlet channels and harvest basins yielding approximately 1-2 tons/ha/year under optimal management (Brummet and Noble, 1995). Pond culture has not been fully exploited and most production in rural areas is unreported, despite its wide application by small scale fish farmers. In Kenya, the earthen pond system is popular due to the low cost of establishment, favorable clay soils and advocacy by extension officers (Musa *et al*., 2012). However, farmers have been encouraged to embrace use of Ultra-violet light-cured liners in places where the soil is porous to reduce water loss through seepage. Depending on whether fertilizers and complete feeding are applied, tilapia ponds can be managed intensively or semi-intensively. In places where ponds are naturally soaked by flooding from rivers and lakes, some fish farmers still practice extensive system of culture (Denny *et al.*, 2006).

2.4 Aquaculture Species in Kenya

The most cultured fish species in Kenya today are the *O. niloticus* (75%) and *C. gariepinus* (15%) (Ngugi and Manyala, 2004). Polyculture of the tilapia with the North African Catfish (*Clarias gariepinus*) is often done to control the prolific breeding of the former. Some exotic species, including the Common carp (*Cyprinus carpio*), Rainbow trout (*Oncorhynchus mykiss*) and Largemouth bass (*Micropterus salmoides*), have been introduced in Kenya for aquaculture purposes (Ngugi *et al.*, 2007). The Rainbow trout was introduced in Kenya during colonial period mainly for sport fishing but has over time gained popularity though its culture is limited to high altitude areas (Ngugi *et al.*, 2007). Trout is temperature restricted thus only cultured at very low temperatures mainly in the Mt. Kenya region. Indigenous species with aquaculture potential include; *L. victorianus, Tilapia esculenta, Tilapia variabilis,* and *Barbius altianalis*. The *Labeo Victorianus,* also referred to as ningu is one among the many species in the genus *Labeo* that is limited to Lake Victoria basin (Fryer and Whitehead, 1959) and is currently under culture trials with significant success (Orina *et al.*, 2018). Other Labeins are widely distributed, with at least 80 species, on the African continent and contributing 16.4% of the African cyprinid fauna (Skelton *et al*., 1991). Among the tilapias, *O. niloticus* has been studied widely and breeding programmes to enhance its aquaculture performance locally is very advanced (FAO, 2016). However, the aquaculture potential of *O. jipe* has been least studied thus informing the current study.

The Common carp was also introduced during the colonial period, but is not favored by the market. The introduction of genetically modified species is still very contentious, but the Fisheries Department is exploring ways of developing genetically improved species by using the endemic strains available (FAO, 2016). The *O. jipe* has not been introduced in aquaculture since there is little information on its culture potential. Therefore, the proposed study sought to determine the culture potential of this fish species using hapas suspended in an earthen pond.

2.5 Natural History of *Oreochromis jipe*

Figure 2.2: Photo of *Oreochromis jipe*

Source: Photo by De Vos L.

The extent of occurrence (EOO) for *Oreochromis jipe* is limited to less than 100 km^2 within two small lakes (Chala and Jipe) and the connecting river, and is suffering from a continued decline in population due to competition for habitat, siltation, over-fishing and weed infestation. This fish is endemic to Lake Jipe, which is approximately 16 km^2 in the Pangani drainage. In Lake Jipe, the fishery for this species declined towards 1958, following the introduction of *O. esculentus*. Combined with the problems of infestation by *Typha dominingensis* and *Cyperus pyparus*, the fishery was closed in 1960. Samples collected by De

Vos in the Kenyan waters of the lake (about 5% by area) in 1998 indicated the existence of the species but at very low abundance. Research on this species shows that they prefer riverine habitats or inshore areas of the reservoir for foraging and refuge.

2.6 Tilapias Stocking Density, Growth, Survival and Yield

The effect of stocking density on growth, survival and yield effects on aquaculture are well recognized for a variety of species (Samad *et al*., 2005; Mazlum, 2007; Garr *et al*., 2011; Khatune-Jannat *et al*., 2012) and seem to affect production in various ways. For instance, both growth performance and survival rate tend to be higher in lower stocking densities in *Oreochromis spp.* (Sorphea *et al*., 2010) whereas in some cases the effect is either temporary (Garr *et al*., 2011) or non-existent (Gokcek and Akyurt, 2007; Southworth *et al*., 2009). Study on the effect of stocking density on the growth and survival of improved and unimproved strains of *Oreochromis shiranus* indicated that fish stocked at higher stocking densities had poor growth.

The effect of stocking density is usually seen to be either density dependent or density independent. Wiener *et al.* (1982) suggested that stocking density that negatively affects fish growth are density dependent. According to Ntanzi *et al*. (2014), increasing stocking density in *O. niloticus* fry results into homogenous growth. However, studies on stocking density of *O. jipe* have not been done and therefore the proposed study sought to determine how stocking density would affect the growth of *O. jipe* fingerlings reared in hapas set in an earthen pond.

Studies show that the high survival rate of *Oreochromis niloticus* fry at high stocking density (82.9% at 5330 fry/m^3) indicate amenability of tilapia to intensive culture (Alhassan *et al*., 2012). This can also be attributed to favorable environmental conditions during the experiment. According to Ntanzi *et al.* (2014), survival rate is significantly affected at extremes of stocking density in *Oreochromis niloticus* fry. Studies show that tilapia fry can survive at high densities of up to around 2670 fry/m^3 but at extremely high densities the survival rate is significantly affected. However, little is known about stocking density of *O. jipe* and therefore the study sought to determine the effect of stocking density on survival of this fish species.

2.6.1 Effect of Diet on Growth and Survival of Fish

Tilapia intensive culture would require the formulation of efficient feed with optimum potency to meet the protein requirements in fish culture during grow-out period (Kenawy,

1993). The study sought to know the optimum protein level leading to optimum growth. The study also sought to determine the effect of locally made feed against commercial feeds on the growth of *O. jipe* from fingerling to post fingerling stage. Most studies are confined to fry stage to young *O. niloticus* and little has been done on *O. jipe*. Research studies show that the whole body composition of fry, fingerling and adult (grow out) of *O. niloticus* is influenced significantly by dietary protein level. Fish that is fed 25% protein diet has lower content of protein and high content of lipid than fish fed 35% or 45% protein diets. These results are similar to those obtained by Wee and Tuan (1988) and Al-Hafedh (1999).

According to Liti *et al.* (2005), studies on growth and economic performance of *O. niloticus* fed on two formulated diets and two locally available feeds in fertilized ponds showed significant differences in mean weights, growth rates and feed conversion ratios. The *O. niloticus* nutritional studies have confirmed that 45% CP diet is optimal for fry, while 35% CP is optimal for fingerlings weighing less than 20 g and post fingerlings weighing 40 g (Al-Hafedh, 1999). However, for commercialization, there is need for an in-depth understanding of the CP levels and the fish's feed assimilation efficiency which is simply calculated as food conversion ratio (FCR).

According to Inayat and Salim (2005), FCR is considered as the best parameter to assess the acceptability of feed and its ultimate performance in fish. In a study by Daudpota *et al*. (2016), they looked at comparison of growth, feed conversion ratio and body composition of juvenile red tilapia (*O. niloticus* X *O. mossambicus*) and Nile tilapia (*O. niloticus*) reared in concrete tanks and found out that FCR values were good and were not significantly different among treatments. However, FCR may vary due to feed quality and feeding regimes, pond productivity, water quality and quality of seed. Furthermore, as reported by De Silva and Davy (1992), feed digestibility plays significant part in lesser FCR by effective consumption. The current study on *O. jipe*, aimed at determining the FCR of this fish species on the basis of stocking density and diet and eventually associate the fish's growth performance to condition factor (CF).

Since the 20th century, CF has been used as an indicator of fish health in fish biology studies with close link to growth and feeding intensity (Froese, 2006). CF decreases with increase in length (Bakare, 1970 and Fagade, 1979). According to Anyanwu *et al*. (2007), CF provides information on the variation of fish physiological status and may be used for comparing populations living in certain feeding, climate and other conditions. Generally, CF

also can be used to determine the feeding activity of a species and to determine whether it is making good use of its feed resource (Anyanwu *et al.*, 2007). According to Khallaf *et al*. (2003), the CF of fish can be affected by a number of factors such as stress, sex, season, availability of feeds and other water quality parameters. Although the feeding habits of *O. jipe* have been studied, the information on condition factor is scanty. Therefore, the proposed study aimed at providing information on condition factor of *O. jipe* as one of the growth parameters in relation to stocking density and diet.

2.6.2 Water Quality in Earthen Ponds Tilapia Culture

Fish are totally dependent upon water to breathe, feed and grow, excrete wastes, maintain a salt balance, and reproduce. Although all of the impacting variables are important, only those that normally cause fish stress or otherwise limit performance in some way are of major concern to aquaculture practitioners. The key water quality variables related to tilapia in ponds are temperature, dissolved oxygen (DO) and hydrogen –ion concentration (pH). According to Abolude (2007), other parameters such as ammonia, nitrates, phosphates, alkalinity and hardness also have significant impacts within aquaculture systems.

Temperature is among the most important environmental variables or external factors and a major metabolic modifier in fishes because fish are poikilothermic. Their activity, behavior, feeding, growth, survival, reproduction is affected by temperature (Dupree and Hunner, 1994) as well as FCR (Martinez-Placious *et al*., 1993). Studies have confirmed that the optimal culture temperature for tilapia ranges between 25°C to 32°C.

According to Mires (1995), *O. niloticus* shows optimum food consumption and growth at temperatures ranging between 31°C -36°C. Stress induced disease and mortality are problematic when temperatures exceed 37°C or 38°C. On the contrary, over-handling at lower temperatures can also result in stress-induced trauma and mortality at temperatures lower than 17°C or 18°C (Schimittou, 2006). This study sought to determine the temperatures suitable for growth of *O. jipe* and how stocking density and diet would affect the water temperature of the culture facilities.

On the other hand conductivity is a measure of ion concentration in water attributed to dissolved salts and inorganic matter. It is related to salt content; the higher the salt content, the higher the conductivity. Freshwater fish generally thrive over a wide range of electrical conductivity. Some minimum salt content is essential to help fish maintain their osmotic

balance; the upper range of tolerance varies with fish species. Conductivity also can be used to give a rough estimate of the total amount of dissolved solids (TDS) in water.

A maximum TDS value of 400 mg/L is permissible for diverse fish production in fish culture (James, 2000). The ability of water to dissolve, combine with, or suspend other elements and compounds can be helpful as a supply of necessary nutrients. A constant level of minerals in the water is necessary for aquatic life. Studies show that changes in the amounts of dissolved solids can be harmful because the density of TDS determines the flow of water in and out of an organism's cells (Mitchell and Stapp, 1992). Concentrations that are too high or too low may limit the growth and may lead to the death of many fish or reefs. TDS are also important for proper osmotic regulation, for instance, the relationship of water versus dissolved solids in the cells and the external environment. Studies indicate that the greater the amount of solids in the water versus the solids in the tissue of the fish will result in a fluid loss via the gills.

Furthermore, the effect of pH on the chemical, biological and physical properties of water systems makes its study very crucial to the lives of the organisms in the medium. Therefore, regular monitoring of pH is essential for intensive operation of freshwater fish culture systems. The *O. niloticus* can tolerate pH as low as 5, however best growth rates are achieved at a pH range of 7 to 9 (Ross, 2000). The proposed study sought to determine the optimal pH level for survival of *O. jipe*.

Ammonia is the principal nitrogenous product of fish metabolism. It originates from the deamination of amino acids and if present at high concentrations, slows growth rates and might increase mortality (El-Sherif *et al*., 2008). In caged tilapia culture, low DO increases ammonia toxicity; however this is largely balanced by decreased toxicity produced by increasing carbon dioxide concentration, which lowers pH (Schmittou, 2006). Little is known on ammonia toxicity in earthen ponds in regard to *O. jipe* culture.

Nitrite is a form of nitrogenous waste product found in water. Typical concentrations of nitrite-N in pond water range from 0.005 to 0.5 mg/L. Through the process of nitrification, bacteria transform ammonia into nitrite and nitrite into nitrate. The toxicity of nitrite to fish varies greatly with the species of fish. Some species such as trout are quite susceptible, while others such as large -mouth bass and bluegill sunfish are very resistant. In general, studies suggest that for freshwater culture the nitrite concentration should be kept below 27 mg/L as nitrite.

Phosphorus is an essential plant nutrient and because it is often in limited supply, adding phosphorus to water will stimulate plant and algae growth. This growth of algae can be undesirable especially in pristine clear-water streams and lakes and optimal in culture pond culture systems. The typical range for surface waters is 0.005 to 0.5 mg/L. Almost all of the inorganic phosphorus (P) in water is in the form of phosphate (PO_4). Units of measure for phosphorus may be as phosphate (mg/L) or based only on the phosphorus ion (mg P/L).

2.7 Theoretical Framework

The von Bertalanffy Growth model (Enberg *et al*., 2008) in figure 2.3 has been applied in this study as the theoretical framework to understand the issues relating to fish growth. This model is widely used and is classified as a statistically based growth model. It was derived by Ludwig von Bertalanffy and it incorporates indeterminate growth and fits well with observed data, for both individual growth trajectories and for population averages. Its mechanistic derivation assumes that the processes of building molecules and new tissues and the process of breaking down of molecules and old tissues have different exponents in their scaling relationships. The acquisition of resources is assured to be proportional to body surface and thus scales with $W^{2/3}$ whereas the release costs of activity and maintenance are assured proportional to body mass and scale as W^1. The result indicate that as the individual grows larger, more and more of the available energy used for maintenance and growth will slow down and eventually stop.

There are also a number of behavioral tradeoffs that make fish compromise their growth rate, for example, under strong predation pressure. Fish might spend more time hiding than foraging and consequently, growth rate will decrease. Similarly, fish may voluntarily abstain from foraging if food-mediated parasites compromised health, survival, or growth. Furthermore, when fish lowers their immune response in order to grow faster and this increases the risks of infections, it may increase overall survival on a longer time scale. Although the von Bertalanffy growth model fits well with observations for fish after maturation, it does less well in describing immature fish growth, and the mechanisms that are underlying have turned out to be false. However, two newer models by Derek Roff, Nigel Lester and colleagues address these drawbacks.

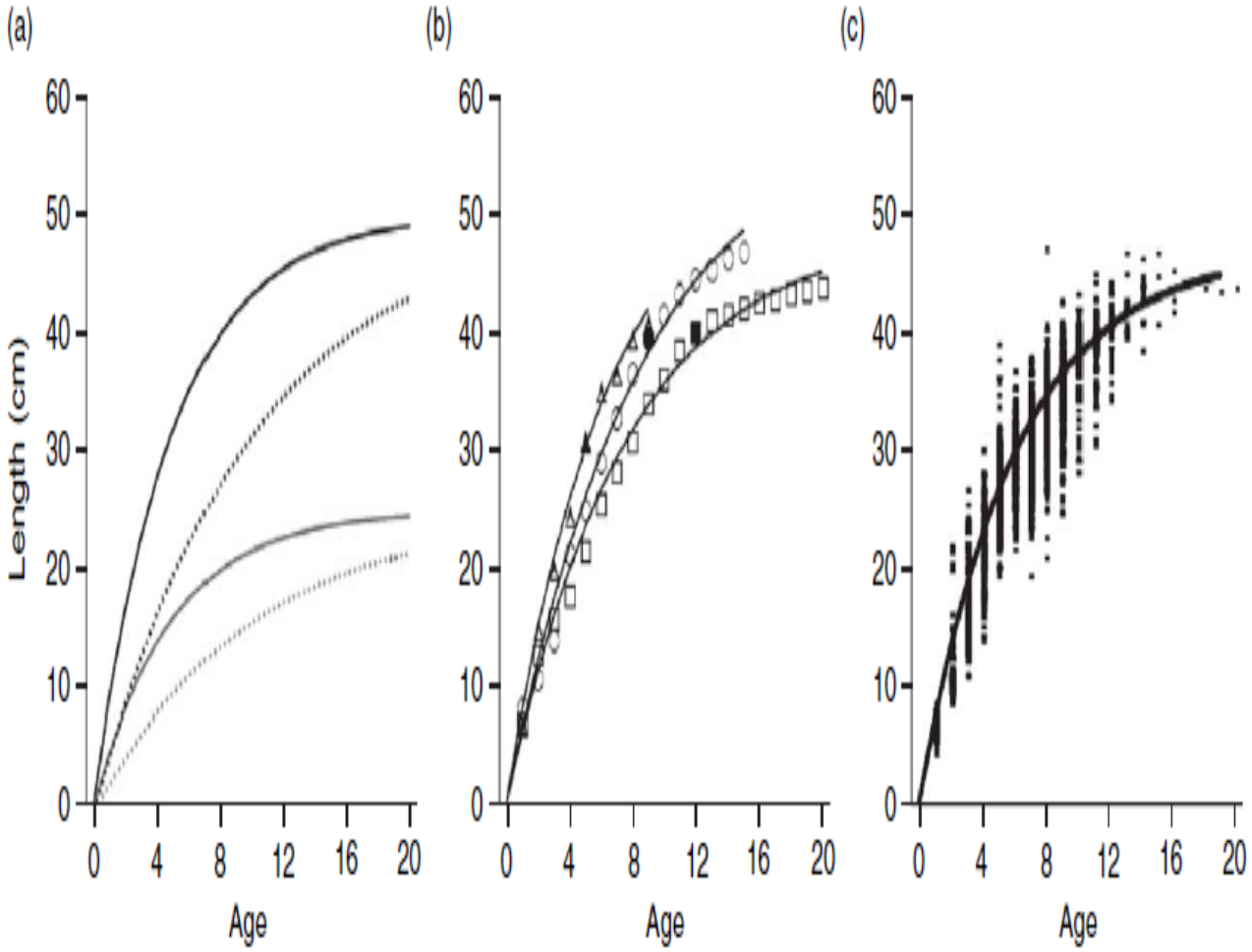

Figure 2.3: The von Bertalanffy growth model

Source: Enberg *et al*., 2008

a) Examples of von Bertalanffy growth curves for different values of asymptotic length L∞(black lines: L∞=50cm; gray lines: L∞=25cm) and growth parameter k (Solid lines: k=0.2, dotted lines: k=0.1)

b) Length-at-age for different smallmouth bass *Micropterus dolomieu* individuals from Lake Opeongo, Canada. Filled symbols represent the observed age at first spawning while fits represent individual von Bertalanffy growth curves.

c) Observations of individual length-at-age across a population of smallmouth bass *M. dolomieu* from Lake Opeongo, Canada. The line is the fitted population-level von Bertalanffy growth curve.

Note: A common assumption when using growth models in life-history theory is that larger size equates to higher fitness (Enberg *et al*., 2008).

2.8 Conceptual Framework

Studies of other tilapines have demonstrated direct relationship between stocking density, growth and survival of the fish with high stocking densities lowering growth and survival. However, high stocking densities with ambient aquatic environmental conditions, high quality feeds and adequate feeding has previously shown tremendous growth and survival among tilapines. Diet with high protein content will definitely affect the growth and survival of fish. The effect of protein content in the local and commercial feed was measured through the fish's length and weight gain, survival, condition factor (CF) and feed conversion ratio (FCR).

Optimal temperature (31°-36°C) is important for successful tilapia culture; however, low or extremely high temperatures adversely affect growth and survival of the fish. Studies indicate that in fish, the level of tolerance to lethal temperatures is dependent upon nutrition status, history of the fish, fish health as well as genetic and environmental effects. Exposure to extreme cold temperatures results in mass mortality.

Hydrogen ion concentration (pH) is essential for the operation of intensive freshwater fish culture systems such as ponds. Extreme low pH will adversely affect the growth and survival of the fish and vice versa. On the other hand ammonia is the principal nitrogenous product of fish metabolism. It originates from the deamination of amino acids. High ammonia levels amounts to toxicity that will adversely affect the growth and survival of the fish.

In this study, several parameters were considered as intervening variables that would have affected the growth and survival of *O. jipe* otherwise. These include; weather, genetics, stress and infections. Fish prefer certain kinds of weather over others. Some fish do not prefer rainy and windy conditions and would go deeper under water. Tilapias, for example, tend to feed best when the weather is warmer unlike when it is cold. On the other hand, the genetic mechanisms that regulate phenotypic traits used for identification of fish populations need to be clarified and well defined. Traditionally, fish populations have been identified based on phenotypic traits although the relative importance of genetic factors on the determination of those traits is generally unclear (Swain and Foote, 1999; Mitchell-Olds *et al*., 2007; Barret and Hoekstra, 2011).

The crowding stress (Ellis *et al*., 2002) may be an important factor by which rearing density could affect the physiology of the fish. Survival conditions and activities used during aquaculture practices cause stress (acute or chronic) and can involve a reduction of fish

welfare. The main relevant factors for the welfare reduction of farmed fish are; genetics and environmental factors, stocking density during growth, starvation, malnutrition, deformities, cataracts, handling and overcrowding (Conte, 2004). Moreover, bacterial infections are responsible for heavy mortality in both wild and cultured fish. These incapacitate fish defense responses and immune reactions.

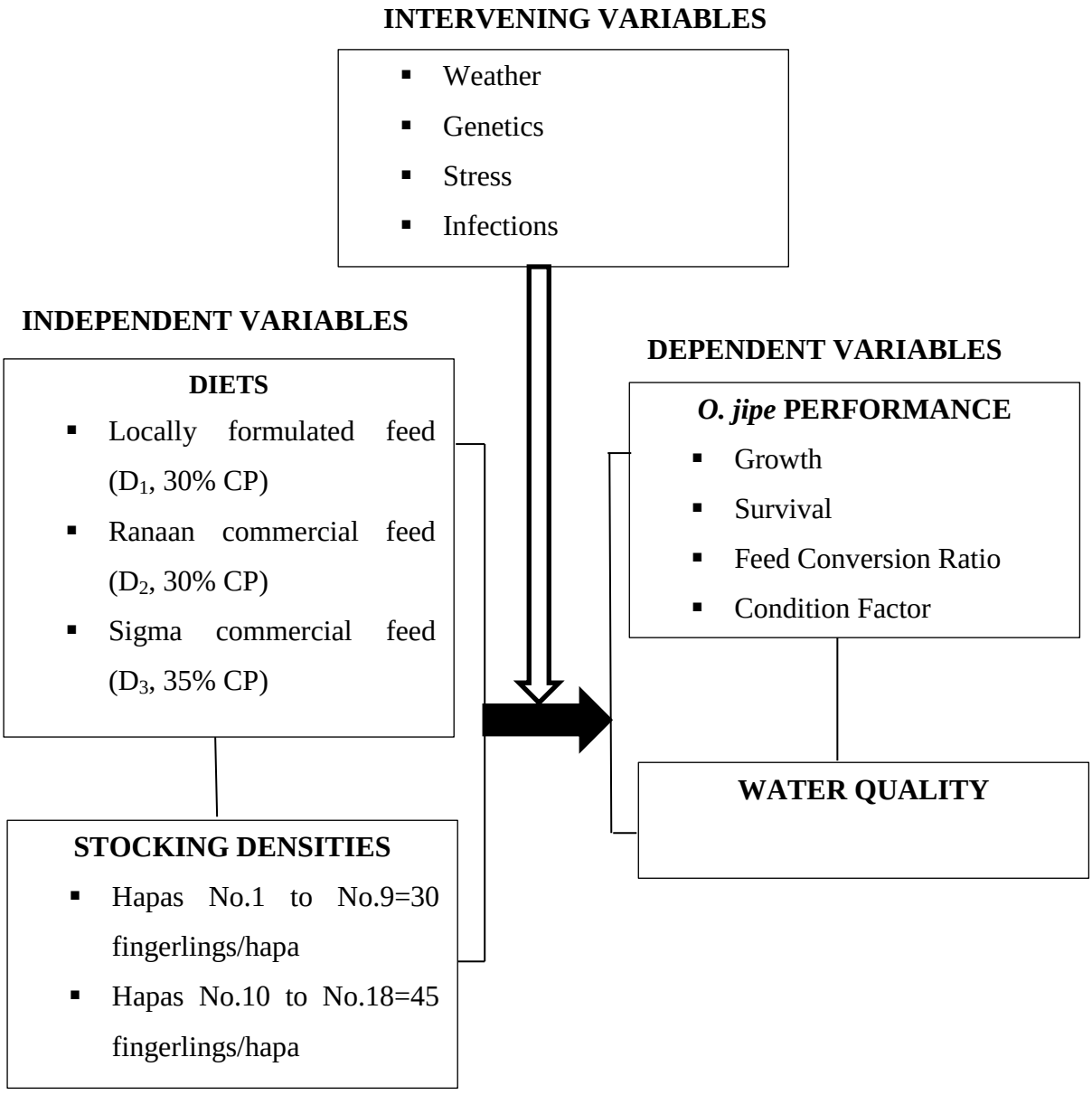

Figure 2.4: Conceptual Framework

CHAPTER THREE
RESEARCH METHODOLOGY

3.1 Introduction

This section outlines the research methodology that was applied in the study. Research methodology encompasses concepts such as research design, sample size and sampling procedure, data collection instruments and data analysis procedure. According to (Kothari, 2004), research methodology is the systematic, theoretical analysis of the procedures applied to a field of study.

3.2 Lake Jipe

Lake Jipe is situated to the southeast of Mt. Kilimanjaro in Taita Taveta County (Coast Region) of Kenya and in the Kilimanjaro region of Manga District in Tanzania. The catchment area has sedimentary soils of metamorphic origin, while the northern and southern parts have sedimentary alluvium soil a product of the incoming rivers. The geology of the area has caused an increase in lake level, leading to an expansion of the lake to the south. Deeply weathered soils are widespread in the area, with highly fertile vertisols (black cotton soils) characteristics of this region, particularly in plains and depressions. Vertisols contain mainly clay that hardens and cracks during the dry season. The climate in the basin is arid to semi-arid except in the highlands where it receives substantially more rainfall than the lowlands. The annual average rainfall is 350 to 750 mm per year. The temperatures around the basin range between 21° C and 38° C and potential annual evaporation is 1950 mm.

3.3 Study Area

3.3.1 Location

The study was carried out at KMFRI Sagana Aquaculture Centre located about 2km Northwest of Sagana Township in Kirinyaga County and approximately 104 km Northeast of Nairobi City (Figure 3.1). It lies at latitudes $0^0$19'S and $37^0$12'E and at an altitude of 1,231 m above mean sea level. The Centre occupies an area of approximately 59.37 hectares with 109 operational ponds of which 72 (150 m^2) are research ponds and the rest used for spawning, fingerling production and grow-out production. The farm is supplied with water from River Ragati by gravity all-year round.

3.3.2 Map of Study Area

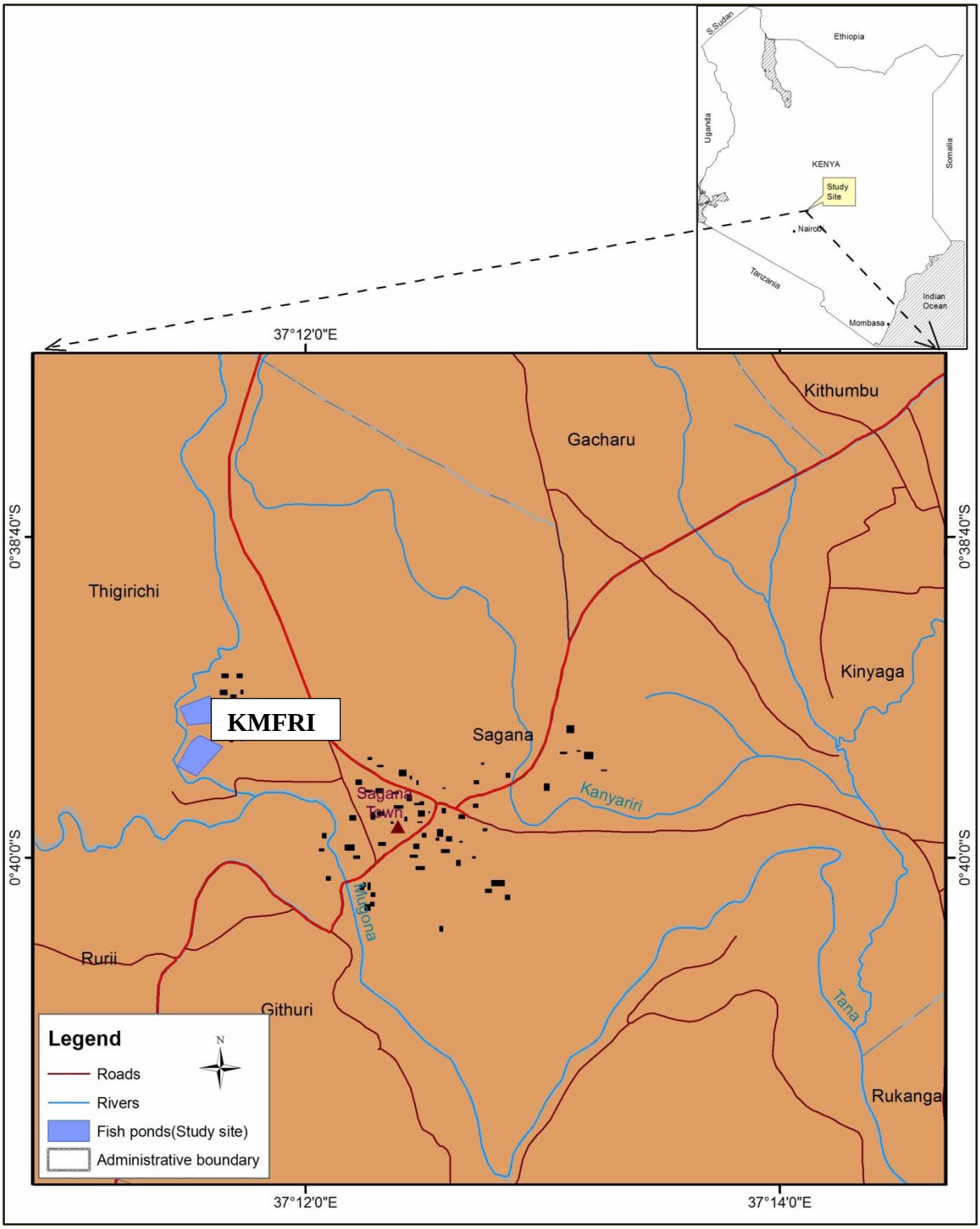

Figure 3.1: Map of Study Area

Source: diva-gis.org

3.3.3 Climate

Sagana has two distinct rainy and dry seasons annually with an average 30 year annual rainfall estimated at 1,166 mm. The warmest season is February through April with a distinct cool season between June and August, when rainfall is at a minimum. Even though there is little rain, the skies tend to be overcast much of the day during the rainy period known as the "short rains" which occurs between October and December. The "long rains" fall from March through May with a single-month peak of 500mm or more in April. Sagana has daily average temperature of 17°C to 23°C, cool season average temperature of 17°C to 19°C and daily minimum temperature of 20°C to 30°C.

3.3.4 Topography

Sagana is situated at the edge of a large plain at the southern foot of Mt. Kenya. Soils were formed on volcanic rocks from Mt. Kenya- latest Pliocene to Pleistocene basalts, phonolites, and pyroclastics. In areas with free drainage conditions on moderate to steep slopes, lateritic and red to reddish brown soils are present. Some areas with black cotton soils indicate that the soils have formed under restricted drainage conditions, which are the result of low rainfall and the presence of level to moderate slopes.

3.3.5 Socio-economics

The agricultural town traces its origin to the 1920 where the agricultural products used to be transported with train. Despite the town lacking essential facilities like banks, colleges and supermarkets, fish farming is a major economic activity adopted in Sagana. The town's current growth is being propelled by Kagio, a busy agricultural market centre 3 km off the Nairobi-Nyeri highway to the east.

3.4 Research Design

The 84 days experiment involved a completely randomized design (CRD) in a 3x2 factorial arrangement (3 diets x 2 stocking densities) in 18 hapas set in triplicates in an 800 m^2 earthen pond. *Oreochromis jipe* fingerlings were sourced from a designated concrete pond where the brood stock is reared within the institution. Sorting was done and fingerlings of average mean weight 1.45 g were obtained. A total of 675 fingerlings were pooled and stocked in hapas and allowed to acclimatize for 18 days. Due to space limitation, the stocking densities were 30 fish/m^2 and 45 fish/m^2 combined with 30% CP for both D_1 (formulated diet) and D_2 (Ranaan commercial feed) and 35% CP for D_3 (Sigma commercial feed). In this

study, D_1 was used as a control treatment. Feeding was maintained at 10% body weight (BW) and adjusted after 14 days of culture. During the acclimatization period, mortalities as a result of stress were replaced continuously. Grading of initial length and weight of 30 fingerlings was taken at the commencement of the experiment to assist in feed calculation and subsequent growth calculations.

3.5 Sampling Procedure and Materials

Sampling of selected water quality parameters was done fortnightly. The main water quality parameters included pH, temperature, conductivity and TDS which were measured using Hanna Multi-parameter HI 9829 Meter, USA. Determination of ammonia, nitrites and phosphates was done using colorimetric /spectrophotometric method.

Ammonium Determination

In an alkaline medium, the dissolved NH_3 reacts with hypochlorite (HClO) to form a monochlooramine. At 20°C and with nitroprussaat (Na (Fe (CN) 5NO).2H2O) as a catalyst, this reaction takes 12 hours to form a blue indophenol in oxidizing medium in the presence of a phenol. Precipitation of Ca and Mg in basic medium is avoided by complexation with sodium citratedihydraat. The blue indophenol complex was then read spectrophotometrically at 630nm.

Nitrites Determination

The nitrite in water was quantified by diazoting with sulfanilamide and coupling with N- (1-naphtyl) ethylene-diamine to form a highly colored azo dye. The absorbance of the colored complex was measured spectrophotometrically at 543 nm.

Phosphate Determination

Phosphates are analyzed by the formation of a phosphorus-molybdate complex. Water sample was allowed to react with a composite reagent containing molybdic acid, ascorbic acid, and trivalent antimony. The resulting complex heteropoly acid is reduced to give a blue solution (phosphor-molybdate complex), of which the absorption was measured spectrophotometrically at 885 nm.

3.6 Experimental Commercial and Local Fish Feed

The 3x2 factorial design *O. jipe* culture trials set in triplicates had three diets which included D_1, an on-farm formulated diet from locally available ingredients to make 30% CP to match D_2 a commercial diet manufactured by Ranaan. Diet D_3, another commercial diet

manufactured by Sigma composed of 35% CP a digression from the other two trial diets due to the manufacturers CP production array limitation. The CP for locally available ingredients for D_1 is as shown in Table 3.1.

Table 3.1: Ingredients of the Formulated Fish Feed (D_1)

Ingredients	Crude Protein (CP %)
Freshwater shrimps (*Caridina nilotica*)	63.5
Maize (*Zea mays*) Germ	12
Wheat (*Triticum aestivum*) Pollard	12
Sunflower (*Helianthus annuus*) seedcake	25.9

3.7 Sampling of Fish

A sample of 30 *O. jipe* fingerlings were measured for wet weight on an electronic balance (Model: EHB-3000 Cap = 3000g d=0.05 g) and total length (cm) using a measuring board to the nearest 0.1 cm. This was to determine the average wet weight and total length of the fish at the start of the experiment. The fingerlings under the various treatments were measured fortnightly to determine growth in total length and body weight. The fingerlings were then returned to the appropriate hapas after weighing. The routine weight measurements were used to determine the specific growth rate (SGR %), feed conversion ratio (FCR), weight gain and condition factor of the fingerlings. Survival was determined by counting the remaining fish in the hapas on each sampling date. The calculations were done as follows:-

Specific growth rate (SGR) = 100 (ln W_1- ln W_0/t) where: - (ln = Natural logarithm, W_0= Initial Weight (g), W_1= Final weight (g) and t = Time (days)…….....1

Feed conversion ratio (FCR) = $\frac{\text{Weight of dry feed given per treatment}}{\text{Wet weight gain in that treatment (g)}}$ ……. 2

Weight gain (%) = $\frac{\text{(Final weight of fish - Initial weight of fish)}}{\text{Initial weight of fish}}$ x 100 ……..….3

The condition factor (K) value was calculated according to Offem *et al*. (2009);
Condition factor, K= W X 100/ L^3 where W is the total body weight and L is the total body length…….…..……. 4

$$\text{Percent survival} = \frac{\text{Initial number of fingerlings in the hapa} - \text{Number of dead fingerlings}}{\text{Initial number of fingerlings in the hapas}} \times 100 \quad \text{..... 5}$$

3.8 Data Analysis

Data analysis consists of examining, categorizing; tabulating and even recombining the evidence to address the initial prepositions of the study. Data collected was coded to enhance basic statistical analysis. Descriptive statistics including means and standard errors (SE) of the growth variables and water quality parameters were determined. Growth and survival over time was represented in graphs. The effects of stocking density and diet were compared on the basis of mean weight and length, mean weight gain (%), specific growth rate, survival and percent survival, feed conversion ratio and average water quality parameters and the means of the variables were analyzed using two-way Analysis of Variance (ANOVA) at $p<0.05$ to test the effects of the two factors (stocking density and diet). ANOVA was considered in doing the study hypothesis due to the large sample size (N=675) and also because the data was normally distributed. Mean separation from ANOVA test was done using Tukey's HSD (Honestly significant difference) at $p<0.05$ to detail any difference among treatments. The t-test was also used to compare the effects of the two stocking densities on the growth variables and water quality parameters. SAS system version 8 statistical software was used for all statistical analysis.

Table 3.2: Summary of Data Analysis

Objective	**Research Hypotheses**	**Statistical Tool**
i. To determine the effect of stocking density on growth of *O. jipe* cultured in hapas.	Ho: Stocking density has no significant effect on the growth of *O. jipe* cultured in hapas.	**Descriptive statistics** Means ± S.E **Inferential statistics** ANOVA
ii. To determine the effect of stocking density on survival of *O. jipe* cultured in hapas.	Ho: Stocking density has no significant effect on the survival of *O. jipe* cultured in hapas.	**Descriptive statistics** Means ± S.E **Inferential statistics** ANOVA
iii. To determine the effect of diet on growth of *O. jipe* cultured in hapas.	Ho: Diet has no significant effect on the growth of *O. jipe* cultured in hapas.	**Descriptive statistics** Means ± S.E **Inferential statistics** ANOVA
iv. To determine the effect of diet on survival of *O. jipe* cultured in hapas.	Ho: Diet has no significant effect on the survival of *O. jipe* cultured in hapas.	**Descriptive statistics** Means ± S.E **Inferential statistics** ANOVA
v. To assess the effect of stocking density and diet on the water quality of culture facilities.	Ho: Stocking density and diet have no significant effect on the water quality of culture facilities.	**Descriptive statistics** Means ± S.E **Inferential statistics** ANOVA

CHAPTER FOUR
RESULTS AND DISCUSSION

4.1 Effect of Stocking Density on Growth Performance Parameters of Fish

From the present study, fish length and weight were not significantly affected by stocking density at $p>0.05$ (Table 4.1). Fish from stocking density of 30 fish/m^2, had a mean length of $7.35^{a}\pm0.15$ cm whereas fish from stocking density 45 fish/m^2 had mean length of $7.24^{a}\pm0.17$ cm (Table 4.1). The mean length and weight were highly, positively and significantly correlated ($r= 0.978$, $P= 0.001$). Specific growth rate (SGR) was not significantly affected ($p>0.05$) by stocking density with the highest SGR reported for stocking density 45 fish/m^2 as shown in Table 4.2. Stocking density did not affect percent weight gain significantly ($p>0.05$) but fish reared at 30 fish/m^2 had higher values of percent weight gain (591.49% to 643.22 %) compared to fish reared at 45 fish/m^2 (522.30% to 679.31%) (Table 4.2).

Furthermore, high stocking density resulted in higher FCR compared to low stocking density however, there was no significant effect ($p>0.05$) of stocking density on the mean FCR values. Consequently, stocking density had significant effect ($p<0.05$) on condition factor of the fish populations and ranged between $1.36^{c}\pm0.02$ and $1.49^{a}\pm0.02$. The lower value of $1.36^{c}\pm0.02$ was recorded for fish reared in stocking density 45 fish/m^2 while the highest value of $1.49^{a}\pm0.02$ was recorded for fish reared in stocking density 30 fish/m^2 (Table 4.2). Stocking density had significant effect ($p<0.05$) on the percent survival of the fish with highest percent survival recorded for stocking density 30 fish/m^2 as shown in Table 4.2.

Table 4.1: Means ± S.E of body length, weight and survival of *O. jipe* as influenced by stocking density.

Stocking Density	Parameters		
	Length (cm)	**Weight (g)**	**Survival (No.)**
30	$7.35^{a}\pm0.15$	$6.22^{a}\pm0.34$	$14.80^{a}\pm0.71$
45	$7.24^{a}\pm0.17$	$6.02^{a}\pm0.39$	$15.13^{a}\pm1.26$

Means with the same superscripts along the column are not significantly different ($p>0.05$) as determined by Tukey's HSD.

Table 4.2: Means ± S.E of Parameters calculated on the growth performance of *O. jipe* at different stocking densities and diets.

Stocking Density(fish/m^2)	Diet	SGR (%)	Weight Gain (%)	Survival rate (%)	Condition Factor (K)	FCR
30	1	2.30^{a}±0.08	591.49^{a}±45.22	25.56^{b}±5.56	1.43^{b}±0.03	1.61^{a}±0.28
	2	2.36^{a}±0.16	643.22^{a}±105.6	28.89^{b}±4.44	1.41^{b}±0.01	1.28^{a}±0.05
	3	2.32^{a}±0.07	604.14^{a}±42.76	35.56^{a}±4.84	1.49^{a}±0.02	1.08^{a}±0.09
45	1	2.15^{a}±0.10	522.30^{a}±48.70	16.30^{c}±0.74	1.41^{b}±0.03	1.78^{a}±0.12
	2	2.24^{a}±0.26	585.29^{a}±152.7	25.93^{b}±8.35	1.42^{b}±0.02	1.21^{a}±0.20
	3	2.45^{a}±0.03	679.31^{a}±20.20	14.07^{c}±4.12	1.36^{c}±0.02	1.83^{a}±0.41

Means with the same superscripts along the column are not significantly different ($p>0.05$) as determined by Tukey's HSD.

Table 4.3: Effect of stocking density on length, weight and survival of *O. jipe* using t-test.

	Parameters		
	Length	**Weight**	**Survival**
t-value	0.50	0.39	-0.23
P-value	0.6198	0.7001	0.8188

Table 4.4: Effect of stocking density on SGR, weight gain (%), survival rate (%), condition factor (K) and FCR of *O. jipe* using t-test.

	Parameters				
	SGR	**Weight Gain (%)**	**Survival rate (%)**	**Condition Factor (K)**	**FCR**
t-value	0.46	0.27	2.58	2.23	-1.38
P-value	0.6535	0.7880	0.0200	0.0403	0.1864

Table 4.5: Analysis of Variance mean squares of fish stocking density, type of diet, time and their interaction effect on the growth and survival of *O. jipe.*

S.O.V	DF	Length	Weight	Survival
Diet	2	1.124^{***}	9.689^{***}	117.482^{*}
Time (weeks)	5	25.229^{***}	124.521^{***}	445.326^{***}
Stocking*Diet	2	0.697^{*}	2.936^{ns}	193.444^{**}
Error	107	0.143	1.201	32.787
C.V		5.182	17.908	38.268
R^2		0.904	0.848	0.473

Key: S.O.V=Source of Variations; DF=Degree of Freedom; C.V=Coefficient of Variations; R^2= Coefficient of determination; ns=Not Significant at p>0.05; *=Significant at p<0.05, **=Significant at p<0.01 and ***= Significant at p<0.001

Table 4.6: Analysis of Variance mean squares of fish stocking density, type of diet and their interaction effect on the growth performance parameters of *O. jipe.*

S.O.V	DF	SGR	WEIGHT GAIN (%)	SURVIVAL RATE (%)	CONDITION K	FCR
Diet	2	0.037^{ns}	11239.951^{ns}	63.792^{ns}	0.001^{ns}	0.302^{ns}
Stocking*Diet	2	0.034^{ns}	9671.0706^{ns}	133.063^{ns}	0.009^{*}	0.267^{ns}
Error	12	0.679	246950.694	967.803	0.016	1.872
C.V		10.328	23.739	36.831	2.554	26.949
R^2		0.185	0.149	0.498	0.635	0.444

Key: S.O.V=Source of Variations; DF=Degree of Freedom; C.V=Coefficient of Variations; R^2= Coefficient of determination; SGR=Specific growth rate; FCR= Feed conversion ratio; ns=Not Significant at p>0.05; *=Significant at p<0.05, **=Significant at p<0.01 and ***= Significant at p<0.001

The fish growth trend in this study, indicate that there was consistent growth pattern in length and weight during the culture period. This could be attributed to the fact that fingerlings were previously well acclimated to the rearing conditions. According to (Rakocy, 1989), growth performance of *O. niloticus* is dependent on water quality parameters such as temperature, pH and ammonia, food quality, energy content of the diet, its physiological status, reproductive state and stocking density. According to Jobbling and Baardvik (1994),

environmental factors affecting feeding behavior or energy expenditure vary with fish stocking density. It is further documented by Boujard *et al*. (2002) that it is difficult to set food accessibility identical for each fish when density is increased because this is a contributing factor to impaired appetite of fish.

In the present study on *O. jipe*, stocking density did not affect the mean body weight, length, SGR, percent weight gain and FCR of the experimental fish. These results contradict earlier studies on *O. niloticus* (Huang and Chiu 1997; Irwin *et al*., 1999; Petit *et al*., 2001) where stocking density was noted to negatively affect the mean body weight, final mean total length, SGR and percent weight gain of *O. niloticus*. The relationship between stocking density and growth observed on *O. jipe* fingerlings in this study also contradict findings reported on the *O. niloticus* (Yi *et al*., 1996; Huang and Chiu *et al*., 1997; El-Sayed, 2002; Abou *et al*., 2007, Muangkeow *et al*., 2007; Gibtan *et al*., 2008) who observed a negative relationship between stocking density and growth on *O. niloticus*.

Studies show that reduced growth of fish at high stocking density can also be related to space limitation (El-Sayed, 2002; Yan *et al*., 2002 and Abou *et al*., 2007). This is contrary to the present study on *O. jipe* because almost similar growth was recorded for both stocking densities. This scenario could be as a result of reduced number of fish in all the hapas hence there was no space limitation and competition for food. In the study by Huang and Chiu (1997), they explained that tilapia is a very aggressive fish and the stocking density effect on growth performance might be expressed by their competition for territories as well as the permanent stress caused by crowding (Ellis *et al., 2002*). The results on *O. jipe* also differ with report by Ruane *et al*. (2002) and Sahoo *et al*. (2004) that high densities result in difficulties for fish to reach the food thus insufficient acquisition of food which lead to reduced feeding rate by individual fish.

The ability of the fish to convert feed given to biomass (FCR) was not significantly affected ($p>0.05$) with stocking density as reported by Osofero *et al*. (2009). This could be explained by the fact that during the study period, a lot of mortalities occurred thus striking a balance among the population in all the hapas. This could mean that the few individuals utilized the food thus bringing indifference with the *O. niloticus* authors and thereby suggesting that lower stocking density does not necessarily affect FCR. The FCR obtained in this study range between 1.08 and 1.83. The insignificant ($p>0.05$) differences among the diets imply that stocking densities of *O. jipe* have no apparent effect on the SGR of the fish.

The results of SGR in this study are higher than those obtained on other studies. Studies by Iluyemi *et al*. (2010) reported SGR of range 0.77 to 1.49 % and that of Attipoe *et al*., (2009) with SGR range of 0.43 to 0.53. Previous study by Osofero *et al*. (2009) on effect of stocking density on growth and survival of *O. niloticus*, reported an inverse relationship between survival rate and stocking density. This report is in agreement with the current study on *O. jipe*.

This assertion on *O. jipe* also contradicts a study by Yousif (2002) who reported that it is a generally accepted principle that increasing fish density will adversely affect fish growth. In that study, the initial fish size was homogenous and the daily supplies of food were adequate hence expecting that the fish within each population or treatment would have slightly different final body sizes. However, in this study, although the initial fish size was heterogeneous for all the treatment, the stocking density had no effect on the final size among individuals of initially non-uniform size. This also could be attributed to the fact that in both stocking densities, there were mortalities in all hapas hence striking a balance in the population present. These results on *O. jipe* is contrary to the study by Aksungur *et al*. (2007) which indicated that social interactions through competition for space and food can negatively affect fish growth. Moreover, from that study, higher stocking densities led to increased stress and that increase in energy requirements caused a reduction in growth rate and food utilization.

4.2 Effect of Stocking Density on Survival of Fish

At the end of the study period, the number of the surviving fish in both stocking densities was not significantly different. Stocking density 30 fish/m^2 had survival of 14.80^{a}±0.71 compared to stocking density of 45 fish/m^2 which had survival of 15.13^{a}±1.26 as shown in Table 4.1. Furthermore, survival was affected with time as shown in Figure 4.1.

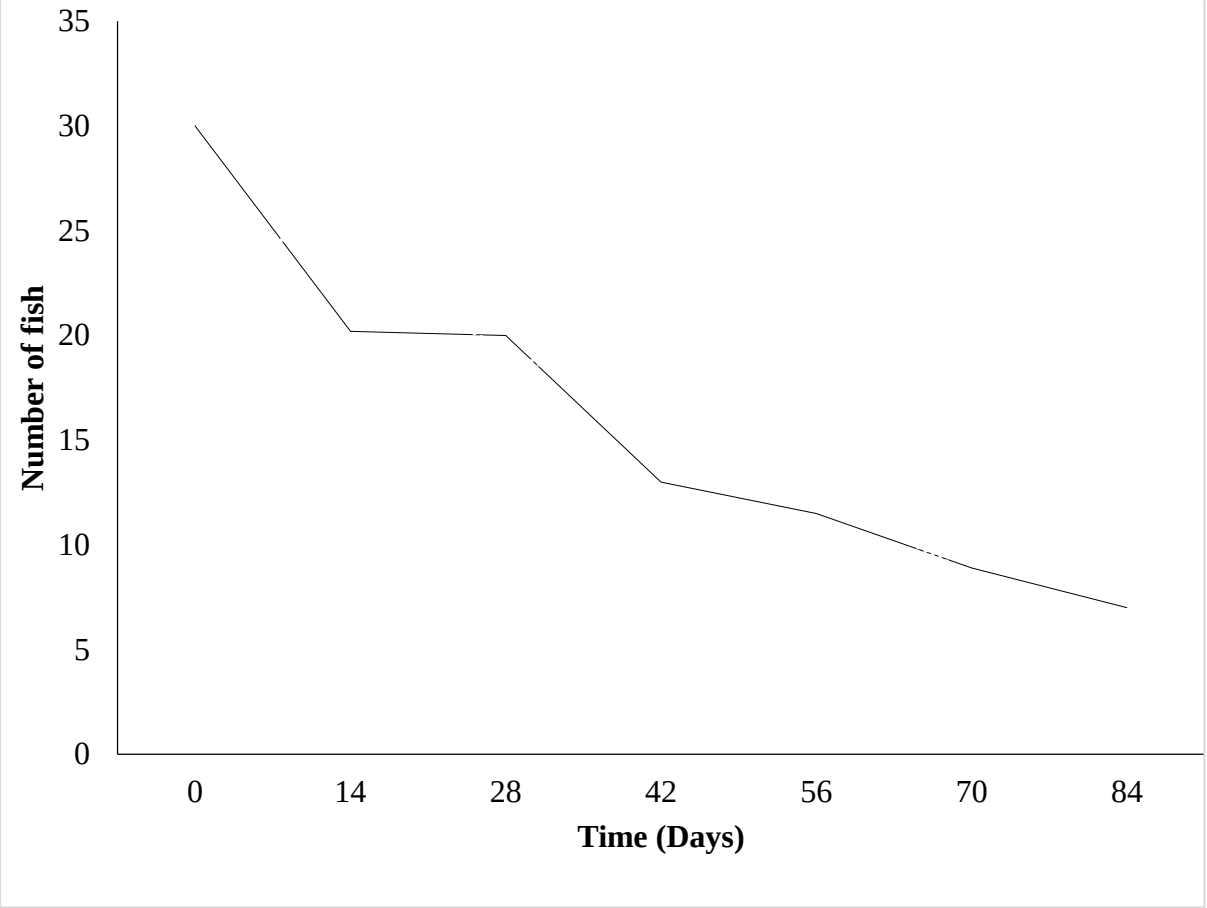

Figure 4.1: Graph showing survival of *O. jipe* against time

In the present study, 47.3% of the current study observations on survival were due to experimental factors (diet, stocking density and time) whereas 52.7% could be due to factors I couldn't account for. Furthermore, there was very high variability in survival of this fish during the study period (C.V= 38.268) (Table 4.5). This could be due to so many factors not highlighted in this study. Survival of *O. jipe* was not density dependent and no significant differences ($p>0.05$) were recorded for the two stocking densities tested. These results, are consistent with the findings of Abou *et al*. (2007) and Yi *et al*. (1996), but contradicts the findings of Szkudlarek and Zakes (2007), Huang and Chiu (1997) and Ellis *et al*. (2002) who recorded a negative relationship between fish survival and stocking density.

4.3 Effect of Diet on Growth Performance Parameters of Fish

In this study, diet was found to have significant effect ($p<0.001$) on the mean length and weight of *O. jipe* as shown in Figures 4.2 and 4.3. Fish fed on D_3 had significantly higher mean length of $7.50^{a}\pm0.19$ cm as compared to fish fed on D_1 and D_2 which had mean lengths

of 7.17^{b}±0.18 cm and 7.21^{b}±0.21 cm respectively. In the 84 days of culture, the fish fed on D_3 had a significantly higher mean weight of 6.68^{a}±0.45 g whereas the fish fed on D_1 and D_2 had mean weights of 5.66^{b}±0.38 g and 6.02^{b}±0.50 g respectively.

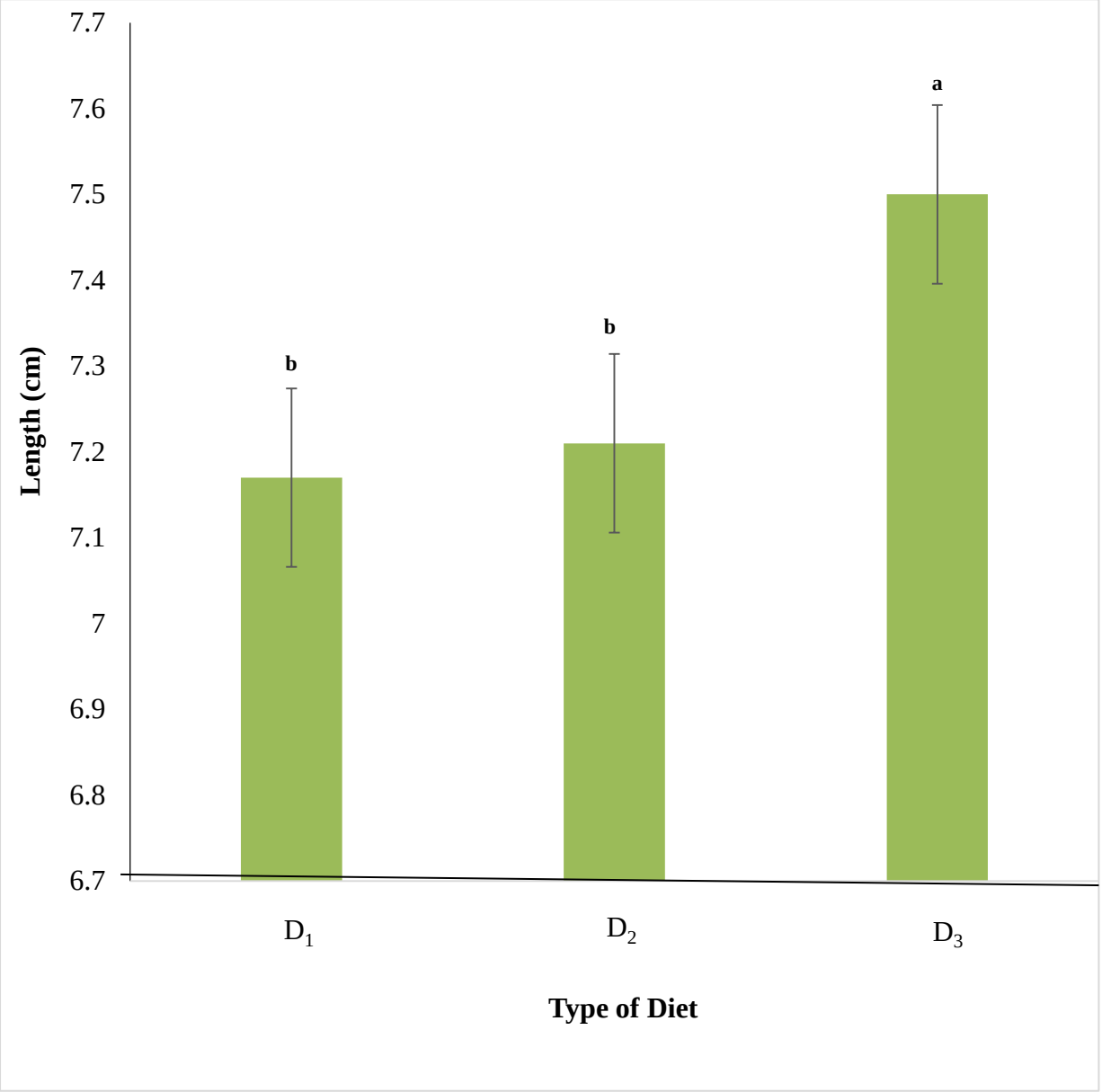

Figure 4.2 Effect of diet on the growth (Length, cm) of *O. jipe*.

Key: Error bars with same letters are not significantly different.

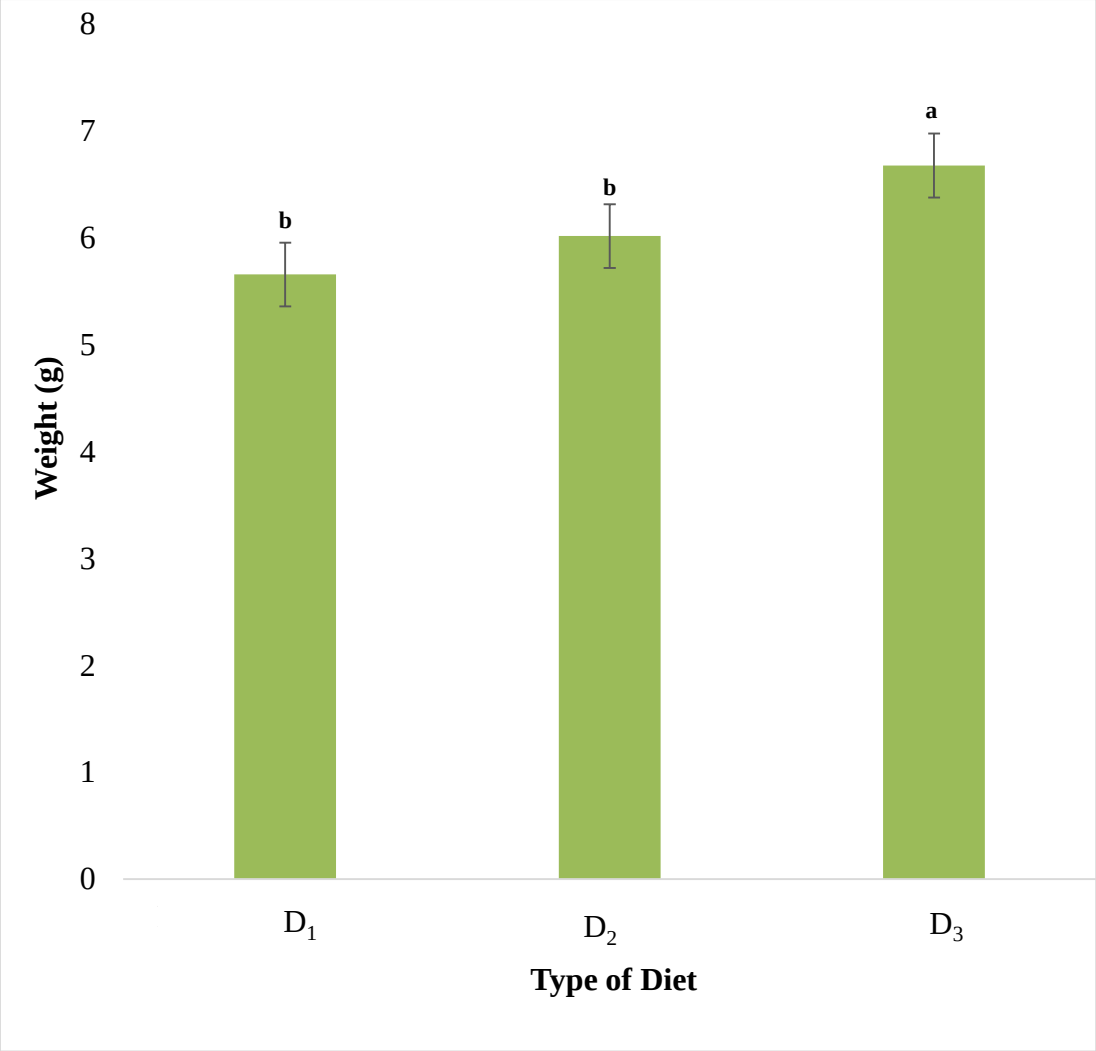

Figure 4.3: Effect of diet on the growth (Weight, g) of *O. jipe*.

Key: Error bars with same letters are not significantly different.

Moreover, diet affected the growth of *O. jipe* with time. Both length and weight increased gradually with time regardless of the type of diet as shown in Figures 4.4 and 4.5 respectively.

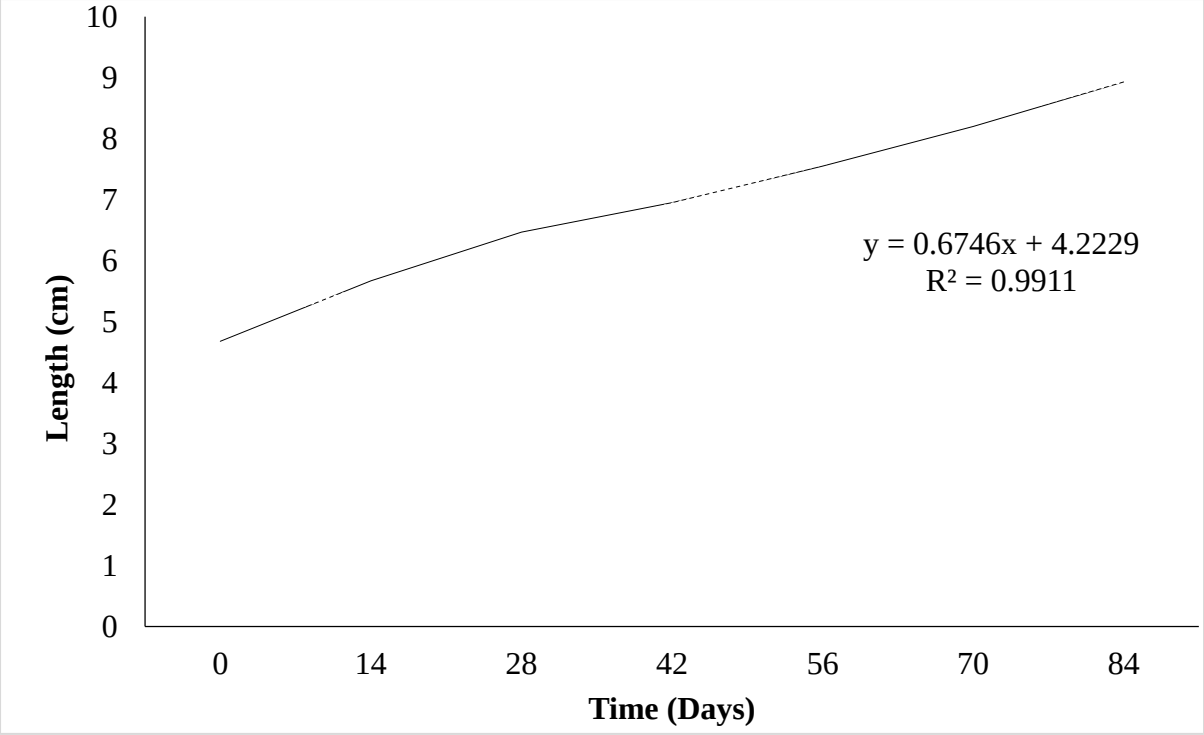

Figure 4.4: Length (Mean ± SE) of *O. jipe* over the 84 days experiment.

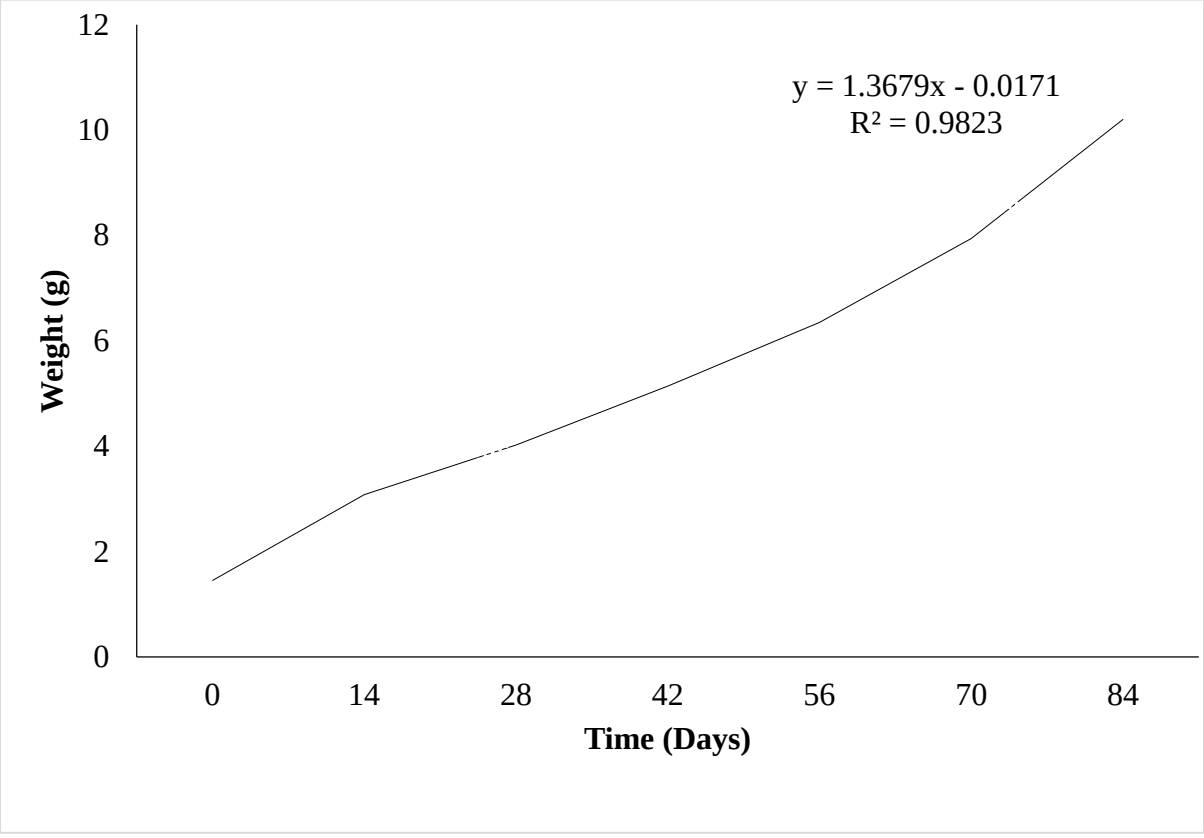

Figure 4.5: Body weight (Mean ± SE) of *O. jipe* over the 84 days experiment.

Furthermore, other growth performance parameters of *O. jipe* fed on different diets in terms of weight gain percent, specific growth rate (SGR%), percent survival, feed conversion ratio (FCR) and condition factor (K) were also calculated (Table 4.2). Specific growth rate (SGR) was not significantly affected by the diet ($p>0.05$) with the highest SGR (2.45 %) reported for D_3 (Table 4.2). Diet led to increased growth rates and consequently increased growth performance. Diet also had no significant effect on percent weight gain ($p>0.05$) and among the diets; D_1 resulted to the lowest value of weight gain (522.30%) as shown in Table 4.2. Diet also did not significantly affect the FCR significantly ($p>0.05$) with the highest FCR of 1.83 being recorded in the D_3. Consequently, condition factor of the fish in different treatments ranged between $1.36^{c}\pm0.02$ and $1.49^{a}\pm0.02$. Both the lower value and highest values was recorded for fish fed on D_3 in different stocking densities (Table 4.2). The percent survival of *O. jipe* at all the treatments was below 50 % (Table 4.2). Fish fed on D_3 in stocking density 45 fish/m^2, recorded lowest percent survivals of (14.07%) but it recorded the highest percent survival of (35.56%) in stocking density 30 fish/m^2.

The highest weight gain in D_3 might be due to the fact that the fish received essential protein in the diet. The low weight gains in D_1 and D_2 might be due to the fact that the fish had received low protein in the feed. Diet D_3, showing higher specific growth rate (SGR) than that of D_2 and D_1 has been shown in Table 4.2. The higher SGR values may also be due to the high amount of energy content in the feed. According to study by Ogunji *et al.* (2007), they worked on 4-5 g fingerlings and reported SGR value of 3.39 at the dietary protein content of 33.32 %. In this study, the mean feed conversion ratio (FCR) of different experimental diets ranged between 1.08 and 1.83 (Table 4.2).

The significantly ($p<0.05$) lowest FCR 1.08 was found in D_3 stocking density 30 fish/m^2 while the highest 1.83 was obtained in D_3 stocking density 45 fish/m^2. This range would slightly agree with that reported by El-Dakar *et al*. (2008) who reported a range of 0.99 to 1.17 for Florida Red Tilapia fed on Fig jam by-product (FJB). The FCR range in this current study is slightly good because it is close to the recommended FCR of 1.5 for aquaculture (Stickney, 1979). But they are much lower compared to *O. niloticus* fed on a commercially prepared diet in a study by Siddiqui *et al*. (1991) who reported FCR values ranging from 3.7 to 4.9 and Liti *et al*. (2006) who reported FCR for *O. niloticus* and *C. gariepinus* to range between 3.40 and 4.04 respectively. The extreme variation could be as a result of differences in the kind of species used, environmental conditions and feed sources.

This notation is in agreement with Guimaraes *et al*. (2008) that efficient utilization of diets may vary within a single species because of the environmental conditions and the kind of fish used. From this study, the FCR values could be attributed to the type of fish species and the prevalent environmental conditions of the study area. In this study there was significant interaction ($p<0.05$) of diet and stocking density on the condition factor (K). The mean condition factor for the *O. jipe* was between $1.36^{c}\pm0.02$ and $1.49^{a}\pm0.02$. This finding indicates that the fish were above average in terms of condition. The condition factor higher than one indicates an isometric growth and suggests good fish health condition, which is desirable in a fish farm (Ayode, 2011).

4.4 Effect of Diet on Survival of Fish

From the present study, diet affected survival of *O. jipe* significantly ($p<0.05$). Diets D_1 and D_3 were not significantly different from each other with survivals of $13.56^{b}\pm1.02$ and $14.33^{b}\pm1.04$ respectively. Diet D_2 was significantly higher in regard to survival $17.00^{a}\pm1.57$ compared to diets D_1 and D_3 as shown in Figure 4.6.

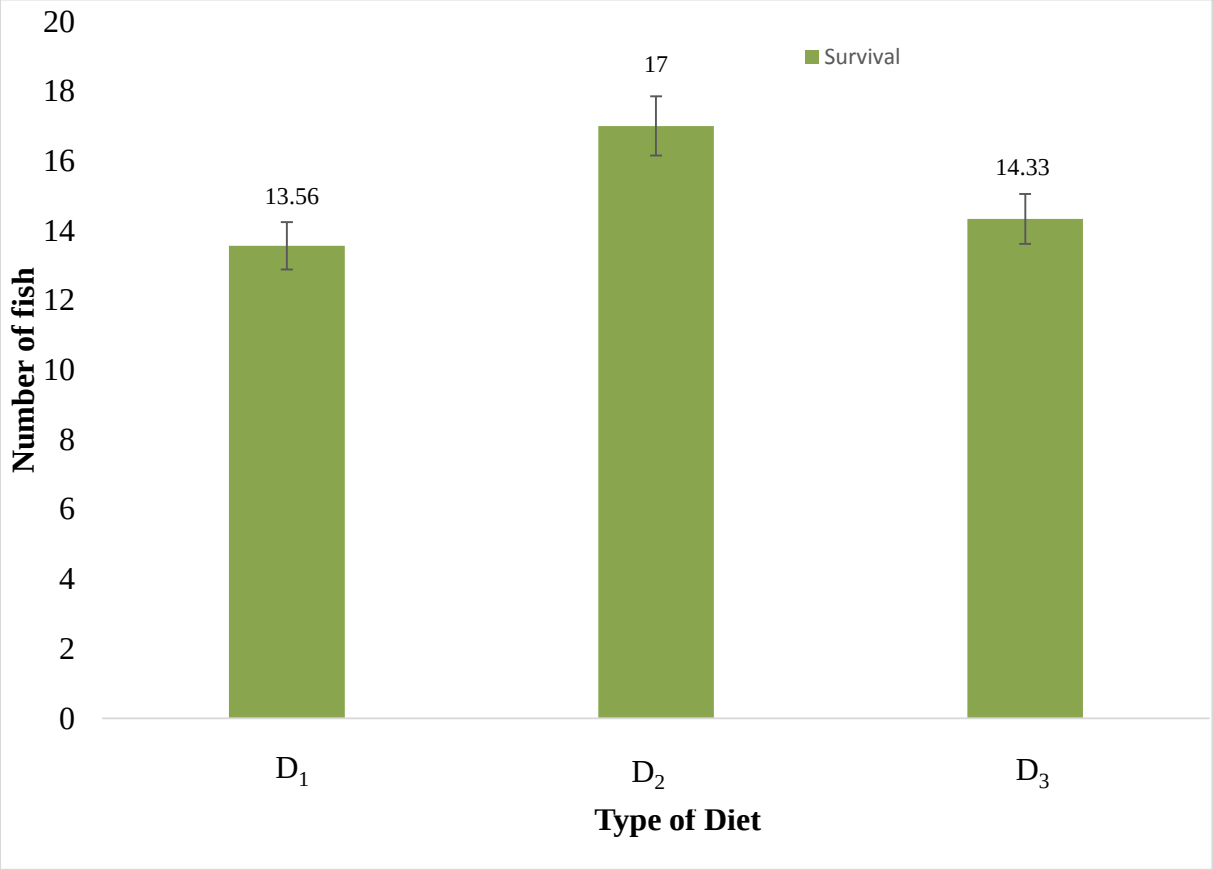

Figure 4.6: Graphs showing effect of diet on survival of *O. jipe*.

The survival rate varied from 14.07% to 35.56% in different diets (Table 4.2). Maximum survival was found on fish fed on D_2. Survival rate as high as 98 % was found in *O. niloticus* reared in pond by Michael and Jian (2002). On the other hand Sumi (2011) found a survival rate of 94 % by feeding 36% protein diet based on fish meal. This is not the case with the current study on *O. jipe* where a survival rate of less than 50% was recorded. Very low survival at the start of the experiment (Figure 4.1) could be attributed to low water levels during the early stages hence increased stress. Furthermore, uneaten food in the hapas might have increased ammonia levels hence resulting to more mortality. This is consistent with the findings of (El-Sherif *et al.*, 2008) who reported that high ammonia concentrations will slow growth rates and eventually result into high mortality. However, survival still remained low even after the water levels were checked. This scenario could be as a result of the low resilience of *O. jipe* to any slight stress especially during sampling periods. This contradicts the findings of El-Sherif and El-Feky (2009) who reported that higher (100%) survival rates could be associated to favorable ecological conditions.

4.5 Water Quality Parameters

The mean values of water physicochemical parameters during the experimental period are as shown in Table 4.7. The pH values in the treatments ranged from 9.55 to 9.86. Stocking density had no significant effect ($p>0.05$) on the mean pH values with the highest value of 9.86 being recorded at stocking density 30 fish/m^2 (Table 4.7). Diet also had no significant effect ($p>0.05$) on the pH values and no significant interaction ($p>0.05$) between stocking density and diet was recorded for the pH values. Mean temperature values in all the diets were relatively equal and ranged from 25.67°C to 26.27°C (Table 4.7). Stocking density had no significant effect ($p>0.05$) on the temperature values and consequently no significant interaction ($p>0.05$) was recorded between the stocking density and diet for temperature values. Mean conductivity values in all the diets were relatively equal and ranged from 53.17 µs to 54.83 µs (Table 4.7). Stocking density had no significant effect ($p>0.05$) on the conductivity values and consequently no significant interaction ($p>0.05$) was recorded between the stocking density and diet for conductivity values. Mean TDS values in all the diets were relatively equal and ranged from 26.33 ppm to 27.33 ppm (Table 4.7). Stocking density had no significant effect ($p>0.05$) on the TDS values and consequently no significant interaction ($p>0.05$) was recorded between the stocking density and diet for TDS values.

Table 4.7: Water physicochemical parameters (Mean ± S.E) monitored over the 84 days experiment.

Hapas	Stocking Density (fish/m^2)	Diets	pH	Temp (°C)	Conductivity (µs)	TDS (ppm)
1	30	D_3	9.70^a±0.42	26.13^a±0.56	54.67^a±0.99	27.00^a±0.52
2	30	D_2	9.55^a±0.37	26.12^a±0.53	54.00^a±0.77	26.83^a±0.48
3	30	D_1	9.69^a±0.28	26.05^a±0.54	53.83^a±0.87	26.83^a±0.48
4	30	D_3	9.59^a±0.36	25.90^a±0.52	54.83^a±1.17	27.33^a±0.61
5	30	D_2	9.57^a±0.37	25.90^a±0.56	53.67^a±0.76	26.83^a±0.40
6	30	D_1	9.77^a±0.26	26.02^a±0.52	54.00^a±0.86	26.83^a±0.40
7	30	D_3	9.76^a±0.27	25.95^a±0.54	53.83^a±0.79	26.67^a±0.33
8	30	D_2	9.78^a±0.25	25.93^a±0.56	53.50^a±0.67	26.50^a±0.34
9	30	D_1	9.86^a±0.24	25.88^a±0.59	54.17^a±1.01	26.83^a±0.48
10	45	D_3	9.58^a±0.38	25.73^a±0.54	54.17^a±0.95	26.83^a±0.40
11	45	D_2	9.56^a±0.38	25.67^a±0.53	54.17^a±0.79	26.67^a±0.33
12	45	D_1	9.65^a±0.37	25.85^a±0.55	53.83^a±1.14	26.67^a±0.49
13	45	D_3	9.63^a±0.33	25.82^a±0.57	53.83^a±0.57	26.83^a±0.40
14	45	D_2	9.55^a±0.38	25.88^a±0.55	53.83^a±0.79	26.67^a±0.33
15	45	D_1	9.56^a±0.28	25.95^a±0.54	53.67^a±0.67	26.67^a±0.33
16	45	D_3	9.76^a±0.27	25.95^a±0.50	53.17^a±0.79	26.33^a±0.33
17	45	D_2	9.55^a±0.34	26.08^a±0.55	53.50^a±0.56	26.50^a±0.22
18	45	D_1	9.68^a±0.28	26.27^a±0.59	53.67^a±0.76	26.50^a±0.34

Means with same superscripts along the column per water quality parameter were not significantly different ($p>0.05$) as determined by Tukey's HSD.

Table 4.8: Effect of stocking density on the water physicochemical parameters of the culture facilities using t-test.

	Parameters			
	pH	**Temperature**	**Conductivity**	**TDS**
t-value	0.57	0.32	0.78	1.23
P-value	0.5678	0.7513	0.4347	0.2214

Table 4.9: Analysis of Variance mean squares of fish stocking density, type of diet and their interaction effect on the water physicochemical parameters of culture facilities.

S.O.V	DF	pH	Temp	Conductivity	TDS
Diet	2	0.109^{ns}	0.080^{ns}	0.898^{ns}	0.259^{ns}
Stocking*Diet	2	0.028^{ns}	0.096^{ns}	1.545^{ns}	0.111^{ns}
Error	102	58.914	163.002	403.778	92.667
C.V		7.873	4.872	3.691	3.564
R^2		0.769	0.311	0.177	0.219

Key: S.O.V=Source of Variations; DF=Degree of Freedom; C.V=Coefficient of Variations; R^2= Coefficient of determination; ns=Not Significant at p>0.05; *=Significant at p<0.05, **=Significant at p<0.01 and ***= Significant at P<0.001

Table 4.10: Effect of stocking density on the water quality of the culture facilities.

Stocking density	Ammonia (mg/L)	Nitrite (mg/L)	Phosphate (mg/L)
30	0.19^{a}±0.04	0.27^{a}±0.03	0.13^{a}±0.04
45	0.20^{a}±0.04	0.39^{a}±0.11	0.17^{a}±0.07

Means with same superscripts along the column per water quality parameter were not significantly different (p>0.05) as determined by Tukey's HSD.

Table 4.11: Effect of stocking density on the water quality of the culture facilities using t-test.

	Parameters		
	Ammonia	**Nitrite**	**Phosphate**
t-value	-0.29	-1.11	-0.47
P-value	0.7721	0.2748	0.6377

Table 4.12: Effect of diet on the water quality of the culture facilities.

Diet	Ammonia (mg/L)	Nitrite (mg/L)	Phosphate (mg/L)
1	0.17^{a}±0.04	0.44^{a}±0.17	0.11^{a}±0.03
2	0.20^{a}±0.05	0.27^{a}±0.03	0.16^{a}±0.05
3	0.22^{a}±0.06	0.28^{a}±0.03	0.19^{a}±0.10

Means with same superscripts along the column per water quality parameter were not significantly different ($p>0.05$) as determined by Tukey's HSD.

Table 4.13: Interaction effect of stocking density and diet on the water quality of the culture facilities.

Diet	Stocking density	Ammonia (mg/L)	Nitrite (mg/L)	Phosphate (mg/L)
1	30	0.13^{a}±0.04	0.25^{a}±0.04	0.09^{a}±0.04
	45	0.20^{a}±0.07	0.64^{a}±0.32	0.12^{a}±0.06
2	30	0.22^{a}±0.08	0.29^{a}±0.05	0.20^{a}±0.09
	45	0.18^{a}±0.06	0.26^{a}±0.03	0.12^{a}±0.04
3	30	0.21^{a}±0.08	0.27^{a}±0.04	0.11^{a}±0.06
	45	0.23^{a}±0.09	0.28^{a}±0.04	0.27^{a}±0.19

Means with same superscripts along the column per water quality parameter were not significantly different ($p>0.05$) as determined by Tukey's HSD.

Table 4.14: Analysis of Variance mean squares of fish stocking density, type of diet and their interaction effect on the water quality parameters of culture facilities.

S.O.V	DF	Ammonia	Nitrite	Phosphate
Diet	2	0.009^{ns}	0.134^{ns}	0.026^{ns}
Stocking*Diet	36	0.010^{ns}	0.189^{ns}	0.049^{ns}
Error	41	0.037	0.131	0.066
C.V		98.53	109.43	0.065
R^2		0.029	0.146	169.25

Key: S.O.V=Source of Variations; DF=Degree of Freedom; C.V=Coefficient of Variations; R^2= Coefficient of determination; ns=Not Significant at p>0.05; *=Significant at p<0.05, **=Significant at p<0.01 and ***= Significant at p<0.001

There was no significant difference (p>0.05) in ammonia between the stocking densities with the highest ammonia value of 0.23 mg/L being recorded at stocking density 45 fish/m^2. Diet had no significant effect (p>0.05) on the ammonia values and therefore ammonia values were relatively low at all the diets in each stocking density. Consequently, there was no significant interaction (p>0.05) between diet and stocking density for ammonia values. Mean values of nitrites were also low in all the treatments except for D_1, stocking density 45 fish/m^2, which was above recommended range of 0.5 mg/L. This could be due to dead individuals decomposing in the hapa. However, there was no significant effect (p>0.05) of stocking density on nitrite values and no significant effect (p>0.05) was recorded for the diets on the nitrite values and therefore, no significant interaction (p>0.05) was recorded between the stocking density and diet for nitrite values. The Mean values of phosphates were also relatively low in all the treatments. There was no significant effect (p>0.05) of stocking density on phosphate values and no significant effect was recorded for the diets (p>0.05) on the phosphate values and therefore, no significant interaction (p>0.05) was recorded between the stocking density and diet for phosphate values.

It can therefore be concluded that in the present study on *O. jipe*, water quality was not affected by stocking density and diet. Only in nitrite value at stocking density 45 fish/m^2, D_1, was there a high value of 0.64 mg/L. This could be as a result of dead individuals decomposing in the hapa or it could be as a result of increased fish biomass in the hapa. The result on nitrite contradicts study by Santhosh and Singh (2007) who recommended that

nitrite concentration in water should not exceed 0.5 mg/L. However, all other concentrations were less than 0.5 mg/L which is the recommended tolerable range for survival and production of tilapia in ponds.

CHAPTER FIVE

SUMMARY OF FINDINGS, CONCLUSION AND RECOMMENDATIONS

5.1 Summary of Findings

Results from the present study indicate that interactive effect of stocking density and diet do not considerably affect growth performance of *O. jipe* in terms of mean weight, percent weight gain, SGR and FCR. However, the two interacting factors affected mean length, survival and condition factor (K). On the other hand, highest stocking density registered the lowest survival. It was also demonstrated that *O. jipe* growth performance in terms of mean length and weight was highest in diet D_3 with CP content of 35%. Stocking density and diet had no significant effect on all the water quality parameters measured.

5.1 Conclusion

i. From the present study, stocking density did not affect growth of *O. jipe*. Since there was no significant difference on mean weight and length from both stocking densities, it can be concluded that stocking density does not affect growth of *O. jipe*.
ii. There was high mortality in higher stocking density imperative that *O. jipe* survival is sensitive to stocking density.
iii. Diet D_3 gave the best for *O. jipe* growth by registering the highest growth rate. Therefore, it can be concluded that diet D_3 (35% CP) is most suitable for hapa-pond-system culture of *O. jipe* regardless of stocking density.
iv. In regard to effect of diet on survival of *O. jipe*, diet D_2 was the highest in survival compared to diets D_1 and D_3.
v. *O. jipe* stocking density and diet had no effect on the water quality of culture facilities.

5.2 Recommendations

i. Low stocking density should be used for *O. jipe* culture to improve both growth performance and survival of the fish.
ii. High CP content feed (D_3) should be used for *O. jipe* culture for maximum growth performance of the fish.

5.3 Further Research

i. Further research should be conducted to examine the effects of other diets and stocking densities on the growth performance of *O. jipe*.

ii. The biology, ecology of the fish and feeding behavior of *O. jipe* should be studied to achieve maximum survival and numbers of fish of desired size.

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APPENDICES

APPENDIX I: NORMALITY TEST

The SAS System 11:28 Tuesday, May 8, 2018 68

The UNIVARIATE Procedure

Variable: LENGTH

Moments

N	109	Sum Weights	109
Mean	7.2693578	Sum Observations	792.36
Std Deviation	1.18144942	Variance	1.39582273
Skewness	0.14678026	Kurtosis	-0.6622794
Uncorrected SS	5910.6972	Corrected SS	150.748855
Coeff Variation	16.2524593	Std Error Mean	0.11316233

Basic Statistical Measures

Location		Variability	
Mean	7.269358	Std Deviation	1.18145
Median	7.150000	Variance	1.39582
Mode	5.610000	Range	5.25000
		Interquartile Range	1.70000

NOTE: The mode displayed is the smallest of 9 modes with a count of 2.

Tests for Location: Mu0=0

Test	-	Statistic-	-----	p Value------
Student's t	t	64.23832	Pr > |t|	<.0001
Sign	M	54.5	Pr >= |M|	<.0001
Signed Rank	S	2997.5	Pr >= |S|	<.0001

Quantiles (Definition 5)

Quantile		Estimate
100%	Max	9.93
99%		9.90
95%		9.24
90%		8.84
75%	Q3	8.11
50%	Median	7.15
25%	Q1	6.41
10%		5.73
5%		5.52
1%		5.08
0%	Min	4.68

The UNIVARIATE Procedure

Variable: LENGTH

Extreme Observations

----Lowest----		----Highest---	
Value	Obs	Value	Obs
4.68	1	9.27	19
5.08	57	9.50	107
5.22	38	9.52	109
5.25	22	9.90	72
5.45	21	9.93	54

The UNIVARIATE Procedure

Variable: WEIGHT

Moments

N	109	Sum Weights	109
Mean	6.07715596	Sum Observations	662.41
Std Deviation	2.69952811	Variance	7.28745202
Skewness	0.76707785	Kurtosis	0.10282404
Uncorrected SS	4812.6137	Corrected SS	787.044818
Coeff Variation	44.4209121	Std Error Mean	0.2585679

Basic Statistical Measures

Location		Variability	
Mean	6.077156	Std Deviation	2.69953
Median	5.600000	Variance	7.28745
Mode	3.000000	Range	12.75000
		Interquartile Range	3.63000

NOTE: The mode displayed is the smallest of 2 modes with a count of 3.

Tests for Location: Mu0=0

Test	- Statistic-	-----	p Value------
Student's t	t	23.50313	Pr > |t| <.0001
Sign	M	54.5	Pr >= |M| <.0001
Signed Rank	S	2997.5	Pr >= |S| <.0001

Quantiles (Definition 5)

Quantile	Estimate
100% Max	14.20
99%	13.83
95%	11.33
90%	9.73
75% Q3	7.63
50% Median	5.60
25% Q1	4.00
10%	3.08
5%	2.98
1%	2.04
0% Min	1.45

The UNIVARIATE Procedure

Variable: WEIGHT

Extreme Observations

----Lowest----		----Highest----	
Value	Obs	Value	Obs
1.45	1	11.40	109
2.04	57	11.44	91
2.28	22	11.75	107
2.46	38	13.83	54
2.61	21	14.20	72

The UNIVARIATE Procedure

Variable: SURVIVAL

Moments

N	109	Sum Weights	109
Mean	15.1009174	Sum Observations	1646
Std Deviation	7.61084138	Variance	57.9249066
Skewness	1.00029831	Kurtosis	1.68653906
Uncorrected SS	31112	Corrected SS	6255.88991
Coeff Variation	50.3998609	Std Error Mean	0.72898639

Basic Statistical Measures

Location		Variability	
Mean	15.10092	Std Deviation	7.61084
Median	14.00000	Variance	57.92491
Mode	10.00000	Range	44.00000
		Interquartile Range	10.00000

Tests for Location: Mu0=0

Test	-Statistic-		----- p Value------
Student's t	t	20.71495	Pr > |t| <.0001
Sign	M	54.5	Pr >= |M| <.0001
Signed Rank	S	2997.5	Pr >= |S| <.0001

Quantiles (Definition 5)

Quantile	Estimate
100% Max	45
99%	39
95%	28
90%	24
75% Q3	20
50% Median	14
25% Q1	10
10%	6
5%	5
1%	4
0% Min	1

The UNIVARIATE Procedure

Variable: SURVIVAL

Extreme Observations

----Lowest----		----Highest---	
Value	Obs	Value	Obs
1	58	30	1
4	107	30	67
5	109	32	21
5	104	39	64
5	72	45	61

The UNIVARIATE Procedure

Variable: MORTALTY

Moments

N	109	Sum Weights	109
Mean	5.33027523	Sum Observations	581
Std Deviation	7.46107807	Variance	55.667686
Skewness	2.8721398	Kurtosis	9.63363827
Uncorrected SS	9109	Corrected SS	6012.11009
Coeff Variation	139.975475	Std Error Mean	0.71464167

Basic Statistical Measures

Location		Variability	
Mean	5.330275	Std Deviation	7.46108
Median	3.000000	Variance	55.66769
Mode	1.000000	Range	44.00000
		Interquartile Range	5.00000

Tests for Location: Mu0=0

Test	-Statistic-		----- p Value------	
Student's t	t	7.458668	Pr > |t|	<.0001
Sign	M	46.5	Pr >= |M|	<.0001
Signed Rank	S	2185.5	Pr >= |S|	<.0001

Quantiles (Definition 5)

Quantile	Estimate
100% Max	44
99%	35
95%	21
90%	12
75% Q3	6
50% Median	3
25% Q1	1
10%	0
5%	0
1%	0
0% Min	0

The UNIVARIATE Procedure

Variable: MORTALTY

Extreme Observations

----Lowest----		----Highest---	
Value	Obs	Value	Obs
0	103	25	22
0	102	26	92
0	96	32	20
0	89	35	94
0	79	44	58

APPENDIX II: STATISTICAL ANALYSIS

The SAS System 11:28 Tuesday, May 8, 2018 49

The GLM Procedure

Class Level Information

Class	Levels	Values
DIET	3	1 2 3
STOCKING	2	30 45
TIME	6	14 28 42 56 70 84

Number of observations 108

The SAS System 11:28 Tuesday, May 8, 2018 50

The GLM Procedure

Dependent Variable: LENGTH

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	130.1288222	13.0128822	91.12	<.0001
Error	97	13.8531778	0.1428163		
Corrected Total	107	143.9820000			

R-Square	Coeff Var	Root MSE	LENGTH Mean
0.903785	5.181587	0.377910	7.293333

Source	DF	Type I SS	Mean Square	F Value	Pr > F
DIET	2	2.2496167	1.1248083	7.88	0.0007
STOCKING	1	0.3355593	0.3355593	2.35	0.1286
TIME	5	126.1494556	25.2298911	176.66	<.0001
DIET*STOCKING	2	1.3941907	0.6970954	4.88	0.0096

Dependent Variable: WEIGHT

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	648.9295111	64.8929511	54.03	<.0001
Error	97	116.5064889	1.2010978		
Corrected Total	107	765.4360000			

R-Square	Coeff Var	Root MSE	WEIGHT Mean
0.847791	17.90762	1.095946	6.120000

Source	DF	Type I SS	Mean Square	F Value	Pr > F
DIET	2	19.3793056	9.6896528	8.07	0.0006
STOCKING	1	1.0760037	1.0760037	0.90	0.3462
TIME	5	622.6030889	124.5206178	103.67	<.0001
DIET*STOCKING	2	5.8711130	2.9355565	2.44	0.0921

Dependent Variable: SURVIVAL

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	2851.481481	285.148148	8.70	<.0001
Error	97	3180.370370	32.787323		
Corrected Total	107	6031.851852			

R-Square	Coeff Var	Root MSE	SURVIVAL Mean
0.472737	38.26797	5.726022	14.96296

Source	DF	Type I SS	Mean Square	F Value	Pr > F
DIET	2	234.962963	117.481481	3.58	0.0315
STOCKING	1	3.000000	3.000000	0.09	0.7629
TIME	5	2226.629630	445.325926	13.58	<.0001
DIET*STOCKING	2	386.888889	193.444444	5.90	0.0038

Dependent Variable: MORTALITY

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	3708.870370	370.887037	15.82	<.0001
Error	97	2274.564815	23.449122		
Corrected Total	107	5983.435185			

R-Square	Coeff Var	Root MSE	MORTALTY Mean
0.619856	90.01418	4.842429	5.379630

Source	DF	Type I SS	Mean Square	F Value	Pr > F
DIET	2	11.796296	5.898148	0.25	0.7781
STOCKING	1	270.750000	270.750000	11.55	0.0010
TIME	5	3407.824074	681.564815	29.07	<.0001
DIET*STOCKING	2	18.500000	9.250000	0.39	0.6751

The GLM Procedure

Least Squares Means

Adjustment for Multiple Comparisons: Tukey

DIET	LENGTH LSMEAN	LSMEAN Number
1	7.17388889	1
2	7.20972222	2
3	7.49638889	3

Least Squares Means for Effect DIET

t for H0: LSMean(i)=LSMean(j) / Pr > |t|

Dependent Variable: LENGTH

i/j	1	2	3
1		-0.40229	-3.62057
		0.9147	0.0014
2	0.402286		-3.21829
	0.9147		0.0049
3	3.620572	3.218286	
	0.0014	0.0049	

DIET	WEIGHT LSMEAN	LSMEAN Number
1	5.66027778	1
2	6.01722222	2
3	6.68250000	3

Least Squares Means for Effect DIET
t for H0: LSMean(i)=LSMean(j) / Pr > |t|
Dependent Variable: WEIGHT

i/j	1	2	3
1		-1.38181	-3.95724
		0.3544	0.0004
2	1.381808		-2.57543
	0.3544		0.0307
3	3.95724	2.575432	
	0.0004	0.0307	

The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey

DIET	SURVIVAL LSMEAN	LSMEAN Number
1	13.5555556	1
2	17.0000000	2
3	14.3333333	3

Least Squares Means for Effect DIET
t for H0: LSMean(i)=LSMean(j) / Pr > |t|
Dependent Variable: SURVIVAL

i/j	1	2	3
1		-2.55213	-0.57629
		0.0326	0.8331
2	2.552128		1.975841
	0.0326		0.1237
3	0.576287	-1.97584	
	0.8331	0.1237	

MORTALTY LSMEAN

DIET	LSMEAN	Number
1	5.05555556	1
2	5.83333333	2
3	5.25000000	3

Least Squares Means for Effect DIET

t for H0: LSMean(i)=LSMean(j) / Pr > |t|

Dependent Variable: MORTALTY

i/j	1	2	3
1		-0.68144	-0.17036
		0.7748	0.9841
2		0.681441	0.511081
		0.7748	0.8661
3		0.17036	-0.51108
		0.9841	0.8661

The GLM Procedure

Least Squares Means

Adjustment for Multiple Comparisons: Tukey

LENGTH H0:LSMean1=LSMean2

STOCKING	LSMEAN	t Value	Pr > |t|
30	7.34907407	1.53	0.1286
45	7.23759259		

WEIGHT H0:LSMean1=LSMean2

STOCKING	LSMEAN	t Value	Pr > |t|
30	6.21981481	0.95	0.3462
45	6.02018519		

SURVIVAL H0:LSMean1=LSMean2

STOCKING	LSMEAN	t Value	Pr > |t|
30	14.7962963	-0.30	0.7629
45	15.1296296		

MORTALTY H0:LSMean1=LSMean2

STOCKING	LSMEAN	t Value	Pr > |t|
30	3.79629630	-3.40	0.0010
45	6.96296296		

The GLM Procedure

Least Squares Means

Adjustment for Multiple Comparisons: Tukey

TIME	LENGTH LSMEAN	LSMEAN Number
14	5.66722222	1
28	6.46666667	2
42	6.95166667	3
56	7.54555556	4
70	8.19777778	5
84	8.93111111	6

Least Squares Means for Effect TIME

t for H0: LSMean(i)=LSMean(j) / Pr > |t|

Dependent Variable: LENGTH

i/j	1	2	3	4	5	6
1		-6.3463	-10.1964	-14.9109	-20.0885	-25.91
		<.0001	<.0001	<.0001	<.0001	<.0001
2		6.346302	-3.85012	-8.56464	-13.7422	-19.5637
		<.0001	0.0028	<.0001	<.0001	<.0001
3		10.19642	3.850119	-4.71452	-9.89212	-15.7136
		<.0001	0.0028	0.0001	<.0001	<.0001
4		14.91094	8.564641	4.714521	-5.17759	-10.9991
		<.0001	<.0001	0.0001	<.0001	<.0001
5		20.08854	13.74223	9.892116	5.177594	-5.82149
		<.0001	<.0001	<.0001	<.0001	<.0001
6		25.91002	19.56372	15.7136	10.99908	5.821486
		<.0001	<.0001	<.0001	<.0001	<.0001

TIME	WEIGHT LSMEAN	LSMEAN Number
14	3.0755556	1
28	4.0227778	2
42	5.1427778	3
56	6.3450000	4
70	7.9383333	5
84	10.1955556	6

The GLM Procedure

Least Squares Means

Adjustment for Multiple Comparisons: Tukey

Least Squares Means for Effect TIME

t for H0: LSMean(i)=LSMean(j) / Pr > |t|

Dependent Variable: WEIGHT

i/j	1	2	3	4	5	6
1		-2.59289	-5.65873	-8.94965	-13.3112	-19.49
		0.1089	<.0001	<.0001	<.0001	<.0001
2	2.592889		-3.06584	-6.35676	-10.7183	-16.8971
	0.1089		0.0326	<.0001	<.0001	<.0001
3	5.658733	3.065844		-3.29092	-7.65244	-13.8313
	<.0001	0.0326		0.0170	<.0001	<.0001
4	8.949649	6.35676	3.290916		-4.36153	-10.5404
	<.0001	<.0001	0.0170		0.0005	<.0001
5	13.31118	10.71829	7.652445	4.361528		-6.17883
	<.0001	<.0001	<.0001	0.0005		<.0001
6	19.49001	16.89712	13.83128	10.54036	6.178832	
	<.0001	<.0001	<.0001	<.0001	<.0001	

TIME	SURVIVAL LSMEAN	LSMEAN Number
14	19.7777778	1
28	21.2222222	2
42	16.1666667	3
56	13.1111111	4
70	10.7777778	5
84	8.7222222	6

Least Squares Means for Effect TIME

t for H0: LSMean(i)=LSMean(j) / Pr > |t|

Dependent Variable: SURVIVAL

i/j	1	2	3	4	5	6
1		-0.75678	1.891948	3.492827	4.715316	5.792271
		0.9739	0.4133	0.0092	0.0001	<.0001
2	0.756779		2.648727	4.249606	5.472095	6.54905
	0.9739		0.0955	0.0007	<.0001	<.0001
3	-1.89195	-2.64873		1.600879	2.823368	3.900323
	0.4133	0.0955		0.6000	0.0622	0.0024
4	-3.49283	-4.24961	-1.60088		1.222489	2.299444
	0.0092	0.0007	0.6000		0.8249	0.2044
5	-4.71532	-5.47209	-2.82337	-1.22249		1.076955
	0.0001	<.0001	0.0622	0.8249		0.8894

The GLM Procedure

Least Squares Means

Adjustment for Multiple Comparisons: Tukey

Least Squares Means for Effect TIME

t for H0: LSMean(i)=LSMean(j) / Pr > |t|

Dependent Variable: SURVIVAL

i/j	1	2	3	4	5	6
6	-5.79227	-6.54905	-3.90032		-2.29944	-1.07695
	<.0001	<.0001	0.0024	0.2044	0.8894	

TIME	MORTALTY LSMEAN LSMEAN	LSMEAN Number
14	17.7222222	1
28	1.8333333	2
42	5.0555556	3
56	3.0555556	4
70	2.3333333	5
84	2.2777778	6

Least Squares Means for Effect TIME

t for H0: LSMean(i)=LSMean(j) / Pr > |t|

Dependent Variable: MORTALTY

i/j	1	2	3	4	5	6
1		9.843544	7.847301	9.086348	9.533782	9.5682
		<.0001	<.0001	<.0001	<.0001	<.0001
2	-9.84354		-1.99624	-0.7572	-0.30976	-0.27534
	<.0001		0.3521	0.9739	0.9996	0.9998
3	-7.8473	1.996243		1.239048	1.686481	1.720899
	<.0001	0.3521		0.8165	0.5440	0.5215
4	-9.08635	0.757196	-1.23905		0.447434	0.481852
	<.0001	0.9739	0.8165		0.9977	0.9967
5	-9.53378	0.309762	-1.68648	-0.44743		0.034418
	<.0001	0.9996	0.5440	0.9977		1.0000
6	-9.5682	0.275344	-1.7209	-0.48185	-0.03442	
	<.0001	0.9998	0.5215	0.9967	1.0000	

The GLM Procedure

Least Squares Means

Adjustment for Multiple Comparisons: Tukey

DIET	STOCKING	LENGTH LSMEAN LSMEAN	LSMEAN Number
1	30	7.28777778	1
1	45	7.06000000	2
2	30	7.36611111	3
2	45	7.05333333	4
3	30	7.39333333	5
3	45	7.59944444	6

Least Squares Means for Effect DIET*STOCKING

t for H0: LSMean(i)=LSMean(j) / Pr > |t|

Dependent Variable: LENGTH

i/j	1	2	3	4	5	6
1		1.808189	-0.62184	1.861111	-0.83794	-2.47413
		0.4654	0.9892	0.4322	0.9596	0.1421
2	-1.80819		-2.43003	0.052923	-2.64613	-4.28232
	0.4654		0.1563	1.0000	0.0961	0.0006
3	0.621841	2.430029		2.482952	-0.2161	-1.85229
	0.9892	0.1563		0.1394	0.9999	0.4377
4	-1.86111	-0.05292	-2.48295		-2.69905	-4.33524
	0.4322	1.0000	0.1394		0.0847	0.0005
5	0.837941	2.64613	0.216101	2.699053		-1.63619
	0.9596	0.0961	0.9999	0.0847		0.5769
6	2.474131	4.28232	1.852291	4.335243	1.63619	
	0.1421	0.0006	0.4377	0.0005	0.5769	

WEIGHT LSMEAN

DIET	STOCKING	LSMEAN	Number
1	30	5.91500000	1
1	45	5.40555556	2
2	30	6.29166667	3
2	45	5.74277778	4
3	30	6.45277778	5
3	45	6.91222222	6

The GLM Procedure

Least Squares Means

Adjustment for Multiple Comparisons: Tukey

Least Squares Means for Effect DIET*STOCKING

t for H0: LSMean(i)=LSMean(j) / Pr > |t|

Dependent Variable: WEIGHT

i/j	1	2	3	4	5	6
1		1.394533	-1.03107	0.471434	-1.47209	-2.72976
		0.7302	0.9063	0.9970	0.6827	0.0786
2	-1.39453		-2.42561	-0.9231	-2.86663	-4.12429
	0.7302		0.1578	0.9397	0.0556	0.0011
3	1.031073	2.425606		1.502507	-0.44102	-1.69868
	0.9063	0.1578		0.6635	0.9978	0.5360
4	-0.47143	0.923099	-1.50251		-1.94353	-3.20119
	0.9970	0.9397	0.6635		0.3825	0.0222
5	1.472092	2.866625	0.441019	1.943526		-1.25767
	0.6827	0.0556	0.9978	0.3825	0.8070	
6	2.729757	4.12429	1.698685	3.201192	1.257665	
	0.0786	0.0011	0.5360	0.0222	0.8070	

SURVIVAL LSMEAN

DIET	STOCKING	LSMEAN	Number
1	30	13.1111111	1
1	45	14.0000000	2
2	30	14.6666667	3
2	45	19.3333333	4
3	30	16.6111111	5
3	45	12.0555556	6

Least Squares Means for Effect DIET*STOCKING

t for H0: LSMean(i)=LSMean(j) / Pr > |t|

Dependent Variable: SURVIVAL

i/j	1	2	3	4	5	6
1		-0.46571	-0.81499	-3.25997	-1.83373	0.553031
		0.9972	0.9641	0.0187	0.4493	0.9937
2	0.46571		-0.34928	-2.79426	-1.36802	1.018741
	0.9972		0.9993	0.0669	0.7459	0.9106
3	0.814993	0.349283		-2.44498	-1.01874	1.368024
	0.9641	0.9993		0.1514	0.9106	0.7459
4	3.259971	2.794261	2.444979		1.426237	3.813002
	0.0187	0.0669	0.1514		0.7111	0.0032
5	1.833734	1.368024	1.018741	-1.42624		2.386765
	0.4493	0.7459	0.9106	0.7111		0.1712

The GLM Procedure

Least Squares Means

Adjustment for Multiple Comparisons: Tukey

Least Squares Means for Effect DIET*STOCKING

t for H0: LSMean(i)=LSMean(j) / Pr > |t|

Dependent Variable: SURVIVAL

i/j	1	2	3	4	5	6
6	-0.55303	-1.01874	-1.36802	-3.813	-2.38676	
	0.9937	0.9106	0.7459	0.0032	0.1712	

DIET	STOCKING	MORTALTY LSMEAN	Number
1	30	3.72222222	1
1	45	6.38888889	2
2	30	3.66666667	3
2	45	8.00000000	4
3	30	4.00000000	5
3	45	6.50000000	6

Least Squares Means for Effect DIET*STOCKING

t for H0: LSMean(i)=LSMean(j) / Pr > |t|

Dependent Variable: MORTALTY

i/j	1	2	3	4	5	6
1		-1.65206	0.034418	-2.65018	-0.17209	-1.7209
		0.5665	1.0000	0.0952	1.0000	0.5215
2	1.652063		1.686481	-0.99812	1.479973	-0.06884
	0.5665		0.5440	0.9175	0.6777	1.0000
3	-0.03442	-1.68648		-2.6846	-0.20651	-1.75532
	1.0000	0.5440		0.0877	0.9999	0.4992
4	2.650185	0.998122	2.684603		2.478095	0.929286
	0.0952	0.9175	0.0877		0.1409	0.9380
5	0.17209	-1.47997	0.206508	-2.4781		-1.54881
	1.0000	0.6777	0.9999	0.1409		0.6338
6	1.720899	0.068836	1.755317	-0.92929	1.548809	
	0.5215	1.0000	0.4992	0.9380	0.6338	

The MEANS Procedure

DIET	N Obs	Variable	Mean	Std Error
1	36	LENGTH	7.17	0.18
		WEIGHT	5.66	0.38
		SURVIVAL	13.56	1.02
		MORTALTY	5.06	1.15
2	36	LENGTH	7.21	0.21
		WEIGHT	6.02	0.50
		SURVIVAL	17.00	1.57
		MORTALTY	5.83	1.36
3	36	LENGTH	7.50	0.19
		WEIGHT	6.68	0.45
		SURVIVAL	14.33	1.04
		MORTALTY	5.25	1.25

The MEANS Procedure

STOCKING	N Obs	Variable	Mean	Std Error
30	54	LENGTH	7.35	0.15
		WEIGHT	6.22	0.34
		SURVIVAL	14.80	0.71
		MORTALTY	3.80	0.47
45	54	LENGTH	7.24	0.17
		WEIGHT	6.02	0.39
		SURVIVAL	15.13	1.26
		MORTALTY	6.96	1.33

The MEANS Procedure

TIME	N Obs	Variable	Mean	Std Error
14	18	LENGTH	5.67	0.07
		WEIGHT	3.08	0.12
		SURVIVAL	19.78	1.62
		MORTALTY	17.72	2.57
28	18	LENGTH	6.47	0.08
		WEIGHT	4.02	0.16
		SURVIVAL	21.22	1.85
		MORTALTY	1.83	0.57
42	18	LENGTH	6.95	0.07
		WEIGHT	5.14	0.19
		SURVIVAL	16.17	1.66
		MORTALTY	5.06	0.83
56	18	LENGTH	7.55	0.10
		WEIGHT	6.35	0.27
		SURVIVAL	13.11	1.30
		MORTALTY	3.06	0.64
70	18	LENGTH	8.20	0.11
		WEIGHT	7.94	0.34
		SURVIVAL	10.78	1.13
		MORTALTY	2.33	0.42
84	18	LENGTH	8.93	0.13
		WEIGHT	10.20	0.45
		SURVIVAL	8.72	0.83
		MORTALTY	2.28	0.43

The MEANS Procedure

DIET	STOCKING	N Obs	Variable	Mean	Std Error
1	30	18	LENGTH	7.29	0.25
			WEIGHT	5.92	0.56
			SURVIVAL	13.11	1.17
			MORTALTY	3.72	0.85
	45	18	LENGTH	7.06	0.26
			WEIGHT	5.41	0.53
			SURVIVAL	14.00	1.71
			MORTALTY	6.39	2.13
2	30	18	LENGTH	7.37	0.29
			WEIGHT	6.29	0.68
			SURVIVAL	14.67	1.31
			MORTALTY	3.67	0.89
	45	18	LENGTH	7.05	0.30
			WEIGHT	5.74	0.74
			SURVIVAL	19.33	2.80
			MORTALTY	8.00	2.51
3	30	18	LENGTH	7.39	0.24
			WEIGHT	6.45	0.56
			SURVIVAL	16.61	1.14
			MORTALTY	4.00	0.74
	45	18	LENGTH	7.60	0.31
			WEIGHT	6.91	0.71
			SURVIVAL	12.06	1.59
			MORTALTY	6.50	2.38

The CORR Procedure

4 Variables: LENGTH WEIGHT SURVIVAL MORTALTY

Simple Statistics

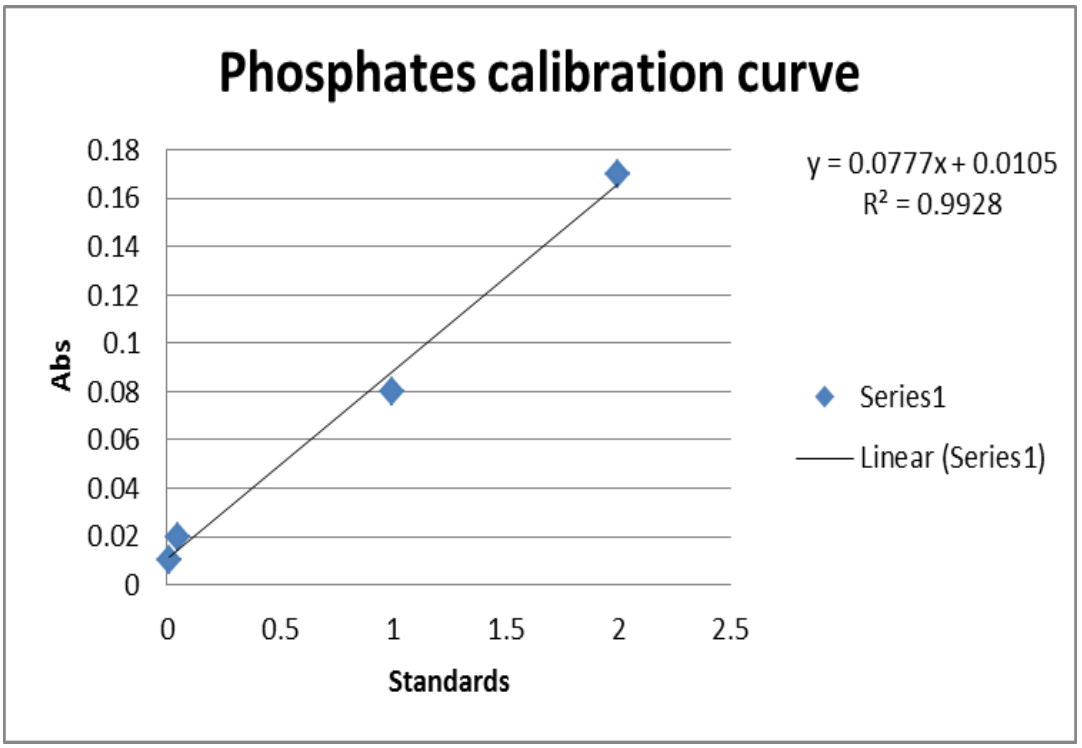
Variable	N	Mean	Std Dev	Sum	Minimum	Maximum
LENGTH	108	7.29333	1.16001	787.68000	5.08000	9.93000
WEIGHT	108	6.12000	2.67462	660.96000	2.04000	14.20000
SURVIVAL	108	14.96296	7.50816	1616	1.00000	45.00000
MORTALTY	108	5.37963	7.47796	581.00000	0	44.00000

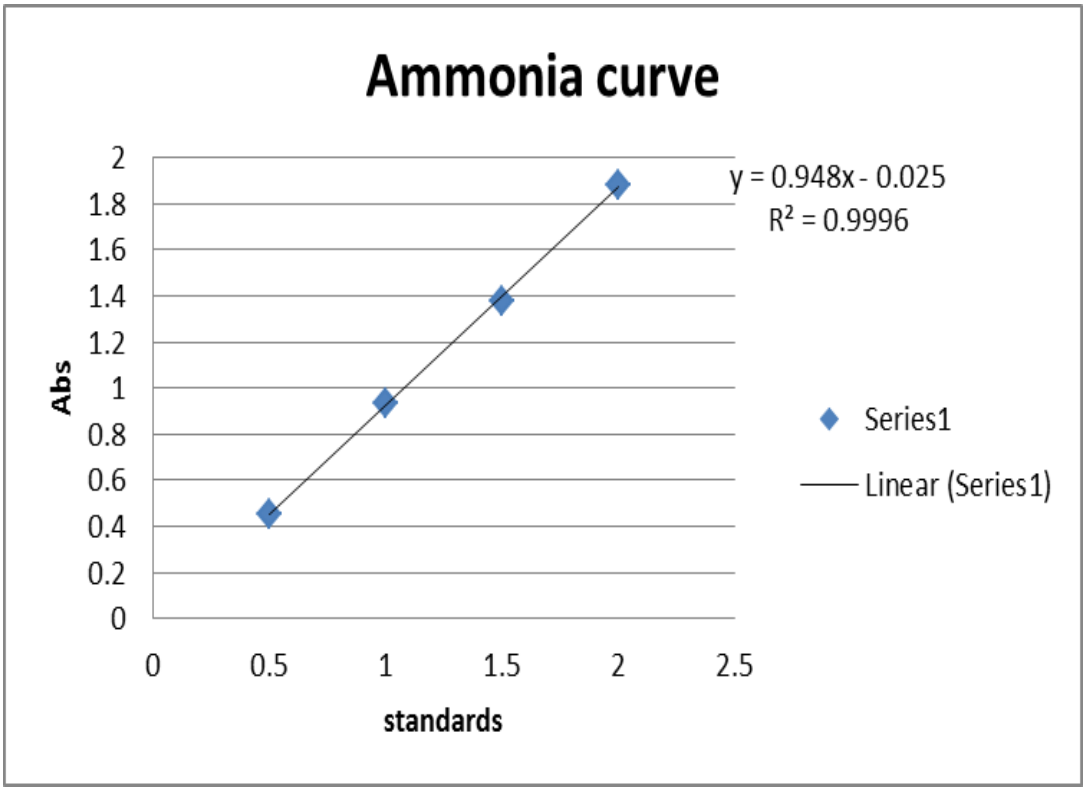
Pearson Correlation Coefficients, N = 108

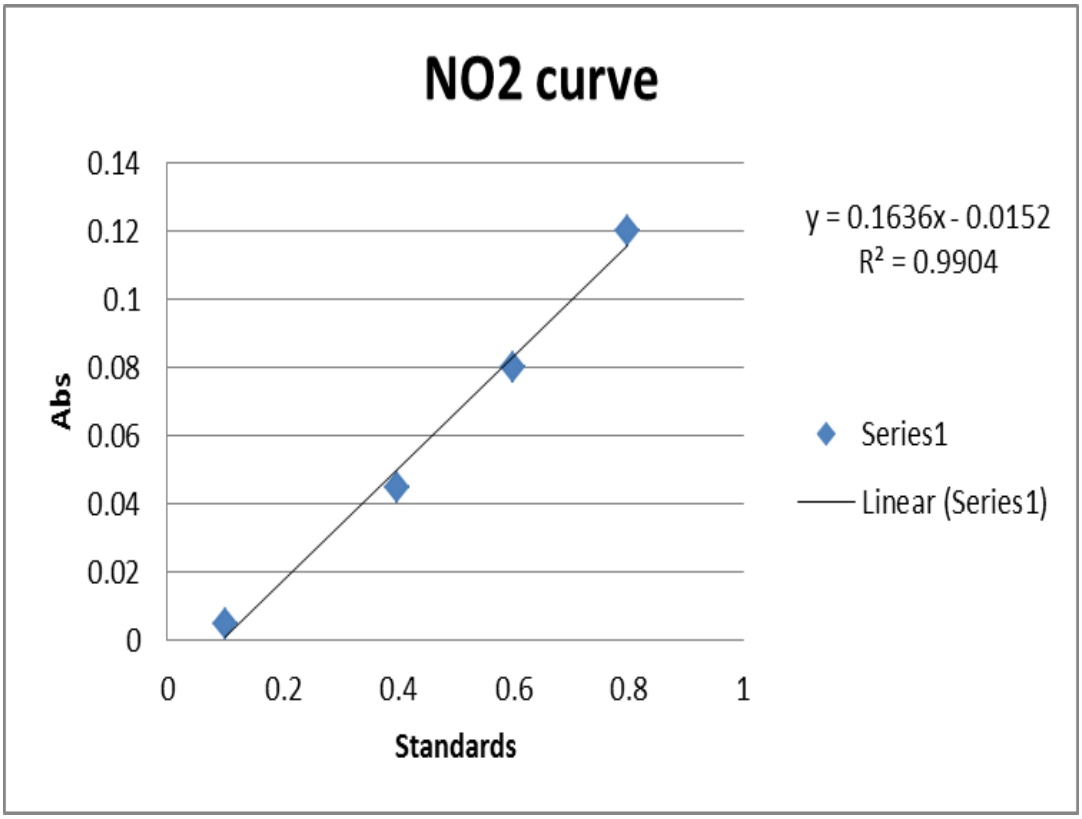
Prob > |r| under H0: Rho=0

	LENGTH	WEIGHT	SURVIVAL	MORTALTY
LENGTH	1.00000	0.97808	-0.65484	-0.53562
	<.0001	<.0001	<.0001	
WEIGHT	0.97808	1.00000	-0.65171	-0.45443
	<.0001	<.0001	<.0001	
SURVIVAL	-0.65484	-0.65171	1.00000	0.08981
	<.0001	<.0001	0.3553	
MORTALTY	-0.53562	-0.45443	0.08981	1.00000
	<.0001	<.0001	0.3553	

APPENDIX III: WATER QUALITY CALIBRATION CURVES






NO2 curve
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Abs
0
0.2
0.4
0.6
0.8
1
Standards
y = 0.1636x - 0.0152
R² = 0.9904
Series1
Linear (Series1)