



UNIVERSITY OF GHANA

**EVALUATION OF NILE TILAPIA (*Oreochromis niloticus*, Linnaeus 1758)
FINGERLING PRODUCTION AT THE AQUACULTURE DEMONSTRATION
CENTRE - ASHAIMAN, GHANA.**

BY

JOYCE BUERNORKI LUTTERODT

(10636681)

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DECLARATION

This dissertation is the result of research work undertaken by Joyce Buernorki Lutterodt in the Department of Marine and Fisheries Sciences, University of Ghana under the supervision of Dr. Samuel Addo and Dr. Winnie N. A Sowah. I do hereby declare that the dissertation consists entirely of my own work and that no part of it has been previously published or submitted for a degree or diploma elsewhere.

Signature:

Joyce Buernorki Lutterodt

Date

(Student)

Signature:..... ..

Dr. Samuel Addo

Date

(Principal Supervisor)

Signature..... ..

Dr. Winnie N. A. Sowah

Date

(Co-supervisor)

ABSTRACT

The Nile tilapia, *Oreochromis niloticus* (Linnaeus, 1758) fingerling production is important for continual expansion of the global tilapia aquaculture. This study evaluated the Akosombo Strain Nile tilapia fingerling production at the Aquaculture Demonstration Centre-Ashaiman, Ghana. A total of 1350 female brooders of mean weight 150.7 ± 41.8 g and 450 males of mean weight 218.6 ± 63.1 g were stocked into nine outdoor concrete tanks of size 50 m² each in a sex ratio of 3:1 respectively for 14 days. From the estimated 675,000 eggs produced by the females, a total of 138,631 fry were harvested resulting in 20.5% hatching success. The survival rate of the fry after hormonal treatment was 79.5% with estimated FCR of 1.46 and SGR of $6.05 \pm 0.35\% \text{day}^{-1}$. For growth to the fingerling stage, the fry were stocked into an earthen pond of size 1200 m² for 24 days at an initial weight of 0.23 ± 0.04 g. The final mean weight of fingerlings harvested was 2.47 ± 0.55 g with FCR of 1.09, SGR ($3.26 \pm 0.18\% \text{day}^{-1}$) and a survival rate of 75.3%. The estimated final standing crop was 1708.4 kg ha⁻¹. Results from statistical analysis indicated that there were no significant differences among fry produced in the breeding tanks ($p=0.73$). Water quality measurements in the breeding tanks, fry tanks and fingerlings pond were respectively $29.03 \pm 0.51^{\circ}\text{C}$, $28.07 \pm 1.79^{\circ}\text{C}$ and $27.07 \pm 1.68^{\circ}\text{C}$ for temperature; $3.56 \pm 0.04 \text{ mgL}^{-1}$, $3.62 \pm 0.18 \text{ mgL}^{-1}$ and $3.74 \pm 0.21 \text{ mgL}^{-1}$ for DO; 7.38 ± 0.19 , 7.35 ± 0.18 and 7.56 ± 0.25 for pH; salinity were $0.23 \pm 0.01\%$, $0.24 \pm 0.02\%$ and $0.29 \pm 0.02\%$, and ammonia levels of $0.12 \pm 0.06 \text{ mgL}^{-1}$, $0.01 \pm 0.002 \text{ mgL}^{-1}$ and $0.04 \pm 0.01 \text{ mgL}^{-1}$ respectively. The study concludes that the Centre can increase production of fingerlings if the current management practice at the breeding stage of production is improved.

DEDICATION

I primarily dedicate this work to God Almighty who has been with me from the start to the end of this project and made it a success. Secondly, to my lovely family for their love and support, encouragement emotionally and financially. God richly bless you.

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TABLE OF CONTENTS

	Page
DECLARATION	ii
ABSTRACT.....	iii
DEDICATION	iv
ACKNOWLEDGEMENTS	v
LIST OF FIGURES.....	ix
LIST OF TABLES.....	xi
LIST OF PLATES	xii
CHAPTER ONE	1
1.0 INTRODUCTION	1
1.1 Background.....	1
1.2 Problem Statement.....	3
1.3 Objectives of Study	6
CHAPTER TWO	7
2.0 LITERATURE REVIEW	7
2.1 Overview of Tilapia Production.....	7
2.2 Holding Facilities for Tilapia Fingerlings Production.....	9
2.2.1 Tank Production of Fry	9
2.3 Brooder Stocking and Spawning	10
2.4 Fry Harvesting, Growth and Sex Reversal	12
2.5 Incubation of Eggs.....	14
2.6 Water Quality Monitoring	15
CHAPTER THREE.....	19

3.0 MATERIALS AND METHODS	19
3.1 Study Area	19
3.3 Brooder Stocking.....	21
3.4 Fry Harvesting.....	22
3.5 Hormonal Sex Reversal of Fry	23
3.6 Fingerling Production in Nursery Pond.....	24
3.7 Water Quality	25
3.8 Statistical Analysis	25
CHAPTER FOUR	26
4.0 RESULTS	26
4.1 Water Quality in the Production Facilities.....	26
4.1.1 Temperature	26
4.1.3 pH.....	32
4.1.4 Salinity.....	34
4.1.5 Ammonia	36
4.2 Production Characteristics of Brooders.....	37
4.3 Production Characteristics of Fry and Fingerlings	38
CHAPTER FIVE	39
5.0 DISCUSSION.....	39
5.1 Water Quality Parameters	39
5.2 Brooder Production	41
5.3 Fry Production Characteristics	41
5.4 Fingerling Production.....	42
CHAPTER SIX	43

6.0 CONCLUSIONS AND RECOMMENDATIONS	43
6.1 Conclusions	43
6.2 Recommendations	43
REFERENCES	45
APPENDIX.....	56

LIST OF FIGURES

Figure 3.1	Map of Ghana showing the Aquaculture Demonstration Centre.....	19
Figure 4.1	Mean Temperature variation in breeding tank during spawning stage during the study period at Aquaculture Demonstration Centre.....	27
Figure 4.2	Mean Temperature variation in Fry tanks during the fry hormonal treatment stage at the Aquaculture Demonstration Centre.....	27
Figure 4.3	Mean Temperature variation in earthen pond during fingerling production during the study period at the Aquaculture Demonstration Centre.....	28
Figure 4.4	Mean values of Dissolve Oxygen variation in tanks during the breeding during at the Aquaculture Demonstration Centre.....	29
Figure 4.5	Mean Dissolve Oxygen variation in fry tanks during the fry hormonal treatment stage at the Aquaculture Demonstration Centre during the study period	30
Figure 4.6	Mean Dissolve Oxygen variation in earthen pond during fingerling production at the Aquaculture Demonstration Centre during the study period	30
Figure 4.7	Mean pH variation in tanks during the breeding stage at the Aquaculture Demonstration Centre during the study period.....	31
Figure 4.8	Mean pH variation in fry tanks during the fry hormonal treatment at the Aquaculture Demonstration Centre during the study period.....	31
Figure 4.9	Mean pH variation in earthen ponds during the fingerling Production at the Aquaculture demonstration Centre during the study period.....	32

Figure 4.10	Salinity variation in tanks during the breeding at the	
	Aquaculture Demonstration Centre.....	33
Figure 4.11	Salinity variation in fry tank during the breeding stage at the	
	Aquaculture Demonstration Centre.....	34
Figure 4.12	Salinity variation in earthen pond during the fingerlings production	
	stage at the Aquaculture Demonstration Centre	34
Figure 4.13	Mean Ammonia for Breeding, Fry and Fingerling from tanks and	
	pond at the Aquaculture Demonstration Centre.....	35

LIST OF TABLES

Table 4.1 Mean water quality parameters for the different stages of production of Nile tilapia fingerlings at the Aquaculture Demonstration Centre, Ashaiman from 15 January – 7 March , 2018. Values are means $\pm$ standard deviation.....	27
Table 4.2. Production characteristics of Nile tilapia brooders at the Aquaculture Demonstration Centre, Ashaiman. Values are means $\pm$ standard deviation.	37
Table 4.3. Production characteristics of fry and fingerlings at the Aquaculture Demonstration Centre, Ashaiman. Values are means $\pm$ standard deviation.	38

LIST OF PLATES

Plate 1 Aerial view of the Aquaculture Demonstration Centre.....	19
Plate 2. Filling of cleaned concrete tank with clean water from the Ashaiman Reservoir	21
Plate 3 Fry harvested into a basin for stocking in a tank for hormonal treatment..	22
Plate 4. Hormonal feed preparation (left), Hormonal feed shade drying (right).....	22

LIST OF APPENDIX

Appendix I	Single factor anova showing the significance differences between	
	fry produced in the breeding tanks	55

LIST OF ABBREVIATIONS

ADC	Aquaculture Demonstration Centre
ARDEC	Aquaculture Research and Development Centre
CSIR	Council for Scientific and Industrial Research
DO	Dissolved Oxygen
FAO	Food and Agricultural Organization
FCR	Feed Conversion Ratio
FME	Federal Ministry of Environment
GSS	Ghana Statistical Service
MoFAD	Ministry of Fisheries and Aquaculture Development
MT	Metric Tonnes
MT	17 α methyltestosterone
NPDC	National Development Planning Commission
SGR	Specific Growth Rate
WRI	Water Research Institute

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Human populace has increased over the years from 7.3 billion in 2016 to 7.6 billion in 2018 (World population review, 2018) and aquatic food products is on high demand in general by these growing global population. Global fish production utilized for direct human consumption was estimated at 146 million metric tonnes (MT) in 2016 (FAO, 2016). Fish production from capture decreased from 82 million MT in 2011 to 79 million MT in 2012 and most of the main fishing areas cannot produce enough (Ferreira, 2016). Global demand for food fish would not be met if these supplies should be retained. According to FAO (2016), globally, 260 million MT was produced and aquaculture contributed 106 million MT in live weight (FAO, 2017), which is nearly 50%. Therefore, aquaculture seems to have the capacity to make available food fish for global needs. Consequently, it has seen a great level of development and expansion in almost all regions of the world with the least of the development being in Africa (FAO, 2006). An estimated 5% of the African population depend mostly or partially on fisheries for their livelihood (Asmah, 2008), therefore aquaculture makes a significant contribution to food security.

Aquaculture since the 1970s has been a very fast-growing industry. According to FAO (2008) this growth can be estimated at 9% per annum and it is anticipated to go up to 41% (56.3 million tonnes) by 2020 (Carlos *et al.*, 2015). Freshwater fishes dominate global aquaculture production (FAO, 2012) of which the Nile tilapia, *O. niloticus* is the most consumed and the most cultured fish species worldwide and in Ghana (Sarpong *et al.*, 2005).

Yosef (2009) reported that, annual global tilapia production, which turned 1.5 tonnes in 1950, went up to at least 1.5 million tonnes in 2002 and. in 2010, the increment reached three million tonnes. Tilapia is a group of fish species that have famous parental care. A total of about 800 species were identified locally to West Africa and Asia with the Nile tilapia (*Oreochromis niloticus*) being the maximum cultured species in cages, ponds and pens (Kuton & Akapo, 2012). The Nile Tilapia is widely produced due to its short replica rate, lenience to tough environments, ability to withstand disease infections and the prospect to be raised under numerous farming structures (Yosef, 2009). Tilapia is likewise very successful in reproduction and this performance has damaging consequences in its culture, in that within a constrained environment, out of control multiplication of the fish results in producing dwarf fish population of poor market price (Suman & Samir 2010). To control this problem, all-male tilapia is produced via sex reversal (Megbowon & Fashina-Bombatta, 2010). All-male sex reversed fingerlings are actually very high in demand in production system due to the fact that reproduction is reduced at some stage in the cycle while growth is promoted (Megbowon & Fashina-Bombatta, 2012). Fry or fingerling is the maximum important factor that permits cyclic production (Bhujel, 2011) and the increase of the tilapia productiveness largely hinged on the ability of hatchery workers to provide quality fry/fingerlings. Therefore, fingerling production remains vital to the continued expansion of tilapia aquaculture globally (Green, 2006) with focus on Ghana. The inadequate supply of tilapia seed, mainly fingerlings in consideration is a lone important limitation to the enhancement of aquaculture (Munguti *et al.*, 2014). Study of the status of cultivated tilapia indicates that the shortage of an effective approach for seed

cultivation can each wane efforts to sustain recent farmers in grow out and prevent the implementation of enhanced methods. The cultivation of grow out fish starts with the stocking of fry or juveniles right into a cultivation environs that assures optimum and rapid development to permit yield in the least feasible period.

1.2 Problem Statement

Ghana is a mid-income nation with a population size of 26 million and a rapid growing economy exporting cocoa, gold, oil (Nickerson, 2014) and fish (non-traditional) export commodity. Fisheries sector's contribution to AGDP and GDP in 2016 was 6.1% and 1.1% respectively (GSS, 2017). The country earned about US\$318 million in 2014 as against US\$183 million in 2013, representing an increase of 34.4%, (Okyere & Palm, 2015). Total fish production for 2016 was 465,356.00 MT as against a national fish requirement of 1,132,332.04 MT in the same year. The fish deficit was therefore 666,975.39 MT; hence, only 41% of the annual fish requirement was met from local production (NDPC, 2017). Fish is also a cheaper source of animal protein contributing 60% to total protein intake in the diet of the average Ghanaian. This makes fish and fish products very important in the economy. However, the country is not self-sufficient in fish production as prospects for higher landing from capture fisheries continue to dwindle. The high per capita fish consumption of 19.8 kg (MOFAD, 2016), the deficit in fish supply and high demand for tilapia have created an enabling business environment for the growth of the aquaculture industry. A forecast of 120,000 metric tonnes was to be produced by 2017 and this would have created an annual average of 900 direct job opportunities (Okyere & Palm, 2015) but this was not achieved. Although the Nile tilapia and the African catfish are the core

cultivated species in the country, such as *Heterobranchus* sp and *Clarias gariepinus*. Other minor species like *Heterotis niloticus* are considered for culture. The Nile tilapia represents over Eighty percent of farmed fish harvest, while African catfish *Clarias gariepinus* and *Heterobranchus* species make up the remaining twenty percent of cultured fish (FAO, 2016).

Ghana is endowed with Lake Volta, the largest artificial lake in Africa and one of the largest in the world. It has a surface water area of 8,484 km² during the early life of the Lake in 1964, a shoreline of 880 km and length of 400 km with other associated riverine systems. The geo-ecological climate of the country is generally favourable for aquaculture all year round (Hiheglo, 2008). Lake Volta hosts over 58 fish farms with more than 1700 individual cages, accounting for over 80% of the volume of total aquaculture production. In 2016, cage culture accounted for more than Eighty-eight percent of overall aquaculture production, whereas ponds/tanks and dams/dugouts/reservoirs accounted for 7.3% and 4.7% respectively (MOFAD, 2017). Aquaculture production has seen a slow increase from 720 MT in the late 1990's to about 52,470 MT in 2016 (FAO, 2016; MOFAD, 2017). The low production of farmed fish in Ghana in the face of rapid national population growth rate of 2.6% per annum is giving rise to fish and nutritional insecurity, particularly among women and children. Among the factors attributed to the low aquaculture production is inadequate access and low utilization of certified fingerlings as a result of limited number and capacity of hatcheries producing improved fingerlings. Fish farmers depend on their own sources, other farmers and the wild for brood stock and fingerlings but this is unsustainable farming practice that cannot improve production efficiency.

According to Glover, (2016), figuring out pleasant practices is critical in any trade for offering appropriate and genuine standards for better tasks. For tilapia cultivation to broaden for sustainability, there's a requirement of identifying quality practice to guide those who need to begin seed production and to permit the ones previously in it to discover in what ways they would be able to enhance their production. with the intention to satisfy the prevailing seed market

Mono sexed tilapia fingerlings are preferred for stocking due to their fast growing ability (Megbowon & Fashina-Bombatta, 2010). Fish seed requirement in Ghana is not satisfied and the situation is worsened by the poor quality of seeds produced due to the inability of hatchery systems to meet the increasing demand (Padi & Attipoe, 2006). The quality of fish seed is very important because the harvest size of the fish is affected by the quality of the seed stocked (Sarfo, 2007). An average of 50 million fingerlings is needed annually to meet the fish seed deficit in Ghana (Rurangwa *et al.*, 2015). In view of that, fingerling production is critical to the continuing enlargement of tilapia aquaculture in Ghana (FAO, 2012). More hatcheries are needed to produce tilapia fingerlings for supply to farmers in order to meet the above fish seed deficit.

Currently the Aquaculture Demonstration Centre produces 1.2 million tilapia fingerlings annually (ADC, 2017). This level of production could possibly increase if there exist some baseline data on the hatchery activities at the Centre that could be analyzed scientifically to identify pitfalls and implement strategies for improvement of their operations.

1.3 Objectives of Study

The main aim of this study was to evaluate the production characteristics of Nile tilapia fingerlings at the Aquaculture Demonstration Centre, Ashaiman near Accra of the Ministry of Fisheries and Aquaculture Development for improved productivity. The specific objectives were to:

- Evaluate the spawning characteristics of the brooders used at the Centre
- Determine the growth performance of the fry and fingerlings under their culture conditions.
- Assess water quality in the culture facilities used in the fingerlings production.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Overview of Tilapia Production

The second most cultured fish species in aquaculture is tilapia after carps and it is farmed in about 85 countries according to FAO (2006) as stated by Kuton & Akapo (2012). Its foundation can be traced to Africa and the middle East and has been added to nations globally. It is rapidly recognized worldwide via the middle-class and upscale manufacturers as it serves as the principal supply of protein for the lower and the middle class (FAO, 2012). It is inexpensive and available animal-supply diet in nations with diets and nutritional insecurities (Fiedler *et al.*, 2015).

African populace is presently 1.2 billion and it is anticipated to attain three billion in 2020 (World meter, 2018). For food fish consumption to multiply to 23 kg for persons per annum (FAO, 2016), resources need to increase from about nine million tons to nine points seven million tonnes annually in 2020. To sustain imminent requirements, capture fisheries must to be sustained (Asmah, 2008) and if possible improved, and aquaculture increased to over 260% i.e. an annual mean of more than 8.3% by 2020 in sub-Saharan Africa only (Adeoye *et al.*, 2005), that is notably better than recent tiers. Approximately forty-three percent of the African region is classified as having the capability for cultivating tilapia, African catfish and carp (Ridler & Hishamunda, 2001) as referred to by Asmah, (2008). Of which according to the authors, 15% is taken into consideration to be suitable, with the ability for yields of up to 2.0 crops/year for Nile tilapia.

In Ghana, 80% of overall aquaculture production is derived from tilapia production (FAO, 2015 – 2017). It is far a delicacy for both the middle and lower class and consumed by

most religious groups nationwide (Asmah, 2008). According to Soto-Zarazúa *et al.*, (2011), *O. niloticus* all male tilapia cultivation has a financial necessity to its manufacturers and dealers, with a growth in employment within the region outstripping international populace. Growth and employment in conventional agriculture being a vital supply of earnings and livelihood for masses of millions of humans globally.

Significantly is the provision of quality seed that can be broadly disbursed to meet tilapia farming. (Gibtan *et al.* (2008). Increase in overall performance of *O. niloticus* relies on genetic materials, high-quality feed, energy content of the feed, stocking density and environmental factors. Remedios *et al.* (2008) additionally reported that, development in fishes is a complicated method by way of which ingested energy is converted to biomass. The effectiveness of this conversion is regulated through the increase capacity of the organism and various abiotic elements consisting of feed provided; temperature and unfavourable environmental factors introduced about by way of the situations wherein the fish are cultured. The aforementioned factors are consideration as exogenous factors which substantially influence increase in various ways varying on the dominating situation of the production stage. Feed supplied varies significantly within differing environmental conditions, extremely significantly to variations in the quantity and high-quality of the feed sources supplied by way of those environments. Temperature and different environmental elements show the advancement of increase and the survival of the fingerlings whether it will likely reach its peak or not. When suited heights of these factors are attained high survival rates, top-quality growth can be measured and production increment might be attained

2.2 Holding Facilities for Tilapia Fingerlings Production

In Ghana, fish-holding systems commonly used are floating cages found mainly in Lake Volta, earthen ponds and concrete tanks. Of all cultivated fish in Ghana, about Eighty-eight percent are derived from floating cages (Rurangwa *et al.*, 2015), with seven percent harvested from ponds three percent and the rest three percent from dug-outs and dams (FAO 2016).

Tilapia fry and fingerlings are most often produced in earthen ponds and tanks (Bhujel, 2013). Notwithstanding, net enclosures called hapas, aquaria and tanks fabricated from wooden, fiberglass, metallic, plastic or concrete are also used (Ujwala, 2009). Tilapia can reproduce without difficulty in ponds, irrespective of pond dimension and intensity, when the environmental necessities (temperature, salinity, and so on.) and biological criteria (stocking density, sex ratio, etc.) are met (El-Sayed, 2006). According to Guerrero (1997) as stated by Bolivar (2008), fry rearing in ponds is subject to predation and cannibalism. The selection of facility will rely on the requirement for fingerlings. The Aquaculture Demonstration Centre where this study was conducted uses concrete tanks and earthen ponds for fry production.

2.2.1 Tank Production of Fry

According to Ujwala, (2009), tank cultivation of tilapia fry and fingerlings is practiced where space for ponds is restrained or costly to obtain. Other materials, such as fiberglass or plastic lined pools, may be used. The tanks may be rectangular, square or circular made of wood, concrete, bricks, fiberglass, or plastic with individual water inlets and drains. Tanks may be located in enclosed buildings, outside or under partial cover. Temperature

is an important factor influencing tank location. A minimum water depth of fifty cm to 75 cm should be insisted to inhibit drastic water temperature variations in outdoor tanks. Greater control over water management, easy disease control, easy observation of fish and regular conservation is likely than with alternate methods. Fish may be simply harvested with dip-nets or a small seine, and well-built tanks can take a lifetime (Ujwala, 2009). Tank of surface area 50 m² to 100 m² and a depth of 1 m are used for fry production as stated by Bocek (2004).

2.3 Brooder Stocking and Spawning

The “Akosombo strain”, a genetically improved strain of the wild strain of *O. niloticus* found in Ghanaian waters and produced by Research Scientists from the Water Research Institute of Council of Scientific and Industrial Research (CSIR), is the farmed tilapia used predominantly in tilapia aquaculture in Ghana. Breeding and selection of this strain started 1999 in collaboration with the World Fish Center (Daily Graphic, 2012). It was produced by reciprocal crosses of four populations viz Nawuni, Yeji, Kpando and farmed stock from Nsawam (Mireku, 2017). It has the capability to develop at the least 30% quicker than the identical species inside the wild and this has warranted its recommendation to be used inside the Aquaculture industry in Ghana (Rurangwa *et al.*, 2015). Poor brood stock productivity, as a result of low fecundity and asynchronous spawning cycles, is a serious setback on commercial tilapia production and its future expansion (Tahuon *et al.*, 2008) Marketable fry cultivation, medium-size tilapia brood stocks (150–250 g) are required (Bhujel, 2000), whereas several brood stocks may spawn when they are as lesser as 60 g as cited by Peterman (2011). According to FAO (2017), the stocking ratio for females to

males is 1-4:1. The breeding process starts when the male establishes a territory, digs a craterlike spawning nest and guards his territory. The ripe female spawns in the nest, and immediately after fertilization by the male, the female collects the eggs into her mouth and moves off. The female incubates the eggs in her mouth and broods. Hussein (2004), stated that hatching of eggs take place after 70–90 hours in the mouth at $28\pm 1^{\circ}\text{C}$. Ujwala (2009), also stated that the ideal spawning and rearing temperatures for *O. niloticus* range from 25 to 33°C . The female holds the hatched larvae and gives parental care until the swim up stage when the yolk sac is absorbed. He also stated that, incubating and brooding takes place within 6 – 10 hours. After fry are released, they may swim back into her mouth if danger threatens. Being a maternal mouth brooder, the number of eggs per spawn is small in comparison with most other pond fishes. Egg number is proportional to the body weight of the female. According to (Towers, 2015), 90-300 g female produces as much as 500 eggs per spawning, while a female weighing 600-1000 g can produce 1000 to 1500 eggs. The male remains in his territory, guarding the nest, and is able to fertilize eggs from a succession of females.

Towers (2015) recommended a ratio of 1 male: 2-4 females for brooder fish, a stocking density of 3-5 / m^2 and fry harvest within 13-14 days, fed on 30-45% protein as stated in Peterman (2011) for optimum reproduction, spawning efficiency, larval growth and survival. This author obtained a final yield estimated at 400-3,000 fry / m^2 /month. Whiles Bhujel (2013) also stated that 3-4 fish/ m^2 at a sex ratio of 1 male to 3 females stocked is ideal for fingerling production and that the brooders should be fed twice at 3 – 5% of their body weight. It has been ascertained that greater seed output can be acquired from ponds filled with new water than from ponds with water used for long intervals (Bhujel 2000) and

that low fry production can be experienced due to partial harvesting and cannibalism in tanks. In fry/fingerling production, therefore, some principles/guidelines need to be adhered to.

2.4 Fry Harvesting, Growth and Sex Reversal

According to Bocek (2004), fry can be harvested with a 1.5 to 2 mm mesh (mosquito-mesh) seine net gently drowned through the tank every 3 to 4 days starting 10 to 11 days after stocking brood fish. The seine can be drowned just above the tank bottom so the brood fish can escape under the net. Female brood fish carrying eggs may spit out their eggs if captured. The eggs may die and fry production is reduced (Bocek 2004). *O. niloticus* females usually release fry from their mouths when captured. Harvested fry are very fragile and should be kept in water as much as possible to avoid damage and stress. According to Bhujel (2013), fry rearing is done in two-stage process; rearing after harvesting (hormonal sex reversal) from brooder tanks and advanced fry rearing to attain larger fingerlings over a time period.

The Nile tilapia matures early and therefore has the capability to spawn monthly. These qualities result in the over-population of stocked tilapia ponds, slow growth due to overcrowding of the fish resulting in unequal market size fish as stated by Fashina-Bombata & Megbowon (2012). Due to the constraints stated above, the male culture of tilapia is desired because they have the capability to grow faster than the females (Megbowon & Mojekwu, 2013) and therefore it is more profitable than the mixed-sex production. According to Carlos *et al.* (2015) anticipated survival for mono-sexed culture

is 90% or greater and 500 g fish can be produced when stocked at 50 g fingerlings, with a growth rate of 2.5 g/day.

According to Phelps & Popma (2000) in Peterman (2011), the cultivation of all male tilapia can be achieved by techniques such as separating the males and females manually, Hybridization, Chromosomal manipulation and hormonal sex reversal. Among these three (3) methods, chromosomal manipulation and sex reversal (Methyl testosterone treatment) of the Nile tilapia fry is the most easy and consistent technique to produce all male tilapia stocks, which reliably grow to a big or unvarying size than mixed sex Nile tilapia (Phelps & Popma, (2000).

The Nile tilapia, sex reversal implies the treatment administration of male steroid to newly hatched fry so that the undifferentiated gonadal tissue of generic female develops testicular tissue, which makes them function reproductively as males (Megbowon *et al.*, 2009). The weight of first feeding tiny fry of Nile tilapia is about 0.01g. According to Peterman (2011), Hormone treatment is administered between 2- 4 weeks by which time there is differentiation in the gonadal tissues.

FAO (2017) stated that fry are stocked at 3000 to 4000/m² in hapas or tanks with water exchange. Bhujel (2013) also stated that 1000–1200/m² is an ideal initial stocking density for fry the first week of harvest and fed 35% crude protein, this is reduced to 300–400/m² in the second week at 10-20% biomass per day. By the close of a three (3) to four (4) week sex-reversal phase. Rations could be administered four or more times per day (Bhujel 2013) by satiation or ad libitum or restricted ration. It was stated that, feeding ad libitum may result in higher growth rates but may not be the most economical way to culture the fish as it is hard to verify satiation levels in fish. Feeding to satiation can lead to

overfeeding, feed wastage, and poor water quality. Sex-reversed fry reach an average of 0.2 g after 3 weeks and 0.4 g after 4 weeks. Other components such as stocking density, feeding, temperature and other environmental conditions (Bocek *et al.*, 1992) affects the fry survival after hormone treatment as cited by Odin & Bolivar (2011). It was cited by Vera Cruz (1991) that the sex reversal treatment unit affects the value of fingerlings yield. According to Vera Cruz & Mair (1994) in Odin & Bolivar, (2011), more than 70% survival rates was recorded for hormonal treated fry in outdoor tanks with water exchange for at least once a day. Rokacy (2005) reported constant use of aerators and water exchange to remove accumulated waste reduced high mortality in tank and predators like frog and birds could represent another cause of high mortality. The average efficacy of sex-reversal varies from ninety-five to hundred percent dependent on the strength of management (FAO, 2017).

2.5 Incubation of Eggs

The use of artificial incubation units includes the removal of eggs and sac fry from the mouth of females and incubating them artificially has been a successful technique of tilapia fry rearing (Hussain 2004). According to Bolivar (2008), the advantage over natural incubation could be the elimination of cannibalism, high manufacturing of equal-sized fry, accelerated spawning synchrony, shortened inter-spawning intervals, discount of hatching time and facilitation of research on tilapia genetics and reproduction. According to Hussain (2004), the hatching jars should be attached to a recirculating system, where fresh water normally at 28 ± 1 °C comes straight from a header tank by gravity and fertilized eggs from each female incubated separately in a jar. Eggs could be incubated artificially in plastic,

fiber glass or simple plastic glass jars supplied with clear water and separated according to their five developmental stages into each jar (Bhujel, 2013).

Bhujel (2013) stated that, nursing the fry starts when it attains a weight of 0.2 –1.0 g; the fry nursing period ranges from a few days to a month or so, and the time period depends on demand for fry. He also reported that small (<2 cm) fry are susceptible to predation by other fish and birds and have lower tolerance to poor water quality. Boyd (2013), also stated that fry weight gain after sex reversal (28 days) is 0.1 to 1.0 g. The first month of the production cycle is crucial to survival (Bhujel, 2013). The stocking density in ponds was 25 –200 fry / m² and the survival rate in nursery production of the Nile tilapia fry was above 60% when the fish was reared for 1 – 3 months and the final standing crop exceeded 5,000 kg ha⁻¹ (Boyd 2013).

2.6 Water Quality Monitoring

Fish are cold blooded organisms and carry out all their bodily functions in water. they're completely reliant on water to respire, feed and develop, excrete wastes, and reproduce; consequently, identifying the physical and chemical qualities of water is vital to quality fingerling production (Solomon & Momoh, 2017). Thus, the first most important factor that affects production cycle in fish is the quality of water (Alabaster & Lloyd, 2013). The behavior and growth performance of Nile tilapia have been assessed underneath various components along with ammonia and temperature (El-Sherif & El-Feky, 2009 as cited by Carlos *et al.*, 2015). According to Bolivar (2008), water temperature is a vital issue controlling the rate of metabolism in fishes, consequently rapid alternate in water temperature points to immediately modifications in fish metabolism. This variation ends

in reduction in feeding, which affects spawning (Bolivar, 2011). La Don, (2000) as cited by Solomon & Momoh, (2017) stated that the temperature of the water influences the activity, feeding, increase and production of all fishes ((Boyd, 1982). According to Federal Ministry of Environment FME (2006) & Swann (2006) the temperature range of 20-33°C is recommended as permissible limit standard for aquatic life whiles Bhujel (2000) recommended 24 - 30°C as good for reproduction in the Nile tilapia and above 35°C to be very poor. Other researchers like Ngugi *et al.*, (2007) gave a range of 20-35 °C whiles FAO (2011) and Makori *et al.*, (2017) gave ideal range of 21 – 36 °C.

The quality of water can also be evaluated by measuring the pH, which gives a hint of its acidity or alkalinity. As stated by Solomon & Momoh (2017), the principal reason of controlling pH in natural water is the carbonate system, which is composed of carbon dioxide, carbonic acids bicarbonates, and carbonate ions Decomposition of organic matter contributes to high values in pH. It was also reported that pH fluctuates by one or two units every day, in the morning, carbon dioxide values are high and pH is low due to respiration at some stage in the night time. After sunrise, algae and other given plant produce carbohydrate and oxygen from carbon dioxide and water by photosynthesis. As the carbon dioxide is removed, the water pH increases and the lowest pH are commonly associated with lowest dissolved oxygen and vice versa. Federal Ministry of Environment FME (2006) of Nigeria, recommended pH value of 6.0-9.0 as suitable for aquatic life which is also suitable for the Nile tilapia according to Guerrero, (1997) Popma & Masser (1999), Nandlal & Pickering (2004) and Peterman (2011). Bardach *et al.*, (1972) in Peterman (2011) cited that tilapia can however tolerate pH from 5-11.

Dissolved oxygen (DO) is an essential physiochemical parameter in aquaculture; low dissolved oxygen levels are responsible for fish mortality, both directly or indirectly (Solomon & Momoh 2017). The recommended DO for aquatic life is 6.8 - 9 mg l⁻¹ (FME, 2006). The Nile tilapia can tolerate DO levels down to 0.3 mg l⁻¹ according to Popma & Masser, (1999) as stated in Peterman (2011). Notwithstanding this capacity to survive acute low DO concentrations, tilapia systems should be controlled to keep DO. above 2 mg l⁻¹. This is due to the fact that chronic exposure to low DO. depresses metabolism, growth and disease resistance (Teichert Coddington & Green, 1993; Nandlal & Pickering, 2004; Peterman, 2011). According to Ross (2002), as stated by Makori *et al.* (2017), the lowest DO for optimum growth is 3 mg l⁻¹ while the preferred DO of above 5 mg l⁻¹ is required for optimum growth. Bhujel (2000) reported that low DO reduces reproduction, causes oocyte atresia, spawning inhibition, decreased fecundity and hatchability.

Un-ionized ammonia (NH₃) levels can suppress feeding at 0.08 mg l⁻¹ (Popma & Masser, 1999, Peterman, 2011) whilst chronic exposure to NH₃ levels ≥ 1 mg l⁻¹ causes mortality especially among juveniles and fry (Popma & Masser, 1999) as stated by Peterman (2011). Extreme limit of ammonia concentration for aquatic organisms is 0.1 mg l⁻¹ according to Santhosh & Singh, 2007, while Bhatnagar & Singh (2010) in Makori *et al* (2017) suggest that ammonia levels of < 0.2 mg l⁻¹ are suitable for pond fishery. Towers (2015) also stated that, ammonia and ammonium strongly impact water quality and too high a level can lead to mortality. Good water quality on tilapia farms relies on a suitable environment to enhance growth. Such an environment can be achieved by maintaining the right balance between feed input and the assimilative capacity of the water. However, the more fish that are grown, the

higher the demand on fish production, and extra factors are needed to attain better water quality.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study Area

This study was conducted at the Aquaculture Demonstration Centre, Ashaiman - Greater Accra Region of Ghana. Other Center's are Pilot Aquaculture Center (PAC) located at Kona-Odomase in the Ashanti Region and Water Research Institute also located at Akosombo in the Eastern Region. The Aquaculture Demonstration Center is enclosed between Longitude N 05.669 77° and Latitude W 000.05 394 (Figure 3 1). The Centre was set up in 1968 by the then Fisheries Directorate of the Ministry of Food and Agriculture but now belongs to the Ministry of Fisheries and Aquaculture Development (MoFAD). The Centre takes its source of water from the Ashaiman Irrigation Reservoir which was set up by the Irrigation Development Authority (GSS 2014). The Ashaiman Aquaculture Demonstration Centre has sixteen (16) nursery tanks of surface area 50 m² each. There are five (5) large earthen ponds, the largest has a surface area of 2100 m² and the remaining four (4) are of same size, 1500 m² (Plate 1). The ponds and tanks have an average depth of 1 m. The main responsibility of the Ashaiman Aquaculture Demonstration Centre is to produce Nile tilapia (*Oreochromis niloticus*) and African catfish (*Clarias gariepinus*) fingerlings for grower fish farmers in Ghana and neighbouring countries. Total annual production was 1.2 million in 2017 (ADC, 2018). The Centre also provide extension services and training to small-scale farmers as well as hand-on training for student interns. The Center is managed by a Farm Manager, four (4) professionals, one (1) Technical Assistant, three (3) labourers and six (6) farm hands (casual).

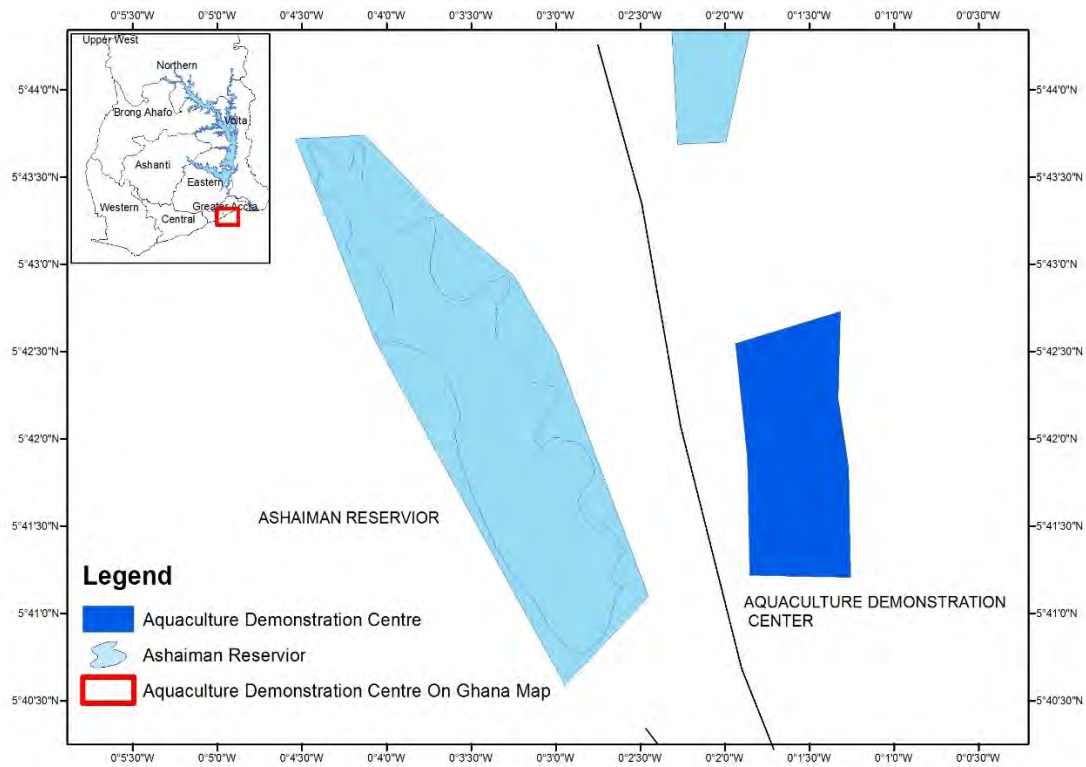


Figure 3.1 Map of Ghana showing the Aquaculture Demonstration Centre.



Plate 1 Aerial view of the Aquaculture Demonstration Centre.

Source and Date: Jason Quashigah, 19/04/16.

3.2 Preparation of Culture Facilities

Culture facilities used for fry production were eleven (11) rectangular concrete tanks of length 10m and breadth 5m (50 m²) of which nine (9) were breeding tanks and two (2) were for hormone treatment of fry. The tanks were cleaned and filled with water from the reservoir (Plate 2). Two (2) earthen ponds of surface area 1500 m² were used as nursery ponds where fry were raised to the fingerlings stage.



Plate 2. Filling of concrete tanks with clean water from the Ashaiman Reservoir.

3.3 Brooder Stocking

One thousand five hundred (1,500) brooders of weight 30g were brought from the Aquaculture Research and Development Centre (ARDEC) of the Water Research Institute (WRI) and separated into two sexes manually. They were then conditioned in tanks for a week during which period they were fed Nile tilapia brooder diet containing 33% crude protein. Females had an average weight of 150.7 ± 41.8 g while the males weighed 218.6 ± 63.1 g. Brooders were stocked at a ratio of 3 females to 1 male, at a stocking rate of 4

brooders per m². Each spawning tank was stocked with 200 brooders. Brooders were fed to satiation for 12 days before fry harvesting.

Five hapas were stocked with a male and female each with an average weight of 200 and 150 respectively for fecundity test.

3.4 Fry Harvesting

Fourteen days after stocking of brooders, fry were harvested from the surface of the water with a drag net. This process of fry harvest was repeated until all fry were collected. After the fry harvest, brooders were collected, sexed and placed into net hapas for resting. All the fry obtained from the nine spawning tanks (Plate 3) were transferred into one concrete tank for hormonal treatment to all male. The total number and average weight of the fry harvested in each spawning tank was estimated.



Plate 3 Fry harvested into a basin for stocking in a tank for hormonal treatment

3.5 Hormonal Sex Reversal of Fry

Fry stocked into new tank were treated with 17α Methyltestosterone (MT) for all male sex reversal. The hormone was incorporated into the feed of the fry and administered for 28 days. It was prepared a day before fry harvesting by the following methods: One kilogram of a complete crumbled feed (Aller Aqua, Busum, Germany) of particle size 0.2 mm- 0.4 mm with 64% crude protein level was measured into a clean basin. An amount of 0.06 g of the hormone was poured into 250 ml of alcohol (70%) and thoroughly mixed. The mixture was sprayed uniformly on the feed and mixed again with gloved hand to break crumbs that may have formed due to the high moisture (Plate 4). The treated feed was sieved to remove unwanted materials and to obtain a smooth feed. It was then spread on a clean sheet for shade drying. The feed was stored in a sealed container after drying and used to feed the fry. They were fed ad-libitum four times a day. Fry were sampled and weighed weekly. The following indices were calculated from the data generated (Kuton & Akapo, 2012).



Plate 4. Hormonal feed preparation (left), Hormonal feed shade drying (right).

The following production parameters of the fry were estimated based on the mathematical relationships:

$$\% \text{ Hatching} = (\text{No. of fry harvested} / \text{Total no. of eggs expected}) \times 100$$

$$\text{Specific Growth Rate (\%day}^{-1}\text{)} = (\text{Log}_e W_f - \text{Log}_e W_i / \text{Time}) \times 100$$

Where W_f = Final body weight; W_i = Initial body weight

Where Time is in days

(Kuton & Akapo, 2012)

$$\text{FCR} = \text{Feed intake (g)} / \text{Total weight gain (g)}$$

(Kuton & Akapo, 2012)

$$\text{Survival Rate (\%)} = (\text{Number of fish harvested} / \text{Number of fish stocked}) \times 100$$

(Yousouf *et al.*, 2007)

$$\text{Final standing crop (kg ha}^{-1}\text{)} = (\text{Total biomass} / \text{weight of fish harvested (kg)})$$

3.6 Fingerling Production in Nursery Pond

After the hormone treatment, fry were harvested, counted, weighed and transferred into an earthen pond. This was to grow the fry to fingerlings of average size of 2.4 g. In the nursery pond, the fish were fed four times a day a complete feed (48% crude protein and particle size between 0.5 mm – 1.8 mm (Aller Aqua, Busum-Germany) for the period of 24 days feeding to satiation (*ad libitum*).

After 24 days of growth in the nursery pond, the fingerlings were harvested. The total number and average weight of fingerlings were estimated and percent survival calculated. Fingerlings harvested into the Rachel nets were constantly flushed over night to wash mud that might have gotten into the gills and were conditioned for packaging and transportation to out-grower farmers.

3.7 Water Quality

Water quality parameters such as dissolved oxygen (DO), pH, temperature, ammonia and salinity were taken from the brooder tanks, fry treatment tanks and nursery pond throughout the study period with a Multi-parameter probe (Hydrocheck[®] HC500 and HC 2000, Trace2o Ltd., Berkshire, UK). In the brooder tanks the probe was placed into the tanks at random points each time and the reader handled by the student. In the case of the earthen pond, the student entered the pond with waders, probe placed in the pond, water sampled at random points each time for the study period and readings were taken.

3.8 Statistical Analysis

Single factor Anova test was run with excel to check for significance differences within the breeding tanks and their replica.

CHAPTER FOUR

4.0 RESULTS

4.1 Water Quality in the Production Facilities

4.1.1 Temperature

Table 4.1 shows the overall water quality concentrations for the different production stages (breeding, fry and fingerling production stages) during the study. From the Table, evening and morning temperatures were $29.03 \pm 0.51^{\circ}\text{C}$, $28.07 \pm 1.79^{\circ}\text{C}$, $27.07 \pm 1.68^{\circ}\text{C}$ and $31.82 \pm 0.74^{\circ}\text{C}$, $29.94 \pm 1.8^{\circ}\text{C}$, $28.96 \pm 1.62^{\circ}\text{C}$ respectively for breeding tanks, fry tanks and fingerling pond. The evening values were higher than the morning values. The lowest temperature of ($27.07 \pm 1.68^{\circ}\text{C}$) occurred in the fingerling production pond while the breeding tank had the highest temperature of ($31.82 \pm 0.74^{\circ}\text{C}$). In the breeding tank, the lowest temperature of (28.12°C) occurred on the 9th day of breeding, while the highest (33.19°C) was on the 1st day of stocking (Figure 4.1). Lowest temperature for fry (24.55°C) occurred on the 22nd day while the highest (33.55°C) was on the 8th day of hormonal treatment (Figure 4.2). In the fingerling production pond, the highest temperature for both morning (30.40°C) and evening (31.85°C) were on the 8th day while the lowest for evening was (25.20°C) on the 23rd day and (24.90°C) on the 24th day for morning (Figure 4.3).

Table 4.1 Mean water quality parameters for the different stages of production of Nile tilapia fingerlings at the Aquaculture Demonstration Centre, Ashaiman from 15th January – 7th March, 2018. Values are means $\pm$ standard deviation.

Parameter	Stage of production		
	¹ Breeding	² Fry	³ Fingerling
0600 GMT Temp (°C)	29.03 $\pm$ 0.51	28.07 $\pm$ 1.79	27.07 $\pm$ 1.68
1700 GMT Temp (°C)	31.82 $\pm$ 0.74	29.94 $\pm$ 1.82	28.96 $\pm$ 1.62
0600 GMT DO (mg l ⁻¹)	3.56 $\pm$ 0.04	3.62 $\pm$ 0.18	3.74 $\pm$ 0.21
1700 GMT DO (mg l ⁻¹)	3.93 $\pm$ 0.15	3.82 $\pm$ 0.18	4.03 $\pm$ 0.22
pH	7.38 $\pm$ 0.19	7.35 $\pm$ 0.18	7.56 $\pm$ 0.25
Salinity (‰)	0.23 $\pm$ 0.01	0.24 $\pm$ 0.02	0.29 $\pm$ 0.02
Ammonia (mg l ⁻¹)	0.12 $\pm$ 0.06	0.01 $\pm$ 0.002	0.04 $\pm$ 0.01

¹Breeding stage involved the stocking of brooders until spawning of fry (13 days).

²Fry stage represents the period of hormonal treatment of fry for sex-reversal (28 days).

³Fingerling stage was the period of culturing of fry after hormone treatment to harvest (24 days).

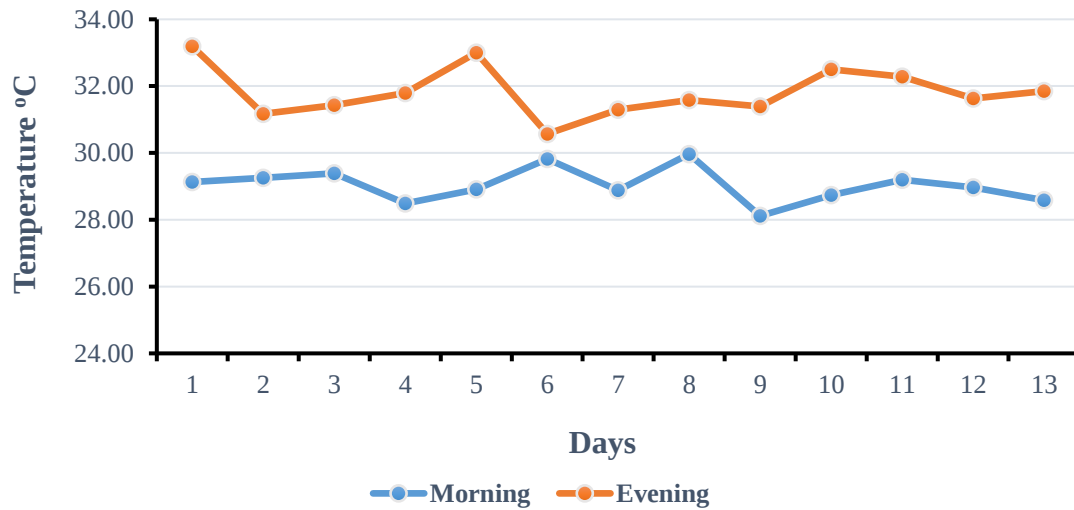


Figure 4.1 Mean temperature variation in breeding tanks during the spawning stage at the Aquaculture Demonstration Centre during the study period.

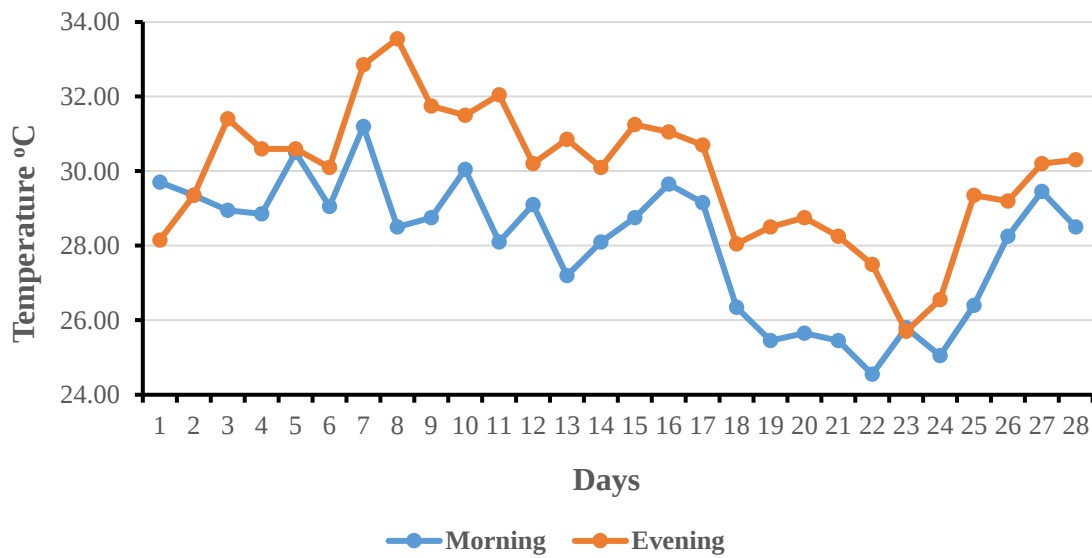


Figure 4.2. Mean temperature variation in fry tanks during the fry hormonal treatment stage at the Aquaculture Demonstration Centre during the study period.

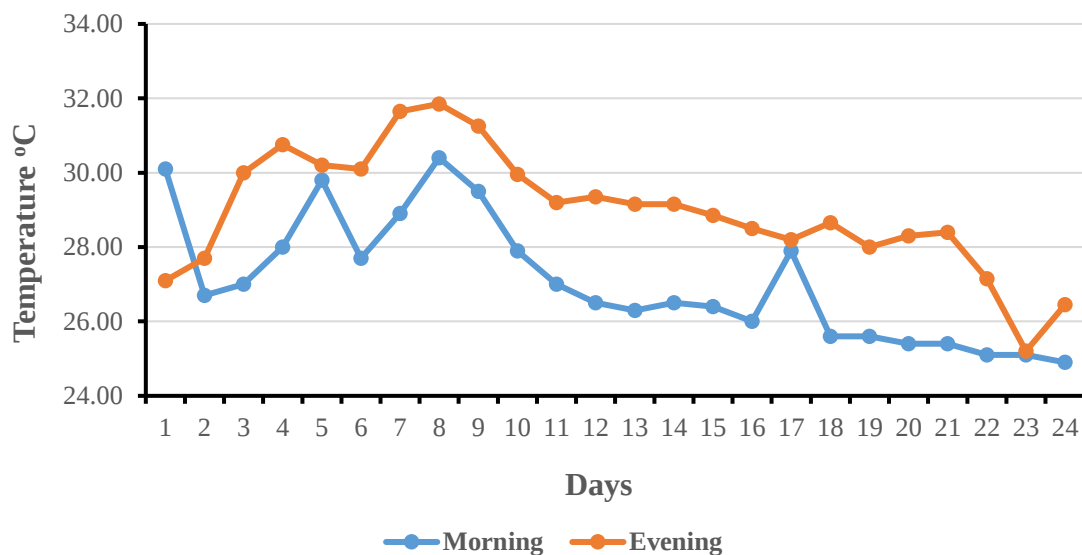


Figure 4.3. Mean temperature variation in earthen pond during fingerling production stage at the Aquaculture Demonstration Centre the study period.

DO in the morning and evening were $3.56 \pm 0.04 \text{ mg l}^{-1}$ and $3.62 \pm 0.18 \text{ mg l}^{-1}$, $3.74 \pm 0.21 \text{ mg l}^{-1}$ and $3.93 \pm 0.15 \text{ mg l}^{-1}$, and $3.82 \pm 0.18 \text{ mg l}^{-1}$ and $4.03 \pm 0.22 \text{ mg l}^{-1}$ in the breeding, fry and fingerlings facilities respectively. The highest value ($4.03 \pm 0.22 \text{ mg l}^{-1}$) occurred in the fingerling pond in the evening (Table 4.1). The mean evening DOs were slightly higher than the morning values. For the breeding tank the lowest DO (3.65 mg l^{-1}) was seen on the 7th day and the highest (4.16 mg l^{-1}) was on day 3 after stocking during the evening whiles the highest for the morning (3.60 mg l^{-1}) were seen on days 6, 8, 9 and 13 (Figure 4.4). In the fry production tank, the highest value (4.20 mg l^{-1}) and lowest (3.37 mg l^{-1}) for morning were seen on days 21 and 10 respectively whiles that for the evening were 4.08 mg l^{-1} and 3.43 mg l^{-1} respectively on days 27 and 1 (Figure 4.5). The fingerling pond gave values of 4.39 mg l^{-1} on day 22 which was the highest and 3.56 mg l^{-1} on day 19 being the lowest (Figure 4.6).

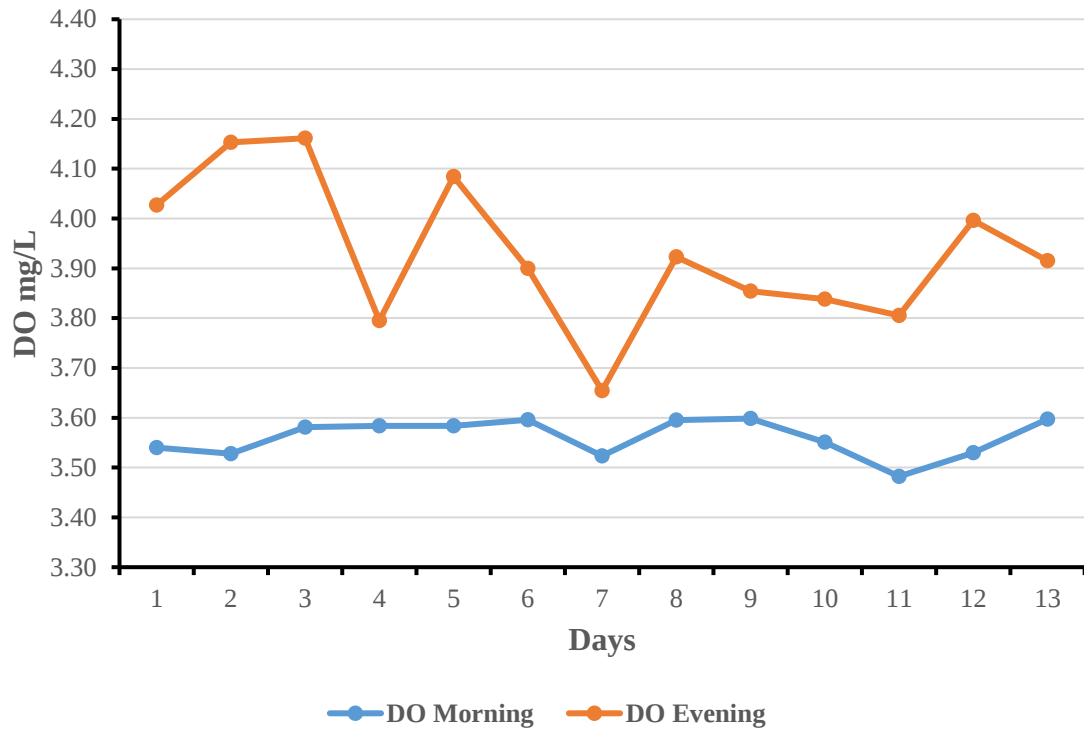


Figure 4.4. Mean values of dissolved oxygen variation in tanks during the breeding stage at the Aquaculture Demonstration Centre during the study period.

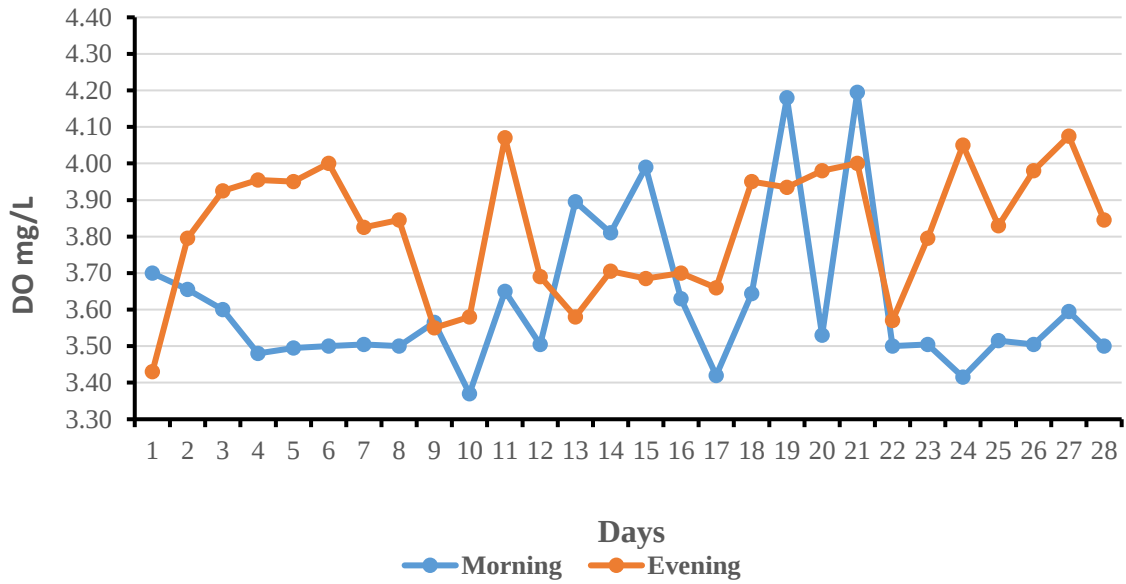


Figure 4.5. Mean values of dissolved oxygen variation in fry tanks during the fry hormonal treatment stage at the Aquaculture Demonstration Centre during the study period.

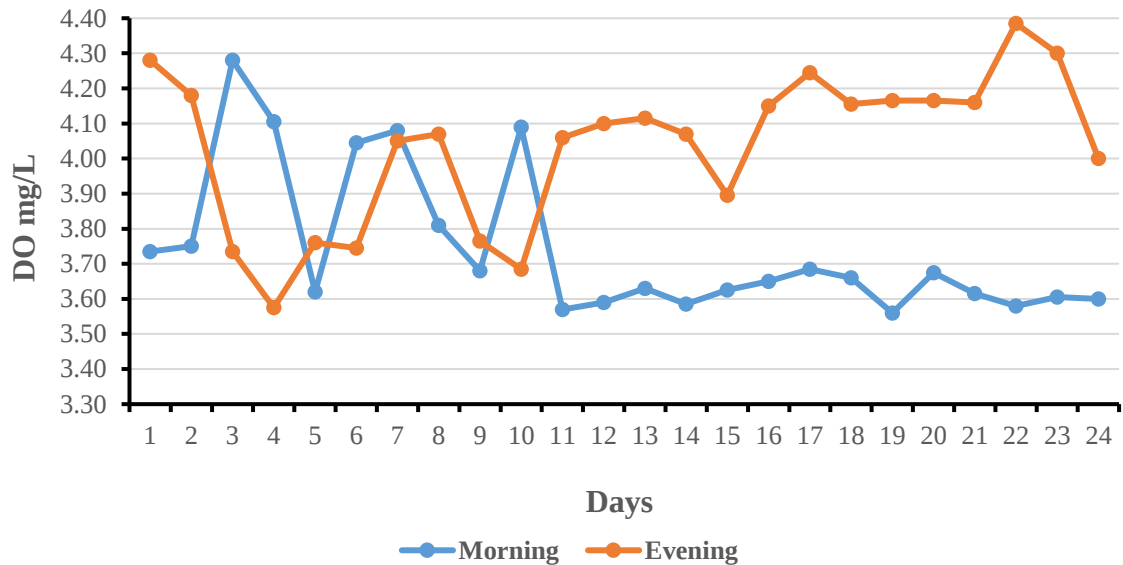


Figure 4.6. Mean values of dissolved oxygen variation in earthen pond during fingerling production stage at the Aquaculture Demonstration Centre during the study period.

4.1.3 pH

The overall mean pH values were 7.38 ± 0.19 , 7.35 ± 0.18 and 7.56 ± 0.25 for the breeding, fry and fingerlings stages respectively (Table 4.1). Highest mean value of 7.56 ± 0.25 was found in the fingerling pond whilst the lowest mean value of 7.38 ± 0.19 occurred in the breeding tank. The highest pH value in the breeding tank (7.64) occurred on day 10 and the lowest (7.10) was on the 3rd day (Figure 4.7). Fry tank had the highest (7.89) on day 8 with the lowest (7.13) on day 21 (Figure 4.8). In the fingerling pond, 7.93 was the highest and 7.17 was the lowest, and these occurred on days 18 and 1 respectively (Figure 4.9).

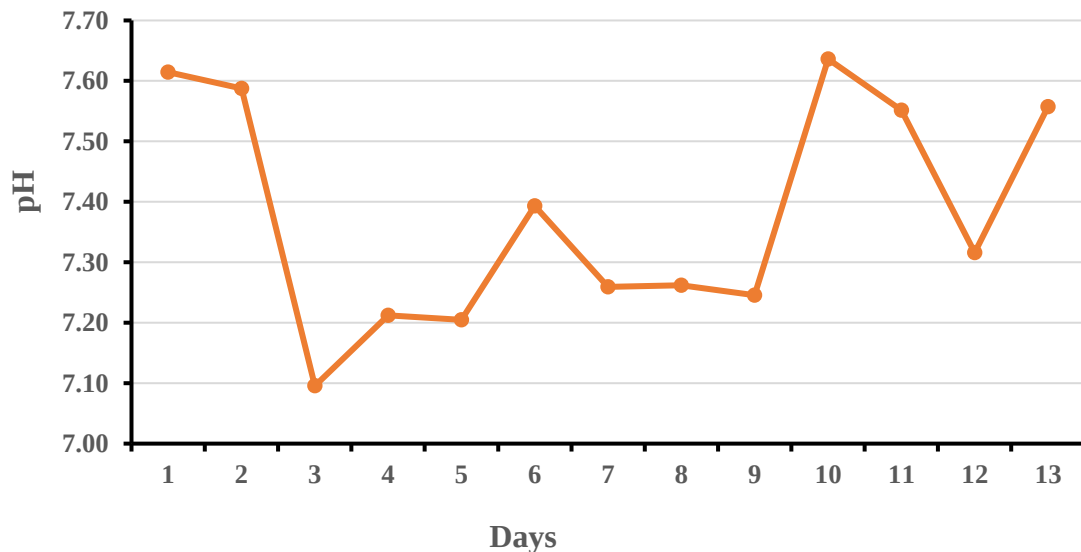


Figure 4.7. Mean pH variation in tanks during the breeding stage at the Aquaculture Demonstration Centre during the study.

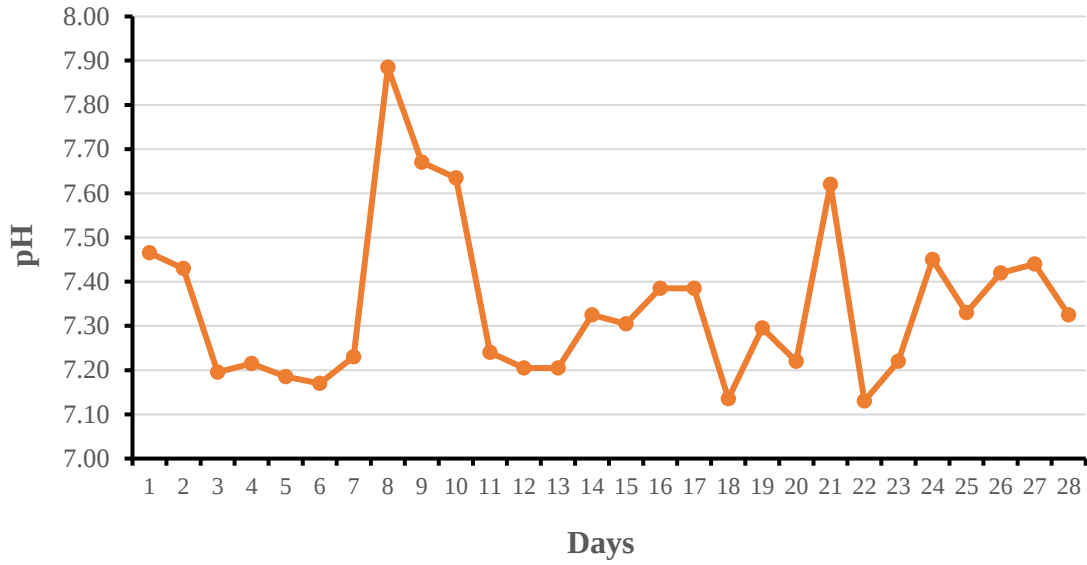


Figure 4.8. pH variation in fry tanks during the fry hormonal treatment stage at the Aquaculture Demonstration Centre during the study.

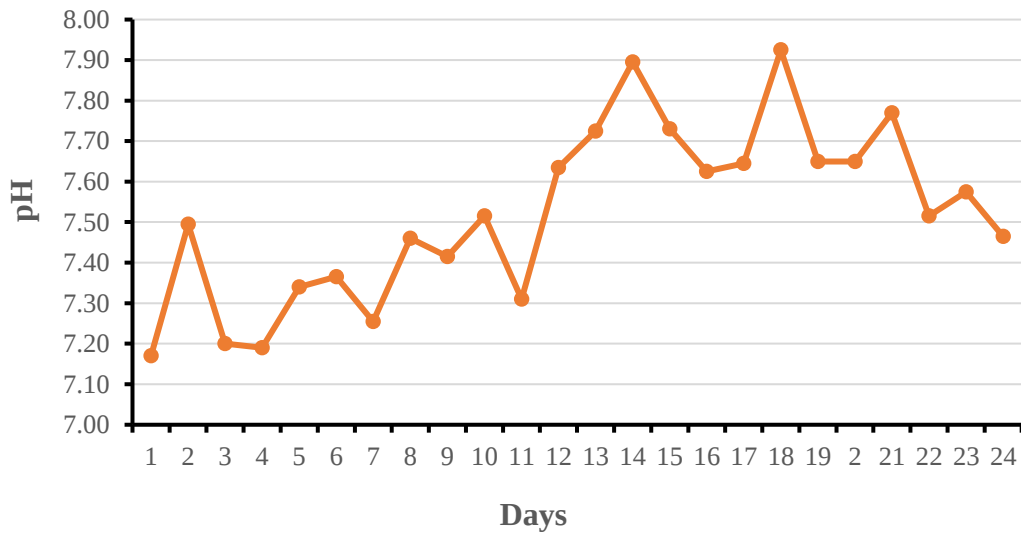


Figure 4.9. pH variation in earthen pond during fingerling production stage at the Aquaculture Demonstration Centre during the study period.

4.1.4 Salinity

The salinity values were $0.23 \pm 0.01\text{‰}$, $0.24 \pm 0.02\text{‰}$, $0.29 \pm 0.02\text{‰}$ (Table 4.1) for breeding, fry and fingerlings production facilities. The fingerling production pond gave the highest mean salinity of 0.29‰ and the lowest 0.23‰ . Within the breeding tanks, the least value (0.22‰) was on the 1st day of stocking and the highest value (0.24‰) on days 3, 7 and 9 (Figure 4.10). The fry production unit had the highest (0.31‰) on day 12 and the least (0.21‰) on days 8 and 10 (Figure 4.11). From Figure 4.12, the highest salinity (0.32‰) occurred consecutively on days 22, 23 and 24, and the least (0.26‰) also on day 2 and continuously through days 8 to 10 during fingerlings production.

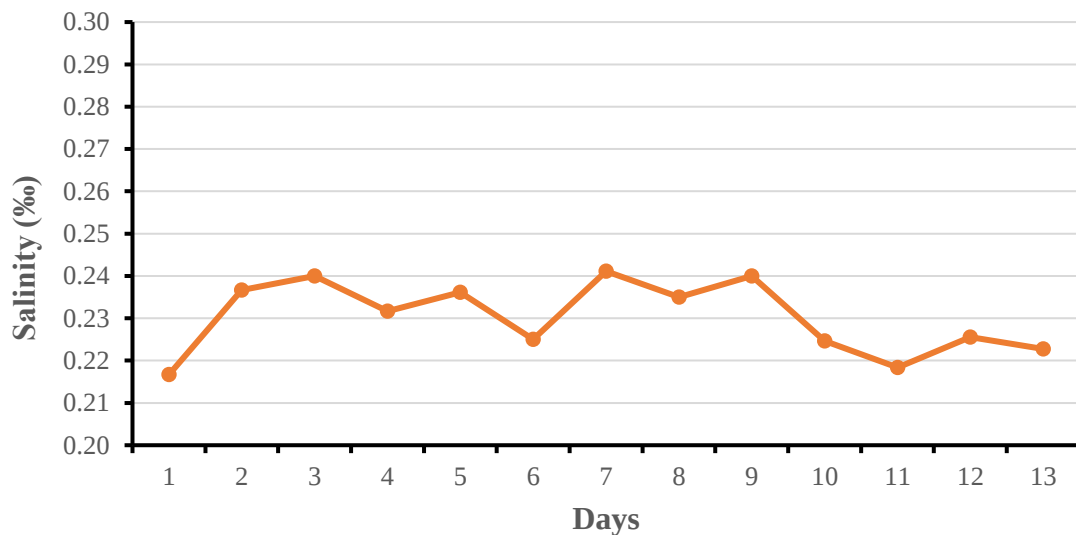


Figure 4.10. Salinity variation in tanks during the breeding stage at the Aquaculture Demonstration Centre during the study period.

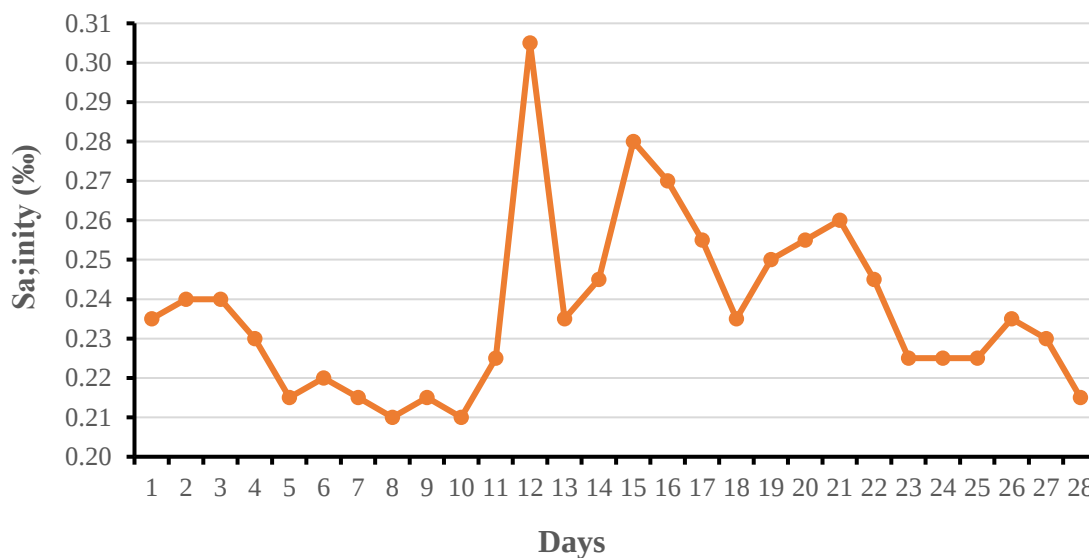


Figure 4.11. Salinity variation in fry tanks during the fry hormonal treatment stage at the Aquaculture Demonstration Centre during the study period.

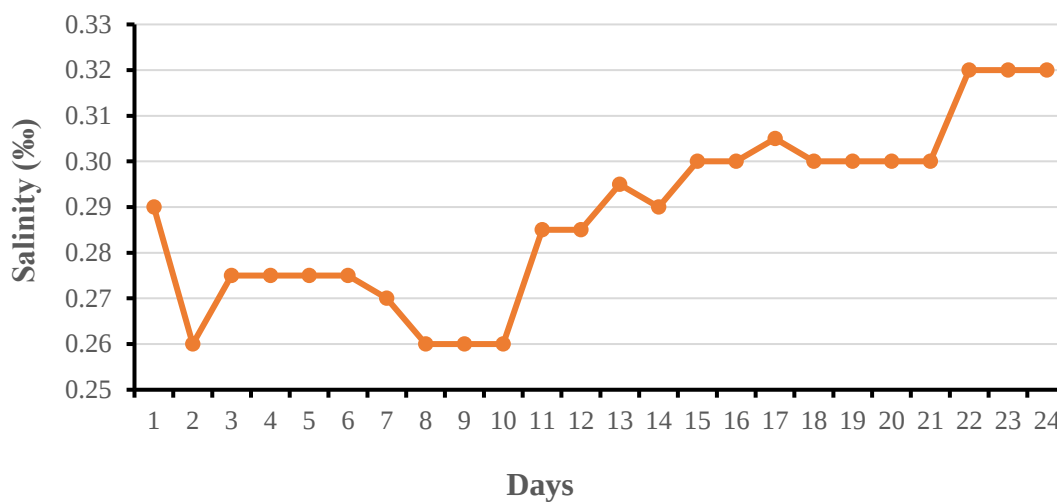


Figure 4.12. Salinity variation in earthen pond during fingerling production stage at the Aquaculture Demonstration Centre during the study period.

4.1.5 Ammonia

The overall mean ammonia concentrations were $0.12 \pm 0.07 \text{ mg l}^{-1}$ for breeding tanks, $0.01 \pm 0.002 \text{ mg l}^{-1}$ in fry tanks and $0.04 \pm 0.01 \text{ mg l}^{-1}$ in the fingerlings production pond (Table 4.1). The breeding tanks had the highest concentration ($0.12 \pm 0.07 \text{ mg l}^{-1}$) while the fry tanks had the lowest ($0.01 \pm 0.002 \text{ mg l}^{-1}$). The first week of breeder stocking recorded lower concentration of (0.07 mg l^{-1}) while the highest concentration of (0.17 mg l^{-1}) were seen in the 2nd week (Figure 4.13). Fry production unit had (0.01 mg l^{-1}) which was the lowest in week 2 and (0.013 mg l^{-1}) the highest in week 3 (Figure 4.13). Highest value (0.05 mg l^{-1}) for fingerling unit was observed on the 7th day (1st week) and the lowest value of (0.03 mg l^{-1}) on the 21st day, (Figure 4.13, 3rd week).

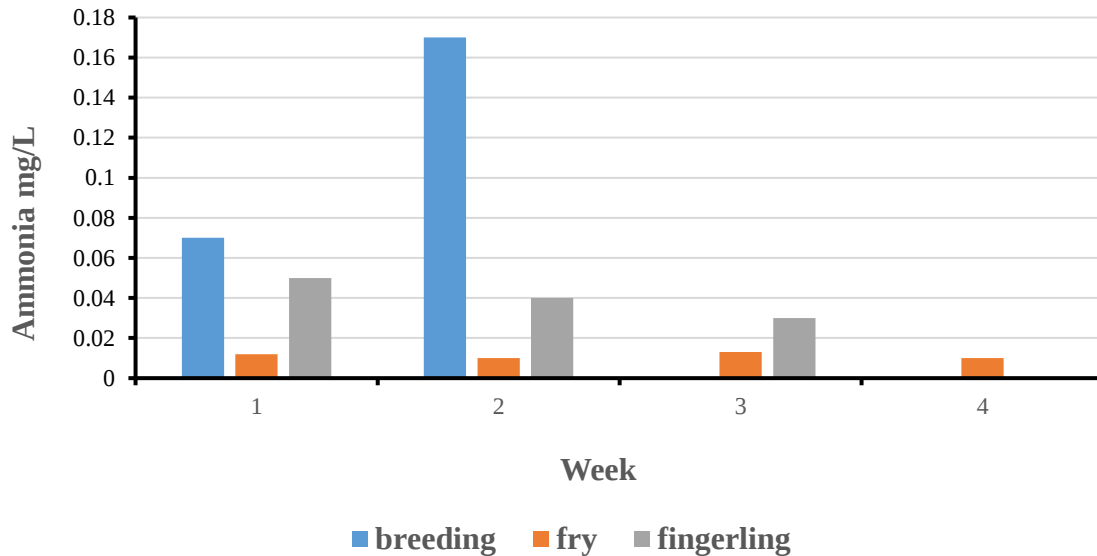


Figure 4.13 Weekly mean variation in ammonia concentration during the breeding, fry and fingerling production stages at the Aquaculture Demonstration.

4.2 Production Characteristics of Brooders

Brooder characteristics is detailed in Table 4.2. Average weight of female brooders was 150.7 ± 41.8 g and that of the males was 218.6 ± 63.1 g. The estimated number of eggs/female was 500 ± 72.1 eggs. A total of 1350 female brooders were used for this study. The estimated overall total number of eggs spawned by the females was 675,000. However, the total number of fry harvested was 138,631. The percent hatched was estimated at 20.5%.

Table 4.2. Production characteristics of Nile tilapia brooders at the Aquaculture Demonstration Centre, Ashaiman during breeding stage of the study. Values are means $\pm$ standard deviation.

Variables	Brooder
Average weight of female (g)	150.7 ± 41.8
Average weight of male (g)	$218.6 \pm 63.$
Average no. of eggs / female	500 ± 72.1
Estimated total no. of eggs from all females	675,000
Estimated total no. of fry harvested (counts)	138,631
Percentage hatching (%)	20.5

4.3 Production Characteristics of Fry and Fingerlings

Production characteristics for fry and fingerlings are in Table 4.3. Average stocking weight per fry was 0.014 ± 0.003 g and 0.23 ± 0.04 g per fingerling. The stocking rates were 2,773 m⁻² for fry and 92 m⁻² for fingerlings. The average weight of the fry after hormonal treatment was 0.23 ± 0.04 g. At the end of the study, the fingerlings attained an average weight of 2.47 ± 0.55 g. The SGR for the fry during the hormonal treatment period was $6.05 \pm 0.35\% \text{day}^{-1}$ whilst the fingerlings showed SGR of $3.26 \pm 0.18\% \text{day}^{-1}$. FCR was 1.46 and 1.09 for fry and fingerlings respectively. From the Table, survival rate for fry was 79.5% and that for fingerlings was 75.3%. The final standing crop estimated was 5069.2 kg ha⁻¹ for fry and 1708 kg ha⁻¹ for fingerlings. Predators like frogs and birds were observed in and around the earthen pond during the period of study. Cannibalism was also observed in the fry tank.

Table 4.3. Production characteristics of fry and fingerlings at the Aquaculture Demonstration Centre, Ashaiman. Values are means $\pm$ standard deviation.

Variable	Fry	Fingerling
Average stocking weight per fish (g)	0.014 ± 0.003	0.23 ± 0.04
Stocking rate (m ⁻²)	2,205	70
Average harvest weight per fish (g)	0.23 ± 0.04	2.47 ± 0.55
Total number harvested	110,200	83,000
Specific growth rate (SGR) (%day ⁻¹)	6.05 ± 0.35	3.26 ± 0.18
Feed conversion ratio (FCR)	1.46	1.09
Percent survival (%)	79.5%	75.3%
Final standing crop (kg ha ⁻¹)	5069.2	1708.4

CHAPTER FIVE

5.0 DISCUSSION

5.1 Water Quality Parameters

The water temperatures (Table 4.1) were within range suitable for reproduction and survival of the Nile tilapia (Bhujel, 2000; Ngugi *et al.*, 2007; Makori *et al.*, 2017). The relatively higher temperature in the breeding tanks could be as a result of the concrete tanks which conserve heat as compared to the fingerling production pond which has a larger surface area.

According to Teichert Coddington & Green (1993), Nandlal & Pickering (2004) and Peterman (2011) suitable level of DO for Nile tilapia fry and fingerling production should be above 2 mg l⁻¹. In the current study, DO levels obtained were above 3 mg l⁻¹ but not more than 4 mg l⁻¹, which though was acceptable for the growth of fry and fingerlings of the Nile tilapia, appeared lower than the optimum (Boyd, 2010; Makori *et al.*, 2017). These authors intimated that the lowest DO occurrences take place at dawn and this might have affected the mean values of DOs obtained in the morning hours. Boyd (2010) attributed low DO values in the morning to bacterial activities, which consume oxygen due to the lack of photosynthesis during the night. Water exchange was done every three days in the concrete tanks for fry during hormonal treatment but no water exchange occurred in the breeding tanks. This might have affected the productivity of the breeders as revealed in the low percent hatch of eggs. The earthen ponds also didn't have aerators and there was no water exchange for the 24 days of fry rearing to the fingerling stage. This could have also contributed to the low DO in that production unit.

pH values obtained in this study (Table 4.1) conformed with other studies from FME, (2006). The pH values for optimal growth of Nile tilapia should be within the ranges of 6 and 9 (Bardach *et al.*, 1972; Guerrero, 1997; Popma & Masser, 1999; Nandlal & Pickering, 2004; FME, 2006; Peterman, 2011). Crane (2006) and Makori *et al.* (2017) also stated that pH values should be within the ranges of 6.1 – 8 for good reproduction and Nile tilapia survival. This means that the water pH at the Centre were suitable for fry and fingerling production.

According to Nadlal & Pickering (2004), salinity level for Nile tilapia production in fresh water could be between the ranges of 5 and 10‰. The salinity values from this study were far below the range by the above authors, which makes the water ideal for the reproduction, growth and survival of the Nile tilapia from the Centre.

The upper limit of ammonia concentration for aquatic organisms according to Santhosh & Singh (2007) is 0.1 mg l^{-1} . Bhatnagar & Singh (2010) and Makori *et al.*, (2017) also cited that ammonia levels of $< 0.2 \text{ mg l}^{-1}$ could be suitable for pond fishery. It can therefore be inferred from these authors that the levels of ammonia for fry and fingerling culture units in this study had minimal to no effect on the growth or survival of the fry and fingerlings. However, higher values of ammonia were obtained in the breeding tanks as compared to the fry tanks. The difference could be attributed to the absence of water circulatory water in the breeding tanks.

5.2 Brooder Production

The low percentage of fry harvested from the breeding tanks could be because of high ammonia build up due to no water exchange in the breeding tanks, which might have prevented optimum egg production and hatching. Furthermore, water quality condition could also influence the hatching of eggs by the maternal brooders. According to Hasan *et al.*, (2016), the oral incubation by the female in nature, is very delicate and gentle hence could be affected by any stressful condition in the environment. Also, cannibalism and incomplete harvesting as stated by Bhujel (2000) could be the reason for the low fry production. The number of times the net is dragged during harvesting of the fry may lead to the destruction and even death of eggs and fry. This might have accounted in part to the low number of fry harvested.

5.3 Fry Production Characteristics

The specific growth rate (SGR) attained for fry during the hormonal treatment could be as a result of the high level of protein (45%) in the feed fed to them. Ahmad *et al.*, (2004) recommended a diet of not less than 45% protein in order to increase growth in hormonal treated fry. In a similar work carried out by Odin & Bolivar (2011) the SGR recorded was $14.12 \pm 0.31\% \text{day}^{-1}$ which was far higher than the value obtained in this work. In the study by Odin & Bolivar (2011), however, the stocking rate was lower (500 m^{-2}) as compared to the current study where the stocking rate was $2,205 \text{ m}^{-2}$, and this could be the reason for the sharp difference in SGR. The DO levels, which was below 5 mg l^{-1} could have influenced growth of the fry and subsequently the SGR value. The FCR obtained from this study was 1.46, which is relatively good and suitable for profitability.

In this study, the percent survival of fry after hormonal sex reversal was 79.5%. This might be due to the presence of predators such as birds and frogs, lack of consistent water exchange and aeration (Rakocy, 2005). However, Vera Cruz & Mair (1994) and Popma & Lovshin (1995), also came out with a survival rate of 70% -80% for tilapia fry using outdoor tanks.

5.4 Fingerling Production

Algal bloom was so much in the pond at the time of harvest and with predators like frogs and birds observed in and around the earthen pond could have influenced the survival rate.

The final standing crop of $1708.4 \text{ kg ha}^{-1}$ obtained was due to the low number of fry produced at the breeding stage. However, with the stocking density between 25- 300 fry m^{-2} , a final standing crop exceeding $5,000 \text{ kg ha}^{-1}$ could be produced (Boyd, 2013).

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The current breeding practice at the Aquaculture Demonstration Centre as revealed by this study showed very low percent (20%) hatched eggs and the total number of fingerlings produced.

That the fry hormonal treatment and nursery/fingerling is feasible and can improve the fry and fingerling production by 75.3% and 79.5% respectively.

Water temperature, pH and salinity levels were within suitable ranges for fingerling production at the Center.

Dissolved oxygen and ammonia concentrations in the breeding tanks could be of management concern as minor adverse fluctuations can negatively affect fingerlings productivity at the Centre.

The final standing crop from the study was 1708.4 kg ha⁻¹.

6.2 Recommendations

- Water from the reservoir should be filtered before use in the breeding tanks to reduce algae bloom and prevent predators like tadpoles from entering ponds and tanks.
- Ponds should be covered with nets to prevent frogs entering ponds and birds predating on fish.

- The egg and fry harvesting method used at the Centre should also be enhanced
This can be done by regular training of staff in modern methods of brooder, eggs and fry handling.
- There should be regular water exchange in the breeding tanks to overcome the low DO and high ammonia levels that were observed during the study.
- The outcome of this study will be discussed with the management and staff of the Aquaculture Demonstration Centre by the student and fish farmers in the Country.

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APPENDIX

Appendix I. Single factor anova showing the significance differences between fry produced in the breeding tanks

Anova: Single Factor						
SUMMARY						
Groups	Count	Sum	Average	Variance		
ONE	2	33168	16584	72866592		
TWO	2	31745	15872.5	41632813		
THREE	2	16279	8139.5	17046961		
FOUR	2	21218	10609	70116482		
FIVE	2	24955	12477.5	28312813		
SIX	2	17113	8556.5	2054365		
SEVEN	2	30304	15152	2367488		
EIGHT	2	21532	10766	27885512		
NINE	2	24468	12234	5685192		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1.52E+08	8	18952690	0.636546	0.732136	3.229583
Within Groups	2.68E+08	9	29774246			
Total	4.2E+08	17				