# BIOLOGY AND AQUACULTURE POTENTIAL OF *Labeo victorianus* (Boulenger, 1901) UNDER DIFFERENT CULTURE SYSTEMS, DIETS AND STOCKING DENSITIES.

**BY**

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**AUGUST 2015**

## DECLARATION

**Declaration by the student**

This thesis is my original work and has not been presented for a degree in any other University. No part of this thesis may be reproduced without prior permission of the author and /or the University of Eldoret.

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## DEDICATIONS

I dedicate this work to my late parents Thomas Nyandega Orina and Veronica Moraa Orina.

## ABSTRACT

A study on the biology and aquaculture potential of *Labeo victorianus* as an aquaculture candidate was conducted at KMFRI Sagana and Sangoro Aquaculture Stations. There was a significant spawning time difference between induced female brooders and those not induced with ovaprim® but no significant difference ($F_{0.05,1,\ 118} = 1.27$; $P = 0.262$; $R^2 = 0.985$ ) between the two Ovaprim® dosages (0.2 and 0.5 ml $Kg^{-1}$). Temperature, unlike river source and ovaprim® dosage had significant effect ($F_{0.05,1,118} = 7879.6$; $P = 0.0001$; $R^2 = 0.927$ ) on the spawning time. Fecundity significantly ($F_{0.05,\ 3,\ 120} = 248.25$; $p = 0.0001$; $R^2 = 0.858$) depended on river source which was also related to fish length and weight. Thereafter, a simulated transport experiment involving broodstock and fingerling weighing 100 ±3.2g, 5 ±1 g and 0.5 ±0.2 g were packaged in 5 L polythene bags with 1.5 L water at 400, 800 and 1200 g $L^{-1}$, 120, 150 and 200 g $L^{-1}$ and 12, 15 and 20 g $L^{-1}$ respectively. Transportation durations within and across treatments had Un-ionized Ammonia increase with increased temperature and pH but remained within recommended ranges for warm water fish with no mortalities. A further 21 days aquaria and 28 days hapa experiments on 3 and 10 days old fry growth and survival were subjected to 3 stocking densities (100, 200 and 300 $m^{-3}$) and 2 diets (*Artemia*® and starter feed- 40% Crude Protein). Unlike in hapas, diet and stocking density had a significant effect on growth and survival in aquaria with stocking density 100 fed using *Artemia*® posing significantly better length and weight gain. A polyculture experiment on 150 $m^2$ ponds stocked at $3/m^3$ had tilapia and Labeo monoculture treatment ponds as controls while polyculture involved ratios 2:1 and 1:2 (*Labeo* : Tilapia). *L. victorianus* in treatment 2 (Lab2**,** Til1**)** had a significantly higher final weight (23.82± 8.05 g) as compared to treatment 3 (Lab1**,** Til2) whose final weight was 17.19± 5.05 g. Survival of polyculture treatment T3 had a significantly ($P$ 0.05) higher survival ( L= 49% and T= 87%) as compared to T2 (L= 31% and T= 69%). Finally, a 3 x 1 factorial design experiment (3 diets and 1 stocking density) of fingerlings weighing 11±1g was replicated in hapas at 22 $m^{-3}$ over 60 days. Fast sinking feed had a significantly higher Daily Weight Gain (0.17), Final Weight Gain (21.32 ±7.61g) and a lower Food Conversion Ratio (1.38) than floating feed. However, the coefficient of determination ($R^2$) was weak due to multicollinearity ($F_{0.05}$, 11, 847 = 6.52; $P = 0.0001$; $R^2 = 7.81$ %).The study findings therefore suggest that a temperature of 26 ±1°C and 0.2 ml $Kg^{-1}$ Ovaprim® dosage is optimal for *L. victorianus* breeding, while a temperature of 18-23°C is ideal for all sizes and load densities on 24 h transport duration. Finally *Labeo*-Tilapia polyculture reared using sinking feeds is recommended but with a further culture systems and diet test for optimal growth and survival to be realized at commercial level.

**TABLE OF CONTENTS**

**LIST OF TABLES**

## LIST OF FIGURES

**LIST OF PLATES**

## ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| °C | Degrees Celsius |
| ANOVA | Analysis of Variance |
| BOD | Biological Oxygen Demand |
| BW | Body Weight |
| CP | Crude Protein |
| DAP | Di-Ammonium Phosphate |
| DO | Dissolved Oxygen |
| DWG | Daily Weight Gain |
| ESP | Economic Stimulus Program |
| FAO | Food and Agriculture Organization of United Nations |
| FCR | Food Conversion Ratio |
| FFEPP | Fish Farming Enterprise Productivity Program |
| GL | Gut Length |
| GPS | Global Positioning System |
| KMFRI | Kenya Marine and Fisheries Research Institute |
| KAPAP | Kenya Agricultural Productivity and Agribusiness Program |
| NARDTC | National Aquaculture Research Development Training Centre |
| NFY | Net Fish Yield |
| RAS | Re-circulative Aquaculture System |
| RSD | Relative Standard Deviation |
| SEED | Fish Fry, Fingerlings and Post fingerlings |

| | |
|---|---|
| SGR | Specific Growth Rate |
| SSA | Sub Saharan Africa |
| TAN | Total Ammonia Nitrogen |
| UIA / $NH_3$ | Un-Ionized Ammonia |

**ACKNOWLEDGEMENT**

My sincere thanks go to my employer; Kenya Marine and Fisheries Research Institute for allowing me to pursue my studies, KAPAP for funding my research work and my supervisors Prof Joseph Rasowo and Prof Don Otieno for relentless guidance. My appreciations also to KMFRI Kisumu technical staff; Mr Zablon Awondo, Mr Daudi Ndere and Mr Caleb Ochiewo who worked tirelessly during broodstock collection from rivers Mara, Migori, Nyando and Yala.

I also wish to recognize the immense support received from Dr. Harrison Charo and all the KMFRI Sagana Technical staff (Mr Ishmael Oketch, Mr Peter Miruka, Mr Elijah Gichana, Mrs Florence Mbugua and Mr Nathan Okworo). Thanks to Mr Joseph Miriti the KMFRI Sagana driver who always ensured my field work logistics never failed.

Finally, I am humbled by the level of patience and understanding exercised by my dear wife, Mrs. Josephine Moraa, and sons Tonny Orina and Tom Orina throughout my studies and thesis write-up. They are a source of great inspiration for my success.

# CHAPTER ONE

# INTRODUCTION

## 1.1 Background of the study

Food security situation in the world previously recording declines over five decades (FAO, 2003) has reported progress towards attaining 2015 Millenium Development Goals (MDG) targets with marked differences across regions persisting thus requiring additional efforts (FAO, 2013). However, food insecurity in the developing countries has been worsened by declining food production efficiency coupled with increasing demands on food resources resulting in highest levels of undernourishment (FAO, 2013) . It is estimated that the world population is about 7.2 billion and it is projected to increase by almost one billion people within the next twelve years, reaching 8.1 and 9.6 billion in 2025 in 2050 ( World Population Prospects, 2012). The situation is grave in Sub-Saharan Africa (SSA) due to over-reliance on subsistence agriculture and erratic climatic conditions and as a consequence the region has been severely hit by chronic malnutrition (FAO, 2013). To remedy the situation, strenuous efforts aimed at increasing food supply have been considered as step gap measures in addressing the endemic food insecurity within these countries. In this front, fish is gaining prominence as an essential source of food to most rural communities.

Fish is an important source of energy, protein and a range of essential nutrients, accounting for about 17% of the global population's intake of animal protein. (FAO, 2014). In Africa where there are numerous aquatic resources, fish has always been obtained from the wild through capture fisheries initiatives. However, a foreseeable future problem from continued fishing is the depletion of natural stocks from the wild.

Therefore, current trends are geared towards aquaculture production to bridge the current food shortage gaps (Ngugi *et al*., 2003; Ngugi and Manyala, 2007).

Aquaculture, despite being a new science in the developing countries, is viewed as an alternative of reducing the widening gap between fish demand and its supply. Global aquaculture production has grown rapidly during the past four decades thereby contributing significant quantities of fish for human consumption. Yet in the African continent Nigeria and Egypt produce over 50% of the total farmed fish and therefore dominating the continents aquaculture production. As yet, many countries in Sub-Saharan Africa including Kenya have the potential to develop aquaculture but they continue to produce negligible quantities of fish. In 2012, SSA contributed a paltry 0.68 % of the world's aquaculture production against Asia's 88.39% (FAO, 2014). Aquaculture development in Kenya dates back to the 1920s but remained at subsistence level until recently (FAO, 2005; Musa *et al*., 2012; ACPFish II 2013) . Serious attempts to introduce fish farming in Kenya were made in the early 1960s with the main objective of producing the much-needed animal protein for the rural populations. Since then, fish culture has not made much progress and has in many cases even declined resulting in the abandonment of fishponds by discouraged farmers (FAO, 2005).

Currently, the main culture species are Nile tilapia (*Oreochromis niloticus*), African catfish (*Clarias gariepinus*) and Common carp (*Cyprinus carpio*) (Ngugi *et al*., 2003; Ngugi and Manyala, 2007). Trout is temperature restricted thus only cultured at very low temperatures mainly in the Mt. Kenya region. *Labeo victorianus* also referred to as ningu is one among the many Labeins in the genus *Labeo* that is limited to Lake Victoria basin (Fryer and Whitehead, 1959). 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).

*L. victorianus* just like other labeins (Reid, 1985; Skelton *et al*., 1991; Weyl and Booth, 1999) is potamodromous and moves into affluent rivers to spawn in vegetated flooded pools during the rainy seasons (Fryer and Whitehead, 1959). However, due to its delicacy in addition to its predictable migratory habits, *L. victorianus* faced considerable fishing pressure to meet the domestic market demand resulting in tremendous population decline. In normal conditions, it is induced to breed in captivity and with good induction techniques, the fish spawn in large numbers (Rutaisire and Booth, 2004). However there are considerable challenges in its culture including knowledge on spawning latency, egg fertilization and hatchability rates, low growth and high mortalities. Light and temperature have been used to manipulate the growth and reproductive performance of many fish species including *C. gariepinus* and *Labeo rohita* (Munro, 1990; Das *et al*., 2005; Kausar and Salim., 2006; Rama *et al*., 2013). Temperature of 28°C has been found to favour the growth of many warm water species while light is species specific. Other than environmental manipulation, fish have been physiologically manipulated to enhance productivity. The successful use of Ovaprim® in inducing ovulation in cyprinid fish is well documented (Pandey and Singh 1997; Mijkherjee *et al*., 2002; Sharma and Singh, 2002; Szabo, 2003; Sarkar *et al*., 2004) enabling enhanced production success.

Due to high local demand stemming from the Fish Farming Enterprise Productivity Program (FFEPP), farmers have recently created a keen interest in culturing *L. victorianus* with no immediate source for quality fingerlings. This has led to demand for

brooders from the wild by fish hatcheries with the aim of meeting the current demand. However, broodstock acquisition from the wild and eventual supply of fingerlings to grow-out farms and other markets will involve transportation (Wyne and Wurts, 2011).

Live fish transportation is one of the most challenging aspects of fish culture resulting from poor water exchange, reduced oxygen, increased suspended solids, ammonia and carbon dioxide accumulation (Emmanuel *et al*., 2013; Islam. and Hossain, 2013). Transport of fish in Kenya is by use of open tanks and oxygenated polythene bags. However, use of oxygenated polythene bags is the most preferred mode of fingerling and broodstock transportation. Other findings (Tang *et al*., 2009; Ashley, 2007; Berka, 1986) indicate that other than water quality, transportation success depends on density and size of fish, fish physical condition, handling time, temperature, capture stress response, packaging, transportation and unpacking for stocking. Transport duration and load density are factors that are closely associated with ammonia, carbon dioxide and nitrogenous waste build up during live fish transportation under a closed mode of transport (Berka, 1986; Amend *et al*., 1982). Ammonia a major fish end product of protein break down is likely to buildup in a fish holding water facility due to decomposition of organic matter while free ammonia($NH_3$) is dependent on pH and temperature (Durborow *et al*., 1997; Das *et al*., 2005; EL-Sherif and EL-Feky, 2008).

Cultured fish growth is dependent on many factors both externally and internally (body system). These range from water quality, food availability, temperature, dissolved oxygen levels, predator prey relationship, digestive system among others. Thus the success of fish culture depends to a large extent on adequate information on nutrient requirements, especially dietary protein, which is the most expensive component in artificial diets

(Mukherjee *et al*., 2011). Several studies have been carried out to evaluate the effect of feeding frequency on growth, survival, feed intake, body composition among other aspects of fish development in different species (Abid and Salim., 2004; Gokcek *et al*., 2008 ; Biswas *et al*., 2006). Specific studies on the culture of Labeins in various parts of the world indicate great potential (Mohapatra *et al*., 2003; Sau *et al*., 2004; Rahman *et al*., 2006; Chakraborty and Mizra, 2009; Narejo *et al*., 2010). Unlike Asia where a lot of progress has been made in mono and polyculture of carps among them *Labeo rohita* (rohu) a delicious and prestigious fish among other Indian major carps (FAO. 2000; Khan *et al*., 2003, Abid and Salim, 2004, Khan *et al*., 2004), Kenya like many other African countries has predominantly cultured *O. niloticus* (Nile Tilapia) and *C. gariepinus* (African catfish). According to FAO (1994), many indigenous fish species are preferred by consumers but have not yet been fully tested as candidate species for aquaculture. *L. victorianus* is among the cyprinids indigenous to Lake Victoria and its tributaries yet to be cultured despite its consumer preference.

**1.2 Statement of the problem**

The migratory behavior of breeding populations coupled with the fishe's delicacy to the local communities has over time resulted in overfishing and eventual decline of *L. victorianus*. By 1969, the imminent collapse of *L. victorianus* fishery in Eastern Africa prompted scientists to recommend the prevention of fishing during spawning migrations (Cadwalladr, 1965). Other aspects leading to *L. victorianus's* decline include ecosystem degradation, overfishing, competition and predation by introduced species (Cadwallar, 1965; Balirwa and Bugenyi, 1980; Ogutu-Ohwayo, 1990). This has resulted to wild stock declines and therefore a limited variety of indigenous fish species available in the market. To forestall the loss and possible extinction of *L. victorianus* and other commercially important fishery of L. Victoria currently under threat, strenuous efforts should be put into research on enhancing fish production through aquaculture intensification, provision of quality seed and feed, high levels of pond management, maintaining good fish health and introduction of a variety of commercially important indigenous fish species to meet consumer preference and ease capture fisheries pressures. Despite the existing local demand for other indigenous species, there has hitherto been an overemphasis on culture of *Oreochromis niloticus* and *Clarias gariepinus*. However the introduction of *L. victorianus,* an indigenous species known to feed on live feeds at early stages of development and later change to phytoplankton combination with live feeds requires a clear understanding of the handling stress response, feeding and breeding habits in captivity to enable its sustainable production for the market.

### 1.3 Justification of the study

*L. victorianus* though known to have a wide distribution throughout the L. Victoria drainage faces a localized decline. Though considered insufficient to threaten the entire population, effects of climate change resulting in prolonged dry spells coupled use of wrong fishing gear and destruction of breeding grounds may accelerate inbreeding among the localised populations. Research on the aquaculture potential of *L. victorianus* under different culture systems, diets and stocking densities is to provide the aquaculture industry with information on the fish's response to confinement. Successful breeding will enable mass production of *L. victorianus* fingerlings at hatchery level to support restocking of wild populations as well as provide seed for grow-out to aquaculture farmers. The culturing of *L. victorianus* will reduce pressure on capture fisheries, alleviate poverty and create employment at various levels of aquaculture value chain in the country.

### 1.4 Objectives of the Study

#### 1.4.1 Overall objective

To determine the effect of different culture systems, diets and stocking densities on the biology and culture potential of *L. victorianus.*

#### 1.4.2 Specific objectives

The following are the specific objectives of the study:

i) To determine the optimal breeding conditions for *L. victorianus* at different temperatures and ovaprim dosage.

ii) To determine the optimal transportation densities for *L. victorianus* brooders, post fingerlings and fingerlings.

iii) To establish the optimal combination of diet and stocking density on growth and survival of *L. victorianus* fry.

iv) To determine the growth performance of *L. victorianus* under poly and monoculture systems in earthen ponds.

v) To determine the effect of floating and sinking formulated feeds against natural pond productivity on growth of *L. victorianus.*

### 1.4.3 Hypotheses

i) Temperature and ovaprim dosage have no effect on spawning latency, egg fertilization, hatching rates and fry survival of *L. victorianus.*

ii) Density and fish size has no effect on the survival of *L. victorianus* during transportation.

iii) Diet and stocking density has no effect on *L victorianus* fry growth and survival.

iv) There is no growth difference between polyculture and monoculture of *L. victorianus.*

v) There is no significant growth difference on *L. victorianus* fed on either sinking feeds, floating feeds or natural pond productivity.

# CHAPTER TWO

# LITERATURE REVIEW

## 2.1 Taxonomy and Systematics of *L. victorianus*

The family Cyprinidae, which includes 2,010 species classified in 210 genera, is one of the most important groups of freshwater fish found in North America, Africa and Eurasia (Nelson, 2006). The genus *Labeo* results from events that separated the old-world tropics from North America and Europe (Reid, 1985). However, before the separation *Labeo* was restricted to Africa and Asia. The genus is widely distributed, with at least 80 species being found on the African continent where it contributes at least 16.4% of the African cyprinid fauna (Skelton *et al*., 1991).

Cyprinid fishes of the genus *Labeo* have been divided into two groups on the basis of the anatomy of the inner surface of their lips which are either papillate or plicate (Tshibwabwa and Teugels, 1995). *L. victorianus* locally known as ningu, is limited in its distribution to the Lake Victoria basin (Greenwood, 1966)**.** *L. victorianus* is known to occupy shallow inshore waters and influent rivers of Lake Victoria. It spends most of its life span in the lake, but spawns in flooded grassland beside both permanent and temporary rivers and streams (Witte and Winter, 1995; Rutaisire and Booth, 2004).

## 2.2 Habitat Dynamics

Lake Victoria, whose 68 000 $km^2$ area is shared between Uganda (45%), Tanzania (49%) and Kenya (6%), is the second-largest body of freshwater in the world by area (after Lake Superior) and home to *L. victorianus* among other fish species. *L. victorianus* is also known to occupy Lake Katwe, Lake Kubigena, Lake Kyoga, the upper and middle Akagera system and the Victoria Nile.

The species *L. victorianus* (Boulenger, 1901), locally known as 'ningu', is limited in its distribution to the Lake Victoria basin and displays a potamodrometic behavior thus moving into affluent rivers to spawn in vegetated flooded pools on the onset of rains (Fryer and Whitehead, 1959; Cadwallar, 1965; Greenwood, 1966; Reid, 1985; Skelton *et al*., 1991; Ochumba and Manyala, 1992; Weyl and Booth, 1999). However, since the introduction of the Nile Perch (*Lates niloticus*) to L. victoria, *L. victorianus* extent of occurrence (EOO) has experienced a decline from a 20 m depth range observed during the 1969–71 survey (Kudhongania and Cordone, 1974) to a 10 m range during the 1997–99 surveys (Okaranon *et al*., 1999, Getabu and Nyaundi 1999, Mkumbo and Ezekiel 1999) with no recent documented EOO trends. *L. victorianus* is now very rare with occasionally encounters in the shallow inshore close to affluent rivers and streams.

**2.3 Food, Feeding Habits and Fish Nutrition of *L. victorianus***

Cyprinids in the wild are known to feed at all trophic levels; higher plants, phytoplankton, zooplankton, zoobenthos, bacteria and attached detritus growing on other fish (Witte and de Winter 1995; Froese and Pauly, 2002; Owori-Wadunde, 2009). They also express seasonal variation on their feeding habits depending on nutritional requirements at varying life stages (Corilee, *et al*., 2012) Their larvae feed on zooplankton at early stages of their lifecycle, but as they grow, they gradually shift from a predominantly animal diet to a more plant one, feeding on detritus, phytoplankton and submerged vegetation (Owori-Wadunde, 2005).

However in aquaculture, feed representing 40-50% of production costs is a vital component and protein remains its most expensive constituent (Craig and Helfrich, 2002;

Munguti and Charo-Karisa, 2011; Muzzammil *et al*., 2013). Thus the success of culturing *L. victorianus* just like other aquaculture species depends to a large extent on adequate information on nutrient requirements, especially dietary protein, which is the most expensive component in artificial diets (Davies and Goivea, 2010). Feeds and feedstuffs contain nutrients and energy sources essential for fish growth, reproduction, and health. Deficiencies of these substances can reduce growth rates or lead to diseases, and, in some cases, excesses can cause a reduction in growth rate. Dietary requirements can be established for energy, protein and amino acids, lipids, minerals, and vitamins (El-Sayed and Teshima, 1992).

**2.4 Reproductive Behaviour and Fecundity of *L. victorianus***

Fecundity is species dependent and can also be affected by nutritional aspects, fish size (length and weight) and seasonality (Alam and Pathak, 2010). *L. victorianus* just like other members of the genus (Reid, 1985; Skelton *et al*., 1991; Weyl and Booth, 1999) is potamodromous and moves into affluent rivers to spawn in vegetated flooded pools (Fryer and Whitehead, 1959). The term fecundity means the egg laying capacity of a fish or the number of ripe eggs produced by a fish per spawning season. Fecundity is species dependent and can also be affected by nutritional aspects, fish size (length and weight) and seasonality (Alam and Pathak, 2010). This aspect helps to explain the variation of population as well as making efforts to increasing fish yields through aquaculture and management of wild stocks.

**2.5 Induced Breeding of *L. victorianus***

According to Munro (1990), fish reproductive processes are controlled by environmental cues as well as by endogenous biological rhythms. The latter is mediated through actions of various hormones along the brain hypothalamus-pituitary-gonad axis. Naturally environmental stimuli are detected and relayed to the brain resulting in a release of hormones and neurotransmitters that regulate ovulation (Yaron, 1995; Peter and Yu, 1997).

To meet the high fish demand by the ever increasing world human population, there is need to manipulate a cultured fish's reproductive system. Manipulation of a fish's reproductive system under culture conditions requires an understanding of natural spawning patterns and other influential factors (Rutasire, 2003). To ensure intensive fingerling production of a given species in controlled conditions, the mastery of artificial reproduction techniques is key. Hypophysation by use of an exogenous administration of a pituitary extract has been a practice until when ovaprim (sGnRH-A) came into the market. Ovaprim usage has been widely tested with considerable success on other *Labeins* (Montchowui *et al*., 2011; Akhtar and Bhuiyan , 2012). The reproductive biology of *L. victorianus* is still largely unknown. Other than an overview of *L. victorianus* breeding biology and ecology (Cadwalladr, 1965; Rutasire, 2003; Rutaisire and Booth, 2004), information on fecundity, ovaprim dosages, fertilization rates, hatching rates, survival, optimal breeding environment of broodstock from different rivers in Kenya is not available.

### 2.6 *L. victorianus* Performance under Different Culture Systems and Diets

Supplementary feeds are an important source for supporting fish production considering that confined fish have no access to a variety of natural food which is a source of all required nutrients. Supplementary feeds enhance survival, growth and production performance. Several studies have been carried out to evaluate the effect of feeding frequency on growth, survival, feed intake, body composition among other aspects of fish development in different species of *Labeo* ( Msiska, 1990; Khan *et al*., 2003; Chakraborty and Mizra, 2009; Mukherjee *et al*., 2011; Montchowui *et al*., 2011; Ahmad *et al*., 2013; Mokoro *et al*., 2013).

Specific studies on the culture of Labeins in various parts of the world indicate great potential (Erfanullah and Jafri, 1995; Hasan *et al*., 1997; Sau *et al*., 2004; Rhman *et al*., 2006; Chakraborty, *et al*., 2007; Mokoro *et al*., 2013). Unlike Asia where a lot of progress has been made in culturing of carps among them *Labeo rohita* (rohu) a delicacy and prestigious fish among other Indian major carps (FAO. 2000; Khan, *et al*., 2003, Abid and Salim, 2004, Khan, *et al*., 2004), Kenya like many other African countries is yet to exploit the potential of available commercial important fish species including *L. victorianus*. According to FAO (1994), many indigenous fish species are preferred by consumers but have not yet been fully tested as candidate species for aquaculture.

*L. victorianus* is among the cyprinids indigenous to L. Victoria and its tributaries yet to be cultured despite its consumer preference. There is no information on the culture potential of *L. victorianus* thus limiting interest on its culture. Culture studies conducted extensively on other *Labeins* indicate great potential (Rutaisire and Booth, 2004; Sau *et al.*, 2004; Rahman *et al.*, 2006; Chakraborty and Mizra, 2009).However, there is paucity

of information on the culture potential, feeding and nutritional requirements of *L. victorianus* in captivity.

# CHAPTER THREE

# METHODOLOGY

## 3.1 Study Area

The studies were carried out between June 2012 and April 2014 at the KMFRI Sangoro and Sagana Aquaculture Research Stations (Fig 3.0). KMFRI Sagana, within Kirinyaga County, is located 2 km from Sagana township and 105 km Northeast of Nairobi City. It lies at latitudes $0^0$19'S and $37^0$12'E. and an altitude of 1231 metres above mean sea level (Liti *et al*., 2005). The research station covers an area of approximately 59 hectares of which 20 hectares is under fishponds which 72 (150$m^2$) are research ponds.. The main agricultural activities in Kirinyaga County is farming of coffee, rice, banana, mango and maize. Sagana area has river Ragati as its main source of water which eventually drains into Tana River. KMFRI Sangoro is located in Kisumu county, Nyakach sub county 70 km off Kisumu city to the South. It lies at latitudes 0340N 58.410E; 0420N 50.440S at an altitude of 1140 metres above sea level. The research station depends on Sondu - Miriu river for water which is pumped to a major holding facility situated on a higher ground within the station.

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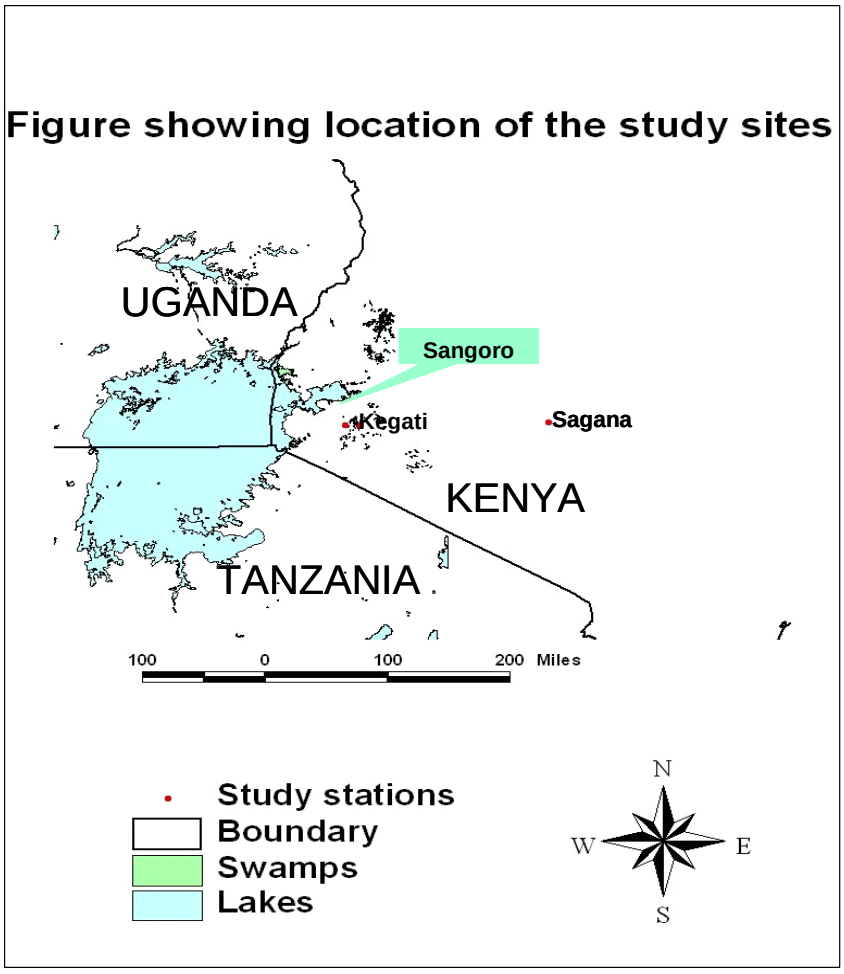


**Figure 3.0: KMFRI Sangoro and Sagana Aquaculture Research Stations Study Sites. (Source: Author, 2014)**

The two study sites were selected due to their similarity in climatic conditions and availability of infrastructural facilities and space that support the research. Rivers Mara and Migori located on the South Rift and Rivers Nyando and Yala located in Central Nyanza were the four main sources of L. victorianus broodstock. Every year, Mara and Migori rivers experience long rains between March and December. Long rains occur

between March to end of May and short rains occur in the months of September to December at the lake zone to western Kenya (Kenya Met Dept,2013).

### 3.2 Identification of Breeding Grounds

A preliminary survey on possible breeding grounds for *L. victorianus* was carried out at the Mara, Migori, Nyando and Yala rivers. The identified broodstock collection points in the four rivers were marked using a GPS for ease of location during broodstock collection. The GPS coordinates were generated using an android mobile phone (Samsung GT-S5303) and the information synchronised to the central server system. The generated server GPS coordinates information was then used to generate a map indicating the broodstock collection sites from the four target rivers (Fig 3.1). The time for collection of the ripe fish was predicted based on cyclic variations of gonadosomatic index and the prevalence of oocytes in advanced stages of development (Rutaisire, 2003).

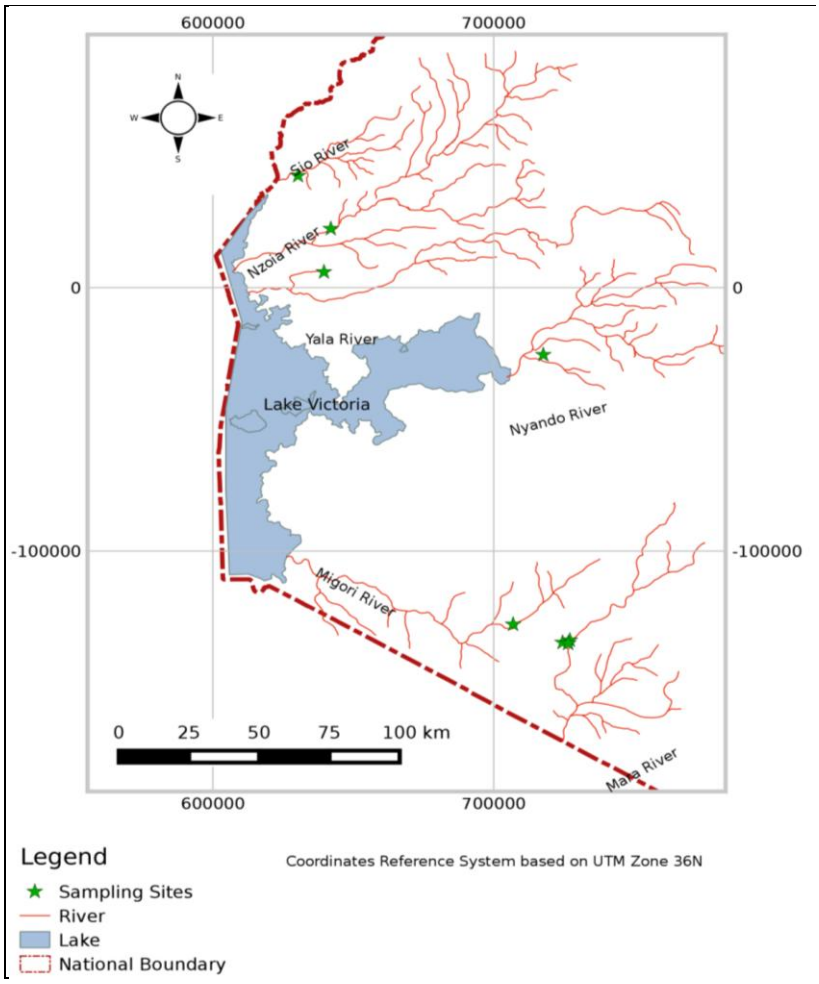


**Figure 3.1: Lake Victoria Kenya waters showing *L. victorianus* broodstock collection sites. (Source: Author, 2014)**

### 3.3 Broodstock Collection and Transportation to Experimentation Stations

A number of factors were taken into consideration during broodstock selection. These included body weight, disease free, no body injuries and a sex ratio of (2:1) male: female. Mature male and gravid female brooders were identified by gently squeezing the belly from the head towards the anal end. Mature males released milt upon gently

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squeezing, while gravid females released golden green eggs. Other ways used to identify gravid brooders was by use of secondary sex traits (Plate 3.0). Just before spawning, females had soft, swollen bellies due to egg development. Prior to spawning, gravid female were identified by their swollen bellies and a pulsating swollen genitalia a phenomenon coupled with high gonadosomatic indices and a dominance of tertiary yolk vesicle oocytes and fresh post uvulatory follicles (Rutaisire, 2003, Rutaisire and Booth 2004).

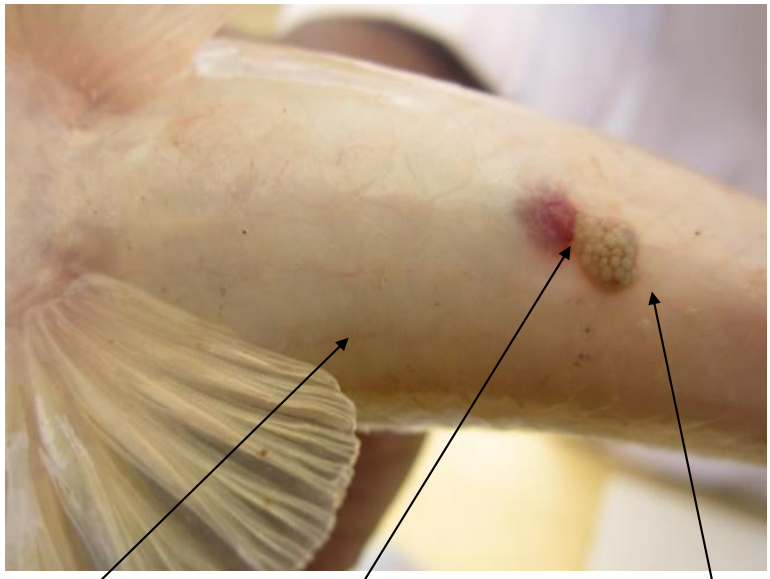


**Plate 3.0: Gravid female releasing eggs upon gentle squeeze. (Source: Author, 2014)**

It is based on this foundational information that 240 broods were collected in the months of July, August and September (2012) by use of an electro-fisher from various points of the four target rivers; Mara (S 01° 13.425' E 035° 02.177' ; S 01° 12.794' E 035° 02.502'; S 01° 13.266'E 035° 01.098'), Migori (S 01° 09.534' E 034° 51.615'), Nyando

(S 00° 14.014' E 034° 57.384') and Yala (S 00° 03.029' E 034° 15.295'). Prior to transportation, brooders were conditioned overnight in a 5x5x5m specially constructed floating cages set within the rivers' collection points after which they were packaged in 5L oxygenated polythene bags filled with 1.5 L of water. To reduce ammonia toxicity effect, 5 g of salt (NaCl, food grade granulated salt) was added to each transportation bag (Gomez *et al*., 1999; Oyoo-Okoth *et al*., 2011).. Selected brooders were transported at night (to avoid rise in temperature) to KMFRI Sagana Aquaculture Research Station hatchery. The brooders were packaged in oxygenated 5 L polythene bags.

**3.4 Experiment on *A*rtificial Breeding**

The study was conducted at KMFRI Sagana Aquaculture Research Station hatchery. A total of 576 brooders (192 Females: 384 Males) due for spawning were harvested using a seine net from 4 (150 $m^2$) broodstock rearing research ponds based on river source. Harvested brooders were quickly transferred to buckets with fresh water and immediately transferred to 8 well aerated hatchery holding tanks measuring 1m x 1m x 3m (depth x width x length) for overnight acclimatization. The acclimatization partly allowed for gut evacuation which limited ammonia build up due to feacal matter from the brooders. Broodstock holding tanks were covered over the acclimatization period (24 h) to avoid jumping out of brooders.

Prior to the start of the experiment, selected gravid female and mature male brooders were collected from the holding tanks at the hatchery using a scoop net 1 inch eyed mesh, weighed using a Sartorius Analytical Balance and their length measurements taken using a 60 cm long measuring board.

By use of a wet towel, female brooders were held with their heads covered to calm them as they got an intramuscular hormone injection (0.2 or 0.5 ml) of Ovaprim® using a 5ml syringe. The injection was administered close to the dorsal fin on the anterior position of the fish. Hormone was released and needle withdrawn gently followed with a gentle rub on the injected area. This process lasted a maximum of one minute to avoid keeping the brooder out of water for a longer time. The induced female brooders were then paired at a ratio of 2♂: 1♀ with ripe male brooders have been introduced to the incubating facility an hour earlier. The incubating unit was then covered with reed mats, fixed with aerators, flow through and submersible heaters depending on the treatment (Plate 3.1).


**Plate 3.1: Aquaria egg incubators for *L. victorianus* from the four rivers. (Source: Author, 2014)**

The experiment used a 3 x 2 x 4 factorial design (3 temperatures x 2 Ovaprim® dosages x 4 populations) with 72 treatments (3 replicates per treatment) in aquaria flow through system. Replicates from each river were subjected to 22± 1°C, 26± 1°C and a control

(ambient room temp-17± 3°C) and two dosages of Ovaprim® (0.2 and 0.5 ml $kg^{-1}$ of fish) of female brooders. Spawning and hatching latency period based on temperature and Ovaprim® dosage was assessed for all the populations from the four rivers. Relative fecundity and fertilization levels were determined by dividing the average weight of one egg against the weight lost after spawning. The fertilization rate of eggs was determined at 2 h after spawning had occurred by randomly taking three samples of approximately 100 eggs in a petri dish. The fertilized eggs (which had an intact nucleus) were counted and this was used for calculating the fertilization percentage. The duration taken from time of inducement to spawning time was also recorded. Hatchability rates were recorded by noting the time of spawning and time of first appearance of hatchlings. Fry survival was calculated by subtracting mortality from initial fry population for each river at close of 3 weeks. Total fry population spawned was calculated by scooping 1 L of incubation unit water with fry and performing a physical count using a 2.5 mm siphoning rubber pipe. This was repeated three times and a final population estimation calculated based on the incubation water volume. In all experiments, water quality parameters; DO, pH and temperature were determined using Hanna Multi-parameter HI 9829. Un-ionized ammonia ($NH_3$) was calculated upon determining levels of pH, temperature and total ammonia nitrogen (TAN). TAN in all experiments was measured by use of ammonia salicylate method as adapted from APHA-AWWA-WPCF (1998).

### 3.5 Experiment on Seed and Broodstock Transport

The study was conducted at KMFRI Sagana Aquaculture Research Station hatchery between January and February 2013. By use of an electro-fisher, mature male and gravid female brooders were collected from two sites along the southern part of Mara river (S

01° 13.425’ E 035° 02.177’ ; S 01° 12.794’ E 035° 02.502’). After capture, fish were packaged into oxygenated polythene bags and transported to the KMFRI Sagana Aquaculture Research Station hatchery. Gravid female brooders were induced using Ovaprim® hormone at 0.2 ml $kg^{-1}$ and paired with ripe males overnight (2♂: 1♀) for spawning. Spawned fry were reared using shell free *Artemia*® for 4 weeks and weaned using 40% CP starter feed in 3 m x 3 m x 1 m liner above ground box units. Brooders used for spawning and post fingerlings and fingerlings spawned at different times were used to set up a simulated transport experiment.

At the start of the experiment, *L. victorianus* brooders, post fingerlings and fingerlings of average weight 100± 3.2 g, 5± 1 g and 0.5± 0.2 g respectively were harvested by use of a seine net and acclimatized by congregating them in flow through concrete tanks for 24 hrs. A uniform length (60 cm) roll of fish packaging polythene material was cut to make a 5 L capacity packaging bag and labeled according to anticipated fish size and load density. Fingerlings and brooders were packaged in the oxygenated 5 L polythene bags filled with 1.5 L of water and 5 g of NaCl added to reduce ammonia toxicity effect (Oyoo-Okoth *et al*., 2011). Fingerling and post fingerling packaging was done at load densities of 12, 15 and 20 $gL^{-1}$ and 120, 150 and 200 g $L^{-1}$ respectively, Brooders were packaged at 400, 800 and 1200 g $L^{-1}$. Each bag had a 15 cm long ¼ inch air pipe extending in and out of the bag with the outside end folded and tied tight with an elastic rubber to ensure it was air tight. A 24 hr observation and recording was performed on mortality, pH, temperature, total ammonia, free ammonia, and DO at 0, 6, 12, 18 and 24 hrs intervals. At each water quality observation interval, 10 ml of water from each bag was drawn upon by loosening the elastic knot and ensuring the inner end was immersed

in water. The outer end of water drawing pipe was placed at edge of collecting beaker (10 ml) to avoid trapping atmospheric Oxygen. Simulation was achieved by manual shaking of bags every 20 minutes over the experiment period to mimic vehicle movement resulting in water mixing. At the end of the transportation, the three fish batches were each acclimatized and held in hapas and mortality monitored over a period of 7 days.

Brooders were subjected to a 3 x 5 factorial design (3 load densities and 5 time durations) with 15 treatments (3 replicates per treatment). Post fingerlings and fingerlings experiment used a 5 x 3 x 2 factorial design (5 time durations, 3 load densities and 2 fingerling sizes) with 45 treatments (3 replicates per treatment).

### 3.6 Effect of Stocking Density and Diet on Growth and Survival of *L victorianus*

#### 3.6.1 Aquaria experiment

A study on the effect of stocking density and diet on growth and survival of *L. victorianus* in aquaria was conducted at the KMFRI Sagana Aquaculture Research Station hatchery between March and April, 2014 . Brooders of average weight 300± 3.2 g were collected from Mara river (S 01° 13.425' E 035° 02.177'; S 01° 12.794' E 035° 02.502') by use of an electro-fisher. To avoid transporting immature or spent fish from the rivers, the collected fish were subjected to standard identification procedures for *Labeine* fish maturity status which included a gentle squeeze on the belly posterior to anterior end in addition to physical observation for maturity (protruding genital papilla, dilated and bulging abdomen). Upon gentle squeeze, mature male brooders produced milt while gravid female brooders produced golden green eggs. The selected 30 (10♀ : 20♂) brooders were transported overnight to KMFRI Sagana hatchery in oxygen pressurized

polythene bags. To reduce ammonia toxicity effect during transportation, 5 g of NaCl was added.

At the hatchery, brooders were acclimatized in well aerated flow through tanks (1 m x 1 m x 3 m) for 12 hrs before start of the experiment . Gravid female were induced by an intramuscular hormonal injection of 0.2 ml $kg^{-1}$ Ovaprim® dosage and paired with mature males at a ratio of 2: 1 (male: female) in flow through $1m^3$ (1m x 1m x1m) PVC tanks. By use of a one inch eyed scoop net, spent brooders were carefully removed from tanks upon spawning and transferred to a 150 $m^2$ earthen recovery research pond. Upon hatching of fertilized eggs, unfertilized eggs were siphoned out to ensure good water quality was maintained.

A 3 x 2 factorial design experiment (3 stocking densities and 2 diets) was used on 10 L capacity aquaria to grow 3 day old fry for 21 days. Fry were weighed (wet weight) to the nearest 0.1mg using a Sartorius Analytical Balance (readability 0.1 mg). Fry of initial weight 0.08± 0.003 mg and length 5.3± 0.07 mm were stocked at 100, 200 and 300/$m^3$ in 18 aquaria (10 L) fitted to a flow through system. A sample of 30 fry were subjected to length and weight data collection every 7 days. Length was measured using a transparent plastic ruler and weights were measured using a Sartorius Analytical Balance (readability 0.0001 mg). Fry length was recorded by placing each fry on the transparent plastic ruler with a drop of water to keep it alive. Water quality parameters in both aquaria and hapa experiments were measured twice a day (0600 h and 1600 h) using Hanna Multi-parameter HI 9829 and any mortalities recorded during each feeding session. Fry were fed to satiation using commercial shell free *Artemia*® and 40% CP formulated starter

feed (Table 3.0). At end of 3 weeks experiment period, all fry were harvested, counted to calculate survival by subtracting final number of fry from total number stocked.

**Table 3.0: Formulated starter feed (40 % CP) proximate composition.**

| Ingredient | % Protein | % Fiber | % Lipids | % Ash | % Carbohydrate | Moisture |
|---|---|---|---|---|---|---|
| Caridina nilotica | 25.3 | 2.4 | 0.83 | 1.2 | - | 9 |
| Cotton seed cake | 12.6 | 11.4 | 2.988 | 5.0 | 4.464 | 11 |
| Wheat Bran | 2.04 | 0.6 | 0.612 | 0.24 | 12.053 | 9 |
| Vitamin premix/mineral | 0.06 | - | - | - | - | - |
| ***Artemia***® | 54 | 6 | 9 | 4 | | 8 |

*Shell free *Artemia*® is a product of Ocean Nutrition™

### 3.6.2 Hapa Experiment

Prior to setting up the experiment, a 2400$m^2$ production pond was drained and left to dry for 2 weeks before treating it with agricultural lime at 200g/$m^2$. The pond was then filled with screened river water and fertilized with chicken manure at 8kg/100$m^2$. It was then left to fertilize for 2 weeks before stocking.

A 3 x 2 factorial design experiment (3 stocking densities and 2 diets) was used in 18 hapas. Fry length and weight were recorded as indicated in the aquaria experiment before stocking at 100, 200 and 300/$m^3$ in 1 mm eyed hapas measuring 1 $m^3$. Fry were fed to satiation using commercial shell free *Artemia*® and formulated starter feed (40% CP) as administered in aquaria experiment (Table 3.0).

At the end of 28 days experiment period, all fry were harvested, final length-weight data of the entire crop recorded and survival determined by subtracting final number of fry from total initial number stocked.

### 3.7 Polyculture *of L. victorianus* and *O. niloticus* in Earthen Ponds

A six month polyculture experiment was conducted at KMFRI Sagana Aquaculture Research Station research ponds (150 $m^2$) between May and November 2013. Fry were reared using shell free *Artemia*® for 4 weeks then transferred them to nursery pond where they were reared to average weight 1.3± 0.1 g using formulated feed (30% CP).

A total of twelve research ponds measuring 10 m x 15 m x 1.2 m were drained and left to dry for 2 weeks before treating them with agricultural lime at a rate of 200 g $m^{-2}$. After 3 days post treatment, ponds were filled with screened river water and fertilized using DAP (Di-Ammonium Phosphate) and Urea at the rates of 2 g $m^{-2}$ and 3 g $m^{-2}$ respectively. The ponds were allowed to fertilize for 2 weeks before stocking. This was followed by

stocking of *L. victorianus* and *O. niloticus* fingerlings weighing averagely 1± 0.1 g at 3 $m^{-2}$ under four treatments (T); T 1 = *L. victorianus* (monoculture), T 2 = (2:1) *L. victorianus* : *O. niloticus* , T 3 = (1:2) *L. victorianus*: *O. niloticus* and T 4 = *O. niloticus* (monoculture). T 1 and T 4 acted as controls of the polyculture trials. Sampling was performed monthly and water quality recorded bi-weekly. The fingerling's initial length-weight measurements were obtained from a randomly selected sample, N = 30. The wet weights were measured by use of a Sartorius Analytical Balance (readability 0.0001mg) and total length by use of a plastic ruler to the nearest 0.1mm. All treatments were fed a 30% CP locally formulated feed (Table 3.1) at 10% BW in the first two months and reduced to 5% in the next 2 months before settling at 3% in the last 2 months. Other parameters collected were survival, biomass, FCR, SGR and water quality variables.

**Table 3.1: Formulated starter feed (30 % CP) proximate composition .**

| Ingredient | % Protein | % Fiber | % Lipids | % Ash | % Carbohydrate | Moisture |
|---|---|---|---|---|---|---|
| *Caridina nilotica* | 15.95 | 1.51 | 0.522 | 0.9 | - | 9 |
| Cotton seed cake | 8.4 | 7.66 | 1.992 | 3.2 | 2.976 | 11 |
| Wheat Bran | 5.52 | 1.61 | 1.656 | 1.2 | 32.61 | 9 |
| Vitamin premix/mineral | 0.13 | - | - | - | - | - |
| *Artemia*® | 54 | 6 | 9 | 4 | | 8 |

*Shell free *Artemia*® is a product of Ocean Nutrition™

### 3.8 Effect of Floating and Sinking Formulated Feeds on Growth of *L. victorianus* in Hapas

A 60 day hapa experiment was conducted using 5 months old fingerlings weighing averagely 11±1.0 g harvested from KMFRI Sagana Aquaculture Research Station research pond. This fingerlings were an excess batch from the polyculture of *L. victorianus* and *O. niloticus* in Earthen Ponds conducted earlier. Prior to harvesting of the fingerlings, a 2400 $m^2$ pond was drained and left to dry for 2 weeks before treating it with agricultural lime at a rate of 200 g $m^{-2}$ . After 3 days post treatment, pond was filled with screened river water and fertilized using DAP (Di-Ammonium Phosphate) and Urea at the rates of 2 g $m^{-2}$ and 3 g $m^{-2}$ respectively. The pond was allowed to fertilize for 2 weeks before stocking.

A 3 x 1 factorial design (3 feeding regimes x 1 density) experiment was set using 9 hapas measuring 1 $m^3$.(1 m x 1 m x 1 m). The 9 hapas mounted at 3m equidistance to allow for pond water mixing were each randomly stocked with fingerlings at 20 $m^{-3}$ from a uniformly graded fingerling batch of 1000. Fingerling stocking was achieved through simple randomization, while treatment hapas were divided into sets of three using block randomization and stocked fingerlings assigned diets. Two sets were subjected to fast sinking and slow sinking supplemental 30% crude protein formulated feed (Table 4) twice daily at 0900 and 1500 h, while the other set (control) depended solely on pond productivity. Experimental fish were sampled biweekly and water quality monitored twice every week. At close of the experiment, a NFY, SGR, DWG, survival and FCR were calculated using the following formulas:

NFY = Total fish harvested (kg) - Total fish stocked (kg)

SGR (% $day^{-1}$) = $(e^g - 1)100$

where $g = (\ln(W_2) - (\ln(W_1))(t_2-t_1)^{-1}$ and $W_2$ and $W_1$ are weights on day $t_2$ and $t_1$ respectively

FCR = Feed given (dry weight) / weight gain (wet weight)

DWG = Final wt of fish / growth period (days)

Survival (%) = (Number of fish harvested / Number of fish stocked) x 100

**Table 3.2: Feed ingredients and proximate composition of the formulated starter feed (30 % CP).**

| Ingredient | % Protein | % Fiber | % Lipids | %Ash | %carbohydrate | Moisture |
|---|---|---|---|---|---|---|
| *Caridina nilotica* | 15.95 | 1.51 | 0.522 | 0.9 | - | 9 |
| Cotton seed cake | 8.4 | 7.66 | 1.992 | 3.2 | 2.976 | 11 |
| Wheat Bran | 5.52 | 1.61 | 1.656 | 1.2 | 32.61 | 9 |
| Vitamin premix/mineral | 0.13 | - | - | - | - | - |

### 3.9 DATA ANALYSIS

The quantitative results were examined by General Linear Model (GLM) and Analysis of variance (ANOVA 1) was used to determine whether the various treatments had signifcant effect on the growth rate and survival. A Tukey pairwise comparison was carried out on transport experiment to create confidence intervals for all pairwise differences between factor level means while controlling the treatment error rates of 0.05 to a level. All statistical analyses were performed using Minitab (Version 17).

# CHAPTER FOUR

# RESULTS

## 4.1 Artificial Breeding Experiments

Spawning time, from time of inducement and pairing, significantly varied among treatments but remained the same among populations. There was a significant spawning time difference between induced female brooders and those not induced with ovaprim® (Table 4.0) but no significant difference ($F_{0.05}$, 1, 118 = 1.27; P = 0.262; $R^2$ = 98.46 % ) between the two Ovaprim® dosages (0.2 and 0.5 ml $Kg^{-1}$). Temperature, unlike river source and ovaprim® dosage had significant effect ($F_{0.05}$, 1, 118 = 7879.6; P = 0.0001; $R^2$ = 92.66 % ) on the spawning time, brooders under 26 ±1 °C responded at 6-8 h, those under 22 ±1 °C responded at 12-18 h and the controls responded at 16-18 h. Fecundity significantly ($F_{0.05}$, 3, 120 = 248.25; P = 0.0001; $R^2$ = 85.78 %) depended on river source which was also related to fish length and weight (Table 1). Mean fertilization and hatching rate were both dependent on temperature with temperature of 26 ±1 °C being the best performer for all populations. There was no significant difference in ovulation based on the two Ovaprim® levels (0.2 and 0.5 ml). Ovulated eggs were transparent and free floating and also their vitelline membrane swelled to averagely 1.75 ±0.1 mm upon coming into contact with water (Plate 4.0).

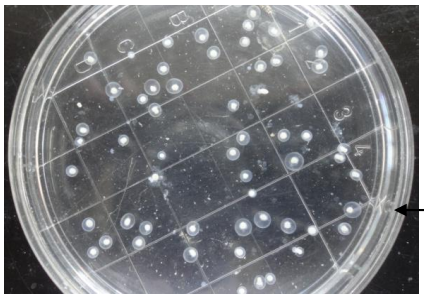


**Plate 4.0: Swelling of egg vitelline membrane upon coming into contact with water. (Source: Author, 2014)**

Larval survival was directly dependent on temperature with 26 ±1 °C having the highest larval survival (89%) and the control had the least survival (67%) which was not significantly different from temperature 22 ±1 °C (71%). Newly hatched larvae are needle like and transparent with a small yolk sac positioned ventral-posterially. Yolk sac reabsorption was not significantly related to the population source and ovaprim dosage but was directly related to temperature. Temperature 26 ±1 °C had the shortest time, 18-24 h post hatching (Table 4.0).

**Table 4.0: Artificial reproduction mean (±SE) results of *L. victorianus* gravid brooders**

| River Source | Ovaprim $kg^{-1}$ | Average female brooder weight (g) | Temperature ° C | No of Female brooders | No of Male brooders | Latency time (h) | Mean fecundity | Mean fertilization (%) | Mean hatching rate (%) |
|---|---|---|---|---|---|---|---|---|---|
| **Yala** | 0.2 | 202.2 ±43.7 | 22 ±1° C | 8 | 16 | 14.2 ±0.9 | 33062 ±7150 | 73.2 ±1.3 | 62.2 ±1.1 |
| | 0.2 | 180.0 ±6.9 | 26 ±1° C | 8 | 16 | 7.6 ±1.5 | 29432 ±1130 | 94.2 ±1.0 | 83.9 ±0.9 |
| | 0.5 | 208.4 ±42.5 | 22 ±1° C | 8 | 16 | 14.0 ±0.99 | 34077 ±6953 | 73.8 ±1.1 | 62.7 ±0.9 |
| | 0.5 | 185.4 ±22.4 | 26 ±1° C | 8 | 16 | 7.7 ±0.70 | 30313 ±3666 | 93.2 ±1.1 | 83.0 ±1.0 |
| | 0.2 | 202.2 ±43.7 | Control | 8 | 16 | 17.7 ±0.91 | 33062 ±7149 | 66.4 ±1.7 | 50.5 ±1.3 |
| | 0.5 | 195.3 ±40.7 | Control | 8 | 16 | 17.2 ±0.75 | 31939 ±6651 | 67.1 ±1.6 | 51.0 ±1.2 |
| **Mara** | 0.2 | 317.4 ±42.0 | 22 ±1° C | 8 | 16 | 14.0 ±0.85 | 51902 ±6868 | 72.7 ±1.6 | 61.8 ±1.3 |
| | 0.2 | 330.0 ±11.7 | 26 ±1° C | 8 | 16 | 7.8 ±0.79 | 53970 ±1908 | 93.7 ±1.0 | 83.4 ±0.9 |
| | 0.5 | 322.4 ±23.9 | 22 ±1° C | 8 | 16 | 14.0 ±1.2 | 52371 ±3905 | 73.7 ±1.3 | 62.7 ±1.1 |
| | 0.5 | 325.7 ±16.0 | 26 ±1° C | 8 | 16 | 7.7 ±0.70 | 53267 ±2610 | 94.2 ±1.0 | 83.8 ±0.9 |
| | 0.2 | 317.3 ±36.4 | Control | 8 | 16 | 17.8 ±0.78 | 51895 ±5948 | 65.8 ±1.6 | 50.0 ±1.2 |
| | 0.5 | 329.9 ±11.6 | Control | 8 | 16 | 17.7 ±0.70 | 53945 ±1900 | 66.6 ±1.4 | 50.6 ±1.1 |
| **Migori** | 0.2 | 319.6 ±28.8 | 22 ±1° C | 8 | 16 | 14.1 ±1.02 | 52264 ±4703 | 73.5 ±1.0 | 62.5 ±0.9 |
| | 0.2 | 344.4 ±29.0 | 26± 1° C | 8 | 16 | 7.7 ±0.60 | 56325 ±4737 | 94.1 ±1.0 | 83.7 ±0.9 |
| | 0.5 | 330.5 ±13.9 | 22± 1° C | 8 | 16 | 14.4 ±0.67 | 54043 ±2270 | 73.9 ±0.6 | 62.8 ±0.5 |
| | 0.5 | 313.2 ±50.8 | 26 ±1° C | 8 | 16 | 7.7 ±1.28 | 51220 ±8299 | 93.3 ±1.0 | 83.0 ±0.9 |
| | 0.2 | 318.0 ±32.8 | Control | 8 | 16 | 18.0 ±0.56 | 52009 ±5358 | 66.2 ±2.0 | 50.3 ±1.5 |
| | 0.5 | 340.8 ±44.3 | Control | 8 | 16 | 17.9 ±0.95 | 55741 ±7244 | 65.8 ±1.4 | 50.0 ±1.1 |
| **Nyando** | 0.2 | 185.3 ±36.9 | 22 ±1° C | 8 | 16 | 13.9 ±0.58 | 30303 ±6038 | 73.2 ±1.0 | 62.2 ±0.9 |
| | 0.2 | 173.6 ±15.9 | 26 ±1° C | 8 | 16 | 7.6 ±0.97 | 28284 ±2495 | 94.4 ±0.7 | 84.0 ±0.6 |
| | 0.5 | 172.8 ±14.9 | 22 ±1° C | 8 | 16 | 14.0 ±0.84 | 29016 ±1408 | 73.5 ±0.9 | 62.4 ±0.8 |
| | 0.5 | 173.5 ±15.8 | 26 ±1° C | 8 | 16 | 7.8 ±0.8 | 28384 ±2592 | 93.2 ±1.1 | 82.9 ±0.9 |
| | 0.2 | 172.8 ±14.9 | Control | 8 | 16 | 17.8 ±0.66 | 28265 ±2432 | 65.9 ±2.2 | 50.1 ±1.6 |
| | 0.5 | 172.8 ±14.9 | Control | 8 | 16 | 17.6 ±0.84 | 28265 ±2431 | 65.0 ±1.1 | 49.4 ±0.8 |

**4.2 Experiment on Seed and Broodstock Transport Densities**

The results of this experiment are presented in Tables 4.1- 4.12. Tables 4.1, 4.5 and 4.9 show the dissolved oxygen (DO) level changes during transport of brooders, post fingerlings and fingerlings. The DO levels for each load densities of brooders under simulated transport experienced a significant ($P< 0.05$) increase during by the first 6 h of transport but experienced no significant difference ($P> 0.05$) between 6 h and 18 h of transportation. At the close of the simulated transport (24 h), there was a recorded significant decrease across all load densities from between 7.60 ±1.36 and 11.96 ±6.44 mg $L^{-1}$ at 18 h to between 6.87 ±1.21and 7.52 ±0.52 mg $L^{-1}$ (Table 4.1).

**Table 4.1: DO changes during transportation of brooders**

| Duration of Transport (hours) | Load density ($gL^{-1}$) | | |
|---|---|---|---|
| | **400** | **800** | **1200** |
| **0** | $4.03 \pm 0.00^{aA}$ | $4.03 \pm 0.00^{aA}$ | $4.03 \pm 0.00^{aA}$ |
| **6** | $13.78 \pm 0.84^{bA}$ | $12.31 \pm 1.43^{bAB}$ | $10.60 \pm 0.99^{bB}$ |
| **12** | $11.43 \pm 4.97^{bA}$ | $11.28 \pm 1.56^{bAB}$ | $12.08 \pm 1.8^{bB}$ |
| **18** | $11.96 \pm 6.44^{bA}$ | $10.29 \pm 2.19^{bAB}$ | $7.60 \pm 1.36^{bB}$ |
| **24** | $7.38 \pm 0.87^{cA}$ | $6.87 \pm 1.21^{cA}$ | $7.52 \pm 0.52^{cAB}$ |

Values are reported as mean ± S.E.M. Means identified by different capital letters in the rows or small letters in the columns were significantly different ( $P< 0.05$) as determined by analysis of variance and Tukey's comparison of mean values.

All load densities displayed a similar trend on pH levels over transportation duration with a significant drop in the first 6 h but no significant difference between 6 h and 12 h. However, there was a significant rise of pH between 12 h and 18 h but had no significant difference between 18 h and 24 h. All load densities recorded no significant difference ( $P > 0.05$) across the load densities over the experiment period (Table 4.2).

**Table 4.2: pH changes during transportation of brooders**

| Duration of Transport (hours) | Load density ($gL^{-1}$) | | |
|---|---|---|---|
| | 400 | 800 | 1200 |
| **0** | $7.30 \pm 0.00^{aA}$ | $7.30 \pm 0.00^{aA}$ | $7.30 \pm 0.00^{aA}$ |
| **6** | $6.87 \pm 0.95^{bA}$ | $7.16 \pm 0.14^{bA}$ | $6.73 \pm 0.27^{bA}$ |
| **12** | $6.91 \pm 0.1^{bA}$ | $6.87 \pm 0.1^{bA}$ | $7.0 \pm 0.02^{bA}$ |
| **18** | $7.2 \pm 0.13^{aA}$ | $7.25 \pm 0.12^{aA}$ | $7.34 \pm 0.23^{aA}$ |
| **24** | $7.13 \pm 0.32^{aA}$ | $7.38 \pm 0.45^{aA}$ | $7.44 \pm 0.25^{aA}$ |

Values are reported as mean ± S.E.M. Means identified by different capital letters in the rows or small letters in the columns were significantly different ( $P < 0.05$) as determined by analysis of variance and Tukey's comparison of mean values

Temperature recorded no significant differences ( $P > 0.05$) across load densities over the 24 h simulated transport period. However, there was a recorded significant rise in temperature from an overall average of 19.29 ± 0.23 ºC to 25.59 ± 2.11 ºC at all load densities between 18 h and 24 h of simulated transportation (Table 4.3).

**Table 4.3: Temperature changes during transportation of brooders**

| Duration of Transport (hours) | Load density ($gL^{-1}$) | | |
|---|---|---|---|
| | 400 | 800 | 1200 |
| **0** | $22.70 \pm 0.00^{aA}$ | $22.70 \pm 0.00^{aA}$ | $22.70 \pm 0.00^{aA}$ |
| **6** | $21.67 \pm 0.92^{bA}$ | $21.23 \pm 0.37^{bA}$ | $22.7 \pm 1.46^{bA}$ |
| **12** | $20.49 \pm 0.76^{cA}$ | $19.78 \pm 0.87^{cA}$ | $18.79 \pm 0.39^{cA}$ |
| **18** | $19.26 \pm 0.27^{cA}$ | $19.33 \pm 0.28^{cA}$ | $19.29 \pm 0.15^{cA}$ |
| **24** | $26.39 \pm 0.85^{dA}$ | $26.37 \pm 0.43^{dA}$ | $25.0 \pm 0.83^{dA}$ |

Values are reported as mean ± S.E.M. Means identified by different capital letters in the rows or small letters in the columns were significantly different ( $P < 0.05$) as determined by analysis of variance and Tukey's comparison of mean values

There was no significant difference ($P > 0.05$) in $NH_3$ across treatments throughout the simulated transport duration. During the simulated transport duration, no significant increase was recorded between 6 h and 18 h within load densities. However, at 18 h $NH_3$ levels of load density 1200 $gL^{-1}$ were significantly higher than load densities 400 and

800 g $L^{-1}$ but experienced no significant difference between 18 h and 24 h. Load density 800 g $L^{-1}$ recorded the highest $NH_3$ levels (0.12 ±0.15 g $L^{-1}$) in the transportation bags at 24 h close of simulated transport experiment (Table 4.4).

**Table 4.4: $NH_3$ changes during transportation brooders**

| Duration of Transport (hours) | Load density (g $L^{-1}$) | | |
|---|---|---|---|
| | **400** | **800** | **1200** |
| **0** | $0.00 \pm 0.00^{aA}$ | $0.00 \pm 0.00^{aA}$ | $0.00 \pm 0.00^{aA}$ |
| **6** | $0.01 \pm 0.00^{aA}$ | $0.02 \pm 0.01^{aA}$ | $0.01 \pm 0.00^{aA}$ |
| **12** | $0.02 \pm 0.00^{aA}$ | $0.02 \pm 0.00^{aA}$ | $0.02 \pm 0.00^{aA}$ |
| **18** | $0.03 \pm 0.01^{aA}$ | $0.04 \pm 0.00^{aA}$ | $0.08 \pm 0.021^{bA}$ |
| **24** | $0.07 \pm 0.04^{bA}$ | $0.12 \pm 0.15^{cA}$ | $0.08 \pm 0.07^{bA}$ |

Values are reported as mean ± S.E.M. Means identified by different capital letters in the rows or capital letters in the columns were significantly different ( $P < 0.05$) as determined by analysis of variance and Tukey's comparison of mean values

Post fingerlings under simulated transport at all load densities recorded a significant increase ( $P < 0.05$) in DO levels at 6 h of transportation followed by a decrease at 12 h. Further decrease was recorded at 18 h with no significant difference by end of simulated transport (24 h). Load density 120 mg $L^{-1}$ had a significantly lower DO levels between 6 h and 24 h of simulated transport as compared to load densities 150 and 200 mg$L^{-1}$. There was a significant difference ($P < 0.05$) across load densities with load density 120 g$L^{-1}$ recording a significantly lower DO level against load densities 150 and 200 g$L^{-1}$ at 6 to 24 h (Table 14.5).

**Table 4.5: DO changes during transportation of post fingerlings**

| Duration of Transport (hours) | Load density ($gL^{-1}$) | | |
|---|---|---|---|
| | 120 | 150 | 200 |
| **0** | $4.03 \pm 0.00^{aA}$ | $4.03 \pm 0.00^{aA}$ | $4.03 \pm 0.00^{aA}$ |
| **6** | $8.70 \pm 1.45^{bA}$ | $9.75 \pm 1.52^{bB}$ | $9.73 \pm 0.28^{bB}$ |
| **12** | $6.99 \pm 1.77^{cA}$ | $8.42 \pm 2.13^{cB}$ | $8.74 \pm 1.37^{cB}$ |
| **18** | $5.81 \pm 1.76^{dA}$ | $6.40 \pm 0.88^{dB}$ | $6.33 \pm 0.89^{dB}$ |
| **24** | $5.02 \pm 1.54^{dA}$ | $6.87 \pm 1.21^{dB}$ | $7.52 \pm 0.73^{dB}$ |

Values are reported as mean ± S.E.M. Means identified by different capital letters in the rows or small letters in the columns were significantly different ($P < 0.05$) as determined by analysis of variance and Tukey's comparison of mean values

There was no significant difference ($P > 0.05$) in temperature across and within treatments at 6 h of simulated transportation. However, while load densities 120 and 200 $gL^{-1}$recorded a significant drop in temperature between 6 h and 12 h, load density 150 $gL^{-1}$ recorded a significant temperature rise from 21.68 ±0.31 ºC to 22.94 ±4.59 ºC. This was though followed with a no significant ($P > 0.05$) temperature difference across all load densities at 18 h and 24 h (Table 4.6). A significant ($P < 0.05$)sharp rise in temperature was recorded at close of the simulated transport (24 h)within all load densities but posed no significant difference ($P > 0.05$) across the load densities.

**Table 4.6: Temperature changes during transportation of post fingerlings**

| Duration of Transport (hours) | Load density ($gL^{-1}$) | | |
|---|---|---|---|
| | 120 | 150 | 200 |
| **0** | $22.7 \pm 0.00^{aA}$ | $22.7 \pm 0.00^{aA}$ | $22.7 \pm 0.00^{aA}$ |
| **6** | $21.68 \pm 0.73^{aA}$ | $21.68 \pm 0.31^{aA}$ | $21.56 \pm 0.28^{aA}$ |
| **12** | $19.79 \pm 0.20^{abB}$ | $22.94 \pm 4.59^{acB}$ | $20.16 \pm 0.38^{abB}$ |
| **18** | $19.31 \pm 0.44^{cA}$ | $18.45 \pm 0.42^{cA}$ | $18.81 \pm 0.19^{cA}$ |
| **24** | $27.96 \pm 0.65^{dA}$ | $28.20 \pm 0.16^{dA}$ | $28.74 \pm 0.22^{dA}$ |

Values are reported as mean ± S.E.M. Means identified by different capital letters in the rows or small letters in the columns were significantly different ( $P < 0.05$) as determined by analysis of variance and Tukey's comparison of mean values

There was no significant difference (P> 0.05) for pH levels within all post fingerling load densities at 6 h of simulated transport. However, there was a recorded significant difference across load densities with load density 120 $mgL^{-1}$ recording a significantly lower pH levels at 6 h as compared to 150 and 200 $mgL^{-1}$. At between 12 and 24 h of simulated transportation, all load densities recorded a significant increase with load density 200 $mgL^{-1}$ recording a significantly higher pH levels (7.59±0.31) as compared to 120 and 150 $mgL^{-1}$ (Table 4.7).

**Table 4.7: pH changes during transportation of post fingerlings**

| Duration of Transport (hours) | Load density ($gL^{-1}$) | | |
|---|---|---|---|
| | **120** | **150** | **200** |
| **0** | $7.30 \pm 0.00^{aA}$ | $7.30 \pm 0.00^{aA}$ | $7.30 \pm 0.00^{aA}$ |
| **6** | $7.15 \pm 0.04^{aA}$ | $7.45 \pm 0.06^{aAB}$ | $7.53 \pm 0.08^{aAB}$ |
| **12** | $7.04 \pm 0.22^{bA}$ | $7.11 \pm 0.25^{bA}$ | $6.91 \pm 0.07^{bA}$ |
| **18** | $7.21 \pm 0.09^{abA}$ | $7.24 \pm 0.10^{abA}$ | $7.22 \pm 0.08^{abA}$ |
| **24** | $7.31 \pm 0.09^{aA}$ | $7.36 \pm 0.05^{aA}$ | $7.59 \pm 0.31^{aAB}$ |

Values are reported as mean ± S.E.M. Means identified by different capital letters in the rows or small letters in the columns were significantly different ( P< 0.05) as determined by analysis of variance and Tukey's comparison of mean values

Free ammonia ($NH_3$) recorded no significant difference (P> 0.05) across and within load densities between start of transport simulation and 18 h. However, $NH_3$ increased significantly at close of transport simulation (24 h) within all load densities (Table 4.8).

**Table 4.8: $NH_3$ changes during transportation of post fingerlings**

| Duration of Transport (hours) | Load density (g $L^{-1}$) | | |
|---|---|---|---|
| | 120 | 150 | 200 |
| **0** | 0.00 ±0.00$^{aA}$ | 0.00 ±0.00 $^{aA}$ | 0.00 ±0.00 $^{aA}$ |
| **6** | 0.01 ±0.01 $^{aA}$ | 0.03 ±0.00 $^{aA}$ | 0.04 ±0.01 $^{aA}$ |
| **12** | 0.03 ±0.02 $^{aA}$ | 0.04 ±0.04 $^{aA}$ | 0.02 ±0.00 $^{aA}$ |
| **18** | 0.02 ±0.01$^{aA}$ | 0.03 ±0.02 $^{aA}$ | 0.03 ±0.01$^{aA}$ |
| **24** | 0.07 ±0.02 $^{bA}$ | 0.08 ±0.02 $^{bA}$ | 0.16 ±0.15 $^{bA}$ |

Values are reported as mean ± S.E.M. Means identified by different capital letters in the rows or small letters in the columns were significantly different (P< 0.05) as determined by analysis of variance and Tukey's comparison of mean values

There was a significant increase in DO levels at 6 h of transportation for all load densities with load density 120 mg $L^{-1}$ having the highest increase from the initial 4.03 ± 0.00 mg $L^{-1}$ to 10.97 ±2.50 mg $L^{-1}$. However, at the end of the simulated transport period (24 h), load density 120 mg $L^{-1}$ recorded the lowest DO levels compared to load densities 150 and 200 mg $L^{-1}$ (Table 4.9).

**Table 4.9: DO changes during transportation of fingerlings**

| Duration of Transport (hours) | Load density (g $L^{-1}$) | | |
|---|---|---|---|
| | 12 | 15 | 20 |
| **0** | 4.03 ±0.00$^{aA}$ | 4.03 ±0.00 $^{aA}$ | 4.03 ±0.00 $^{aA}$ |
| **6** | 10.97 ±2.50$^{bA}$ | 10.10 ±0.77 $^{bB}$ | 9.86 ±1.44 $^{bB}$ |
| **12** | 9.07 ±3.72 $^{bA}$ | 10.19 ±1.74 $^{cA}$ | 8.72 ±1.91 $^{cA}$ |
| **18** | 10.55 ±1.44 $^{cA}$ | 8.02 ±2.39 $^{dA}$ | 7.60 ±2.04 $^{dA}$ |
| **24** | 4.71 ±0.93 $^{dA}$ | 7.28 ±3.04 $^{dB}$ | 6.62 ±3.69 $^{dB}$ |

Values are reported as mean ± S.E.M. Means identified by different capital letters in the rows or small letters in the columns were significantly different ( P< 0.05) as determined by analysis of variance and Tukey's comparison of mean values

There was no significant (P< 0.05) temperature difference across and within all load densities over 6 h of simulated transport period. However there was a significant temperature drop at 12 h and was maintained over to 18 h except for load density 120 mg

$L^{-1}$ which recorded a significant rise. These was followed with a significant rise in temperature at 24 h of simulated transport period across all load densities (Table 4.10).

**Table 4.10: Temperature changes during transportation of fingerlings**

| Duration of Transport (hours) | Load density (g $L^{-1}$) | | |
|---|---|---|---|
| | **12** | **15** | **20** |
| **0** | 22.70 ±0.00$^{aA}$ | 22.70 ±0.00$^{aA}$ | 22.70 ±0.00$^{aA}$ |
| **6** | 21.32 ±0.28$^{aA}$ | 22.48 ±0.84$^{aA}$ | 21.92 ±0.67$^{aA}$ |
| **12** | 19.94 ±0.30$^{bA}$ | 20.17 ±0.19$^{bA}$ | 20.38 ±0.29$^{bA}$ |
| **18** | 21.11 ±4.66$^{dA}$ | 19.20 ±0.12$^{bA}$ | 18.98 ±0.23$^{bA}$ |
| **24** | 28.54 ±0.04$^{cA}$ | 28.42 ±0.36$^{cA}$ | 28.12 ±0.10$^{cA}$ |

Values are reported as mean ± S.E.M. Means identified by different capital letters in the rows or small letters in the columns were significantly different ( $p < 0.05$) as determined by analysis of variance and Tukey's comparison of mean values

No significant difference was recorded across and within all load densities throughout the simulated transport period for pH (Table 4.11).

**Table 4.11: pH changes during transportation of fingerlings**

| Duration of Transport (hours) | Load density (g $L^{-1}$) | | |
|---|---|---|---|
| | **12** | **15** | **20** |
| **0** | 7.30 ±0.00$^{aA}$ | 7.30 ±0.00$^{aA}$ | 7.30 ±0.00$^{aA}$ |
| **6** | 7.31 ±0.32$^{aA}$ | 7.46 ±0.19$^{aA}$ | 7.39 ±0.21$^{aA}$ |
| **12** | 6.97 ±0.10$^{aA}$ | 7.00 ±0.21$^{aA}$ | 6.98 ±0.07$^{aA}$ |
| **18** | 7.24 ±0.25$^{aA}$ | 7.38 ±0.10$^{aA}$ | 7.18 ±0.07$^{aA}$ |
| **24** | 7.39 ±0.01$^{aA}$ | 6.35 ±1.64$^{aA}$ | 7.40 ±0.06$^{aA}$ |

Values are reported as mean ± S.E.M. Means identified by different capital letters in the rows or small letters in the columns were significantly different ( $P< 0.05$) as determined by analysis of variance and Tukey's comparison of mean values

There was no significant ($P> 0.05$) difference in $NH_3$ levels in fingerling transportation bags across all load densities. However, there was a recorded $NH_3$ increase within load densities with time over the simulated transport period. (Table 4.12).

**Table 4.12: $NH_3$ changes during transportation of fingerlings**

| | Load density (g $L^{-1}$) | | |
|---|---|---|---|
| **Duration of Transport (hours)** | **12** | **15** | **20** |
| **0** | $0.00 \pm 0.00^{aA}$ | $0.00 \pm 0.00^{aA}$ | $0.00 \pm 0.00^{aA}$ |
| **6** | $0.03 \pm 0.01^{bA}$ | $0.04 \pm 0.02^{bA}$ | $0.03 \pm 0.02^{bA}$ |
| **12** | $0.02 \pm 0.00^{cA}$ | $0.02 \pm 0.01^{cA}$ | $0.02 \pm 0.00^{cA}$ |
| **18** | $0.03 \pm 0.01^{bcA}$ | $0.04 \pm 0.02^{bcA}$ | $0.03 \pm 0.01^{bcA}$ |
| **24** | $0.09 \pm 0.00^{dA}$ | $0.08 \pm 0.02^{dA}$ | $0.08 \pm 0.02^{dA}$ |

Values are reported as mean ± S.E.M. Means identified by different capital letters in the rows or small letters in the columns were significantly different ( $P < 0.05$) as determined by analysis of variance and Tukey's comparison of mean values


**Plate 4.0: Packaged brooders and fingerlings for simulated transportation. (Source: Author, 2014)**

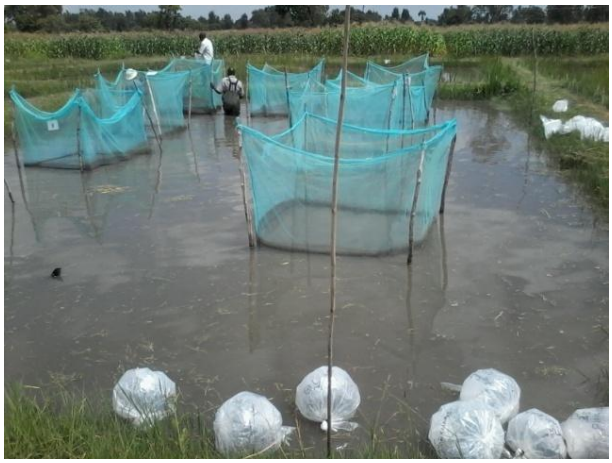

**Plate 4.1: 7 days survival monitoring in hapas after transport simulation. (Source: Author, 2014)**

**Plate 4.2: Taking water quality readings. (Source: Author, 2014)**

### 4.3 Effect of diet and stocking density on growth and survival of *L. victorianus* fry

#### 4.3.1 Aquaria growth experiment

The length, weight and survival of *L. victorianus* reared in aquaria under different stocking densities and diets is presented in Figures 4.0, 4.1 and 4.2 respectively . At stocking all fry sampled for each treatment fell into 1 homogenous group for average length (5.3± 0.07 mm) and weight (0.08± 0.003 mg). At the initial 7 days of aquaria growth, a weak homogeneity in weight gain was in two groups (T12 and T21) and (T22 and T31). Treatment T32 and T31 demonstrate a length gain homogeneity throughout the growth period except in the last 7 days where a weak length growth differential was demonstrated with T32 having a better final length but a weaker weight gain as compared to T31 (Figure 4.0). Only treatments T12 and T22 extended their weight gain homogeneity to day 14 before demonstrating a strong growth differential in the last 7 days of the experiment resulting in a significantly better wet weight of 3.2± 0.07 mg for T12 against 2.4± 0.2 mg for T22 (Figure 4.1). However, unlike other treatments, treatments T11 and T32 fry growth resulted in a strong growth differential by end of day 7 and all through to end of day 21 resulting in T11 having the best average final weight (4± 0.2 mg) and length (19± 0.3 mm) as compared to T32 (1.9± 0.1 mg; 12.8± 0.3mm). Stocking density, diet and a combination of both stocking density and diet therefore had a significant effect ($P< 0.05$) on the growth of *L. victorianus* fry length and weight gain. Fry stocked at 100/ $m^3$ (stocking 1) fed on *Artemia*® (diet1) had the best growth performance among and within treatments. All fry stocking densities reared using *Artemia*® had a significantly ($P< 0.05$) better growth performance (weight) than those

reared using starter feed except T31 (300/$m^3$) whose growth was significantly lower than T12 (Figure 4.1). Unlike length where only T11 and T12 demonstrated a strong growth differential, weight gain demonstrated a strong growth differential within and across treatments throughout the 21 days growth period (Figures 4.0 and 4.1).

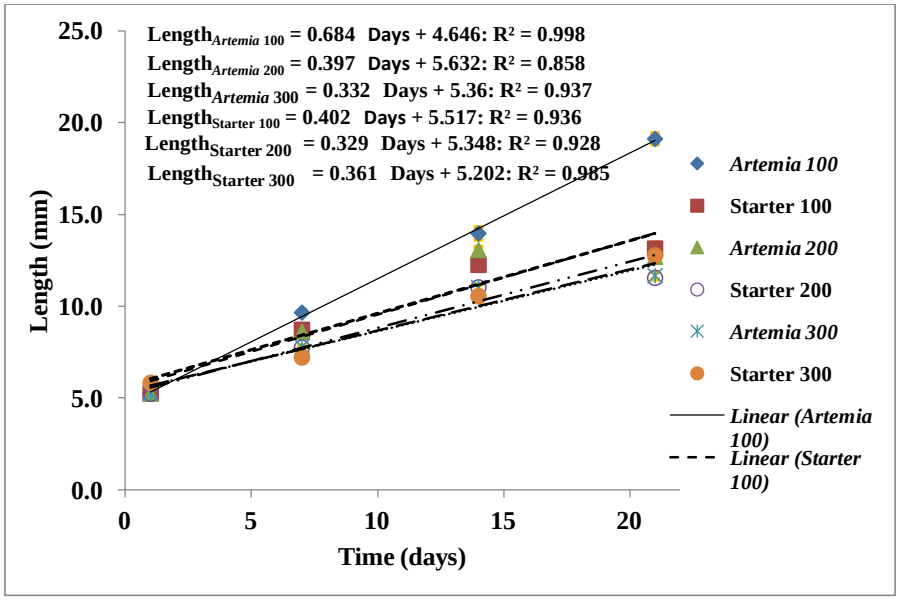


**Fig. 4.0: Length growth trend of *L. victorianus* in aquaria at different densities and diets**

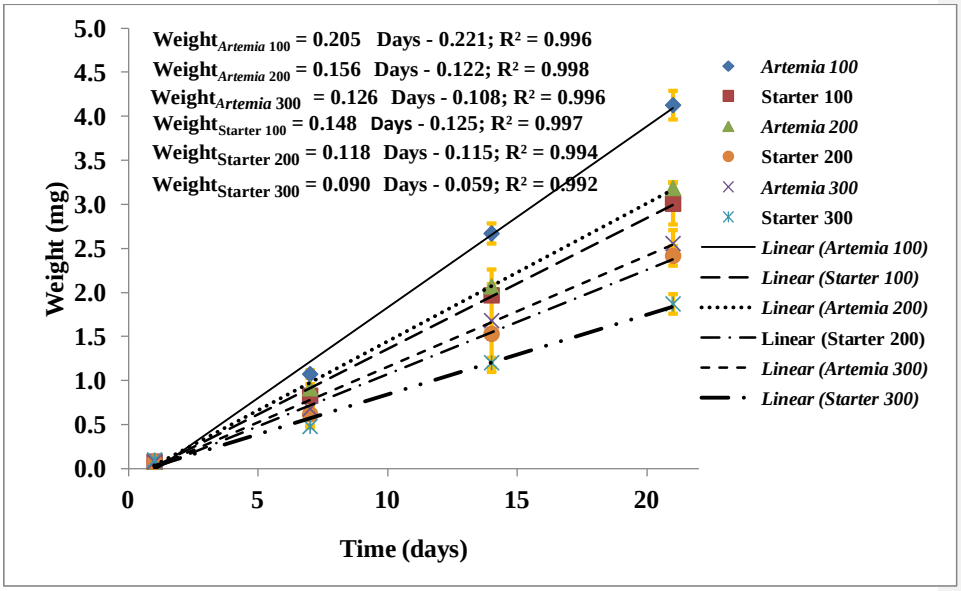


**Fig. 4.1: Weight growth trend of *L. victorianus* in aquaria at different densities and diets**

Unlike stocking density which had no effect on fry survival across treatments, diet had a significant effect (P< 0.05) on survival across treatments (Figure 4.2). Fry reared using diet1 (*Artemia*® ) had a significantly better survival (T11, 92%; T21, 89% and T31, 90%) with no significant difference within treatment as compared to diet 2- Starter feed (T12, 83%; T22, 79% and T32, 72%) which demonstrated a significant survival difference within the treatment.

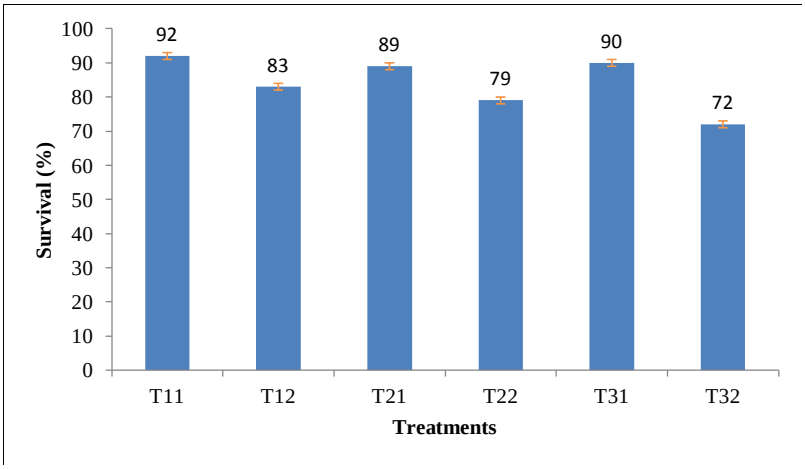


**Fig. 4.2: Mean survival of *L. victorianus* in aquaria based on diets and stocking densities**

### 4.3.2 Hapa growth experiment

All treatments fed on diet 1 had a significantly better growth performance than those fed on diet 2 except treatment T31 which performed significantly lower than treatment T12 under diet 2. Length gain homogeneity was in two groups (T12 and T21) and (T22 and T31) between day 7 and 14 of the experiment (Figure 4.3). Fry fed on diet 2 were all significantly different in final mean weight gain with the lowest stocking density ($100/m^3$) being the best performer (6.5 ±0.05 mg) and stocking at $300/m^3$ (3.9 ± 0.1 mg) had the least performance (Figure 4.4). All treatments except T31 fed on diet 1 had a significantly ($P< 0.05$) better final mean weight than those fed on diet 2 (Table 2). Treatments T11 and T32 fry growth resulted in a strong growth differential within the first 7 days of growth and maintained the trend to the end of 28 days resulting in T11 having the best final length and weight gain (30.43± 0.5mm; 8.13± 0.3 mg) but T21 and T31 final length resulted in no significant difference (Figure 4.3).

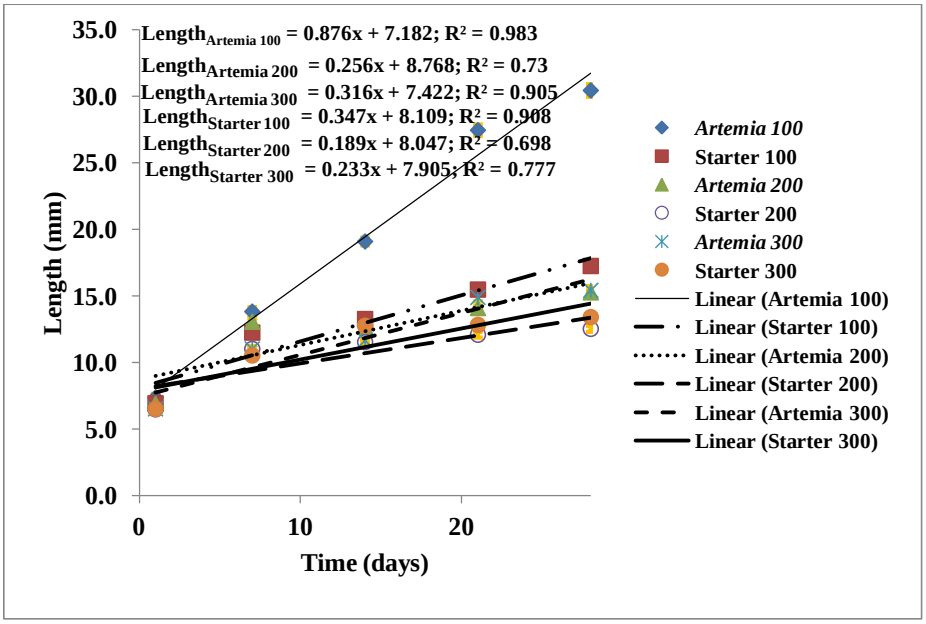


**Fig. 4.3: Length growth trend of *L. victorianus* in hapas at different densities and diets**

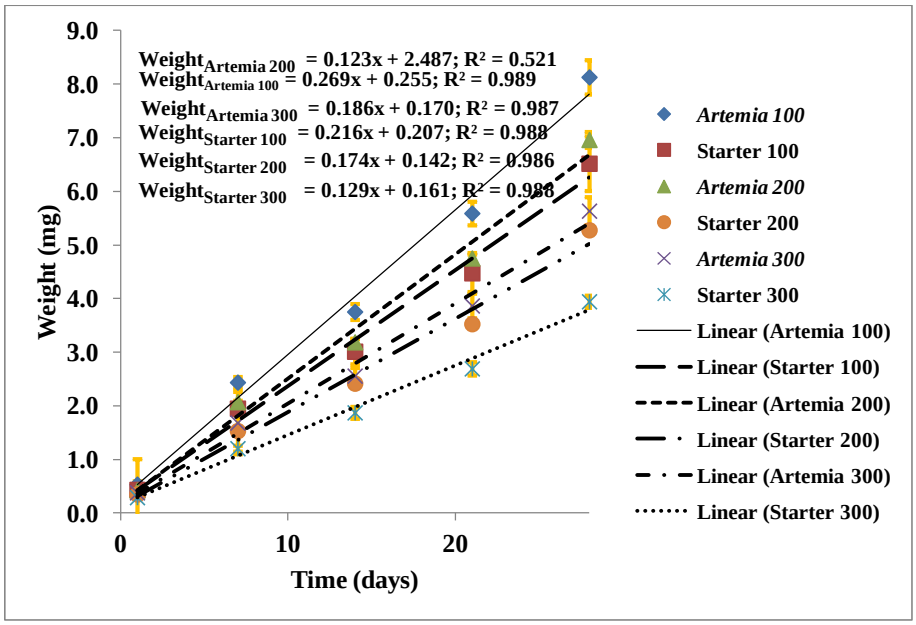


**Fig. 4.4: Weight growth trend of *L. victorianus* in hapas at different densities and diets**

All treatments had survival at above 90% by close of 28 days experiment (Figure 4.5). However, fry stocked at 100/m$^3$ (T11) and 200/m$^3$ (T21) and fed with *Artemia*® had the best survival (97%) while fry stocked at 300/m$^3$ and fed with starter feed had the lowest survival (90%). There was no significant difference in survival for treatments T12 and T22 despite their differences in stocking density and diet. Generally all treatments had very high survival with and across treatments by close of the experiment.

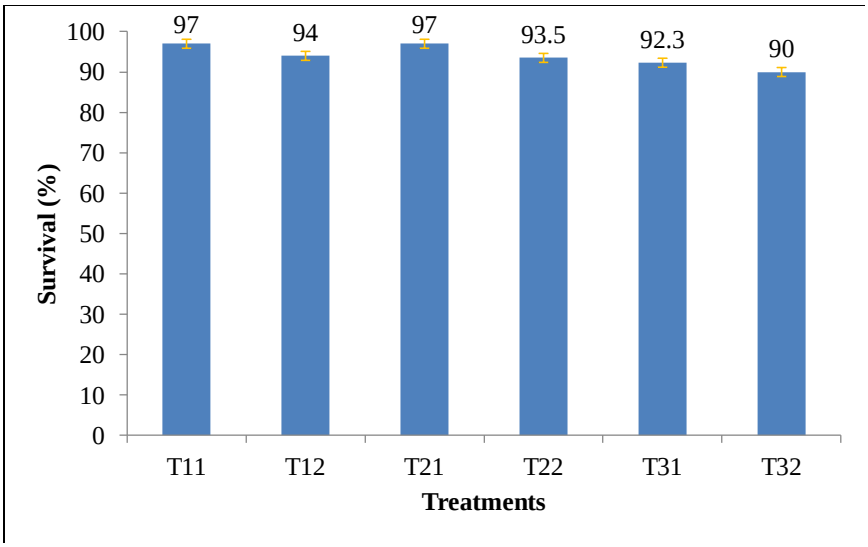


**Fig. 4.5: Mean survival of *L. victorianus* in hapas based on diets and stocking densities**

**Table 4.13: Means of water quality over the experimental period**

| Parameter | Experimental Treatments | | | | | |
|---|---|---|---|---|---|---|
| | T11 | T12 | T21 | T22 | T31 | T32 |
| DO morning ($mgL^{-1}$) | 2.55± 0.16[a] | 2.61± 0.13[a] | 2.55± 0.16[a] | 2.57± 0.16[a] | 2.14± 0.1[b] | 2.53± 0.15[a] |
| DO afternoon ($mgL^{-1}$) | 8.21± 0.95[a] | 8.22± 0.89[a] | 8.22± 0.79[a] | 8.24± 0.69[a] | 8.33± 0.86[b] | 8.23± 0.24[a] |
| Temperature morning (°C) | 23.76± 0.67[a] | 23.81± 0.64[a] | 23.95± 0.34[a] | 23.68± 0.64[a] | 23.82± 0.65[a] | 23.81± 0.60[a] |
| Temperature afternoon (°C) | 28.87± 1.59[a] | 28.89± 1.44[a] | 28.86± 1.56[a] | 28.91± 1.37[a] | 28.86± 1.60[a] | 28.65± 1.45[a] |
| pH morning | 7.32± 0.18[a] | 7.29± 0.17[a] | 7.30± 0.18[a] | 7.28± 0.17[a] | 7.30±0.18[a] | 7.33±0.19[c] |
| pH afternoon | 7.91± 0.05[a] | 7.98± 0.04[a] | 8.01± 0.04[a] | 8.13± 0.04[a] | 8.24± 0.07[c] | 8.07± 0.07[a] |
| TAN ($mg\ L^{-1}$) | 1.1± 0.02[a] | 1.1± 0.02[a] | 1.1± 0.02[a] | 1.1± 0.02[a] | 1.1± 0.04[b] | 1.1± 0.02[a] |

Values are reported as mean ± S.E.M. Means identified by different small letters in the rows were significantly different ( $P < 0.05$) as determined by analysis of variance and Tukey's comparison of mean values.

All treatments had morning and afternoon DO ranging between 2 and 8 mg $L^{-1}$ and a temperature range of 23 to 28 °C in the morning and afternoon respectively. Dawn total ammonia nitrogen (TAN) was 1.1 mg $L^{-1}$ across all treatments. All treatments demonstrated no significant differences (P> 0.05) in the most critical water quality parameters throughout the growth period. Dawn and afternoon dissolved oxygen (DO) in all treatments ranged between 2.11 to 2.52 mg $L^{-1}$ and 7.22- 8.94 mg $L^{-1}$ respectively throughout the growth period.

**Plate 4.3: Collection of samples of *L. victorianus* for length-weight measurements. (Source: Author, 2014)**

### 4.4 *L. victorianus* and *O. niloticus* Polyculture in Earthen Ponds

Survival of polyculture treatment (T3, 1L:2T) had a significantly (p□ 0.05) higher survival ( L= 49% and T= 87%) as compared to T2 (L= 31% and T= 69%, 2L: 1T). Monoculture treatment T4 for *O. niloticus* had a significantly higher survival (80%) than

monoculture treatment T1 for *Labeo* which had 50%. However, treatment T3 still posted best survival of all the treatments at 87% (Table 21).

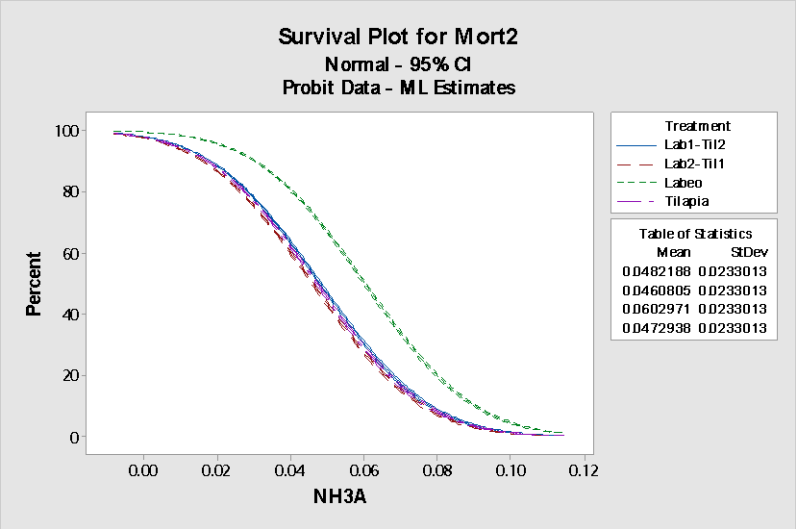


**Fig. 4.6: Survival curve (%) for the four treatments with increase in $NH_3$**

There was a significant growth difference for both species under polyculture and monoculture treatments. Under polyculture, *L. victorianus* in treatment 2 (Lab2**,** Til1**)** had a significantly higher final weight (23.82± 8.05 g) as compared to treatment 3 (Lab1**,** Til2) whose final weight was 17.19± 5.05 g. On the contrary, *O. niloticus* in polyculture treatment T4 (Tilapia) had a significantly higher final weight (104.14± 38.26 g) as compared to T2 (75.46± 28.36 g). Final weight of monoculture treatment T1 (*Labeo*) was significantly lower (13.12 g) as compared to T4 whose final weight was 79±20.04 g. *O. niloticus* under treatment T3 had a the best NFY followed by T4. Generally T3 again had a significantly high DWG(0.57 g) and SGR (2.53 g) but T2 and T4 reported no significant difference (Table 22). *L. victorianus* grown under treatment T2 had significantly higher SGR (1.72 g) followed by T3 (1.56 g) and a similar trend was

reported for DWG, 0.12 g and 0.09 g respectively. There was no significant difference on the net fish yield (NFY) for *L. victorianus* under T2 and T3 but was significantly higher than T1 (Table 4.14).

**Table 4.14: Growth performance, survival and fish yields of monoculture and polyculture treatments for *L. victorianus* and *O. niloticus.***

| Parameter | Experimental Treatments | | | | | |
|---|---|---|---|---|---|---|
| | Treatment 1 (Labeo) | Treatment 2 (Lab2, Til1) | | Treatment 3 (Lab1, Til2) | | Treatment 4 (Tilapia) |
| | *L. victorianus* | *L. victorianus* | *O. niloticus* | *L. victorianus* | *O. niloticus* | *O. niloticus* |
| **Initial Mean Weight (g)** | 1.06± 1.65[a] | 1.36±5.11[b] | 0.94±0.31[c] | 1.41± 5.75[b] | 0.84±0.29[c] | 0.94±0.37[c] |
| **Final Mean Weight (g)** | 13.12± 4.49[a] | 23.82± 8.05[b] | 75.46± 28.36[c] | 17.19± 5.05[d] | 104.14± 38.26[e] | 79± 20.04[c] |
| **Specific Growth Rate** | 1.4[a] | 1.72[b] | 2.35[c] | 1.56[b] | 2.53[d] | 2.38[c] |
| **Survival (%)** | 50.22± 1.86[a] | 31± 1.56[b] | 68.67± 3.1[c] | 48.67± 2.11[a] | 87± 1.4[d] | 79.56± 1.27[e] |
| **DWG (g/fish/day)** | 0.07[a] | 0.12[b] | 0.41[c] | 0.09[a] | 0.57[c] | 0.44[c] |
| **NFY (Kg/pond/180 days)** | 7.24[a] | 9.19[b] | 37.71[c] | 8.6[b] | 63.94[d] | 50.56[e] |

Values are reported as mean ± S.E.M. Means identified by different capital letters in small letters in the rows were significantly different ( $P< 0.05$) as determined by analysis of variance and Tukey's comparison of mean values

There was no significant difference on temperature among all treatments in the morning (0600 h) and afternoon (1400 h) over growth period. Dawn (0600) and afternoon (1400) temperatures ranged between 20.16- 24.49 and 23.76- 31.07 respectively with the sampling months of June (2), July (3) and August (4) recording the lowest. There was no $NH_3$ recorded at 1400 h for all treatments throughout the growth period but posted a significantly higher $NH_3$ for treatment T1. The pH and DO levels at 0600 h and 1400 h recorded significant difference in all treatments. At 0600 h, DO went as low as 2.11 mg $L^{-1}$ and as high as 8.93 mg $L^{-1}$ in T1 at 1400 h. The trends of all water quality parameters are presented in table 4.15.

**Table 4.15: Water quality and nutrients variables in *L. victorianus* and *O. niloticus* mono and polyculture treatments**

| Parameter | Experimental Treatments | | | |
|---|---|---|---|---|
| | **Treatment 1 (*Labeo*)** | **Treatment 2 (Lab2, Til1)** | **Treatment 3 (Lab1, Til2)** | **Treatment 4 (Tilapia)** |
| Temp M (° C) | $22.79 \pm 1.72^{aA}$ | $22.80 \pm 1.77^{aA}$ | $22.75 \pm 1.73^{aA}$ | $22.77 \pm 1.73^{aA}$ |
| Range | (20.19-24.45) | (20.48-24.47) | (20.16-24.49) | (20.36- 24.42) |
| Temp A (° C) | $27.96 \pm 2.89^{aB}$ | $27.85 \pm 2.5^{aB}$ | $27.91 \pm 2.67^{aB}$ | $27.74 \pm 2.7^{aB}$ |
| Range | (23.89-30.92) | (24.23- 31.07) | (23.98-30.21) | (23.76-30.36) |
| DO M (mg $L^{-1}$) | $2.57 \pm 0.34^{aA}$ | $2.64 \pm 0.40^{aA}$ | $2.48 \pm 0.19^{aA}$ | $2.52 \pm 0.3^{aA}$ |
| Range | (2.26- 3.11) | (2.13- 3.29) | (2.27-2.77) | (2.11- 2.98) |
| DO A (mg $L^{-1}$) | $7.70 \pm 1.65^{aB}$ | $8.00 \pm 0.69^{aC}$ | $8.17 \pm 0.72^{aC}$ | $7.95 \pm 1.16^{aC}$ |
| Range | (4.98-8.93) | (6.57- 8.56) | (6.63- 8.71) | (5.67- 8.91) |
| pH M | $7.57 \pm 0.34^{aA}$ | $7.48 \pm 0.27^{aA}$ | $7.47 \pm 0.23^{aA}$ | $7.45 \pm 0.17^{aA}$ |
| Range | (7.19- 8.13) | (7.31- 7.73) | (7.16- 7.85) | (7.12- 7.83) |
| pH A | $8.25 \pm 0.72^{aB}$ | $8.30 \pm 0.42^{aB}$ | $8.38 \pm 0.37^{aB}$ | $8.24 \pm 0.60^{aB}$ |
| Range | (7.06- 8.75) | (7.79- 8.73) | (7.82- 8.72) | (7.12- 8.89) |
| NH3 M ($mgL^{-1}$) | $0.024 \pm 0.02^{bA}$ | $0.017 \pm 0.01^{aA}$ | $0.017 \pm 0.01^{aA}$ | $0.015 \pm 0.01^{aA}$ |
| Range | (0.007- 0.069) | (0.008- 0.035) | (0.007- 0.034) | (0.007- 0.029) |
| NH3 A ($mgL^{-1}$) | $0.00 \pm 0.00^{a}$ | $0.00 \pm 0.00^{a}$ | $0.00 \pm 0.00^{a}$ | $0.00 \pm 0.00^{a}$ |
| Chlorophyll *a* ($mgL^{-1}$) | $182.3 \pm 21^{a}$ | $177 \pm 21^{a}$ | $183 \pm 21^{a}$ | $179 \pm 21^{a}$ |

Values are reported as mean ± S.E.M. Means identified by different capital letters in the columns or small letters in the rows per water quality parameter were significantly different ( $P < 0.05$) as determined by analysis of variance and Tukey's comparison of mean values conditions over 7 months growth period. *M = Morning and A = Afternoon

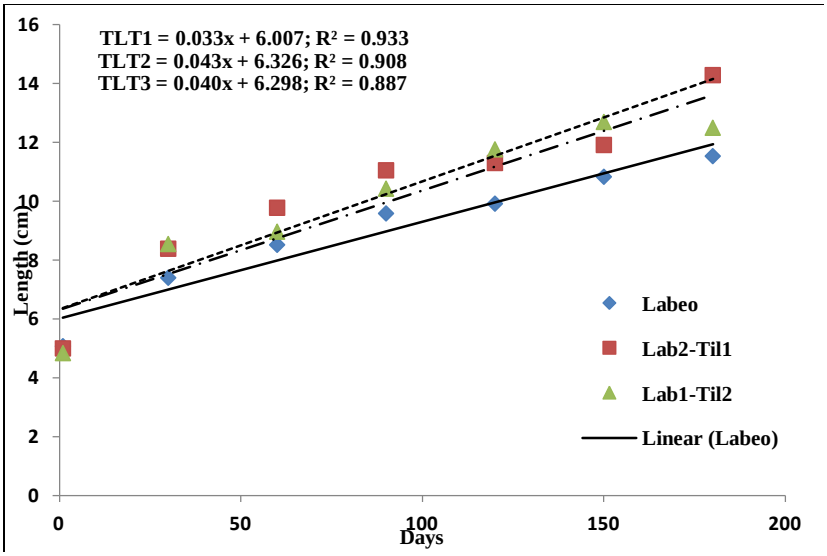


**Fig. 4.7: Growth trends (Length) of *L. victorianus* in polyculture and monoculture treatments**

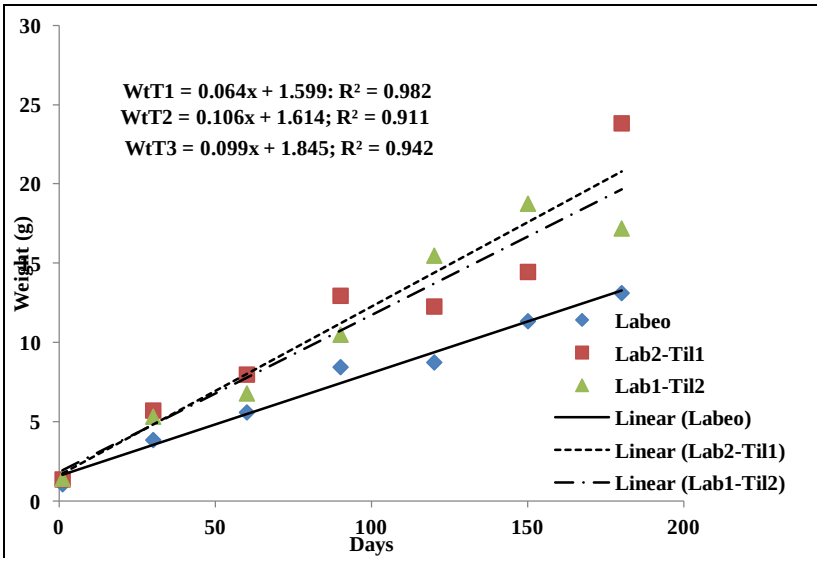


**Fig. 4.8: Growth trends (weight) of *L. victorianus* in polyculture and monoculture treatments**

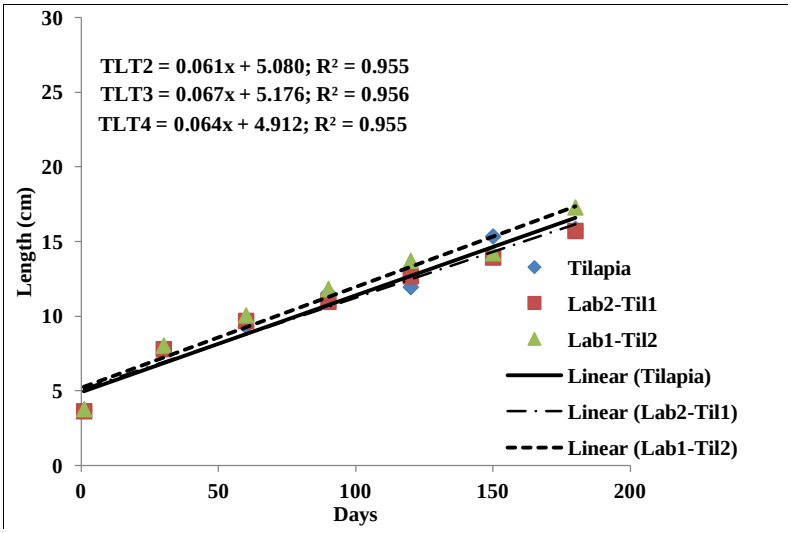


**Fig. 4.9: Growth trends (length) of *O. niloticus* in polyculture and monoculture treatments**

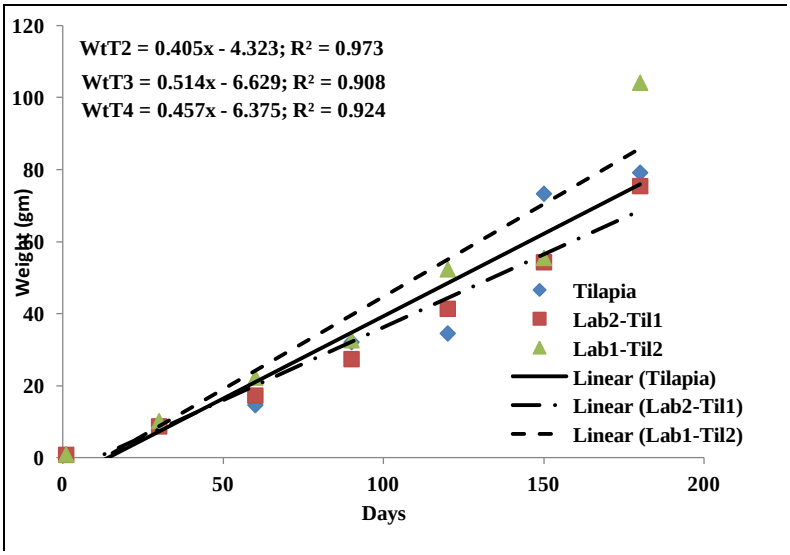


**Fig. 4.10: Growth trends (weight) of *O. niloticus* in polyculture and monoculture treatments**

A weak growth differential for *L. victorianus* was recorded within the first month of growth with a stocking polyculture ratio of 1: 2 (T3S1, *Labeo*: *O. niloticus*) maintaining an overall better performance (Fig 2.4). *O. niloticus* had a general better growth and net yields as compared to *L. victorianus*. A growth differential was recorded for all *O. niloticus* stocked in monoculture and polyculture within the first month of growth. An exponential growth was demonstrated by *O. niloticus* under *O. niloticus- L. victorianus* polyculture (T3S2; 1L:2T) and *O. niloticus* monoculture (T1S1) treatments by the fifth month of growth (Fig 2.4). There was a clear dawn temperature homogeneity for all treatments over the 7 months growth period (Fig 2.6).


**Plate 4.4: *L. victorianus* harvested at end of experiment. (Source: Author, 2014)**


**Plate 4.5: Measuring of *L victorianus* length during sampling. (Source: Author, 2014)**


**Plate 4.6: *O. niloticus* harvested at end of experiment. (Source: Author, 2014)**

**Plate 4.7: Polyculture pond productivity monitored. (Source: Author, 2014)**

### 4.5 Effect of Floating and Sinking Feeds on Growth of *L. victorianus* in Hapas

There was a significant differences (P□ 0.05) in fish growth between dietary treatments. *L. victorianus* fingerlings fed on sinking feed had significantly (P□ 0.05) higher growth than those subjected to floating feed but posed no significant difference with those subjected to natural pond productivity (Fig 3). Fish fed on sinking feed and those that depended on natural pond productivity had statistically similar (P> 0.05) growth performance and food conversion ratio (FCR). FCR for fish fed on sinking feed was significantly (P□ 0.05) better than floating feed and natural pond productivity (Table 23). It is however, important to note that all treatments had FCR within recommended ranges (1.5- 2). The coefficient of determination ($R^2$) was weak due to multicollinearity ($F_{0.05}$, 11, 847 = 6.52; P = 0.0001; $R^2$ = 7.81 %).

**Table 4.16: Treatments response to floating pellets, sinking pellets and natural productivity**

| Parameter | Experimental Treatments | | |
|---|---|---|---|
| | T1 | T2 | T3 |
| Initial Mean Weight (g) | $11\pm5.41^a$ | $11\pm 5.33^b$ | $11\pm 4.45^a$ |
| Final Mean Weight (g) | $15.86\pm 4.19^a$ | $21.32\pm 7.61^b$ | $16.99\pm 7.99^c$ |
| Survival (% of fish stocked) | $96.5^a$ | $98.2^a$ | $93.4^c$ |
| Daily Weight Gain (g/fish/day) | $0.07^a$ | $0.17^c$ | $0.09^a$ |
| FCR | $1.53^a$ | $1.38^b$ | $1.57^a$ |

Values are reported as mean ± S.E.M. Means identified by different small letters in the rows were significantly different ( P < 0.05) as determined by analysis of variance and Tukey's comparison of mean values

All treatments had very high survival with sinking feed treatment (T2) having the best survival (98.2%) followed closely by natural pond productivity -T1 (96.5%) and floating feed (T3) performed least at (93.4%).

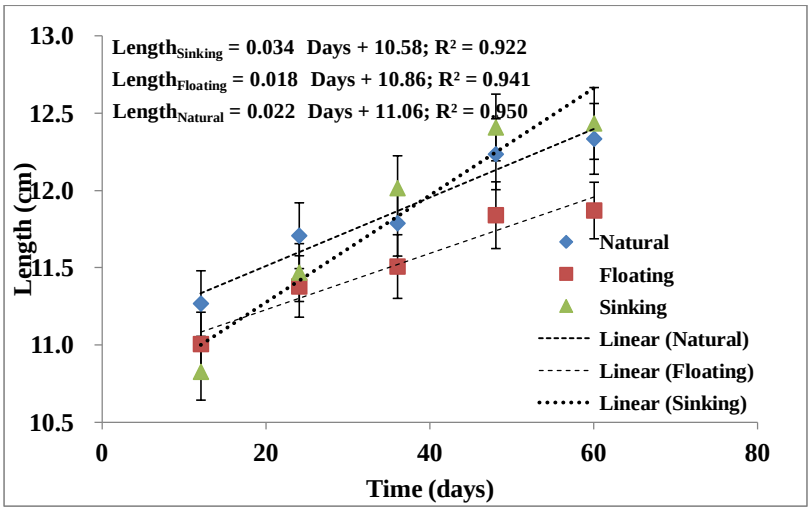


**Figure 4.11: Length growth trends for *L. victorianus* subjected to natural pond productivity, sinking pellets and floating pellets.**

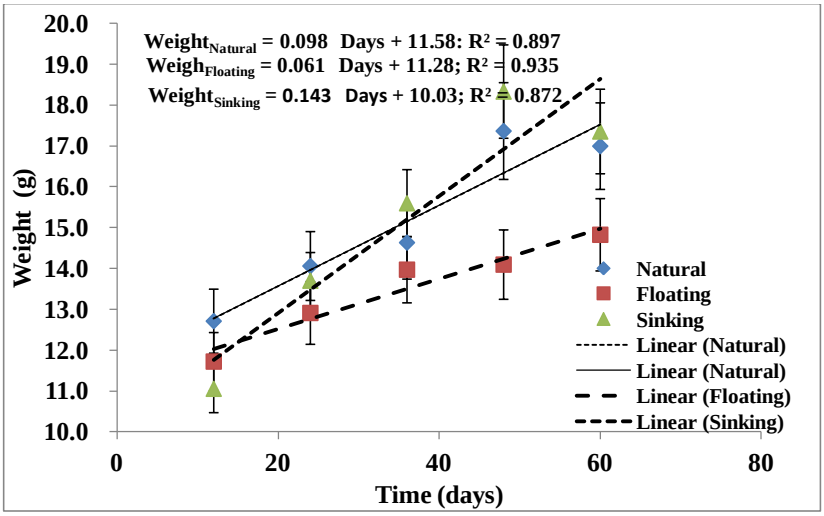


**Figure 4.12: Weight growth trends for *L. victorianus* subjected to natural pond productivity, sinking pellets and floating pellets.**

Growth differential occurred within 2 weeks of stocking for treatment T2 (sinking pellets) while floating and natural pond productivity (T1) treatments maintained a linear

growth for 30 days before demonstrating a weak growth differential to end of experiment (60 days). All treatments demonstrated no significant differences (P> 0.05) in the most critical water quality parameters throughout the growth period. Dawn and afternoon dissolved oxygen (DO) in all treatments ranged between (2.11-2.52 mg $L^{-1}$) and (7.22-8.94 mg $L^{-1}$) throughout the growth period. Most of the water quality variables were not significantly (P□ 0.05) different among treatments (Table 4.17).

**Plate 4.8: *L. victorianus* harvested from hapas after diet experiments. (Source: Author, 2014)**

**Table 4.17: Water quality variables in hapas with fish subjected to different diets (T1, pond productivity; T2, sinking feed; T3, floating feed)**

| Parameter | Experimental Treatments | | |
|---|---|---|---|
| | T1 | T2 | T3 |
| DO morning ($mgL^{-1}$) | $2.35\pm 0.16^{a}$ | $2.34\pm 0.14^{b}$ | $2.33\pm 0.19^{a}$ |
| DO afternoon ($mgL^{-1}$) | $8.22\pm 0.90^{a}$ | $8.25\pm 0.76^{b}$ | $8.25\pm 0.43^{a}$ |
| Temperature morning (°C) | $23.80\pm 0.64^{a}$ | $23.82\pm 0.65^{a}$ | $23.78\pm 0.64^{a}$ |
| Temperature afternoon (°C) | $28.90\pm 1.44^{a}$ | $28.72\pm 1.60^{a}$ | $29.25\pm 1.45^{a}$ |
| pH morning | $7.27\pm 0.17^{a}$ | $7.35\pm0.17^{a}$ | $7.32\pm0.17^{c}$ |
| pH afternoon | $8.21\pm 0.04^{a}$ | $8.21\pm 0.07^{c}$ | $8.21\pm 0.09^{a}$ |
| TAN ($mg\ L^{-1}$) | $1.1\pm 0.02^{a}$ | $1.1\pm 0.04^{b}$ | $1.1\pm 0.02^{a}$ |

Values are reported as mean ± S.E.M. Means identified by different capital letters in the rows were significantly different ( $P< 0.05$) as determined by analysis of variance and Tukey's comparison of mean values

**Plate 4.9: Hapas mounted for the diet experiment. (Source: Author, 2014)**

**Plate 4.10: Stocking of fingerlings in hapas. (Source: Author, 2014)**

# CHAPTER FIVE

# DISCUSSION

## 5.1 Artificial Breeding Protocol and Optimal Breeding Environment

Water quality is among the most critical of considerations during spawning. The water quality has an effect on the survival of the brooders, eggs and egg hatchability rates as well as fry survival. Some of the causes of poor water quality are lack of aeration and or flow through system, high stocking rates of brooders in breeding units and high egg numbers per incubation unit coupled with lack of removal of dead eggs and reduced water exchange in the incubation units.

Several successful studies on use of Ovaprim® in inducing ovulation in cyprinid fish is well documented (Mijkherjee *et al*., 2002; Sharma and Singh, 2002; Szabo, 2003; Sarkar *et al*., 2004; Montchowui *et al*., 2011). The experiment findings indicate that *L. victorianus* gravid brooders can successfully be induced with $0.2mlKg^{-1}$ Ovaprim® (sGnRHa) hormone, a dose that is lower than that recommended by distributors (0.5 ml $kg^{-1}$). The $0.2mlKg^{-1}$ Ovaprim® dosage successfully used in this experiment is also lower than other cyprinind dosage recommendations. (Nandeesha *et al*., 1993; Mijkherjee *et al*., 2002; Mahapatra, 2004; Montchowui *et al*., 2011) an aspect associated with varied levels of dopamine activity between species (Billard *et al*., 1983; Peter *et al*.,1986). Latency period, egg fertilization hatching rates varied with temperature on all populations in which 26± 1°C had the shortest average latency period (7.3± 0.8) while the control had the longest period (17± 1.2). These findings agree with previous studies on *L.*

*victorianus* and *C. gariepinus* (Rutaisire and Booth, 2004; Montchowui *et al*., 2011; Agbebi *et al*., 2013). Mara and Migori rivers brooders had a higher fecundity which was directly related to length and weight (40,000; 26.8±1.23 cm, 280 g) as compared to Nyando and Yala river populations (10,000; 18± 2.14 cm, 160 g). To safeguard the developing embryo of a fertilized egg, a standard microenvironment is developed (swelling of the vitelline membrane) as an adaptation to ephemeral flood conditions, effectively safeguarding the embryo from a wide variety of environmental conditions (Fryer and Whitehead, 1959). The observed swelling of the vitelline membrane of the *L. victorianus* eggs is in agreement with earlier findings for *Labeo mesops*, *Labeo victorianus* and *Labeo parvus* (Msiska, 1990; Rutaisire and Booth, 2004; Montchowui *et al*., 2011). The two gonads of a gravid female sandwiching the air sac are made of a thin transparent delicate membrane. All populations had spawned egg weighing 0.45mg and 1mm diameter but with the vitelline formation upon contact with water, the egg increased in size to 0.2mm after 45min. *L. victorianus* were free floating thus did not require substrate to stick on but required sufficient supply of aeration and water replacement.

Use of 0.2 ml $Kg^{-1}$ on *L. victorianus* gravid female brooders is sufficient a finding that is lower than that recommended by the distributors (0. 5 ml $Kg^{-1}$ dosage). A temperature of 26± 1°C has the optimal effect on latency, fertilization and hatchability rates. Only size (length and weight) had an effect on fecundity thus the recommended wild broodstock source is Mara and Migori rivers.

### 5.2 Optimization of Seed and Broodstock Transport Densities

During live fish transportation, oxygen demand is dependent on water temperature and fish weight (Piper *et al.*, 1982; Berka, 1986). In this study, there was an increase in DO levels with transportation period in most treatments because at the time of sealing the packaging bags, oxygen saturation in the water of the bags is related to atmospheric air. The use of pure oxygen in the packaging bags increased the DO levels in the water up to saturation in relation to the partial pressure of oxygen contained in the bags, as similar observation to Gomez *et al*., (1999).

All load densities for brooders, post fingerlings and fingerlings recorded zero mortality over the 24 h transportation period. There was a close relationship between temperature and pH increase to DO decrease and inversely $NH_3$ increase with transportation time. Fish transported in a closed system such as the packaging bags may experience oxygen deficit due to high load density coupled with prolonged transport period. Incase there are any dead fish during transportation, they also compete with the living ones for oxygen due to the increased bacterial multiplication leading to further production of toxic metabolites. Similarly, slime produced by the fish is another substrate for bacterial growth, resulting in a decrease of the water oxygen content; this process is further intensified when water temperature is high (Berka, 1986). Transportation duration 24 h depicts the lowest DO levels and highest $NH_3$ levels since there is increased metabolic activity resulting from increased temperature leading to increased release of ammonia and oxygen escape from the water.

The brooders tended to settle faster thus involving in minimal movement activity in the packaging bags as compared to post fingerlings and fingerlings. These may have resulted in the lower DO decline for brooders as compared to post fingerlings and fingerlings. According to earlier findings by Iqbal *et al*., (2013), one of the major causes of direct fish mortalities during closed transportation system may be due to high UIA concentrations or prolonged durations of exposure. All transportation periods within and across treatments had UIA increase with increased temperature and pH (Emerson *et al*., 1975; Randall and Tsui, 2002), however, UIA levels were within recommended ranges for warm water fish. Transfer of treatments from the simulation point at the NARDTC hatchery to the research ponds where the final readings were done contributed to the rise of temperature due to direct exposure of packaging bags with fish to the sun. However, this did not have an immediate effect on pH rise.

The study therefore recommends *L. victorianus* transportation load densities of 20 g $L^{-1}$, 200 g $L^{-1}$ and 1200 g $L^{-1}$ for fingerlings, post fingerlings and brooders respectively at a temperature range of 18.4± 0.42 and 22.70± 0.00 °C without compromising water quality. This is supported by the zero mortality recording over seven days post transportation in hapas.

The study findings indicate that water quality used for fish transportation is dependent upon transport duration and load density for *L. victorianus* even though in the current study all water quality parameters were with recommended ranges. UIA build up in the packaging bags is dependent on pH and temperature. The best temperature range for

transportation of *L. victorianus* fingerlings, post fingerlings and brooders for 24 h period is 18-23°C because it posted zero mortality for all load densities.

### 5.3 Effect of Stocking Density and Diet on Growth and Survival of *L. victorianus*

The type of breeding system to be employed in the breeding of *Labeo* is dependent upon the anticipated production levels per spawning session. Breeding systems may include but is not limited to use of aquaria, tanks and fine eyed hapas. Aquaria are used for low production due to egg carrying capacity while large hapas and tanks are used for mass spawning of *Labeo*. All systems are supported with aerators or a flow through system to mimic the natural environment. However, aquaria have a more controlled system as compared to large breeding facilities such as hapas and tanks which may require a lot of energy to rise the water body temperature. It also experiences no predation thus increased survival but this can be compromised if water quality is not well managed.

The growth trend for aquaria and hapa experiments indicated a direct effect of stocking, diet and a combination of stocking density and diet on the growth on *L. victorianus*. Growth differentiation for aquaria treatments stocking density $100/m^3$ for both diets independently gave the best final growth response and indication that density has an effect on the growth performance of the fish. The stocking density effect is further supported by the better growth performance by fry treatment T12 ($100/m^3$ , starter feed) than treatment T31 ($300/m^3$ , *Artemia*®) even though a homogeneity of T12 and T21 was extended from stocking to end of week 2. This indicated that though the fry may be

provided with the best diet (*Artemia*®) for their age, stocking density may hinder their growth.

In hapa experiments, *Artemia*® diet treatments had a significantly better growth performance than commercial starter feed diet except treatment T31 (stocking 300/$m^3$ and *Artemia*®) which performed significantly lower than treatment T12 (stocking 100/$m^3$ and starter feed). The improved performance of T12 at week 3 against T31 was an indication that T31 carrying capacity had reached it threshold as the fry grew thus limiting natural food availability. *L victorianus* is known to feed on zooplankton at early stages (fry) of development before switching to detritus (Owori-Wadunde, 2005). This may have been the major contributory factor in the growth homogeneity in groups (T12 and T21) and (T22 and T31) between week 1 and 2 of the experiment and better growth performance by fry subjected to commercial starter diet.

Fry survival in aquaria was dependent on diet with fry fed on diet 1 (*Artemia*®) having the best survival. *L. victorianus* fry fed with *Artemia*® performed better because they were fed on food that was easy to digest and assimilate considering that at this stage their digestive system was not fully developed. However, in hapa experiment, neither diet nor stocking had a direct effect on survival since all treatments performed significantly well. This is because the pond was well fertilized with chicken manure providing abundance of natural productivity of zooplankton and phytoplankton to all treatments.

### 5.4 *L. victorianus* and *O. niloticus* Polyculture in Earthen Ponds

The productivity of the aquatic system is increased by efficiently utilizing ecological resources within the environment (Ahmad *et al.,* 2013). Stocking two or more complimentary fish species can increase the maximum standing crop of a pond by allowing a wide range of available food items and the pond volume to be utilized (Hassan, 2011). However, studies have also confirmed that improved biomass through fish growth under intensive culture depends upon other factors such as feeding regimes thus posing the challenge of obtaining a balance between a rapid fish growth and optimum use of the supplied feed (Ahmed *et al.,* 2012).

Polyculture combination of 1: 2 (*Labeo*: *O. niloticus*) generally gave the best survival for both species an overall better performance on net fish yields and indication that the stocked ratios may be favorable for polyculture of *L. victorianus* and *O. niloticus*. These polyculture performance may be associated with a positive trophic feeding interaction between the two species. The months of June, July and August experienced a cold season which saw dawn temperatures go as low as 20.16 °C. These low temperatures in the cold season had a direct effect on feeding, growth and survival of both fish species. Though afternoon temperatures rose to as high as 31.07 °C, this never lasted for long due to afternoon rains which resulted in drastically lowered temperatures. The poor growth of *L. victorianus* can also be attributed to low DO levels, a factor attributed to the cold season (June, July and August) accompanied with cloud cover limiting photosynthesizes one of the sources of pond oxygen during day time. There was no major variation of water quality variables and pond nutrient levels throughout the experiment period among and

between treatments indicating therefore that no treatment had an environmental advantage over the other. Though feeding was done twice a day at 0010 and 1500 depending on the weather conditions, *L. victorianus* were never spotted coming for the feed on the surface unlike *O. niloticus* in mono and polyculture treatments. The water quality and pond productivity nevertheless were all within Carp culture ranges despite the fact that this may vary from species to species.

Polyculture combination 1: 2 (*Labeo*: *O. niloticus*) gave the best overall results. However, though the slow growth of *L. victorianus* can be attributed to low temperatures and DO levels, there is need to identify other factors that may have contributed to the poor growth.

### 5.5 Effect of Floating and Sinking Formulated Feeds on Growth of *L. victorianus* in Hapas

A growth intercept for all treatments is demonstrated within the first week of stocking. The three treatments growth curves demonstrate two differential phases, a significantly strong differential growth for sinking feed against the other treatments at week 2 and a weak differential growth for floating feed at week 4 against fish fed on natural pond productivity. Lack of an expected fish exponential growth for all treatments may have resulted from the feeding habit in the wild, lack of adaptation to the pond environment and hapa confinement. Due to the mouth positioning of *L. victorianus*, the fish in this treatment was able to consume the feed immediately while its palatability was still at optimal unlike floating feed which require the fish which is a bottom feeder to come to the surface. This resulted in the differential growth within the first 2 weeks. Much of the

floating feed (90%) was collected in the next feeding session an indication that fish under this treatment hardly came to feed at the surface. Therefore it can be concluded that fish fed on sinking pellets in addition to the rich pond productivity resulted in better growth performance, while those fed on floating feed and natural pond productivity exhausted their main food source (pond productivity) in the hapa confinement resulting in the slowed growth. Thus *L. victorianus* a bottom feeder given sinking feed had a growth advantage over the other treatments.

*L. victorianus* is known to be limited in its distribution to the Lake Victoria basin and displays a potamodrometic behavior thus moving into affluent rivers to spawn in vegetated flooded pools on the onset of rains (Fryer and Whitehead, 1959; Cadwalladr, 1965; Greenwood, 1966; Reid, 1985; Skelton *et al*., 1991; Ochumba and Manyala, 1992; Weyl and Booth, 1999). All broodstock was collected from the wild were found to occupy rocky riverine vegetated environment an indication of high oxygen demand. Dissolved oxygen is one of the most important parameter and a primary limiting factor controlling the food intake, growth and survival of fish (Morkore and Rorvik, 2001; Crampton *et al.*, 2003; Norgarden *et al.*, 2003; Qayyum *et al.*, 2005). The pond DO levels at dawn and afternoon were between (2.11-2.52 mg $L^{-1}$) and (7.22- 8.94 mg $L^{-1}$) respectively an aspect that may have contributed to slowed growth since there was no significant difference (P□ 0.05) among treatments.

## CONCLUSIONS AND RECOMMENDATIONS

It is recommended that *L. victorianus* founder broodstock be acquired from rivers Mara and Migori considering their high fecundity and broodstock size. The collection of founder broodstock and subsequent movement of brooders and fingerlings among farmers should take into consideration a density of 20 g $L^{-1}$, 200 g $L^{-1}$ and 1200 g $L^{-1}$ for fingerlings, post fingerlings and brooders respectively at a temperature range of 18 ºC to 23 ºC , DO of 4 mg $L^{-1}$ to 10 mg $L^{-1}$ and a pH of 6.5 to 9 without compromising water quality. However, considering that all stocking densities experienced zero mortality, there is need for further increase in load density for each fish size. Fry management is critical to seed production and eventual grow-out productivity. The study on fry survival and growth recommends a combination of diet 1 (*Artemia*®) and stocking density 100 but a further live feeds and environmental manipulation using cultured rotifer and photoperiod and temperature variation is recommended for intensive production of *L. victorianus*. Under polyculture conditions in earthen ponds, further growth and survival trials are recommended with the employment of aerators or paddles to sustain dissolved oxygen levels a factor known to affect many fish species growth in addition to change of feed ingredient composition. A keen emphasis on effects of DO and vertical circulation dynamics of *L. victorianus* ponds as well as performing growth trials in other systems such as race ways and RAS which will mimic the river conditions. Based on the results from fast sinking and slow sinking formulated feeds, other feed formulations (fast sinking pellets) should be tested to come up with an optimal diet for recommendable *L. victorianus* commercial aquaculture. Although the current findings have indicated poor *L. victorianus* growth under confinement, the ability to breed the fish and rear fry with ease

will enable restocking of the wild to mitigate the dwindling wild population in Lake Victoria and its tributaries.

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