UNIVERSITY OF EDUCATION, WINNEBA

USING PRACTICAL LESSONS TO ENHANCE TILAPIA PRODUCTION EDUCATION AT THREE TOWN SENIOR HIGH SCHOOLS, DENU IN THE VOLTA REGION OF GHANA

RICHARD TADZO

MASTER OF PHILOSOPHY

2022

UNIVERSITY OF EDUCATION, WINNEBA

USING PRACTICAL LESSONS TO ENHANCE TILAPIA PRODUCTION EDUCATION AT THREE TOWN SENIOR HIGH SCHOOLS, DENU IN THE VOLTA REGION OF GHANA

RICHARD TADZO
(202114741)

A thesis in the Department of Science Education,
Faculty of Science Education, submitted to the school
of Graduate Studies, in partial fulfillment
of the requirements for award of

Master of Philosophy
(Science Education)
In University of Education, Winneba,

JANUARY, 2022

DECLARATION

Student's Declaration

I, **RICHARD TADZO**, hereby declare that, except for references made to people's work which have been duly acknowledged, this thesis is the result of my own research, and that it has neither in whole nor in part been presented for a degree elsewhere.

Signature: ……………………………………….…

Date: ………………………………………..……

Supervisor's Declaration

I, hereby declare that the preparation and presentation of this Thesis was supervised in accordance with the guidelines for supervision of Research work laid down by the University of Education, Winneba.

SUPERVISOR: PROFESSOR K.D TAALE

Signature: …………………………………………

Date: ………………………………………….…

DEDICATION

This work is dedicated to my family for the support they have given me throughout my academic journey.

ACKNOWLEDGEMENT

My foremost gratitude goes to the Almighty God for the wisdom, mercy and protection that He bestowed on me. I express my unflinching gratitude to Professor K.D Taale my supervisor, for the useful corrections and suggestions. I will forever be grateful to him for his critique and the special attention he gave to the work which saw me through the thesis on time.

I am thankful to my beloved wife Mrs. Fugar Issabella and my son, Richmond Tadzo for their enormous contribution toward my education. I am also thankful to the management of Three-Town Senior High School for allowing me to conduct the study in the school. I am thankful to the tilapia fish farmers who provided support to me and the students during our visit to their farms.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

The main objective of this study was to use practical lessons to enhance tilapia production education among form two students of Three-Town Senior High School, Denu in the Volta Region of Ghana. The study used both experimental and observational research design where Eighty-two (82) students were exposed to the construction of tilapia ponds which are conducive for the fish species as well as feeding practices which were used by five tilapia farmers. Feeds which were used by the five tilapia farms whose ponds were visited included; maize-soya beans concentrate, rice ban, potato concentrate and brewery waste. It was also observed that, three of the farmers feed their tilapia stock twice daily, while two farmers feed their stock thrice daily. The study revealed that average temperature of the ponds was 27 °C. The average pH range for the ponds was also recorded at 6.9. The dissolved oxygen for the ponds was also measured at 13ppm DO. It was observed that all the five ponds were less muddy, the ponds also contained less suspended organic and inorganic matter. The conditions which were considered by the farmers in the construction of their ponds included; water source, topography of the land, soil type, vegetation cover and prevention of predators. It was recommended that workshops must be organised for tilapia farmers to equip them with the required technical skills and knowledge on how to prepare their own concentrates. This will help the farmers reduce the cost of operations thereby reducing the cost of tilapia which are brought to the market.

CHAPTER ONE

INTRODUCTION

1.0 Overview

This chapters focuses on the background of the study, statement of the problems, purpose of the study, research objectives, research questions, significance of the study, delimitations, limitations and organization of the study.

1.1 Background of the Study

Tilapia is one of the freshwater fishes which belongs to the family of Chiclidae (Dikel, 2009). According to Dikel (2009), the name tilapia is widely used to refer to all the three species that belong to the Chiclidae family. According to Dikel (2009), there are three different species which belong to the family namely; Tilapia, Sarotherodon and Oreochromis. Lim and Webster (2006) suggest that, these three species of tilapias are naturally distributed in many geographical areas including African lakes and rivers, Nile River, rivers in Israel, Syria and Palestine. However, Lim and Webster (2006) indicate that, tilapia can be cultured in several parts of the world under controlled conditions.

Siddiqui, Hafedh and Ali, (2011) also suggests that, tilapias are easy to culture because of the fact that they growth fast, very resistant to diseases, very tolerant to severe conditions and also easy to breed. Physically, tilapias are shaped like crappie or sunfish but they are generally identified by an interrupted lateral line similar to the features of the Cichlid family of fishers. Tilapias are laterally compressed and deed-bodied with dorsal fins that are long in nature. The forward composition of the dorsal fins of tilapias are heavily spined. The spines are also found in the anal fins and pelvis (Lim & Webster, 2006). There are often broad vertical bars pointed down the sides of fry, fingerlings and some occasions adult tilapias. As it has been mentioned already, one of the factors that has contributed to the popularity of tilapia culture across the globe is the fact that, breeding of all the three species are very easy under both controlled and even severe conditions.

According to Gyamfi (2014), the male of all the three species often excavates their nest at the bottom of the water which are often shallower than 0.998 meters. According to Gyamfi (2014), one single male can mate several females. After a short period of mating, the females spawn their nest. The males fertilize the eggs while the females hold and incubate the eggs in their month until the eggs hatch. According to Ainoo-Ansah (2013), the fry remains in the mouth of the females through yolk sac absorption. Ainoo-Ansah (2013) suggests that, the fry feed and seek refuge in the mouth of their mother (adult female tilapia) until it is able to feed on its own. Lim and Webster (2006) suggest that, sexual maturity of tilapia is determined by age, environmental conditions and size. According to Siddiqui et al., (2011), tilapias that are cultured in lakes grow at a faster rate than those cultured in small farm ponds. Siddiqui et al., (2011), indicates that, the Nile tilapia matures at about ten to 12 months to the weight of between 350 and 500 g in several East African Lakes. Siddiqui et al., (2011), indicates that, under good culture condition, most tilapias can grow to the weight of 1.5 kg between 6 and 12 months.

Although tilapias are known to be one of the most resistant and culture tolerant fishes globally, yet their productive culture require certain environmental conditions. In commercial production of tilapia, it is required that farmers implement efficient aquaculture management practices. Hence significant concern is given to environmental parameters which include temperature, salinity, dissolved oxygen, pH level, ammonia and nitrate concentration. According to Tekelioglu (2016), tilapias cannot produce under temperatures below 16°C. Tekelioglu (2016) further suggests that, tilapias cannot even survive more than ten days under temperature of 10°C or below. Tekelioglu (2016) recommends that, the required temperature for tilapia production should be between the ranges on 25°C to 36°C. Lim and Webster (2006) also add that feeding activities must cease when the water temperature is between 16°C and 17°C or below these ranges.

It has been suggested that, tilapia has marine origin although studies have suggested that, they have undergone evolutions. This explains why some tilapia strains such as euryhaline are able to tolerate higher salinity conditions. Generally, it is known that, there are limitations when it comes to tilapia production in saline waters. For example, Oreochromis spilirus has been cited to have low fecundity (Al-Ahmed, 2012). Studies such as Alfred and Hector (2018) revealed that, Oreochromis niltoicus and Oreochromis massambicu hybrid failed to adapt to 35‰. According to Kutty (2017), increasing water temperature leads to reduction of dissolved oxygen. However, tilapias are known to be one of the fresh water fishes that are able to adapt to low ambient oxygen levels (Tsadik & Kutty, 2015). The study of Bergheim (2012) observed that, specific growth rate (SGR) was positively correlated to dissolved oxygen levels.

The study observed that, medium specific growth rate of 56% correlated with medium dissolved oxygen of 40 to 50% saturation (3-4 mg/L). pH level is one of the parameters that influence production of tilapia on commercial scale. According to Lim and Webster (2006), tilapias are able to adapt and grow well in water that is close to neutral or slightly alkaline. Lim and Webster (2006) suggest that, tilapia well adapt to ponds and lakes that have pH ranges of between pH 6.5 and pH 8.5. According to Lim and Webster (2006), this range of pH can be controlled with the integration of carbonate-bicarbonate buffer system. Lim and Webster (2006) indicate that, during day time, CO_2 levels decrease while pH increases due to photosynthesis activities. Tekelioglu (2016), opines that, since tilapia production often take place in quiet and intense environment, tilapias can withstand wide pH ranges of between pH 5 to pH 11. Imperatively, Lim and Webster (2006) suggest that, the growth rate of tilapia is negatively affected by higher acid content in the waters. Ammonia is one of the major forms of metabolic wastes which are excreted through the kidneys and gills of tilapia.

According to El-Sayed (2017), excreted ammonia from tilapia can be found in two different forms which are; unionized NH_3 (UIA-N) which is harmful to the survival and growth of the fish under culture and ionized NH^{4+} which is less harmful. According to Lim and Webster (2006) toxicity of ammonia is often correlated with water temperature, pH level and dissolved oxygen concentration. Lim and Webster (2006) suggest that, low concentration levels of dissolved oxygen increase ammonia toxicity. Again, Lim and Webster (2006) suggest that, toxicity of ammonia increases in relation to higher water temperature. When pH levels exceed the neutral level, an increasing portion of excreted ammonia covert from ionic form ($NH4^+$) to toxic unionized (NH_3). According to Lim and Webster (2006), mass mortality occurs between 3 to 5 days when ammonia concentration is higher than 2mg.

According to Lim and Webster (2006), tilapias often rely on a wide variety of natural food organisms including some aquatic macrophytes, plankton, benthic and planktonic aquatic invertebrates, detritus, decomposing organic matter and larval fish. According to Dikel (2009), heavy nutritious supplemental feeding regimes contribute to about 40 to 50% growth rate of tilapia. This implies that, good and quality feeding practices is required to maximize tilapia production. Bergheim (2017) cites tilapias are filter feeders since they can harvest plankton from water efficiently.

Yet most species of tilapia do not physically filter the waters through the gills as compared to filter feeders such as silver carp and gizzard shad. The gills of tilapia often secrete mucous that trap plankton. The plankton-rich mucus is then swallowed. According to Atwood et al., (2011) digestion and assimilation of plant foods occur along the length of the intestine of the fish.

In contemporary times, tilapia production has become a major economic venture across the globe especially in Ghana. Gyamfi (2014) attributes this to the increase demand for tilapia as food. According to Gyamfi (2014), there is higher demand for tilapia when has resulted in higher market price and investment. Ainoo-Ansah (2013) also adds that, the economic values of tilapia production have led to increase development of technology and innovation to boost production. According to Gyamfi (2014) tilapia production is one of the economic ventures in Ghana that employs about 7000 people. Tilapia production since 2010 has been major source of income and livelihood for several people in Ghana.

Putting the economic and nutritional values of tilapia production into perspective, it become imperative that, studies such as this current one is carried out to enlighten the youth on how they can adopt practical and affordable mechanisms to enter into tilapia production to enhance the expansion of the Ghanaian economy. According to Ainoo-Ansah (2013), the teaching of tilapia production using practical lessons will inculcate in students the needed practical knowledge of the discipline and it will stimulate students' interest in venturing into it after school so as to boost the sector, and considering that fisheries is important to the economic development of Ghana and being the single most dominant economic activity in the coastal zone and along the Volta Lake, major rivers and in other water bodies.

1.2 Statement of the Problem

Empirically, tilapias are one of the well-known fresh water fishes that are popular in the aquaculture business yet, commercial production of tilapia can be very complex, time consuming and can also lead to loss if the farmer lacks relevant and practical knowledge on production of the fish. According to tilapia farmers in Ghana lose between 25 to 40% of their stock due to bad farm management practices. Anane-Taabeah, Quagrainie and Amisah, (2015) attribute this situation to lack of technical know-how on tilapia production. According to Anane-Taabeah et al., (2015), there is the general perception that, tilapia has higher market price hence the venture of commercial tilapia production is profitable. Because of this perception, most tilapia farmers fail to undertake practical and technical training to gain adequate knowledge on the behaviour of the fish, their feeding regimes, environmental requirements among others. Gyamfi (2014) also suggests that, tilapia production is although lucrative yet very expensive especially when the farmer lack the practical and technical know-how.

According to Ainoo-Ansah (2013), most tilapia farmers in Ghana lack relevant information and knowledge on the fact that, tilapia production requires technical and practical know-how on the favourable conditions under which the fish must be cultured. According to Gyamfi (2014), most tilapia farmers in Ghana do not know that, tilapia do not grow well in stressful environments with low dissolved oxygen and higher temperature. Hence, most tilapia farmers fail to implement better practices that moderate or regulate the temperature and dissolved oxygen concentration of their tilapia ponds. In order to raise tilapia to larger desirable size, there is the need to add supplementary feeding to fertilize the tilapia ponds. What is key to note is that, supplementary feeds for tilapia is very expensive yet most tilapia farmers lack the practical and technical know-how on how to produce their own nutritious concentrates. While there have been several advocacies for youth in entrepreneurship in Ghana, most of technical and vocational based courses and programmes in senior high schools in Ghana are still theoreticised due to lack of practical logistics and facilities.

According to Gyamfi (2014), one of the key areas that, provide practical entrepreneurial skills to SHS leavers in Ghana is tilapia production yet, most biology and agriculture-based topics on tilapia production in Ghana are theory based due to lack of facilities such as fish ponds and budgetary constraints. While tilapia production is considered as very lucrative and enterprising, the advocacy for youth in tilapia production must be practical based hence the urgent need for this study to be conducted to provide evidence based as well as result oriented practical pathway that can be adopted in the teaching and learning of tilapia farming in second cycle schools in Ghana.

1.3 Objectives of the study

The main objective of this study was to use practical lessons to enhance tilapia production education among form two students of Three-Town Senior High School. The specific objectives this study included the following;

1. Use practical lessons to educate students on the feeding practices in tilapia production.
2. Use practical lessons to educate students on the conditions favourable for tilapia production.

3. Use demonstration to teach students on pond requirements for tilapia production

1.4 Research Questions

The following research questions were raised to guide the achievement of the research objectives;

1. What practical lessons can be used to educate students on the feeding practices in tilapia production?
2. What practical lessons can be used to educate students on the conditions favourable for tilapia production?
3. What demonstration lessons can be used to teach students on pond requirements for tilapia production?

1.5 Significance of the Study

Since advocacy on youth in entrepreneurship in Ghana is on the ascendency, it has become imperative that SHS students are encouraged to enter into tilapia production which is cited globally as one of the emerging lucrative aquaculture businesses. While the young students are encouraged to enter into tilapia farming, it is imperative that, they are equipped with practical and technical know-how on the venture. In effect, the significance of this study is based on two major premises. Firstly, it will equip young students with practical skills that would enable them venture into tilapia production after completion of Senior High School. The study outcome would enlighten student participants on the behaviour of tilapia, their feeding practices their required environmental and external conditions and parameters for productive aquaculture. The outcome of this study would also enlighten students on the economic importance of tilapia production which will act as a key motivating factor to encourage the youth into tilapia production leading to expansion of the Ghanaian aquaculture and fisheries sector. For practice, the outcome of this study would provide evidence-based findings on best practices that tilapia farmers in Ghana can adopt to enhance their production in order to minimize tilapia mobility while maximizing maturity and growth rate. Theoretically, the findings of this study add to the body of literature on practical tilapia production in Ghana. In effect, Ghana Education can adopt the findings of this study and integrate them into the syllabus on subjects such as biology and agriculture that expose students to tilapia and its aquaculture conditions. The findings of this study would also serve as an empirical basis upon which future studies can be based on.

1.6 Delimitations of the Study

Geographically, the research was carried out in Three-Town Senior High School located at Hedzranawo-Denu in the Ketu South Municipality of Volta Region. The study involved form two students. This implies that teachers and students in forms one and three are excluded from the study. Thematically, the study was confined to the assessment of the effects of pond size and depth on tilapia production in terms of growth rate and size. The study also examined the effects of water quality on tilapia production in the context of growth rate and size. The study also covered the assessment of recommended feeding practices that enhance growth rate and size of tilapia under culture. The study further considered the assessment of the economic importance of tilapia production.

1.7 Limitations of the Study

One of the major limitations the study encountered was the challenge of lack of logistics to take the study through practical demonstration on how to prepare tilapia feed. None of the farmers whose tilapia farms were visited had the technical know-how on the preparation of tilapia feeds. None of them also had logistics (technology) to prepare tilapia feed. The school also lacked the facilities to undertake such practical lessons. In light of this the researcher could not demonstrate to the students how to prepared tilapia concentrates. Hence, whatever skills were learnt is limited to the students who visited the sites.

1.8 Organisation of the Study

The study was organised and presented five chapters. Chapter one highlights the background to the study, problem statement, research objectives, and questions, significance, scope and limitations of the study. Chapter two presented a thorough review of literature on the concepts and theories that underpin the study. Chapter three presents into detail the methodology which was employed to meet the objectives of the research and make it a success. Chapter four presented the interpretation and analysis of data that were obtained for the study while the fifth chapter presented the summary, conclusion, and recommendations of the study.

CHAPTER TWO

LITERATURE REVIEW

2.0 Overview

This chapter presents a thorough review and discussion of relevant literature of the concepts and thematic areas of the study. The chapter opens the review and discussion on biology of Tilapia, the production of Tilapia on commercial scale in Ghana. The chapter further discusses conditions that influence the aquaculture of tilapia (how certain factors such as water quality and feeding practices affect tilapia production in terms of growth and size). The economic importance of tilapia production is also discussed as part of the literature review.

2.1 The Biology of Tilapia

Tilapia is one of the commonest fish species consumed across the globe especially in Ghana. The fish belongs to the Cichlidae family. According to Gupta and Acosta (2004), there are three genera of tilapia which are well known across the globe. They include *Tilapia, Oreochromis and Sarotherodon*. These three species of tilapia are naturally found and distributed in Palestine, Nile River and some lakes and rivers in Africa. As it has already been stated in the earlier part of the discussion, tilapia is the commonest fish found in the aquaculture industry due to the fact that, the fish is very resistive to diseases, very easy to bread, grow fast, tolerate a wider range of environmental conditions including salinity and temperature. Physically, tilapias are shaped like crappie or sunfish but they are generally identified by an interrupted lateral line similar to the features of the Cichlid family of fishers. Tilapias are laterally compressed and deed-bodied with dorsal fins that are long in nature. The forward composition of the dorsal fins of tilapias are heavily spined. Figure 1 illustrates the structure of tilapia.

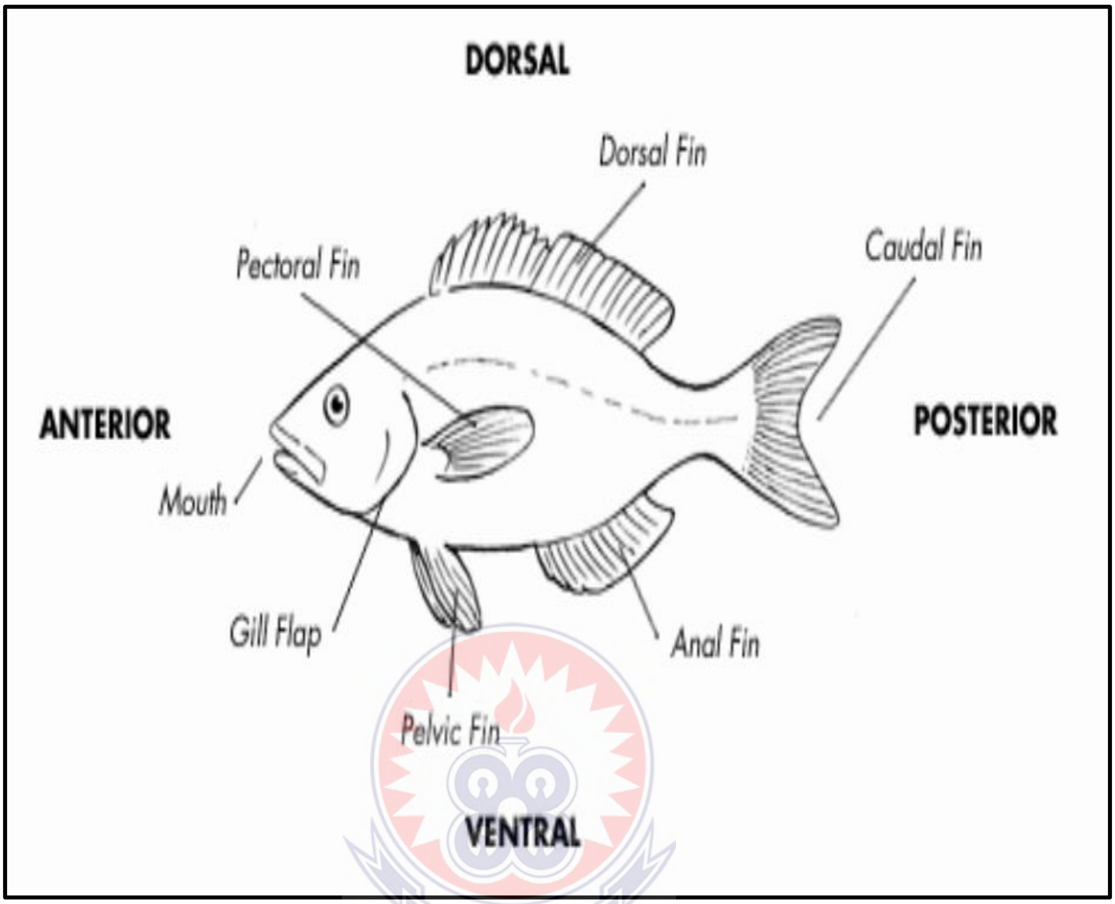


Figure 1: Physical Structure of Tilapia (Lim & Webster, 2006)

The spines are also found in the anal fins and pelvis (Lim & Webster, 2006). There are often broad vertical bars pointed down the sides of fry, fingerlings and some occasions, adult tilapias. Identifying tilapia in terms of sex is relatively easy. According to Gupta and Acosta (2004) male tilapia has two opening in front of the annal fin. The large opening is the anus while the smaller opening which is located at the tip I the urogenital pore. As illustrated in Figure 1, it can be seen that, the female tilapia has three major openings which include the genital pore, the anus and the urinary pore. The genital pore in male tilapia is often bigger than in female tilapias.

According to Gupta and Acosta (2004), the sex of tilapia is not easy to identify util is has reached the weight of 15 g and above.

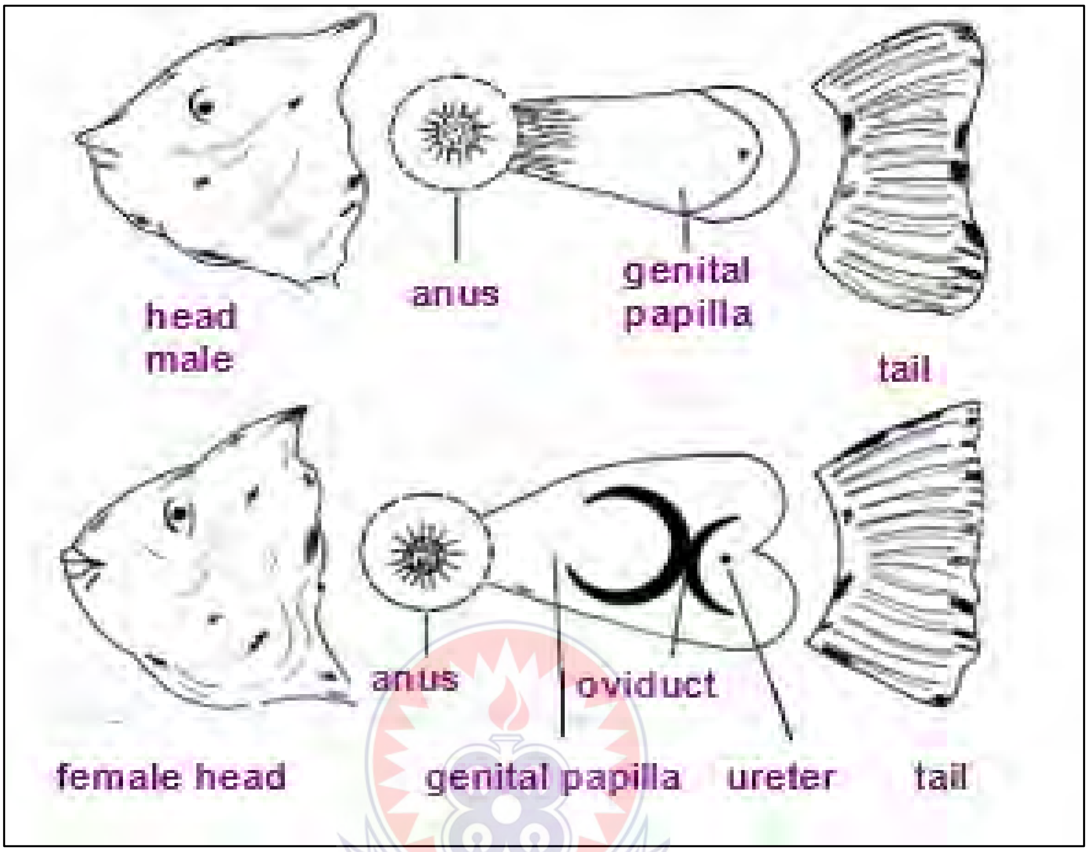


Figure 2: Sex identification of tilapia (Lim & Webster, 2006)

According to Gyamfi (2014), the male of all the three species often excavates their nest at the bottom of the water which are often shallower than 0.95 meters. According to Gyamfi (2014), one single male can mate several females. After a short period of mating, the females spawn their nest. The males fertilize the eggs while the females incubate the fertilized eggs. According to Ainoo-Ansah (2013), the fry remains in the mouth of the females through yolk sac absorption. Ainoo-Ansah (2013) suggests that, the fry feed and seek refuge in the mouth of their mother (adult female tilapia) until it is able to feed on its own. Lim and Webster (2006) suggest that, sexual maturity of tilapia is determined by age, environmental conditions and size. According to Siddiqui et al., (2011), tilapias that are cultured in lakes grow at a faster rate than those cultured in small farm ponds. Siddiqui et al., (2011), indicates that, the Nile tilapia matures at about ten to 12 months to the weight of between 350 and 500 g in several East African Lakes. Siddiqui et al., (2011), indicates that, under good culture condition, most tilapias can grow to the weight of 1.5 kg between 6 and 12 months.

Although tilapias are known to be one of the most resistant and culture tolerant fishes globally, yet their productive culture require certain environmental conditions. In commercial production of tilapia, it is required that farmers implement efficient aquaculture management practices.

Hence significant concern is given to environmental parameters which include temperature, salinity, dissolved oxygen, pH level, ammonia and nitrate concentration. According to Tekelioglu (2016), tilapias cannot be cultured on commercial basis under temperatures below 16ºC. Tekelioglu (2016) further suggests that, tilapias cannot even survive more than ten days under temperature of 10ºC or below. Tekelioglu (2016) recommends that, the required temperature for tilapia production should be between the ranges on 25ºC to 36ºC. Lim and Webster (2006) also add that, feeding activities must cease when the water temperature is between 16ºC and 17ºC or below these ranges.

2.2 Commercial Production of Tilapia in Ghana

The fishery industry is classified into two broad components which include marine (sea and lagoons) and inland (rivers, lakes and ponds). According to Anane-Taabeah et al., (2015), the aquaculture sector of the fishery industry in Ghana begun gaining momentum in the last 15 years when the Ministry of Agriculture decided to reduce the country’s reliance on the Atlantic Ocean for fish foods. The ministry intensified advocacy for aquaculture with specific focus on tilapia farming. With financial and technical support from the Dutch and Chinese governments, more Ghanaians begun showing interest in tilapia farming. Today, tilapia production takes up to 90% of the aquaculture industry of Ghana. The Ministry of Fisheries and Aquaculture estimated about 2000 tilapia farms on the Volta River and major lakes such as Bosumtwi in 2018. The figure was projected to reach 5000 by close of 2023.

This shows how tilapia production is increasing at a faster pace in Ghana. According to Anane-Taabeah et al., (2015), revenues from tilapia production contributed about 27% of aggregate revenues generated from the fishery sector in Ghana. Anane-Taabeah et al., (2015) also predicted that, the contribution of tilapia in terms of fishery revenues to Ghana will reach 38% by closed of 2025. It is not surprising that, commercial tilapia production is gaining significant progress in Ghana because of increased consumption. According to Sarpong et al., (2019), 4 out of every 10 households in cities in Ghana such as Accra and Kumasi consume tilapia on daily basis. Sarpong et al., (2019) further adds that, individuals among the working class consume at least 1.5pounds of tilapia every week.

It is important to note that, not all water bodies in Ghana support tilapia farming due to the environmental requirement of tilapia farming yet the notable freshwater bodies that support commercial tilapia fish farming include Volta River which covers close to 8482km^2. According to Cobbina (2019), the Volta River support tilapia farming due to the fact that, it is oligotrophic in nature; meaning it has low mineral nutrient content which is best for tilapia production. According to Cobbina (2019), about 53% of tilapia production in Ghana are done either on the Volta River or lake. Other important water bodies that support commercial tilapia farming include Lake Bosumtwi, Weija Lake and Kpong reservoir. Aside fresh water tilapia farming on these key water bodies, there are also about 703 ponds that are engaged in commercial tilapia production across Ghana (Cobbina, 2019).

According to Cobbina (2019), over 20,000 Ghanaians are directly involved in Tilapia in Ghana within each of them earning an average monthly net income of GHS 1,250.00. The number of people engage in tilapia production as well as direct income earning are expected to reach 30,000 and GHS 2000 by close of 2025 (Cobbina, 2019). These figures suggest that, commercial tilapia production in Ghana is going to be more lucrative hence the need to equip the youth especially SHS leavers with practical aquaculture skills that will enhance their involvement in the commercial tilapia production sector.

Tilapia aquaculture production in Ghana grew rapidly, from 2,000 tons in 2006 to over 30,000 tons in 2013. Tilapia has been the dominant aquaculture species; its share in the country's total (inland) aquaculture production2 increased from 88 percent in 2006 to 95 percent in 2013. Other aquaculture species in Ghana include Clarias gariepinus (African catfish) and the *Heterobranchus* species and *Heterotis niloticus (African bonytongue*) and, to a limited extent, Parachanna obscura (African snakehead) and various Chrysichthys species (Claroteid catfishes). Although these non-tilapia species are popular among pond farmers (Frimpong et al**.**, 2011), the increasing share of tilapia in the country's total aquaculture production suggests that the development of other species has not grown as fast as tilapia aquaculture. However, the lack of consistent reporting, especially of pond and tank production, precludes a strong conclusion. Tilapia aquaculture or aquaculture in general accounted for a small yet increasing share of total fish production in Ghana. From 2006 to 2013, the share of tilapia in the country's inland (freshwater) fish production and total fish production (including inland and marine) increased from 2.3 to 25.2 percent and from 0.5 to 9.4 percent, respectively.

Although the FAO statistics do not provide disaggregated data on tilapia production from capture fisheries, it is believed that capture fisheries, particularly artisanal fisheries, account for most of the tilapia production in the country. Tilapia, primarily the native Oreochromis niloticus, Tilapia zillii and various species or subspecies of Sarotherodon, are common components of inland capture fisheries production. All major waterbodies contribute to tilapia production, but the Volta River makes the most significant contribution. Lake Bosomtwi is also an important source of tilapia for the Kumasi metropolis in the Ashanti region (Antwi-Asare & Abbey, 2011). According to the estimation of the authors, up to 90 percent of tilapia aquaculture production in Ghana could be from cage systems, with pond culture contributing only 900–2 500 tons in 2012.

It is worth noting that before cage tilapia aquaculture started its surging contribution, Ghana’s tilapia aquaculture production in 2004 was 760 tons. Based on projections from surveys conducted in 2010–2012 (Anane-Taabeah, et al. 2015), there were between 70 and 100 cage farms in the country. Of these, the top three to four farms appeared to account for approximately half of the total production in 2012.

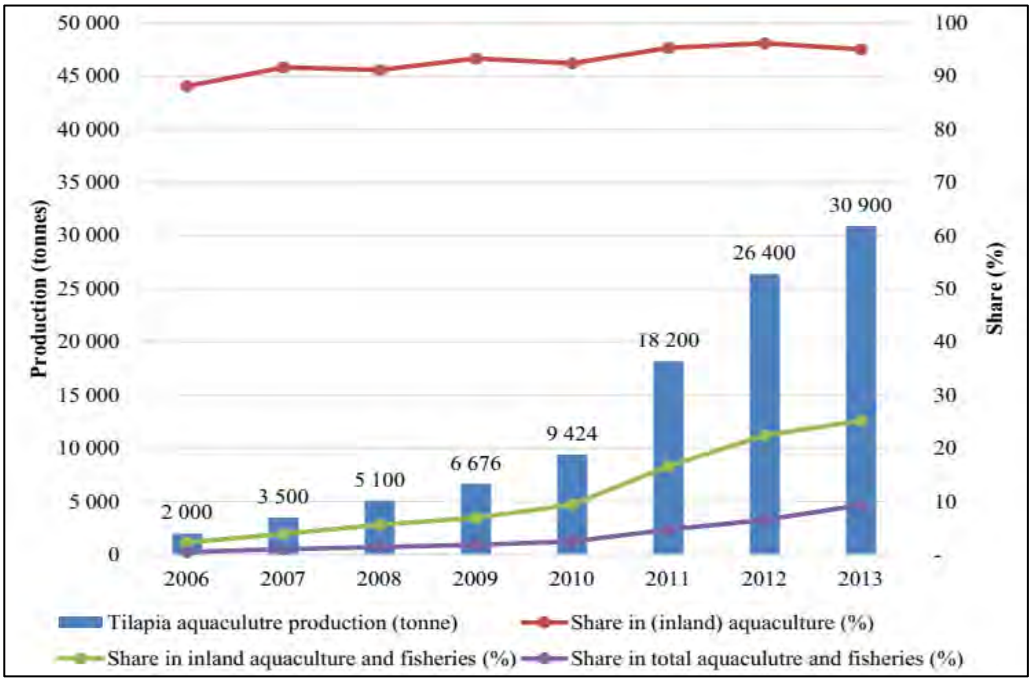


Figure 3: Tilapia production in Ghana (Anane-Taabeah et al., 2015)

2.3 Impacts of Tilapia Production in Ghana

According to Kabila and Amisah (2007), tilapia aquaculture in Ghana is relatively young yet is economic implications can be discussed from several angles. Kabila and Amisah (2007) explained that, commercial tilapia production is becoming one of the major sources of employment where people who live around major water bodies such as the Volta River, Weija Lake, Kpong Reservoir and Lake Bosumtwi. Cobbina (2019) estimated that, over 20000 people are directly involved in tilapia farming around these major water bodies. Cobbina (2019) projected that, the figure is likely to increase to 30000 by close of 2025 due to increase demand and ready market for tilapia. According to Frimpong and Anane-Taabeah (2017), more than 7000 Ghanaians are engaged in pond and cage tilapia farming in other water bodies aside the major lakes and rivers in Ghana. Frimpong and Anane-Taabeah (2017), further add that, the tilapia production does not only offer employment opportunities to farmers alone but also those within the supply chain system of the sector. According to Frimpong and Anane-Taabeah (2017), tilapia production creates indirect jobs for fish mongers, market women, fish feed producers, drivers, cage producers, net manufactures among others. According to Cobbina (2019) the value chain of tilapia production even expands to include restaurants, hotels and other small and medium scale food joints across the country. The direct impacts of tilapia production translate into income and wealth creation among individuals within the value and supply chain. According to Cobbina (2019) employees on commercial tilapia farms earn an average of GHS 1,250.00 on monthly basis. In 2012 alone, tilapia revenues from tilapia production contributed 27% of the total revenues generated from the fishing industry of Ghana (Anane-Taabeah et al., 2015). Imperatively, it is important to note that, tilapia production is very lucrative and will continue to show significant growth due to increase demand hence the need to advocate and train the youth to develop interest in the sector.

2.3.1 Social Impact

The social performance of tilapia farming in Ghana is an area that has not received sufficient attention historically because until recently aquaculture as a whole has not contributed significantly to domestic fish production. The fisheries sector as a whole was widely cited to contribute only 3–5 percent of the agriculture component of the total GDP (Gyamfi, 2014). WorldFish (2011) suggested that the fisheries production value in Ghana is equal to nearly 20 percent of the country's agricultural GDP and 7 percent of its total GDP. Fisheries statistics have been rarely separated from the general agriculture sector. Among some of the most fisheries dependent countries, Ghana ranked sixth in overall fisheries dependency (combining nutritional, macroeconomic and employment dependence) and third on nutritional dependency after Maldives and Cambodia (WorldFish, 2011).

However, the socio-economic contributions of aquaculture are usually included in the contributions of fisheries as a whole and rarely measured distinctly. Amidst many caveats about the reliability of data and model assumptions, Kassam (2013) estimated the regional multiplier effect of small-scale pond farming in the Ashanti region of Ghana at 2.3–2.6 (implying that every dollar generated from pond farming would induce US$1.3–$1.6 of additional income in other sectors in the region) and a national (both direct and indirect) multiplier effect of 4.3–5.0. Comparatively, small- and medium-scale cage farms in the Eastern region were estimated to have a regional multiplier effect of 1.5–1.6 and a national multiplier effect of 2.1–2.3.

Similar estimates were not available for large cage farms due to unavailability of budget and expenditure data, but it was expected that these would have a lower multiplier effect because most of the large farms were foreign owned and employed significant expatriate labour (Kassam, 2013). With rapid growth in aquaculture over the past few years and the creation of a separate Ministry of Fisheries and Aquaculture Development, a significant improvement is expected in the reporting of public- and private-sector aquaculture statistics and social performance of the sector in the years ahead. Thus, with the exception of a few country-level numbers, which may be outdated, or thevalidity of which is sometimes questionable, the analysis of the social performance of aquaculture in this paper would be based on a few recent case studies.

2.3.2 Food and Nutrition Security

The importance of fish in the nutrition of Ghanaians and the preference for tilapia over many species is well documented. According to FAO statistics,18 per capita fish consumption in Ghana in 2011 was 27 kg/person per year (live weight equivalent), higher than the world average of 19 kg/person per year and the average of 11 kg/person per year in Africa. WorldFish (2011) cited the WorldFish/FAO "Big Numbers Project" and the QUEST-Fish project that showed that 60–73 percent of animal protein in the Ghanaian diet is fish. Specifically for tilapia, Asmah (2008) studied the tilapia consumption patterns in four regions of the country (Ashanti, Eastern, Greater Accra and Volta) and reported that about 90 percent of households consume tilapia regularly or occasionally.

Asmah (2008) estimated that per capita consumption of tilapia ranged from 9.0 to 20.5 kg per year, with the Volta region recording the highest rate and the Ashanti region recording the least. On the aggregate, Asmah (2008) deduced that 74,444 tons of tilapia were consumed in Ghana annually at the time of the study. The study of Kassam, (2013) also estimated the annual demand for tilapia in Ghana to be in the range of 60 000–120 000 tons. The livelihood and nutrition impacts of fish farming to households appear to differ among poor and non-poor households. Poor fish farming households ate more fish than non-poor fish farming households because the latter tended to substitute meat (associated with higher social prestige in Ghana) for fish.

Thus, fish plays a significant role in rural household food security. However, among all groups surveyed, including non-fish farming households, food intake measured by simple food counts and food consumption scores was found to be high, although Kassam (2013) inferred that fish farming households had slightly better food adequacy. More work, however, remains to be done in Ghana to promote farmed tilapia consumption. The preference for wild fish over farmed fish has been consistently reported (Anane-Taabeah, 2008; Asmah, 2008; Darko, 2011).

2.3.3 Employment

At the national level, the fisheries sector is estimated to employ about 10 percent of the population (WorldFish, 2011) This estimate is largely for the fisheries sector as a whole, and most people engaged in the sector would also be employed in other sectors, leading to the tendency to overestimate the contribution of the sector to employment. Given that aquaculture contributed approximately 4 percent of total fish consumed in Ghana in 2012 (Ainoo-Ansah, 2013) and assuming that the fisheries and aquaculture sector employments are proportional to domestic fish consumption, the optimistic number of people employed by fish farming full time or part time in the entire value chain is about 100 000. A majority of these people will earn additional income from other jobs. Other occupations that fish farmers could be involved in include crop farming, artisanal fishing, and civil servants and traders. Fish farming is often the secondary or tertiary occupation for the majority of farmers (Anane-Taabeah et al., 2015; Kassam, 2013).

2.3.4 Livelihood Impacts

Fish farming households in the Ashanti region of Ghana, both poor and non-poor, derived about 8 percent of their household income from fish farming (Kassam, 2013). Capture fisheries still seem more attractive to fishers than aquaculture. Fishers who lacked savings had difficulty in accessing credit to run their business; those who were newer to marine fishing were more willing to consider integrating fish farming (Anning et al., 2012). Kassam (2013) reported that 85 percent of rural Ghanaian respondents to a survey on fish farming and poverty claimed that low-income fish farmers usually earned less profit than high-income fish farmers. Among rural households in the Ashanti region, Kassam (2013) reported over 30 percent higher average household income for fish farmers than non-fish farmers. However, there was no significant difference in per capita household income among these groups. Non-poor fish farmer households in the study were slightly larger on average (8.1 persons) compared with non-poor, non-fish farmer households (7.3 persons).

Asmah (2008) recounted specific benefits of cage farm workers to include regular incomes, free meals at work, informal interest-free loans given by employers, employer contributions to social security and health-care coverage, and the education gained through their employment. Traders also gained income and employed temporary help to clean fish for selling.

2.4 Tilapia value chain

The fishery value chain in Ghana, and in particular the tilapia value chain, has been analyzed quite comprehensively in recent years (Antwi-Asare & Abbey, 2011; Anane-Taabeah, et al., 2015). Antwi-Asare and Abbey (2011) distinguished two value chains for tilapia in the country, and defined the farmed tilapia value chain as the modern urban-biased value chain in contrast with the artisanal value chain based on fish captured from lakes and rivers. When carefully examined, however, the tilapia value chain in Ghana can be described as a much more complex chain of activities, from input supply to consumption with several short chains (example, the artisanal and farmed tilapia value chains) typical of many value chains.

The tilapia value chain begins with input suppliers at the top of the chain supplying input for capture and/or culture of tilapia. For capture fisheries, input suppliers focus on gear such as nets, twines, and ropes and traps, among others. Input suppliers for aquaculture on the other hand are more diversified and provide inputs including brood stock, fingerlings and feed, in addition to providing harvesting gear (Anane-Taabeah et al., 2015). Once the fish is harvested, distinct value chains can be identified for both the artisanal value chain and the farmed tilapia value chain. Thus, the modern urban-biased value chain may be described as one type of the farmed tilapia value chain (Anane-Taabeah et al., 2015). It appears that the modern urban-biased value chain has the advantage of traceability in terms of products and profit flow through the chain. Particularly for farmers that have their own distribution or sales points, product quality can be improved from consumer feedback and profit margins can be monitored effectively. Both the artisanal and modern urban-biased value chains have similar and overlapping actors and key players.

For instance, traders in both the artisanal and modern urban-biased value chains perform similar roles and maintain their marketing power within the value chain. On the other hand, the role of processors varies significantly between the two value chain types. While processors in the artisanal value chain actively undertake one of the five traditional processing methods – salting, drying, smoking, frying and fermenting (Antwi-Asare & Abbey, 2011) processors in the farmed tilapia value chain mainly engage in gutting and scaling of the fish (Anane-Taabeah et al., 2015) and are often traders as well. In fact, processors in the farmed tilapia value chain are usually not distinguished from traders, and they have often been more conveniently considered as the same entities (Hamenoo, 2011; Simpson, 2012; Kassam, 2013). This is because almost all farmed tilapia is either sold fresh without ice or fresh on ice (Abban, Ofori and Amenvenku, 2009; Simpson, 2012), similar to what has been reported elsewhere in Africa (Macfayden, Nasr-Allah & Al-Kenawy, 2012).

Fish not considered fresh may be preserved by freezing, salting and drying, or smoked (Abban et al., 2009). As observed by Antwi-Asare and Abbey (2011) and Anane-Taabeah et al., (2015), the tilapia value chain mainly serves local and national markets, with little or no focus on international markets. Particularly for fresh tilapia, the local demand has been high until recently and the uncompetitive prices discourage export.

Figure 4: The Tilapia Value Chain (Macfadyen et al., 2011)

2.4.1 Tilapia farmers

Kassam (2013) differentiated aquaculture engagements in Ghana into four categories:

i. small scale pond farms owned by poor farmers with minimal use of inputs;

ii. small-scale pond farms owned by relatively well-to-do farmers who use better management practices;

iii. small- and medium-scale cage farms mostly owned by Ghanaians whose socio-economic circumstances and education levels are better than pond farmers;

iv. large-scale cage farms owned mostly by foreigners.

Anane-Taabeah et al. (2015) considered all cage farms commercial ventures and categorized them into three groups: large scale (greater than 50 cages per farm); medium scale (between 10 and 50 cages); and small scale (less than 10 cages).

Policymakers in Ghana have also used various criteria to define small-, medium- and large-scale farms (Cobbinah, 2019). Small-scale pond farms with small volume sales of fresh fish at the farmgate to neighbours and small-scale traders/processors have difficulties in establishing necessary linkages to cold chains and urban markets because of a number of constraints, including unpredictable production volume and quality, wide geographic dispersion and the lack of infrastructure, leading to large transaction costs for coordination. Such farmers therefore face a high risk of post-harvest losses that forces them to sell on credit to traders or be price takers, with traders being opportunistic beneficiaries and not always honouring the terms of payment (Simpson, 2012; Anane-Taabeah et al., 2015).

Simpson (2012) also reported that the small- and medium-scale cage farms face similar constraints, with processors and traders being keenly aware of the perishability of the product once harvested, forcing farmers at the end of the day to sell fish at low prices. According to the Fisheries Commission in 2006, the aquaculture sector in Ghana had seven main high-performing commercial farmers and 2869 small-scale farmers. In terms of farming systems, the industry had 180 cages with a total volume of 5266 m3 and 76 pens with a total area of 6.73 hectares. Anane-Taabeah et al. (2015) estimated slightly more than 70 cage and pen farms, but no rigorous estimate of volume was made in that study.

Data provided by the Fisheries Commission in the period 2006–2009 suggested that pond fish production was highest in the Western region by the number of farmers and ponds (1650 and 2 550, respectively). In terms of surface area, the Brong Ahafo region had the largest production capacity of about 139 hectares. Cobbinah (2019) updated estimates of pond numbers in the regions putting Ashanti region at the top with 7084 ponds, followed by Brong Ahafo (5975) and Eastern (5393). This suggests that pond numbers have been rapidly increasing in the past decade or so, and previous estimates might have missed many ponds.

These numbers have often been cited with usually small, but sometimes large and unexplained variations. Other reports of the number of pond-based farms in Ghana variously estimate 4 000–6 000 with a total pond area of 600 to 1000 ha (Asmah, 2008; Abban et al., 2009; Ainoo-Ansah, 2013). Adding to the confusion, many reports seem to consider the number of ponds and the number of farms interchangeable numbers. From what is known, there is no published authoritative census of fish farms in Ghana that is systematically updated.

Although Asmah (2008) reported an annual rate of growth in pond-based fish farms at 16 percent in 2006 in the Ashanti region, corroborating Abban et al. (2009) that the Ashanti region may have surpassed the Western and Brong Ahafo regions in the number of ponds. The growth rate of farms in other regions have not been reported previously, and all estimates may be moderated significantly by high attrition rates of pond farms.

2.4.2 Tilapia traders

The tilapia trading system in Ghana varies slightly between captured fisheries and cultured fisheries. Traders can be classified into three groups: wholesalers, distributors and retailers, depending on the quantity of fish they purchase for sale (Antwi-Asare and Abbey, 2011; Anane-Taabeah et al., 2015). A major difference between tilapia trade in wild-caught and cultured fish is that processors play a prominent role in the former. Processors in the captured fisheries sector purchase fresh tilapia from fishers, and after the fish has been processed, they sell it mostly to wholesalers. However, because farmed tilapia is marketed mostly fresh (Abban et al., 2009; Anane-Taabeah et al., 2015) with little value addition, the function performed by processors in the tilapia trade is mostly lacking in the farmed tilapia sector traders who do not travel to fish landing sites. Many tilapia traders do not discriminate between farmed and wild tilapia; thus, it may be assumed that the same number of traders deal in both farmed and wild tilapia.

Tilapia price determination is usually done using two main approaches: existing market price approach and the cost-plus (or percentage markup) approach. Farmgate prices are often influenced by market prices (Anane-Taabeah et al., 2015). However, large commercial fish farms are able to dictate their farmgate prices, which traders have no control over. Wholesalers and retailers usually use the cost-plus approach in fixing their prices (Anane-Taabeah et al., 2015).

Asmah (2008) found that trading in cultured tilapia was more profitable than trading in wild tilapia, with gross profit margins of GHC 0.49/kg and GHC 0.25/kg, respectively, for wholesalers and retailers combined. This was due to lower wholesale prices for cultured tilapia as reported in 2006. According to Anane-Taabeah et al., (2015) revealed that some traders preferred trading wild tilapia to cultured tilapia. The size of fish was the major determinant of preference. Apparently, tilapia that reached major retail centers were usually large sized. Consequently, price determination was easier for traders. On the other hand, farmed tilapia came in various sizes and was usually dominated by smaller sizes, which traders and consumers alike wanted to purchase cheaply.

2.4.3 Tilapia processors

Except for packaging on ice to preserve the freshness of fish during sales, there is not much opportunity for storage and later sales once small-scale cage farms harvest their fish (Plate 10). The risk of cage farmers receiving disadvantageous prices is compounded by the fact that the partial harvest of cages is generally infeasible, and consequently 2–4 tons of fish could be hauled to shore in a single harvest event (Rao et al., 2012; Simpson, 2012). Large cage farms that own cold trucks and cold storage facilities and have outlets in urban centers are to some extent immune to the risk of the large supply depressing the price experienced by pond farms and small- and medium-scale cage farms (Kassam, 2013). Fish processors are recognized as part of the post-harvest sector in Ghana (Cobbina, 2019).

Fish processing is a women-dominated activity (Cobbina, 2019; Antwi-Asare and Abbey, 2011; Anane-Taabeah et al., 2015) Processors in the tilapia value chain are usually not part of any recognized association. Thus, determining the number of people employed in the sector is challenging, and at best only estimates can be provided. Anane-Taabeah et al., (2015) found that processors in the farmed tilapia value chain work in clusters or groups of about ten women. To reduce post-harvest losses, most tilapia from capture fisheries is processed mainly through salting and drying, and smoking before sales to consumers (Antwi-Asare & Abbey, 2011).

2.4.4 Feed producers

In 2013, there were about 12 commercial feed suppliers (brands) in Ghana, only one of which was a local producer (Plate 2). Almost all cage farmers use commercial feeds. However, Asmah (2008) reported that only about 2 percent of non-commercial farmers (who constituted 97 percent of farmers the author surveyed in 2006) used commercial feeds. About 70 percent of commercial feeds used in the country are imported with the remaining 30 percent being produced locally using local and/or imported ingredients. The major aquafeed companies and brand names on the Ghana market include Cargill, Coppens and Raanan. Other known names are Biomar, China Tilapia Feed, Guabi (Pira), Inter-aqua, Nicoluzzi, Zeigler and PT Matahari Sakti (launched in 2014), Aqua Feed and Aqua Engine. Raanan Fish Feed Ltd, the first fish feed company in Western Africa, is the only locally established company with an installed capacity of 24,000 tonnes per year. In 2012, Raanan Fish Feed's actual production was about 500 tons per month,6 and in 2013 it was reported to be 1,000 – 1,400 tons per month. Some of the other companies listed are planning to or may have already moved to local production (Awity, 2013).

Tilapia farmers also use imported feeds from Brazil, China, Denmark, France, Indonesia, Israel, the Netherlands, the United States of America and Viet Nam (Hamenoo, 2011; Awity, 2013; Anane-Taabeah et al., 2015). As of 2013, large-scale cage farms use mostly imported feeds (Kassam, 2013). Larger pond farms such as Kumah Farms and Bosomtwi Integrated Aqualife Village make their own custom fingerling and grow-out feeds (Plate 3) and also purchase various commercial feeds (Agbo, 2009; Leschen, 2011). Their stated motivation for on-farm feed manufacturing is to cut cost.

The price of fish feed varies by crude protein content (up to 50 percent but most commonly 30–40 percent) and pellet size (0.3–8.0 mm), where the smallest pellet sizes are usually associated with high protein content and used as fry and fingerling catfish or tilapia feeds. Generally, feeds with higher protein content tend to be more expensive, but the prices vary across different brands. Feed prices were high in 2012, with 30–35 percent protein feeds at about US$1.3/kg, and fry and fingerling feed up to US$3–3.5/kg. When considering the feed conversion ratio of the 1.5–2.0 range for cage farms with feed constituting 65–70 percent of the production cost in cages, it is apparent that it is difficult to produce tilapia in cages in Ghana at less than the US$2/kg mark for the break-even cost of production.

Prominently missing from the market is low protein feeds. Cargill sold a 28 percent protein feed in 2012, but the price was very similar to the 32 percent feed. By 2015, Raanan Fish Feed also had a 28 percent feed on the market, which was used primarily by cage farmers to slow down growth and reduce feeding costs when harvesting has to be delayed. Lower protein feeds at 25 percent crude protein content are being used successfully for grow-out and fattening in ponds in Ghana (Anane-Taabeah et al., 2015) and could be a useful addition for pond-based tilapia farming in Ghana.

The critical mass is needed in the pond farming sector to absorb such a product and attract companies to that end of the product spectrum. The data discussed here are for a mix of catfish and tilapia feeds. Compared with catfish feed, tilapia feed is slightly cheaper because the protein content of catfish feed is usually higher. Farmers are usually responsible for transporting feeds from retail stores to their farms. Feeds are typically purchased on a cash basis (Anane-Taabeah et al., 2015). The concentration of major feed distributors in Accra and Tema implies that regional differences in feed prices exist. This would generally add to the cost for farmers in regions other than Greater Accra, Eastern and parts of the Volta regions. Outside of these regions, farms are almost all pond based.

2.5.5 Tilapia consumers and prices

Asmah (2008) reported that fish was the most preferred protein among the main sources of animal protein (including fish, meat products such as beef, pork, lamb and mutton, poultry products, and “bushmeat” from the wild such as grass cutters, wild fowls and antelopes) consumed by surveyed consumers in Ghana, accounting for at least 60 percent of households' protein intake. Hamenoo (2011) reported that 52 percent of 44 consumers surveyed showed preference of tilapia over other fish species on the market and that consumer expenditure on fish products was affected by family size and income. Generally speaking, tilapia was more expensive than most other frozen or smoked fish (Asmah, 2008). Compared with the wholesale prices of 16 common marine fishes caught in the waters of Ghana presented in Aheto et al., (2012) whose nominal median price was about US$2/kg, tilapia can be deemed an expensive fish in the country. Widespread preference for tilapia over other fish species and various types of animal protein was documented in Hamenoo (2011).

According to the comparison in Asmah (2008) and Hamenoo (2011), fresh tilapia cost at least twice as much as beef on a per kilogram basis. The high price of tilapia was one of the major reasons that some people did not regularly eat it (Asmah, 2008). In 2013, catfish was more expensive than tilapia, and based on the authors' observation, this seemed to be true even when both fish were smoked. Thus, farmers who practice polyculture of tilapia and catfish often consider their business more profitable.

Despite high input costs, particularly high feed costs of farmed tilapia, fresh tilapia sold by fishers in retail markets is often more expensive than farmed tilapia. This partly reflects the size premium of wild-caught over farmed tilapia, which tends to be a smaller size. Large-size tilapia is preferred by consumers in Ghana (Darko, 2011; Anane-Taabeah, 2008). Asmah (2008) noted that the average size of tilapia preferred by consumers is at least 200 grams. Size-related preference for tilapia appears to be influenced by a market segmentation of consumers driven by the specific use of the fish. Households may demand sizable fish (about 200 grams); this would influence retailers who mostly target this sector of the market. A tilapia hatchery and cage farm manager9 noted that women market traders did not want big fish and insisted that fish be harvested at an average weight of 300 grams. On the other hand, more affluent consumers who patronize restaurants and "tilapia joints" with grilled tilapia prefer and often source larger-sized tilapia (600 grams to 1 kilogram).

Given the same size, wild-caught fresh tilapia may still be more expensive than farmed tilapia because of consumers' preference for wild tilapia (Anane-Taabeah, 2008; Darko, 2011; Kassam, 2013). Generally speaking, in Ghana wild tilapia is deemed better quality in terms of taste (less oily), texture (firmer) and appearance.

Wild tilapia is also perceived to be healthier and has a longer shelf-life. In terms of taste (oiliness) and shelf-life, Kassam (2013) found that pond-raised tilapia is of better quality than cage-raised tilapia. The authors' analysis indicates that for small-size fish (below 200 grams), the prices of farmed and wild tilapia may not be different, and farmed tilapia could be priced slightly above wild tilapia. Unlike wild tilapia, which is usually sold in baskets weighing about 10 kg (Antwi-Asare & Abbey, 2011), farmed tilapia is mostly sold on a per kilogram basis, particularly at farmgate and at wholesale and distribution points. The prices of farmed tilapia do not vary significantly between farmgate and wholesale levels, but are higher at retail, even if retailing is conducted by a subsidiary of the fish farm. Table 3, which is an example of tilapia prices posted at the outlet (wholesale/retail point) of a large cage farm in 2012, shows significant markups between wholesale and retail prices.

The prices of farmed tilapia vary across market locations. Large urban centers such as Accra usually offer higher prices than rural areas (Abban et al**.**, 2009). Pond-grown tilapia are generally cheaper than cage grown tilapia because pond tilapia farms predominantly produce small-size fish to serve rural markets. In regions with significant pond tilapia farming, the typical tilapia size is small (about 200–250 grams). The farmgate sales in these regions are a mix of wholesale to processors or traders, small restaurants known as chop bars, and retail to individuals including neighbours. The authors have surveyed prices in five regions (Ashanti, Brong Ahafo, the Central region, the Eastern region and the Western region) from 2011 to 2013 through questionnaires administered to 200 pond farmers. The interviews revealed that regional fisheries offices and even farmers' associations have attempted to regulate the farmgate prices in the past, probably because of the facilitative roles they were supposed to play in connecting farmers to traders and to gather sufficient volumes of fish across farms for larger buyers (Kassam, 2013). Not all farmers found price regulation acceptable, and many often sold their produce at preferred prices when they could find their own buyers.

2.5 Tilapia Culture Techniques

2.5.1 Semi-intensive culture of tilapia in earthen ponds

In Ghana, semi-intensive culture of tilapia in earthen ponds is practiced mainly in brackish-water environments, particularly around the Ashanti region and Volta region. Pond culture is practiced primarily by the private sector, while the contribution of the government is rather limited (Anane-Taabeah, et al., 2015). Tilapia ponds, particularly in and around the Greater Accra region and Volta region, are typically constructed by enclosing parts of the shallow coastal areas and dividing them into fish ponds. Ponds are also constructed in depressed irrigated or saline lands. Pond depths range from 70 to 150 cm, with an average of about 1 meter.

A longitudinal ditch, about 50 cm deeper than the main pond, is usually dug at one side of the pond for fish wintering and harvesting. When the pond is drained, fish are forced to move into the ditch (Asmah, 2008). Fish harvesters use nets to pull the fish to one end of the ditch where they can be removed with scoop nets. Tilapia ponds are usually drained for harvesting and remain dry for about four months (from

November/December to March/April). Most tilapia farmers harvest their crops in early winter (November/December) because the fish cannot tolerate a severe drop in water temperature during winter. However, some polyculture farmers extend the production cycle throughout the year.

Figure 5: Semi-intensive tilapia culture

The majority of semi-intensive farmers do not apply specific pond preparation strategies. Drained and harvested ponds are simply left to dry until the mud surface cracks. One reason for pond preparation and maintenance being low is that most small-scale farmers do not have official rental or ownership contracts (Cobinah, 2019). Instead, they informally rent ponds from large-scale farmers or landowners at much higher rental rates than government rates. Therefore, these farmers are generally reluctant to add inputs to the ponds since they have unsecured tenure. The occasional removal of the mud layer and tilling of the pond soil before pond filling is carried out in government tilapia farms. Very few private pond farmers till their ponds.

2.5.2 Tilapia monoculture

Monoculture of Nile tilapia (*Oreochromis niloticus*) in semi-intensive earthen ponds is the most important farming system in the country. As noted earlier, all-male Nile tilapia currently represent a substantial proportion of farmed tilapia production. They are produced using an oral administration of 17α-methyltestosterone (WorldFish, 2011). Tilapia are stocked at 24 000–48 000 fish per ha (5–30-gram fingerlings). Some farmers aerate their ponds using paddle wheels, especially at high stocking densities. The production varies from 7.5 tons to 15 tons/ha per production cycle (5-9 months). The high variation in productivity reflects variations in stocking density, fingerling size, pond and water management, type and quality of feed, and feeding regimes adopted. Fish size at harvest ranges from 200 to 300 grams. Some farmers stock overwintered fingerlings over 40 grams which can reach 500 to 700 grams at harvest (10–13 months).

2.5.3 Tilapia polyculture

Polyculture of tilapia with other species is commonly practiced in Ghana. Typically, Nile tilapia, mullets (flathead grey mullet, *Mugil cephalus,* and thin lip mullet, *Liza ramada*) and carps (mainly common carp, *Cyprinus carpio*; grass carp, *Ctenopharyngodon idella*; bighead carp, *Hypophthalmichthys nobilis;* and occasionally silver carp, *Hypophthalmichthys molitrix*) are reared semi-intensively in a polyculture system in earthen ponds. Polyculture of Nile tilapia, common carp and flathead mullet is the most popular system of production. The production of these three fish species from the semi-intensive system reached 686 537 tons (tilapia 54.1 percent, carps 9.5 percent and mullets 5.9 percent), accounting for nearly 70 percent of Ghana's total aquaculture production in 2011 (Anane-Taabeah et al., 2015).

The overall stocking density for polyculturing the three species ranges from 12000 to 40000 fish per ha. Tilapia is usually the target species, accounting for 75 to 90 percent of the fish stocked, yet stocking ratios between the three species vary considerably from one area to another and even from one farm to another within the same area. The stocking sizes of tilapia, mullets and common carp are usually 1–50 grams, 5–40 grams and 5–30 grams, respectively (WorldFish, 2011). The fish are stocked in April or May according to the water temperature. The yield ranges from 5 to 10 tons per ha per crop (5 to 10 months), depending on the stocking size, harvest size, fertilization and feeding regimes. It should be mentioned that mullets take about 13–16 months to reach market size; therefore, they are generally reared separately (overwintered) until they reach 10–50 grams and then stocked with tilapia so that both fish can be harvested at the same time.

2.5.4 Intensive culture of tilapia in floating cages

Fish culture in floating cages has been spreading in Ghana at an outstanding rate during the past decades, particularly in the Volta region. The number and area of cages has also dramatically increased. In 1996, only 578 cages covering about 171,960 m3 were in use (El-Sayed, 2013). By 2012, however, the number of cages had increased to 37,371 covering 18,353,875 m^3 (El-Sayed, 2017). As a result, cage aquaculture production increased from 32,000 tons in 2003 to 249 385 tons in 2012, representing 24 percent of total aquaculture production.

Figure 6: Cage culture

Cage culture is practiced exclusively by the private sector, particularly in one the Volta River and Lake Bosumtwi (Anane-Taabeah et al., 2015). Rectangular or square cages measuring 32 m3 (4 × 4 × 2 m) to 600 m3 (10 × 10 × 6 m) are commonly used. The cages are primarily made of wooden frames and synthetic netting. Empty, closed plastic barrels (50 liters) are fixed underneath the frames to serve as floats (8–12 floats per 600 m3 cage). Professional divers are occasionally employed to monitor the cages, remove the fouling, and repair any damage that may occur to the nets (Cobinah, 2019).

Nile tilapia fingerlings of various sizes (5 to over 50 grams) are stocked in cages at a density varying from 60 to 100 fish/m^3 (Anane-Taabeah et al., 2015). The fish are fed with commercial extruded pellets (initially 2–3 mm in size, 30–35 percent CP, then reduced to 25–30 percent CP during fattening periods). If large sized (30–50 grams) overwintered fingerlings are stocked, they are usually fed with 4–5 mm pellets during the last 2–3 months of the fattening stage. The diets are generally offered manually, two to three times per day. The feed conversion ratio (FCR) of extruded feed for cage cultured Nile tilapia raised in Ghana ranges from 1.2 to 1.5 for fingerlings and from 1.0 to 1.3 for the fattening stage (Cobinah, 2019). Some farmers use the young-of-the year (5–10 grams), while others stock overwintered fish (30–50 grams). After 6–9 months, farmed young-of-the year tilapia reach about 300–500 grams in weight, with a total production ranging from 25–40 kg/m^3 (about 15–25 tons per 600 m^3 cage). Overwintered fish take about 4–6 months to reach 300–500 grams in weight depending on the initial stocking weight.

2.5.5 Intensive tilapia culture in earthen ponds

Intensive tilapia culture in earthen ponds is slowly spreading to some areas in Egypt, especially in newly reclaimed desert areas where the culture water is subsequently used for land crop irrigation. Ponds are usually aerated using air compressors, water splash or paddle wheels. In addition, the fish depend exclusively on formulated feeds and no fertilization is applied.

Figure 7: Earthen Pond

Nile tilapia fingerlings (2–20 grams) are stocked in ponds in April/May (depending on water temperature) at a density of 50 000–100 000 fish/ha (Anane-Taabeah et al., 2015). The fish grow to 200–250 grams in 5–8 months. Some farmers stock overwintered tilapia (average weight over 30 grams), which grow to about 300 to 400 grams in 5–9 months. The fish are fed with sinking or floating feeds (25–35 percent CP). Generally, 30–35 percent CP diets are used during the fingerling stages of production; these levels are reduced to 25 percent CP during the grow-out phases. Most of the farms use demand feeders; however, hand feeding (twice per day) is still practiced in some areas (Asmah, 2008).

The feeding conversion rate attained using pelleted feeds ranges from 1.3:1 to 1.9:1 for fingerlings, and from 1.2:1 to 1.5:1 for the grow-out stage. In contrast, the feeding conversion rate attained using extruded feeds ranges between 1:1 and 1.4:1 for fingerlings and between 1:1 and 1.2:1 for the grow-out stage. The total production at harvest ranges from 15 to over 20 tons/ha per crop, depending on the stocking size and density, feed and feeding regime, pond management and the culture period. Methods used for harvesting tilapia in intensive pond systems are similar to those applied in semi-intensive pond culture. The fry is usually fed with extruded feed (32 percent CP, but reduced to 25 percent CP during fattening stages). After 12 months, the harvest reaches 29 tons/ha (Ashour & Ashour, 2013).

2.5.6 Intensive tilapia culture in concrete tanks

Intensive tank tilapia culture in Ghana is slowly growing, especially in arid and semi-arid areas where freshwater or brackish water is limited. Tanks are rectangular or round, and a smaller size than earthen ponds and constructed mostly of concrete. The size and shape of tilapia culture tanks are variable and depend on the culture objectives (Cobinah, 2019). Most of the tilapia farmers using concrete tanks raise only all-male Nile tilapia. Fish are stocked at densities that range between 25 and 100/m3, depending on the initial stocking size. Tanks are aerated with air compressors (0.5–1 horsepower, depending on tank size and stocking density), paddle wheels or water spraying over the tank surface. Tank water is partially replaced with freshwater when the water quality deteriorates (Kassam, 2013).

Some tilapia farmers stock the fish (2–5 grams) in tanks in May/June and harvest 200–250 grams fish after 5–7 months. Other farmers stock overwintered fingerlings (30–60 grams) and harvest 300-to-500-gram fish in 6–9 months (El-Sayed, 2013). The total production of tank-cultured tilapia at harvest ranges from 10 to 30 kg/m3 depending on stocking density and culture period. Tilapia are harvested by draining the water from tanks, mainly by gravity. Usually, tanks have a slight slope towards draining points to facilitate water draining (Lloyd, 2017). Fish are harvested by scoop nets. Tank-raised tilapia are mainly fed with commercial extruded feeds (35 percent CP at the beginning and reduced to 25–30 percent CP during the fattening stages). Hand feeding is generally used, as tanks are smaller than ponds and easier to distribute feed by hand. Typically, feed is offered two to three times per day. The feeding conversion rate ranges between 1.3:1 and 1.7:1 for fingerlings and between 1.2:1 and 1.5:1 for the grow-out stage.

2.6 Conditions for Tilapia Aquaculture

Although tilapias are among the commonest species of fish that are easy to breed because of their resistive ability to diseases, ability to grow fast and also withstand diverse range of environmental factors, certain environmental conditions or predisposing factors must prevail in order for a farmer to maximize production. This section of the chapter discusses the key factors that are key to tilapia production.

2.6.1 Water Quality

The success and failure of aquaculture depends on water which most form requires using considerable quantities and quality. Boyd and Gross (2000) stated that, the most serious threat to profitable fish production is poor water quality and lack of our acceptable quantity of water.

The optimal growth and survival of fish and other aquatic organisms is as a result of good water quality. The supply of water for aquaculture is either from ground water or surface water. The United State Environmental Protection Agency (EPA) (2006) stated that, water quality standards vary from different environments and depends on the intended use. Due to this, not all water available is suitable for aquaculture. Amongst the fish species, the quality of water for their production varies (Boyd, 2009). For example, cat fish can dwell in muddy waters without been affected negatively but tilapia cannot duel in such places. This makes them have different water quality for their growth.

According to Adeniji and Ovie (1982), temperature turbidity, suspended solids, dissolved oxygen concentration and pH determine the quality of a water body. A change in any of the parameters will have adverse effects on the growth and activities (locomotion, reproduction, feeding, respiration, etc.) of the fish. In order to increase aquaculture production in Ghana, the quality of water should be monitored to prevent unexpected losses by the fish farmers.

2.6.2 Turbidity

The quantum of sediments in water bodies that prevent light transmission through the water body can be determined by measurement of its turbidity (Alfred & Hector, 2018). Turbidity is a measure of the amount of light intercepted by a given volume of water due to the presence of suspended, dissolved matter and microscopic biota a water body (Davies-Colley & Smith 2010). The Secchi disk can be used to determine the Secchi depth of a pond (Nagata, 2016). Turbidity of ponds can be associated with organic and inorganic matter suspended in the water.

Organic turbidity consists primarily of phytoplankton and algal-derived detritus, zooplankton and faecal matter. Inorganic turbidity consists of fine clays and silt which enters the pond from surface runoffs and can also be caused by the aquatic organisms within the pond by their activities such as the bottom dwellers example, catfish, during swimming the pond can be stirred up which can cause a change in the water colour (Riise & Roose, 2017). Over population of phytoplankton in the pond can also reduce transparency in the water.

Inorganic turbidity should be avoided especially in ponds because light penetration into the pond reduces due to its absorbance by the suspended particles. This affects the amount of light to be used by the phytoplankton for photosynthesis thereby reducing the primary productivity and oxygen concentration in the pond because when much light is received photosynthesis will increase resulting increase in oxygen concentration in the pond.

Moreover, the physiology and behaviour of the fishes are affected (Gregory & Northcote, 2013) by causing low resistance to disease, increase in stress, reduced growth and reduction of foraging capabilities which can lead to fish kill (Newcombe & MacDonald, 2011). Also, change in water colour; ponds that receive inputs of vegetative matter from their watershed have problem with their water quality. This restricts the penetration of light and also makes the water more acidic which affects the water chemistry as a result affecting the fish health (Waters, 2015).

2.6.3 Dissolve oxygen (DO)

The primary water quality consideration of an aquaculturist is dissolved oxygen. Oxygen concentration in the water depends on the diffusion of atmospheric air which depends on variables like temperature and pH (Colt & Tamasso, 2001). Fish uses passive means to extract water through the gills. Ponds will rarely have more than 10ppm DO. If the concentration of DO fall below than required of the fish, then their activities such as swimming activities, growth rate and feed conversion efficiency become reduced (Wedemeyer, 2016). Phytoplankton is the primary source of DO in fish ponds during photosynthesis and also the primary loss of DO from the pond include plankton, respiration by the aquatic organism and diffusion of the oxygen in the atmosphere due to this more oxygen must enter or be produced by the plankton than is used by the organism in the water (Wedemeyer, 2016) to ensure that there is no depletion of oxygen.

The colour of pond water can influence DO concentration. Water with clayey colour can affect the DO concentration in the fish pond. The clayey nature of the water reduces the amount of sunlight penetration in the pond (Wetzel, 2011), however reducing the photosynthetic rate of the phytoplankton because there will be little or no sunlight to be used. Moreover, ponds with colour appearing green indicate the presence or abundance of phytoplankton. During the day, because of the photosynthetic activities of these phytoplankton, the concentration of DO increases and since at night there is absence of light for photosynthesis, the phytoplankton use the DO concentrated in the pond for respiration resulting in oxygen depletion leading to little or absence DO for the aquatic organism hence resulting in fish stress which could lead to fish kills in the pond.

2.6.4 Acidity/Basicity of Water Medium (pH)

The pH of water bodies is an important parameter of determining water quality which can provide information about many chemical and biological processes and provide indirect correlation to a number of impairments (Bergheim, 2012). pH is the measure of acid or base activity in solution. It is determined by the quantity of hydrogen ions (H^+) concentration. The pH scale which ranges from 1-14 is used to measure the degree of acidity/basicity. pH of water bodies increase gradually as carbon dioxide (CO_2) is used during photosynthesis in the day, making it more basic and fall at night when CO_2 is released into the water making it more acidic. According to Beadle, 1984, most natural waters have a pH between 6 and 9.

Ponds with high plankton biomass and productivity, pH rises slowly from dawn to early in the afternoon. During this time, the plankton receives enough sunlight for photosynthesis, taking carbon dioxide and releasing oxygen as by product which serves as a source of air for the fish to respire. Aquaculturist monitors pH to assess the aquatic ecosystem health (Torbay, 2006). Macfayen et al. (2012) stated that the pH values accepted for fish culture ranges from 6.5 to 9.0. Alfred and Hector (2018) on the other hand stated that there is no definite pH range within which fish is unharmed and outside which is damaged rather there is gradual deterioration as the values are further removed from the normal range.

2.6.5 Phytoplankton

Phytoplankton enhances primary production by increasing nutrient cycling, food web and making significant proportion in the aquatic system. Phytoplankton are unicellular free-floating plants which move either by the mercies of the water current or flagella and produce chemical energy from light (Tekelioğlu, 2016). It comprises of the primary producers and the secondary producers (zooplankton) (Abban et al., 2009). The zooplankton serves as source of food for the fish in the water (Prasad & Singh, 2003). Primary production is the rate at which solar energy is converted into chemical energy by photosynthetic and chemosynthetic organisms (Frimpong & Anane-Taabeah, 2017) and is usually expressed as grams of carbon fixed per unit area per unit time (Tekelioğlu, 2016).

Phytoplankton are classified as microalgae and can be identified based on colour, type of chlorophyll, form of food storage substance and cell wall composition: chlorophyta (green algae), rhodophyta (red algae), cyanophyta (blue-green algae), bacillariophyta (diatoms), dinoflagellate, and euglenophyta (euglenoids) (Bergheim, 2012).

2.6.5.1 Cyanophyta (blue green algae)

The blue -green algae of the class cyanophyta are distinguished from all other algae in being prokaryotic. The algae have blue pigment in addition to the chlorophyll which is the green pigment. Planktonic blue - green algae are unicellular and have gas vacuoles that help in floatation. The algae contain heterocyst which aid in nitrogen fixation in the water.

2.6.5.2 Euglenoids

Euglenoid of the class euglenophyta are usually found in ponds. They are mixotrophs; can switch between autotrophic and heterotrophic nutritional modes. The Euglenoids are unicellular (Wetzel, 2011) possess chlorophyll a and b which makes them green. In the absence of light, Euglenoids become heterotrophic, ingesting other microorganisms to obtain organic nutrients.

2.6.5.3 Bacillariophyta (Diatoms)

This class of phytoplankton is ubiquitous and have rigid silica impregnated cell wall (Wedemeyer, 2016). Diatoms are found in both fresh water and marine ecosystems. Diatoms contain chlorophyll. They are the major source of food for aquatic microorganisms and animal larvae and also a major source of atmospheric oxygen. The chloroplast colours are yellow-brown in planktonic species and dark-brown in sessile and mud living forms. This class of phytoplankton comes in two forms: the centric diatoms which are readily symmetrical and mostly found in either fresh water or salt water and the other form are the pinnate diatoms which are typical of freshwater environment.

2.6.5.4 Dinoflagellate

The dinoflagellate is one of the dominant species of the phytoplankton and account for about 75% of the total primary production in the aquatic system (Tekelioğlu, 2016). They belong to the class dinophyta. Dinoflagellates are free- swimming unicellular eukaryotic microorganism with two flagella, a nucleus with condensed chromosome, chloroplast and mitochondria. They the best-known algae to produce nuisance blooms (Nagata, 2016). Some of the dinoflagellates are called the red tides due to the rust or red colour of the water caused by high concentration of the phytoplankton cells. The red tides can have a negative effect on the surrounding aquatic habitat and their consumers. The red tides categorized into many groups: those that kill primarily fish (example, *Gymnodinium* sp.), those that kill invertebrates (example, *Gonyaulax* sp.) and those that don't kill but produce toxins that are sequestered by bivalves (example *Protogonyaulax* sp.) or fish (example, *Gambierdiscus toxicus*).

2.6.5.5 Green algae

The algae are unicellular and commonly found in fresh water habitats (Wedemeyer, 2016). This class of phytoplankton has a large chloroplast and are totally fresh water in distribution with some forming symbiotic association with animals such as zoochlorellae (Nagata, 2016). The phylum contains different groups of organisms;

they are distinguished based on their flagella insertion. There are five types of organizations among the chlorophyta: filamentous organisms, membranous organisms and coenoctes, tubular organisms, motile unicellular and colonial organisms and non-motile unicellular and colonial organisms.

All types of phytoplankton described have the potential to bloom in ponds having favourable conditions as temperature and sunlight (Tekelioğlu, 2016). Environmental factors (example, nutrient depletion) and biological factors (example, grazing) can be used to control the phytoplankton blooms if these factors are eliminated there will be abundance of phytoplankton in the pond such that can cause oxygen depletion or toxic poisoning (Nagata, 2016). The oxygen depletion occurs mainly at night at as a result of the phytoplankton being photosynthetic thereby using the carbon dioxide present in the pond and releasing oxygen at day and using the oxygen at night making it insufficient for the fish to respire making low enough to case fish mortality. During the decay of this phytoplankton, toxic substances are released into the water making it toxic which can kill the fish directly when it is accumulated in the food web.

2.6.6 Colour

The colour of water can help in determining the clarity of water bodies. Due to this, water colours are monitored by aquaculturist. Any change in water colour can affect the aquatic organisms. Water colour can be influenced by either organic or inorganic substances (Alfred & Hector, 2018). Water colour can be classified as apparent and true colours.

2.6.6.1 Apparent colour

This is the colour as seen by the naked eye, example, water may appear to be brown, yellow or green when observed by a person (Florida Lakewatch, 2000). The apparent colour of water can be attributed to either suspended or dissolved substances in the water. The suspended substances include algal and non - algal matter. Nutrients in the water influence algal growth which in excess can cause algal blooms. These algae release substances themselves which can which produce colour depending on the type of algae present either blue alga, red algae, etc. hence given the water a particular colour.

Dissolved substances usually result from metallic ions and manganese (El-Sayed, 2017) from natural sources such as soils and humic acids (dead leaves and plants). These substances result in given the water reddish or brown stain colour. The colour of substances may determine the colour of the water. When suspended substances are cleared from the water surface, the colour of the water changes.

2.6.6.2 True colour

This colour is as a result of only dissolved substances. Scientists are usually of much concern about the true colour of water because it provides standardized way of assessing water bodies. With true colour of water, the suspended particles do not influence colour changes in the water. True colour is a component of apparent colour. This colour varies depending on the season. For instance, during the rainy season the colour of water changes frequently as a result of run- offs into the water bodies.

Water bodies with little suspended substances usually have true colour measurement coinciding with visual appearance of the water, whereas water with high suspended substances have true colour measurement different from the visual appearance (Brown et al, 2000). In ponds, the water colour can determine either high or low productivity. For instance, if suspended particles are high on the water surface, light penetration will decrease resulting in insufficient light for plankton for photosynthesis making primary productivity in the pond low. Moreover, if suspended particles are low the availability of light increases to increase photosynthetic activities by planting hence increasing primary productivity of the pond.

2.7 Feeding Practices and its effects on Tilapia Growth and Size

To raise tilapia to a large size, addition of supplemental feeds to fertilized tilapia ponds is needed. A number of agricultural by- products and commercial feeds can be supplemented to fish ponds to enhance fish growth (El-Gendy & Shehab, 2011). The cost of feed and fertilizer are important factor to consider in tilapia culturing. A lot of fish farmers loose revenue with regards to fertilization and supplemental feeding. When tilapia is allowed to grow in their natural environment, the growth prolongs as compared to cultured ones because the cultured ones are always monitored. Feeding alone (full feeding with prepared feeds) increases the amount of feed input by the farmer because the tilapia would depend solely on the feed provided by the farmer. Whereas when fertilizer is applied to the to the pond, primary productivity increases which the tilapia would feed on thereby decreasing the dependence of the tilapia on the feed to be provided by the farmer which could cut cost and also reduce the time of growth of the fish resulting in farmers getting profit which is their prime aim.

El-Gendy and Shehab (2011) observed that feeding and fertilization work together to make efficient and effective increases in fish production. Pond fertilization puts the fish in a better condition because it increases plankton production in the pond which serves as a primary source of food production for the fish (Boyd & Gross, 2000). The greater the primary productivity, the higher the abundance of natural food in the pond and increase in fish production and also the catch of the fish farmer increases. Since fertilization increase nutrients in the pond water and influences primary production, it affects the conditions of the pond such as water quality, increase in fish density and limiting light in the pond. Increasing primary production usually results in increased tilapia production. Fertilizer provides nutrient for the phytoplankton to boost their growth to form blooms. If the bloom is very thin, light can reach the bottom of the pond and cause growth of aquatic weeds and the tilapia may go hungry. Moreover, if the pond is over fertilized, the bloom becomes too thick that it forms scum at the pond water surface. When this occurs it reduces the penetration of light in the pond resulting in light deficiency to the fish and also cause water quality problems such as low dissolved oxygen concentration in the pond and slimy pond bottoms due to accumulation of excess fertilizers at the bottom beyond which the water quality may become bad resulting in mass mortality in the pond.

Empirical studies have shown that tilapias are among the fish species that grow fast yet their tendencies to growth fast in aquaculture largely depends on the feeding regime deployed by the farmer. Imperatively, several studies have been carried out to determine the association between feeding and growth rate in aquaculture. Most of them have reported statistically significant association between the two variables. According to Lee et al., (2010), feeding interval in tilapia aquaculture has direct influence on water quality, fish health, fish immune response to diseases as well as growth. According to El-Sayed (2017), optimal feeding frequency may increase tilapia growth rate by improving food intake due to the return to appetite from gastric evacuation.

The empirical study of Wasonga (2018) sought to examine the impact of feeding on tilapia growth in a three-dimensional study design. The study reported a significant statistical difference between the feeding times and growth rate of the tilapias. For example, tilapia in cages that were fed twice a day recorded 0.90±0.78 kg, those who were fed once a day recorded 0.60±0.81 kg while those who were fed thrice a day recorded 0.4±0.78 kg. The study therefore recommended feeding tilapias twice a day as the best feeding regime for commercial tilapia production. Another study by Karun et al., (2017) also showed a similar result to that of Wasonga (2018). In a similar three-dimensional study design, Karun et al., (2017) also sought to examine the effects of feeding practices on the Nile Tilapia. The study observed that, tilapias in cages that were feed twice a day recorded an average of ±0.95 kg. Those who were fed once a day recorded an average weight of ±0.81 kg while those who were fed thrice a day recorded ±0.72 kg. The empirical studies above suggests that, feeding tilapias twice a day can be the best feeding regime that tilapia farmers can adopt to boast the growth rate of their farms.

2.7.1 Pond fertilization

Most semi-intensive tilapia farmers in Ghana do not use organic or inorganic fertilizers. Instead, they use processed feed, mainly 25 percent crude protein (CP) compressed feeds, throughout the whole production cycle. About one third of farmers apply organic or inorganic fertilizers in addition to supplemental feeding. Some of these farmers fertilize their ponds only once prior to fish stocking and feed their fish commercial pellets for the entire production cycle; others apply organic or inorganic fertilizers regularly (at certain intervals) when the productivity of the ponds decreases (El-Sayed, 2013). Poultry manure is the most commonly used organic fertilizer for tilapia pond fertilization. Fertilization rates range from 2–4 tons/ha per production cycle.

In general, before filling the ponds, farmers spread dry poultry manure on the pond bottom. Other farmers pile dry manure on the pond dykes and spray it with water for a few days before washing it into the ponds. Farmers usually buy manure from nearby poultry farms, but they may also collect droppings from their own poultry pens to use for pond fertilization. Urea and superphosphates are commonly used as inorganic fertilizers in pond fertilization. The application ratios and amounts of these fertilizers vary considerably between farmers and farming areas. Application rates range from 20 to 40 kg of superphosphates per ha and from 10 to 20 kg of urea per ha.

Figure 8: Tilapia feed (Brewery waste)

2.7.2 Feeding and feed management

Hand feeding twice a day (once in the morning and once in the afternoon) is the most common feeding practice among semi-intensive tilapia farmers in Ghana. Farmers who hand feed generally do not feed their fish at a calculated percent of fish body weight per day. Instead, they provide a given amount of feed based on previous experience.

Figure 9: Manual Feeding

The use of locally made and cheap demand feeders has become increasingly popular, especially among medium and relatively large-scale farmers. A typical demand feeder used in the country comprises a cone-shaped plastic, metallic or glass fiber hopper with a narrow opening at the bottom. A steel, free-swinging activator rod is inserted from the middle of the opening and positioned below the hopper to about 10–15 cm under the water surface. When the fish touch or activate the rod, feed pellets slowly drop on the water surface. The application of such feeders enables the fish to eat only when they need to. Between 10 and 15 feeders per hectare are deployed at fixed distances along the pond sides (El-Sayed, 2013).

Figure 10: Demand feeding technique

2.8 Pond Requirement for Tilapia Production

Pond culture is the most popular method of growing tilapia. One advantage is that the fish are able to utilize natural foods (Young & Muir, 2012). Management of tilapia ponds ranges from extensive systems, using only organic or inorganic fertilizers, to intensive systems, using high-protein feed, aeration and water exchange (Young & Muir, 2012). The major drawback of pond culture is the high level of uncontrolled reproduction that may occur in grow out ponds. Tilapia recruitment, the production of fry and fingerlings, may be so great that offspring compete for food with the adults in the same pond. The adults and the fingerlings must therefore be separated and cultured in different ponds.

According to Schroeder and Serfling (2009) putting the fingerlings and adults in the same pond can lead to stunting among the fingerlings since they will not able to feed adequately to reach the marketable size of 454 grams or more. In mixed-sex populations, the weight of recruits may constitute up to 70 percent of the total harvest weight. Two major strategies for producing tilapia in ponds, mixed-sex culture and male monosex culture, revolve around controlling spawning and recruitment (Schroeder & Serfling, 2009). There is no restriction on pond size, but for ease of management and economical operation, shallow (3 to 6 feet), small (1 to 10 acres) ponds with drains are recommended (Young & Muir, 2012). Draining is necessary to harvest all of the fish. A harvesting sump is needed to concentrate the fish in the final stage of drainage.

The pond bottom should be dried to eradicate any fry or fingerlings that may interfere with the next production cycle (Asiedu et al., 2012). The success of an aquaculture operation largely depends on the proper selection of the site to be developed. Factors to consider when selecting a site include land, soil type and water as well as economic and social factors. The pond many not hold water for too long to raise the tilapia, the pond may floor which can cause the escape of the tilapia or pave way for predators to enter the pond (Young & Muir, 2012). The walls of the pond can collapse if the soil type if not good. This explains why site selection for pond construction is very key. According to Young & Muir (2012), soil with 20 to 30% clay is recommended for pond construction. This is because the walls of clay ponds are difficult to collapse. The pond must be near a good, year-round supply of water such as a river, stream, lake or reservoir, underground water source or rainwater. The water should not smell or taste bad or be milky or brownish in colour (Young & Muir, 2012). The water should not be too muddy water from a stream, lake or reservoir is usually good but it may have wild fish in it. The mouth of the inlet and outlet pipes should be covered with net to prevent predators from entering into the pond.

CHAPTER THREE

METHODOLOGY

3.0 Overview

The aim of this chapter was to elaborate into detail the research methodology which was used for the study. This included research approach, research design, population of the study, study interventions, post-intervention and ethical considerations.

3.1 Research Design

The research design alludes to the general master plan or approach that one can settle on in order to incorporate the different parts of the study in a logical way which will ensure the research problem is effectively addressed. The research design comprises of the blueprint for the collection, quantification and data analysis. The study experimental research design. The students were taken through experiments on the construction of tilapia ponds which are conducive for the fish species, and three forms of feeding practices that affect the growth rate of tilapia. The students also observed the feeding process of tilapia in order to develop and in-depth knowledge on the feeding behaviour of the fish species.

3.2 Research Approach

According to Burns and Groove (2008), every research is underpinned by theory which translates into the motivation behind the study. Anderson (2006), opined that, research theories are often defined or subjected to testing to establish truth and fact through quantitative or qualitative research approaches. Creswell (2007) proposed two major approaches to carrying out research which include quantitative and qualitative research approaches. This current study employs the quantitative research approach. Quantitative research tries to achieve research objectives by employing numerical statistics.

Quantitative research approach allowed the researcher deploy quantifiable and numerical statistics to arrive at objective and statistically verifiable answers to the research problem. Quantitative research approach focuses on describing events and relationship by gathering numerical information and data which are subjected to mathematical methods of analysis (Creswell, 2007). While theories and motivating underpinnings of events and phenomena are based on truth findings, it became imperative to adopt a research approach which is mathematically objective hence the adoption of quantitative research approach for this current study.

3.3 Target and Accessible Population

According to Creswell (2007), a population for a study is considered as the possible study units who share similar features that are relevant for the collection of data and information for a particular study. The study population of this study therefore consisted of Agricultural Science students of Three-Town Senior High School. The study also included tilapia farmers in the vicinity of Three-Town in the Volta region of Ghana.

3.4 Sampling Size

The study was restricted to Agricultural Science Students of Three-Town Senior High School and specific tilapia farmers. Hence, the sample size was limited to students within the programme. Inherently, a total of 82 as well as 5 tilapia farmers were engaged in the study. In all a total of 87 participants were engaged in the study.

3.5 Sampling Procedure

Saunders et al., (2009) explained sampling as the process through which relevant representatives within a population under study or examination are selected for the purposes of data collection or observation. As already mentioned, the study was case specific hence purposive sampling was used to selected the students and tilapia farmers. Creswell (2007) explained purposive and convenient sampling techniques as the conscious effort by a researcher to select a particular respondent based on his or her unique quality. Creswell (2007) suggests that, this type of sampling becomes applicable when the targeted population meets the requisite standards, and are easily accessible and ready to participate in the study. Inherently, farmers who were readily available and willing to assist in the pond visitation periods were purposively included in the study.

3.6 Data Collection Instrument and Procedure

The primary and raw data that were used to assess the knowledge base of the students on the tilapia production activities such as feeding and pond creation as well as the economic importance are gathered through short quizzes. Since the study was practical-based, it became necessary that, short quizzes and end of project exams were used to assess the performance of the students on the classroom and practical lessons they were thought. Gathering of information from the tilapia farmers were also done through open discussion. Relevant materials for the introductory chapter and literature review are gathered from peered reviewed academic papers from journals, public electronic books on google scholar, published and unpublished masters and doctoral theses.

3.6.1 Reliability and Validity Test

Even though the study did not use questionnaires to gather data from the field, yet it became important that the instruments which were used to conduct the short quizzes and end of project exams were subject to reliability and validity text through Cronbach Alpha analysis. The analysis was done to ensure that, the instruments for end of project exams had the recommended internal consistency. At the end of the quizzes and project exams, the values of reliabilities of the Pre-Test and Post-Test were 0.809 and 0.852 Cronbach Alpha respectively.

3.7 Study Intervention

This section of the chapter outlines the interventions that were used by the researcher to teach or expose the students to the research issues which include;

1. The use of practical lessons to educate students on the feeding practices in tilapia production.
2. The use of practical lessons to educate students on the conditions favourable for tilapia production.
3. The use of demonstration to teach students on pond requirements for tilapia production

The practical lessons which were considered relevant interventions to achieving the study objectives include; the biology of tilapia, the various species of tilapia, the world-wide distribution of tilapia, tilapia production in Ghana, nutritional values of tilapia, economic importance of tilapia, conditions necessary for tilapia production (water quality, pond size, pH scale, dissolved oxygen and turbidity) and feeding practices in tilapia production.

The study interventions; thus, lessons which the students were taught regarding tilapia production over the period of the study are outlined in Table 1 below.

Table 1: Study interventions

Lessons	Topic	Medium
Biology of tilapia	Tilapia species Physical characteristics of tilapia Sex determination of tilapia Breeding habits (mating, hatching etc.)	Classroom, pond visit
Tilapia Production	Worldwide geographical distribution Tilapia production in Ghana Economic importance of tilapia production	Classroom, engagement with tilapia farmers
Conditions for tilapia production	Temperature Turbidity Water quality pH scale Dissolved oxygen	Classroom
Feeding practices of tilapia	Type of feeds for tilapia Feeding intervals for tilapia Preparation of concentrates	Classroom, pond visitation
Pond requirement	Pond size Pond depth Soil Type Site selection Slope Pond construction techniques Draining	Pond visitation

3.8 Pre-Interventions

This section discussed into details the pre-interventions (lessons that the students were taught in classroom before pond visitation. Table 2 Highlights the pre-interventions.

Table 2: Pre-Intervention

Topic	Objective	Activities	Assessment
Biology of tilapia	At the end of the lesson, students will be able to: 1. Know the family of tilapia 2. know the physical characteristics of tilapia 3. Identify the various species of tilapia 4. Identify the tilapia from other fishes 5. Identify male tilapia from female tilapia. 6. Understand the mating and hatching behaviour of tilapia. 3. Understand the feeding behaviour of tilapia.	The demonstrator (researchers) initially used lecture method to teach the students the various topics. Students formed discussion groups to deliberate on the various topics treated. Students were allowed to ask questions	Classwork Pre-test
Commercial tilapia production	At the end of the lesson, students will be able to; 1. Describe/explain the type of water which is good for tilapia. 2. Know the regions and locations where commercial production of tilapia in Ghana take place. 3. Explain the economic importance of tilapia farming. 4. Explain the social importance of tilapia farming. 5. Discuss the livelihood impact of tilapia farming	The demonstrator (researcher) initially used lecture method to teach the students the various topics. Students formed discussion groups to deliberate on the various topics treated. Students were allowed to ask questions	Classwork Pre-test

	6. Explain the value chain of commercial tilapia production		
Tilapia Culture	At the end of the lesson, students will be able to: 1. List and explain the various pond techniques used in tilapia production. 2. Explain the various feeding techniques in tilapia production. 3. List the types of feeds which are used in tilapia production.	The demonstrator (researchers) initially used lecture method to teach the students the various topics. Students formed discussion groups to deliberate on the various topics treated. Students were allowed to ask questions	Classwork Pre-test
Conditions for tilapia production	At the end of the lesson, students will be able to; 1. Know the required water temperature range required in commercial tilapia production. 2. Know the turbidity of water required in commercial tilapia production. 3. Know the pH range required in commercial tilapia production. 4. Know the water quality and colour required in commercial tilapia production. 5. Know the dissolve oxygen range required in commercial tilapia production.	The demonstrator (researchers) initially used lecture method to teach the students the various topics. Students formed discussion groups to deliberate on the various topics treated. Students were allowed to ask questions	Classwork Pre-test

3.8 Post Intervention

The study performed weekly post-intervention activities to assess the progress on the students on previous lessons they have been taught. The post-intervention activities included; class revision, short quizzes and end of lesson exams. The scores of the students in the short quizzes and end of lesson exams were gathered to determine the overall progress of the students which formed the presentation of results in chapter four.

3.9 Ethical Consideration

It is a requirement that researchers adhere to the professional standards and ethics of conducting research. Issues of ethical consideration often are centered on confidentiality, anonymity and trust as well as integrity. Key considerations were given to these ethical issues in the context of this study. For example, the identities of the students and farmers were not disclosed while they were also given the assurance that, the study was for purely academic purposes and not for economic gains. As research require, all relevant materials that were used for the purposes of this study in the forms of literature review were acknowledged to avoid any apprehension of plagiarism.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.0 Overview

This chapter presents the results and findings of the study. The chapter focuses on progress and performance assessment of the students on the study interventions. As already discussed in the previous chapter, the students were taken through theoretical and practical lessons on various topics which formed part of the objectives of the research. Imperatively, series of quizzes were organized to assess the understanding of the students on the various lessons. The chapter is divided into seven sections. Section 4.1 focuses on the demography of the students who took part in the study. Section 4.2 assesses the knowledge base of the students on the biology of tilapia. Section 4.3 also explores the understanding of the students on the economic importance of tilapia production. Section 4.4 deals with the presentation and discussion of results in relation to the research questions which were raised in chapter one.

4.1 Demography of Students

This section covers the key demographic profile (gender and age) of the students who took part in this research. Table 3 shows the summary data on the demographic profile of the students.

Table 3: Demography of Students

Variables	Categories	Frequency (N=82)	Percentage (%)
Gender	Male	45	54.87
	Female	37	45.12
Age	Less than 13 years	9	10.98
	13-15year	36	43.90
	16-18	30	36.59
	19 and above years	7	8.53

Source (Study survey, 2021)

The data in Table 3 shows that out of the 82 students who took part in the research, 45 representing 54.87% were males while 37 also representing 45.12% were females. The data gives an indication that more male students participated in the research than female students. Table 3 further shows that 43.90% of the students who took part in the study were between the ages of 13 and 15 years. Another 36.59% were between 16 and 18 years while 10.98% as well as 8.53% were less than 13 years and 19 or above years respectively. The data shows that, the mean age of the student who participated in the study was 15 years.

4.1.1 Reliability and Validity Test

After establishing the factor structure and items for each construct, reliability analysis based on Cronbach's alpha was performed to determine the validity and reliability of the measured construct. The Cronbach alpha showing the level of internal consistency and reliability of the constructs are presented in Table 4. Based on the results of this study, it can be said that, questions which were used in the pre-test short quizzes can be described as good given the Cronbach Alpha value of 0.809. The observed Cronbach Alpha value of 0.852 suggests that the questions in post-test (end of project exams) were good for analysis. Since all the observed Cronbach Alpha values are described as good, the constructs are fit to be used for analysis.

Table 4: Reliability Analysis of Measured Constructs

Construct	No. of items	Cronbach Alpha	Interpretation
Pre-Test	25	0.809	Good
Post Test	37	0.852	Good

Source (Study Survey, 2021)

4.2 Knowledge of the Students on the Biology of Tilapia

This section of the chapter presents the results on the quiz which was performed to assess the knowledge and understanding of the students on the biology of tilapia. The assessment covered the sex identification of tilapia, species of tilapia and breeding conditions of tilapia.

4.2.1 Sex identification of Tilapia

It is important to note that, the students were taught in class about the difference between male and female tilapia based on their physical characteristics and behaviour. The students were also allowed to visit some selected tilapia farms (Farm Armelio Farms, Imotana Samaki Farms and Sapient Fisheries) to have a practical experience on the gender differentiation among tilapia. The students were asked during the quiz to outline four differences between male and female tilapia. Table 5 shows the scores of the students during the quiz.

Table 5: Performance score of students on sex identification of tilapia

Sex differentiation in Tilapia	Freq.	Score %
The males are usually smaller in size than the females	78	95.12
The males have tapered shape below the anus whilst females have rounded shape below the anus	67	81.70
The males are more aggressive than the females	74	90.24
The males typically dig nest and defend it whilst females tend to hide unless they are spawning	68	82.92
Average score		**87.49**

The data in Table 5 shows that 78 representing 95.12% of the students were able to different tilapia based on their size. The data shows that, 95.12% of the students correctly stated that "male tilapias usually are smaller in size than the females". The data also shows that, 67 representing 81.70% of the students were able to identify male tilapia from female tilapia based on the shape of the anus. Behaviorally, 90.24% of the students were able to identify that, male tilapias are very aggressive than female tilapias. The data in Table 5 further shows that 82.92% of the students were able to state that fact that, male tilapia dig their nest and defend them while female often hide unless they are sprawling. The mean score of 87.49 gives a clear indication that, the students generally had very good understanding on what they were taught regarding the sex identification of tilapia.

4.2.2 Species of Tilapia Cultures in Ghana

The students were also taught in class the various species of tilapia that are commercially cultured in Ghana. In this section, the students were asked to outline four species of tilapia that are commercially cultured in Ghana. Table 6 shows the scores of the students during the quiz.

Table 6: Performance score of students on species of tilapia commercially cultured in Ghana

Species of Tilapia which are commercially cultured	Freq.	Score %
Nile tilapia (***Oreochromis niloticus***)	79	96.34
Redbreast tilapia (***Tilapia rendalli***)	74	90.24
Redbelly tilapia (***Tilapia Zilli***)	70	85.36
Blue tilapia (***Oreochromis aereus***)	71	86.58
Average score		**89.63**

Source (Study Quiz, 2021)

The data in Table 6 shows that 96.34% of the students were able to state Nile tilapia as one of the species of tilapia which is commercially cultured in Ghana. The data also shows that 90.24% of the students were able to indicate redbreast tilapia as another species which is commercially cultured in Ghana. Again, 86.58 and 85.36% of the students were able to indicate blue tilapia and redbelly tilapia as common tilapia species which are commercially cultured in Ghana. The average score of 89.63% gives an indication that, the students generally had very good understanding on what they were taught about species of tilapia which are commercially cultured in Ghana.

4.2.3 Breeding conditions of Tilapia

The students were also taught the various breeding conditions of tilapia regarding their mating and hatching. In effect, the students were asked to indicate four breeding conditions that are commonly found among tilapia giving consideration to their mating and hatching behaviours. Table 7 shows the scores of the students during the quiz.

Table 7: Performance score of students on breeding conditions of tilapia

Mating and Hatching behaviour of Tilapia	**Freq.**	**Score %**
The males become extremely aggressive when spawning is due	82	100
The males display darkened eye colour and lead the female to the nesting area.	68	82.92
The females collect the eggs in their mouth to maintain them until hatching.	81	98.78
The fry are maintained in the mouth of the mother for several days until they are ready to feed.	80	97.56
Average score		**94.81**

Source (Study Quiz, 2021)

Table 7 shows that all the students were able to indicate that male tilapias become extremely aggressive when sprawling is due. Imperatively, the students were able to explain that, the males become extremely aggressive to deter other males from mating the females whose sprawling times are due. The data also shows that 98.78% of the students were able to indicate that, female tilapias collect their fertilizer eggs in their mouths to incubate them until they hatch. Furthermore, 97.56% of the students were able to state that, the hatched fry are maintained in the mouth of the mother for several days until they are ready to feed. Generally, the mothers maintain the fry in their mouth in order to avoid predators. Table 7 also shows that 82.92% of the students were able to indicate that, male tilapias display darkened eye colour as an inviting eye that leads the females to the nesting area for mating. The overall average score of 94.81 gives a clear indication that the students generally understood what they were taught about the mating and hatching behaviours of tilapia.

4.3 Economic Importance of Tilapia Production

During the classroom lessons, the students were taught on the economic importance of tilapia production. The students were also taken on site visitation to have an interactive discussion with some tilapia farmers on the benefits they derive from tilapia pond farming. In generally, the students got insightful knowledge on the various benefits of tilapia production which included generation of income, source of food, job creation and source of recreation. During the quiz, the student was asked to outline and explain four importance of tilapia farming based on what they have been taught in class and discussions with the tilapia farmers. Table 8 shows the results of the performance of the students during the quiz.

Table 8: Performance score of students on importance of tilapia farming

Importance of Tilapia farming	**Freq.**	**Score %**
Source of income to tilapia farmers and sellers	82	100
Source of employment for tilapia farmers and sellers	82	100
Source of food	82	100
Source of entertainment and recreation	82	100
Average score		**100**

Source (Study Quiz, 2021)

Table 8 shows that, all the students were able to state income generation to tilapia farmers and sellers as one of the economic importance of tilapia farmers. The data also shows that all the students were able to state source of employment as another major economic importance of tilapia production. It can also be inferred from Table 8 that all the students were able to report source of food as another importance of tilapia farming. Again, all the students were able to indicate source of entertainment as another importance of tilapia production. The overall average percentage score gives an indication that all the students have very good understanding on what they were taught as the economic importance of tilapia farming in Ghana.

4.4 Analysis of Results on the Research Questions

This section of the chapter deals with presentation of results as well as discussion of findings surrounding the research questions which were raised in the chapter one. The discussion is to establish whether the findings of the study agree or disagrees with existing literature.

4.4.1 What are the Feeding Practices in Tilapia Production?

The students were also taught the various feeding practices in commercial production of tilapia. They were also sent on visitation at some selected tilapia farms to experience how the farmers feed their tilapia. The topics that the students were taught in this section included; the type of feed for tilapia and feeding intervals for tilapia. Essentially, the researcher intended to take the students through practical demonstrations on how to prepare tilapia concentrate through the help of the tilapia farmers. However, it came out that none of the tilapia farmers prepare their own tilapia concentrates. From the classroom lessons and pond visitations, it was revealed that, the major feeds used by the tilapia farmers included; maize and soya concentrate, potato concentrate, rice ban, concentrate from centrosema leaves, brewery waste and cotton seed concentrate. Table 9 shows the frequency at which the farmers used the aforementioned feeds.

Table 9: Type of feed for commercial tilapia production

	Frequency		
Type of feed	**Daily**	**Thrice a week**	**Twice a Week**
Maize and Soya Concentrate	3	1	1
Potato concentrate	2	1	0
Rice ban	3	0	2
Centrosema leave concentrate	0	0	2
Brewery waste	2	0	1
Cotton seed concentrate	0	2	1

Source (Study survey, 2021)

The data in Table 9 shows that, 3 out of the five tilapia farms which were visited fed their stock with maize and soya concentrate on daily basis. The data also shows that 1 one of the farms fed the stock with maize and soya concentrate thrice a week while another farmer fed the stock with maize and soya concentrate with maize and soya concentrate twice a week. Table 9 also shows that 3 of the farmers feed their farm with race ban on daily basis while another 2 farmers also feed their farms with rice ban twice a week. The data further shows that 2 of the farmers feed their farms with potato concentrate on daily basis whilst another farmer also fed his stock with potato concentrate thrice a week. Two of the farmers also used brewery waste to feed their farms on daily basis. It can also be inferred from Table 9 that 2 of the 5 farms that were visited used cotton seed to feed their stock thrice a week. From the data presented in Table 9, it can be said that the feed that is mostly used by tilapia farmers include; maize and soya concentrate, rice ban, potato concentrate and brewery waste.

4.4.1.1 Feeding intervals in Tilapia production

This section of the analysis also sought to examine the feeding intervals to establish the number of times that tilapias are feed in a day.

The tilapia farmers demonstrated to the students the time frames they use to feed their tilapias. Table 10 shows the report on the feeding intervals of tilapia per the knowledge gathered from the farmers.

Table 10: Feeding frequency of Tilapia

Category	Feeding Frequency	Freq.	Score %
Adult	Twice a day	3	60
	Thrice a day	2	40
Fingerlings	Thrice a day	5	100

Source (Field Survey, 2021)

The data in Table 10 shows that 3 out of the 5 tilapia farms that were engaged in the study fed their tilapia twice every day. According to these farmers, this feeding practice were implemented by them to save cost of production since feeding the tilapia twice a day did not have any significant impact on the growth rate and size of the tilapia. It can be inferred from Table 10 that 2 out of the five farms that were visited also fed their tilapia thrice a day. According to these two farmers, they implement such a feeding regime in order to increase the growth rate and sizes of the tilapia.

It is important to note that, the fingerlings were fed by all the farmers thrice every day. Table 11 shows the feeding times which were observed during the pond visitation.

Table 11: Feeding times of tilapia

Feeding times	Frequency
Morning	
8:00 to 9:00 am	2
9:30 to 10: am	3
Afternoon	
12:00 to1:00 pm	2
2:00 and 4:00 pm	3
Evening	
5:00 to 5:30 pm	2

Source (Study survey, 2021)

The data in Table 11 shows that 2 out of the 5 farmers who were visited as part of the study fed their tilapia between the hours of 8:00 and 9:00 am in the morning. Another 3 of the farmers also fed their stock between the hours of 9:30 and 10: 00 am in the morning. It can also be inferred from Table 11 that 2 of the farmers fed their stock between the hours of 12:00 and 1:00 pm in the afternoon whiles 3 farmers also fed their stock between the hours of 2:00 and 4:00 pm in the afternoon. The data also shows that 2 out of the farmers (farmers who fed their stock thrice a day) fed their stock between the hours of 5:00 and 5:30 pm in the evening. The discussion presented above suggest that, feeding of tilapia begins at 8:00 am and ends at 4:00 pm when they fish are fed twice a day. Feeding however ends at 5:30 pm when the farmer decided to feed the stock thrice a day.

The study observed that, all the farmers fed their fingerlings three times a day. This finding generally agrees with the empirical study of Lee et al., (2010). As demonstrated in this study, the farmers had separate ponds for their fingerlings. This aided them to design a favourable feeding regime for the fingerlings. This was similar to what was observed in the study of Lee et al., (2010). In this study, it was observed that, the fingerlings were fed three times a day by the farmers in order to enhance their growth rate. The study of Karun et al., (2017) also found a statistical association between feeding regime and the growth rate of fingerlings in their three-dimensional study design. It was observed by Karun et al., (2017) that, the fingerlings that were fed three time a day had better growth rate than those that were fed twice a day. Those that were fed three times a day grew 17.5% in size than those that were fed two times a day.

Those that were fed three times a day also had faster growth rate than those that were fed twice a day. Imperatively, this study also observed that, three of the farmers fed their adult tilapia twice a day while two of the farmers also fed their adult tilapia three times a day. Generally, this study showed per the experience of the farmers that, whether the tilapias were fed twice a day of thrice a day had no influence on the growth rate of the tilapia. This finding is similar to what was observed by Wasonga (2018) whose study saw no statistical difference between the number of times that tilapia is fed and their growth rate in terms of size and weight. Wasonga (2018) recommended feeding tilapia twice a day as the best feeding regime since feeding the tilapia thrice a day showed no significant effect on the growth rate of tilapia in commercial production. Feeding the tilapias twice a day saved cost whiles it also enables the tilapia to optimize the feed (Wasonga, 2018).

It was observed in this study that, the dominant feeds used by the tilapia farmers included; maize and soya concentrate, rice ban, brewery waste and potato concentrate. This finding agrees with Lee et al., (2010) and Wasonga (2018) who reported the feeds use in tilapia production to include rice ban, cereal concentrate (maize, peanut, soya beans) and brewery waste.

Figure 11: Sample of tilapia feed (soya and maize concentrate)

4.4.2 What are the Conditions Favourable for Tilapia Production?

During the classroom lessons, the students were taught the various environmental conditions which were required for tilapia production. The environmental requirements included; temperature, turbidity, water quality, pH scale and dissolved oxygen. The students were also taken to the nearby tilapia pond where they were asked to measure the temperature, dissolved oxygen and pH scale of the pond. At the end of the classroom discussion and pond visitation, it was established that, the environmental conditions which were required for tilapia production are determined by factors in Table 12.

Table 12: Environmental conditions for tilapia production

Environmental conditions	Required range/ required conditions
Temperature	27 ºC
pH scale	6.9
Dissolved oxygen	13ppm DO
Turbidity	Less mud, less phytoplankton and less suspended organic and inorganic matter
Water quality	Clean and non-muddy water, light green water colour

Source (Study survey, 2021)

From Table 12, it can be seen that the average temperature for all the five ponds which were visited in the course of the study was recorded at 27 ºC. The average pH range for all the five ponds was also recorded at 6.9. The dissolved oxygen for all the five ponds was also measured at 13ppm DO. It was observed that all the five ponds were less muddy, the ponds also contained less suspended organic and inorganic matter. This implies that, the turbidity of all the five ponds was very good for tilapia production. It was further observed that, the water contained in all the five ponds were clean and light green in colour. This also indicated that, the water quality for all the ponds was very good for tilapia production.

Findings of the study revealed that, the average temperature range for all the five tilapia farms which were visited was 27 ºC. This finding connotes with the studies of Tekelioglu (2016); Siddiqui et al., (2011) whose also recorded the required temperature range for tilapia at 25ºC to 36ºC. Tekelioglu (2016) explained that tilapia flourished in terms of feeding, mating, hatching and growth rate when the temperature of the pond is between the recommended range of 25ºC to 36ºC. According to Tekelioglu (2016) temperatures below 17ºC are not recommended for tilapia production since such temperature impede the ability of the fish to swim, feed, mate and hatch.

Furthermore, the average pH for all the five ponds that were visited in the course of the study was recorded at 6.9. The recorded pH fell within the recommended range of 6.5 to 9.0 which was observed by empirical studies such as Sharper and Lancey (2004); Lim and Webster (2006); Delince (2012) and El-Sayed (2017). The average dissolved oxygen for all the five ponds which were visited during the study was recorded at 13ppm DO. Again, the recorded dissolved oxygen in this study correlate with what was recommended by empirical studies such as Riise and Roose, (2017) and Nagata (2016).

It was observed that none of the ponds that were visited was muddy. All the ponds were also light green in colour and clean as well. These findings also agree with Adeniji and Ovie (2012); Webb and Walling (2012) and Bergheim (2012). Regarding the turbidity of the ponds, it was observed that all the ponds had less mud, less suspended organic and inorganic matter and less phytoplankton. The farmers implemented weekly cleaning of the ponds as well as monthly draining of the ponds. This was to ensure that, the faecal matter of the tilapia is draining out and also prevent the water from becoming muddy. These findings also agree with Gyamfi (2014) whose study also observed draining and regular cleaning of ponds as measures to maintain the require turbidity for tilapia production.

The students were asked during the quiz to outline the various environmental conditions that are required for tilapia production. Table 13 shows the results of the performance of the students during the quiz.

Table 13: Performance score of sudents on environmental conditions required for tilapia production

Environmental conditions	Freq.	Score %
Temperature	59	71.95
pH scale	46	56.09
Dissolved oxygen	58	70.73
Turbidity	76	92.68
Water quality	78	95.12
Average score		**77.31**

Source (Study Quiz, 2021)

The data in Table 13 shows that 95.12% of the students were able to state the required water conditions for tilapia production. Again 92.68% of the students were able to state the turbidity requirement for tilapia production. Also, the data in Table 13 shows that 71.95% of the students were able to state the temperature requirement for tilapia production while 70.73% were able to indicate the dissolved oxygen requirement for tilapia production. The data further shows that only 56.09% of the students were able to indicate the pH requirement for tilapia production. The average score of 77.31% shows that the students generally understood what they were taught on the environmental conditions necessary for tilapia production except the case of pH requirement were the average score was below 60%.

4.4.3 What are the Pond Requirement for Commercial Tilapia Production

The students were also exposed to the various pond requirements for tilapia production during the pond visitations. The lessons centered on pond size, pond depth, soil type, pond construction techniques, site selection consideration and draining of ponds. The data on the pond conditions of the five ponds which were visited are presented in Table 14.

Table 14: Pond requirements

Indicators	Range/Requirement
Average Size	10.38 m x 21.09 m
Average depth	1.65 m
Soil type	Clay dominant
Topography	Flat

Source (Study survey, 2021)

The average width of all the 5 ponds were recorded at 10.38 meters while the length was also recorded at 21.09 meters. According to the farmers, there are no requirement regarding the width and length in pond construction for tilapia farming. The size of the pond largely depends on the capital of the farmers as well as the number of stocks in each pond. From the site visitation it was observed through the help of the farmers that, each of the ponds for the adults contained an average of 100 and 150 tilapia. This was to control their growth rate in relation to their feeding regimes. The ponds for the fingerlings also contained an average of 200 and 250 fingerlings. The average depth of all the five ponds which were visited was recorded at 1.65 meters. According to the farmers, they constructed their ponds shallower in order to ensure easy harvesting. The soil type of all the five ponds visited during the study were clay dominant. All the five ponds were also sited on flat land.

Consideration for Site Selection

Through the help of the tilapia farmers, the students were taught on the various factors that are very necessary during the selection of site for tilapia pond construction. These factors included;

1. Water source
2. Topography of the land
3. Soil type

4. Vegetation cover
5. Predators

Water source: according to the farmers who were visited during the study, the most important factor that must be considered during the construction of tilapia pond is water source. Essentially, the study observed all the five ponds were close to water bodies that flowed through estuaries to the sea. According to the farmers, their pond needs constant supplier of water even in dry seasons.

Topography: centered on the sloppiness of the land which is selected for the pond construction. According to the tilapia farmers, flat land should always be selected for tilapia pond construction. These is because, when the land is sloppy, it poses post-harvest losses especially when there is excessive rainfall which lead to the pond overflowing its walls. In such circumstances, the tilapia can swim to nearby water bodies thereby causing serious losses to the farmers.

Soil type: as illustrated in Table 14, the dominant soil for all the five ponds that were visited in the course of the study was clay. According to the farmers, clay soil is compact and able to sustain water for a very long period of time. The compactness of clay makes it difficult for the walls of the ponds to break even during excessive rainfall.

Vegetation cover: According to the farmers, fish ponds must not be constructed in areas where there is thick vegetation cover. Essentially, the researcher and the students observed that all the five ponds were constructed in open spaces where there was easy access to sunlight. According to the farmers, the ponds must be constructed in place where there is easy access to sunlight in other help in the activities of phytoplankton.

Predators: The tilapia farms should not be constructed in predator prone zones. The farmers classified predators to include snakes, catfish, birds and thieves. It was observed that three of the farms had permanent security guards for offered security against theft on the farms. three of the farms also covered the surface of their ponds with mosquito-like net to prevent birds and snakes from getting access to their ponds.

Figure 12: Nets for covering of pong against predators

Although the average width of all the five ponds was recorded at 10.38 meters while the length was recorded at 21.09 meters yet the farmers generally agreed that, there is no recommended size (length and width) in pond construction. This finding is similar to what was observed in the study of Young and Muir (2012). According to Young and Muir (2012), the size of tilapia pond largely depends on the financial resources of the farmers as well as the farmers ability to maintain the pond. The farmers also affirmed that their respective pond size during construction was largely dependent on their capital and ability to maintain the pond (Battish, 2012). It was revealed in this study that, the average depth of all the five ponds that were visited was recorded at 1.65 meters. This finding agrees with Asiedu et al., (2012) whose study recommended the depth range for tilapia farming to be between 1.5 meters and 1.7 meters. According to Asiedu et al., (2012), shallow depth is recommended for tilapia farming because it enhances easy harvesting.

According to Young and Muir (2012) site selection is very key in tilapia pond construction. In this study, it was observed that, all the ponds that were visited were located close to water source, they had protective measure against predators and theft. The ponds were also situated on flat land where the soil type was clay dominant. Imperatively these findings generally agree with the study of According to Young and Muir (2012) whose study identified the soil for pond construction to contain at least 20 to 30% clay. According to Young and Muir (2012), clay soil is compact and able to maintain water for a long period of time. The walls clay ponds are also strong since it is able to withstanding collapse during excessive rainfall.

From the discussions above, it can be said that the findings of the study on the various research objective generally agree with empirical studies.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.0 Overview

This chapter presents the summary of the study, conclusions and recommendations which are made for practice, policy formulation and further research.

5.1 Summary

The main objective of this study was to use practical lessons to enhance tilapia production education among form two students of Three-Town Senior High School. The specific objectives this study included the following; utilization of practical lessons to educate students on the feeding practices in tilapia production, utilization of practical lessons to educate students on the conditions favourable for tilapia production and utilization of demonstration to teach students on pond requirements for tilapia production. The study used both experimental and observational research design where 82 students were taken through experiments on the construction of tilapia ponds which are conducive for the fish species as well as feeding practices which were used by five tilapia farmers. This section of the chapter presents the summary of key findings.

Feeding Practices in Tilapia Production

The study revealed that the dominant feeds which were used by the five tilapia farms whose ponds were visited in the one-month period of the study included; maize and soya beans concentrate, rice ban, potato concentrate and brewery waste. Other feeds which were occasionally used by some of the farmers included; cotton seed concentrate and centrosema leave concentrate. It was also observed that, three of the farmers feed their tilapia stock two times daily, while two farmers also feed their stock three times daily. Most importantly, the study did not observe any significant difference ($p > 0.05$) between the feeding times and the growth rate of the tilapia. It was further observed feeding of tilapia begins at 8:00 am and ends at 4:00 pm when they fish are fed twice a day while it ends at 5:30 pm when the farmer decided to feed the stock thrice a day.

The results of the end of project quiz also revealed that, the students who took part in the study generally understood the feeding practices and their effects on growth rate in commercial tilapia production.

Conditions Favourable for Tilapia Production

The study revealed that average temperature for all the five ponds which were visited in the course of the study was 27 °C. The average pH range for all the five ponds was also recorded at 6.9. The dissolved oxygen for all the five ponds was also measures at 13ppm DO. It was observed that all the five ponds were less muddy, the ponds also contained less suspended organic and inorganic matter. It was also revealed at the end of the stud that, the water contained in all the five ponds were clean and light green in colour. Generally, the study showed that the temperature, pH range, dissolved oxygen, turbidity and water quality of all the five ponds was very good for tilapia production. The results of the end of project quiz also revealed that, the students who took part in the study generally understood the temperature requirement, pH condition, water quality, turbidity and dissolved oxygen requirement which are favourable for commercial tilapia farming.

Pond Requirement for Commercial Tilapia Production

The average width of all the 5 ponds were recorded at 10.38 meters while the length was also recorded at 21.09 meters. The average depth of all the five ponds which were visited was recorded at 1.65 meters. Inherently, the study revealed that, none of the ponds were over populated. It was observed that, each of the ponds for the adults contained an average of 100 and 150 tilapia The ponds for the fingerlings also contained an average of 200 and 250 fingerlings. The conditions which were considered by the farmers in the construction of their ponds included; water source, topography of the land, soil type, vegetation cover and prevention of predators. It was observed that all the five ponds were near water source. It was also observed that all the five ponds were sited on flat lands. Again, it was observed that, clay soil formed a major component of the soil type of all the five ponds. Moreover, it was observed that all the five ponds were located at places where there was no thick vegetation cover. This was to allow constant supply of sunlight to the ponds. It was observed that three of the farms had permanent security guards for offered security against theft on the farms. three of the farms also covered the surface of their ponds with mosquito-like net to prevent birds and snakes from getting access to their ponds.

Learning Outcomes of the Practical Lessons

The results of the end of project quiz further revealed that, the students generally understood the pond requirements as well as factors which are considered in pond construction for commercial tilapia production. The initial assumption was raised in the introductory section of chapter one of this study was that, most subjects in agricultural science are theoreticised hence students find it difficult to appreciate and apply concepts and models that are thought in the classroom. Majority of the students could not different between male and female tilapia before the practical lessons at the various ponds. However, the findings of the study have clearly demonstrated that, the practical lessons have enlightened the students on the topical issues such as biology of tilapia, pond requirement etc. which they were thought. Series of practical lessons during pond visitations also enlightened the students on the feeding regimes and types of feeds which are recommended for commercial tilapia production. Based on these outcomes, the study can conclude, practical lessons in Agricultural Science can enhance the level of exposure of student on agricultural issues. Hence policy makers within the educational sector of Ghana must integrate more practical lessons in Agricultural science programmes at various Senior High Schools in Ghana.

5.2 Conclusions

From the findings of the study, it can be concluded that, tilapia farmers adopt best feeding practices which enhance their production yield. However, the small-scale tilapia farmers in Ghana lack the knowledge and technical know-how on the preparation of concentrates to feed their farmers. The conclusion drawn here is that, most tilapia farmers including small scale and large-scale farmers import feeds for their farms.

It can also be concluded that, tilapia farmers give proper consideration to relevant environmental and site selection conditions which are needed for commercial tilapia farming. The study showed that, the farmers ensured that, the ponds had the recommended temperature range, pH range, dissolved oxygen range, turbidity and water quality. The study can conclude that ensuring best environmental and site selection practices enhance growth and yield in commercial tilapia production.

The study concluded that feeding tilapia can be twice on daily basis since there was no significant difference in terms of growth rate and size of farmers who fed their stock twice a day and those who fed their stock three times daily.

The study concluded that, learning outcomes of the practical lessons made the teaching and learning process on all the topic much easier. The students were able to understand apply the concepts such as biology of tilapia, feeding regime in commercial tilapia production and pond requirement for commercial tilapia production.

5.3 Recommendations

The following recommendations have been made for practice, policy and future research.

Recommendation for practice

Since the study showed no significant difference between twice a day and thrice a day feeding in terms of growth rate and size of tilapia, it is recommended that, commercial tilapia farmers must implement twice per dial feeding regime thus; between 8:00 and 8:30 am in the morning as well as 4:00 and 4:30 pm in the evening. This feeding regime will help tilapia and other fish farmers to reduce the cost of feeding as well as enable the tilapia make optimum utilization of their feed.

Recommendation for Policy

The Ministry of Fisheries in conjunction with the Ministry of Agriculture and donor agencies must provide support in terms of funding and capacity building in production of concentrates. Workshops must be organized for tilapia farmers to equip them with the require technical skills and knowledge on how to prepare their own concentrates. This will help the farmers reduce the cost of operations thereby reducing the cost of tilapia which are brought to the market.

Educational Policy

The learning outcomes of the practical lessons have clearly demonstrated that, the study had better understand and appreciation as well as insights on biology of tilapia, feeding regimes and conditions necessary for commercial productions. It is therefore recommended that, policy makers in the educational sector of Ghana must integrate more practical lessons in the curriculum of agricultural science programmes across senior high schools in Ghana. This will make the teaching and learning process much easier for both students and tutors. Essentially, integration of practical lessons into curriculum will also improve learning outcomes thereby improving the performance of students.

Recommendation for Further Studies

Since the students in this study were not taken through demonstrations on how to prepare tilapia feed concentrate, further studies can be carried out in this area by future researchers. This will further equip students with relevant knowledge and skills which will enable them prepare their own concentrate should they venture into commercial tilapia production.

REFERENCES

Abban, E. K., Ofori-Danson, P.K. & Amenvenku, F. K. Y. (1994). *Fish and Fisheries of a Reservoir as Index of Fishery and Aquaculture Potential of Reservoirs*. Institute of Aquatic Biology, Technical Report No. 136.

Adeniji, H. A., & Ovie, S. I., (2012), *Study and appraisal for the water quality of the Ase Oli and Niger Rivers NIFFER Annual Report*, 2012, pp 15-20.

Agbo, N.W. (2009). *Development of a small-scale commercial fish farm in the Ashanti Region of Ghana: a case study of Mr. Poku Gyinae of "Bosomtwi Integrated Aqualife Village*". Sustainable Aquaculture Research Networks in Sub-Saharan Africa (SARNISSA).

Aheto, D.W., Asare, N.K., Quaynor, B., Tenkorang, E., Asare, C. & Okyere, I. (2012). Profitability of small-scale fisheries in Elmina, Ghana. *Sustainability***,** 4: 2785–2794.

Ainoo-Ansah, J. (2013). Tilapia farming in Ghana: breeding, feed advances support rising output. *Global Aquaculture Advocate: the global magazine for farmed seafood***.** November/December 2013.

Ainoo-Ansah, J., (2013). The rise of tilapia farming in Ghana. Available at *https://www.aquaculturealliance.org* [Accessed on 8th June, 2021]

Al-Ahmed, A.A. (2012) A review of tilapia culture in Kuwait. *World Aquaculture*, 32 (2), pp 47-48.

Alfred, E., & Hector, M. (2018). Salinity tolerance and reproductive performance of Nile tilapia, Oreochromis niloticus. *Delta Journal Science*,18(7): 239–261.

Anane-Taabeah, G. (2008). *Effect of different diets on the organoleptic qualities of cooked Nile tilapia*, Oreochromis niloticus (Linn.). Kwame Nkrumah University of Science and Technology, Kumasi, Ghana. (Undergraduate thesis).

Anane-Taabeah, G. (2017). *Harnessing the opportunities and overcoming constraints to widespread adoption of cage aquaculture in Ghana*. Virginia Polytechnic Institute and State University, Blacksburg, USA. (MSc. thesis).

Anane-Taabeah, G., Quagrainie, K.K., & Amisah, S. (2015). Assessment of farmed tilapia value chain in Ghana. *Aquaculture International*. DOI 10.1007/s10499-015-9960-1

Anderson, L. (2006). Analytic Autoethnography. *Journal of Contemporary Ethnography*, *35*(4), 373–395. Available at https://doi.org/10.1177/0891241605280449 [Accessed on 26th May 2021]

Anning, A., Egyir, I.S., Kwadzo, G.T-M. & Kuwornu, J.K.M. (2012). Willingness of marine artisanal fishermen to integrate in enterprise mix: evidence from Ghana. *Journal of Economics and Sustainable Development*, 3(1): 56–66.

Antwi-Asare, T.O. & Abbey, E.N. (2011). *Fishery value chain analysis: Ghana***.** FAO report. available at www.fao.org/fileadmin/user_upload/fisheries/docs/Ghana_edited.doc**).**

Ashour, A. & Ashour, M. (2013). *Successful experience in freshwater fish farming in Egypt***.** Paper presented at the 3rd Annual Meeting of Arab Experts and Administrators on "Fisheries Research and Technology Transfer in the Arab Countries", 3–5 December 2013, Cairo, Egypt.

Asiedu, B., Failler, P., & Beyens, Y., (2012) Enhancing aquaculture development: mapping the tilapia aquaculture value chain in Ghana. *Reviews in Aquaculture*, 2015(7), pp 1-9

Asmah, R. (2008). *Development potential and financial viability of fish farming in Ghana***.** Institute of Agriculture, University of Sterling, UK. (Unpublished PhD thesis).

Atwood, H. L., Fontenot, Q. C., Tomasso, J.R. & Isely, J. J., (2011) Toxicity of nitrite to Nile tilapia: effect of fish and environmental chloride. *North American Journal of Aquaculture*, 63(12), pp 49-51

Awity, L. (2013). On-farm feed management practices for Nile tilapia **(***Oreochromis niloticus***) in** Ghana. *In* M.R. Hasan & M.B. New, eds. *On-farm feeding and feed management in aquaculture,* pp. 191–211. FAO Fisheries and Aquaculture Technical Paper No. 583. Rome, FAO.

Battish, S. K., (2012), *Freshwater Zooplankton of India*, Oxford and IBH Publshing Company Limited, New Delhi.

Bergheim, A., (2012). Water quality criteria in recirculation systems for tilapia. *IRIS – International Research Institute of Stavanger*, 4068 Stavanger, Norway.

Boyd, C. E., & Gross, A., (2000), *Water use and conservation for inland aquaculture ponds.* Fisheries management and Ecology 7 (1-2): 55-63.

Boyd, C. E., (2009), *Water Quality Management and Aeration in shrimp farming*, Fishes and Allied Aquaculture Department Series No. 2, Birmingham AL, Aubum University Press.

Brown, C. D., Canfield, D. E. Jr., Bachmann, R.W. & Hoyer, M. V., (2000), Nutrient chlorophyll relationships: an evaluation of empirical nutrient-chlorophyll models using Florida and north-temperate lake data, *Canadian Journal of Fisheries and Aquatic Sciences*. 57(8): 1574-1583.

Burns, F., & Grove, D., (2008) Social Research: Issues, Methods and Process, 3rd edition.

Cobbina R. (2019) Aquaculture in Ghana: economic perspectives of Ghanaian aquaculture for policy development. United Nations University, Reykjavik, Iceland. 49 pp

Colt, J. E., & Tomasso, J. R., (2001), *Hatchery water supply and treatment*. pp 91-186. In: Wedemeyer, G.A., (Ed). Fish Hatchery Management, 2nd Edition. American Fisheries Society, Maryland, USA.

Creswell, J. W., (2007). *Qualitative inquiry and research design: Choosing among five approaches* (2nd Ed.). Sage Publications, Inc.

Darko, F.A. (2011). *Consumer preference for farmed fish in Ghana and Kenya: opportunities for domestic demand-driven aquaculture***.** Purdue University, West Lafayette, USA. (Unpublished MSc. thesis).

Davies-Colley, R. J., & Smith D. G., (2010), *Suspended Sediment, Turbidity and Clarity of Water*, a Review. Unpublished draft.

Dawes, C. J., (2008), *Marine Botany*, 2nd edition. John Wiley and Sons Incorporated., New York, NY.

Delince G., (2012), *Ecology of fish pond ecosystem with reference to Africa*, Kluwer Academic Publisher (127-160): 41-55.

Dikel, S., (2009). Tilapia Farming. Ankara, Agricultural Ministry of Turkey.

Dillon, C. R., & Rodgers, J. H., (2010). *Thermal effects on primary productivity of phytoplankton, periphyton, and macrophytes in Lake Keowee*, SC. Water Resources Research Institute. Clemson University, Clemson, SC.

El-Gendy, M.O. & Shehab M.T. 2011. Studies on alternative fish culture with both monosex males of tilapia and some winter field crops. *Egyptian Journal of Aquatic Biology & Fisheries*, 15: 363–367.

El-Sayed, A.-F. M. (2017). Tilapia culture. Wallingford, CABI

El-Sayed, A.-F.M. (2013). On-farm feed management practices for Nile tilapia *(Oreochromis niloticus)* in Egypt. *In* M.R. Hasan & M.B. New, eds. *On-farm feeding and feed management in aquaculture,* pp. 101–129**.**

EPA, (2006) "*Water Quality Standards Review and Revision*". Washington DC.

Florida Lakewatch, 2(000) *A Beginner's Guide to Water Management –Nutrients*. Information Circular #102. Florida LAKEWATCH, Department of Fisheries and Aquatic Sciences, University of Florida/Institute of Food and Agricultural Sciences (UF/IFAS), Gainesville, Florida.

Frimpong, E. A., & Anane-Taabeah, G. (2017). *Social and economic performance of tilapia farming in Ghana*. FAO Fisheries and Aquaculture. Rome, Italy. Pp. 49-90.

Frimpong, E.A., Agbo, N.W, Amisah, S., Tettey, E., Akpaglo, P. & Anane-Taabeah, G. (2011). *Development and diversification of species for aquaculture in Ghana***.** A report submitted to the United States Agency for International Development (USAID), Aquaculture and Fisheries Collaborative Research Support Program (AquaFish-CRSP), Oregon, USA. 17 pp.

Gregory, R. S., & Northcote, T. G., (2013), *Surface, plantonic, and benthic foraging by juvenile chinook salmon (Oncorhynchus tshawytscha) in turbid laboratory conditions* Canadian *Journal of Fisheries and Aquatic Sciences*, 50(12), pp 233-240.

Gupta, M.V. & Acosta, B. O., (2004). A review of global tilapia farming practices. *Aquaculture Asia, IX (1)*: pp 7–16.

Gyamfi, S., (2014) "*Development of A Simple Unified Method for Monitoring Pond Water Quality of The KNUST Fish Ponds- Kumasi"* Unpublished Thesis submitted to Kwame Nkrumah University of Science and Technology.

Hamenoo, E.K. (2011). *The role of the market in the development of aquaculture in Ghana***.** Norwegian College of Fisheries Science, University of Tromso, Norway. (MSc. thesis).

Kabila, A., & Amisah, S., (2007), Economic analysis of Nile tilapia production in Ghana. *Journal of International Agriculture*. 12(7), pp 107-117.

Kaliba, A.R., & Amisah, S. (2007). Potential effect of aquaculture promotion on poverty reduction in sub-Saharan Africa. *Aquaculture International: Journal of European Aquaculture Society*, 15(6): 445–459.

Karun, T., Satit, K., Uthaiwan, K., & Pichanpop, P., (2017) Effects of feeding frequency on growth performance and digestive enzyme activity of sex-reversed Nile tilapia, *Oreochromis niloticus* (Linnaeus, 1758). *Agriculture and Natural Resource,* 51(1), pp, 292-298.

Kassam, L. (2013). *Assessing the contribution of aquaculture to poverty reduction in Ghana***.** SOAS, University of London. (PhD thesis).

Kutty, M. N., (2017). Metabolic responses of tilapias with special reference to ambient oxygen. In: Physiology of Tropical Fish Symposium Proceedings, pp. 43- 52. Int. Congress on the Biology of Fishes. San Francisco, July 18, 2017.

Lee, S. M., Hwang, U. G., & Cho, S. H., (2010) Effects of feeding frequency and dietary moisture content on growth, body composition and gastric evacuation of juvenile Korean rockfish (*Sebastes schlegeli*) *Aquaculture*, 187 (2010), pp. 399-409

Leschen, W**.** (2011). *Moving African aquaculture toward commercialization: selected participant profiles***.** SARNISSA. 63 pp.

Lim, C., & Webster, C. D., (2006). Tilapia: biology, culture, and nutrition. New York, Food Products Press.

Lloyd, D. S., (2017), *Turbidity as a water quality standard for salmonid habitats in Alaska*, *North American Journal of Fisheries Management* 7(2), pp 34-45.

Macfadyen, G., Nasr-Allah, A., & Al-Kenawy, D. (2012) Value-chain analysis of Egyptian aquaculture. Project Report 2011-54.

Macfadyen, G., Nasr-Allah, A., Kenawy, D.A., Ahmed, M.F.M., Hebicha, H., Diab, A.S., Hussein, S.M., Abouzied, R.M. & El-Naggar, G.O. (2011). *Value-chain analysis of Egyptian aquaculture*. Project Report 2011-54. Penang, Malaysia, WorldFish. 84 pp.

Nagata, H., (2016), *Relationship between chlorophyll a concentration and water transparency in the seas adjacent to Japan*, Bull. Japan Sea National Fish Resource Institute, 46: 25-43.

Newcombe, C.P. & MacDonald, D. D., (2011), Effects of suspended sediments on aquatic ecosystems, *North American Journal of Fisheries Management*, 11(12), pp 72-82.

Prasad, B. B., & Singh, R. B., (2003), Composition, abundance of phytoplankton and zoobenthos in a tropical water body, *National Environment of Pollution and Technology*, 2(1), pp 255-258.

Rao, D., Perrino, E.S. & Barreras, E. (2012). *The sustainability of tilapia fish farming in Ghana***.** Boston, USA, Blue Kitabu Research Institute. Available at www.bluekitabu.org/blue-kitaburesearch-instit/divya-rao-the-sustainabilit.pdf).

Riise, J. C., & Roose, N., (2017), *Benthic metabolism and the effects of bioturbation in fertilized polyculture fish pond* in North West Thailand.

Sandifer P. A., Miglarese , J. V., Calder, D. R., Manzi,J. J., & Barclay, L. A., (2010), *Ecological characterization of the sea island coastal region of South Carolina and Georgia*,. U.S. Fish and Wildlife Service, Office of Biological Services, Washington, DC. FWS/OBS-79/42.

Sarpong, D. B., Quaatey, N. K., & Harvey S. K., (2019) The economic and social contribution of fisheries to gross domestic product and rural development in Ghana. FAO Sustainable Fisheries Livelihoods Programme (SFLP), GCP/INT/735/UK, 53(1) pp, 17-29.

Saunders, M., Lewis, P. and Thornhill, A. (2009) Research Methods for Business Students. Pearson, New York.

Schroeder, G. L., & Serfling, S. (2009). High-yield aquaculture using low-cost feed and waste recycling methods. *American Journal of Alternative Agriculture*, *4*(2), 71–74.

Sharper, A., & Lancey, J. P. (2004) *Performance of Tilapia in Indian Waters and its Possible Impact on the Native Ichthyofauna*. IPFC Proceedings, Bogor, Indonesia, 24–29 June, 2005.

Siddiqui, A.Q., Al Hafedh, Y. S. & Ali, S. A. (2011). *Effect of dietary protein level on the reproductive performance of Nile tilapia, Oreochromis* niloticus (L.). *Aquaculture Research* 29(11), pp 349-358.

Simpson, G. (2012). *Opportunities for small-scale suppliers within the tilapia value chain in Ghana: a case study of fish farming in Achavanya***.** International Institute of Social Studies, Erasmus University, the Netherlands. (Unpublished MA thesis).

Tekelioğlu, N., (2016). Tilapia Culture and Its Problems in Turkey. *Journal of Fisheries & Aquatic Sciences*. 23(7). 31-49.

Torbay Council, (2006), *Municipal waste Management*, Strategy for Torbay Consultation

Tsadik, G. G., & Kutty, M. N., (2015). *Influence on ambient oxygen on feeding and growth of the tilapia*, Oreochromis niloticus (Linnaeus). Working paper ARAC/87/WP/10. African Regional Aquaculture Centre, Port Harcourt, Nigeria, pp. 13.

Wasonga, G. A., (2018) Effects of feeding frequency on specific growth of tilapia (Oreochromis niloticus) fingerlings in hapa nets in fish ponds at in Kenya, *Journal of Aquaculture & Marine Biology,* 7(2), pp 95–98.

Waters, T. F., (2015), *Sediment in Streams. Sources, Biological Effects, and Control*, American Fisheries Society Monograph 7. American Fisheries Society, Bethesda, Maryland.

Webb, B. W., & Walling, D.E., (2012), *Water Quality II: Chemical Characteristics*, In: Rivers Handbook: Hydrological Ecological Principles (eds: Calow, P. and Petts, G.E.). Blackwell Scientific, Oxford, UK.

Wedemeyer, G. A., (2016), *Physiology of fish in intensive culture systems*, Chapman & Hall, London, UK.

Wetzel, R. G., (2011), *Limnology: Lake and river ecosystems*, 3rd ed. San Diego, CA: Academic Press

WorldFish. (2011). *Improving employment and income through development of Egypt's aquaculture sector (IEIDEAS)***.** IEIDEAS Project, Year 1 Operational Report. 30 pp

Young, J. A., & Muir, J. F. (2012). Tilapia: Both Fish and Fowl? *Marine Resource Economics*, *17*(2), 163–173.

APPENDIX A

PRE-TEXT ONE

THREE-TOWN SENIOR HIGH SCHOOL; DENU-KETU SOUTH
MUNICIPALITY

NAME………………………………….……………… DATE………………

CLASS…….............

Part 1: Multiple Choice (2 marks)

INSTRUCTION: Circle the letter that best complete the statement or answers question.

1. Tilapia is one of the freshwater fishes which belongs to the family of?

A. Chiclidae
B. Nile Fish
C. Sarotherodon
D. Oreochromis

2. Which of the following belong to the family of tilapia?

A. Chiclidae
B. Nile Fish
C. Oreochromis
D. African Lake Tilapia

3. Which of the following helps to identify the sex of tilapia?

A. Lateral Fin
B. Size
C. Head
D. None of the above

4. Pick the odd one among the following.

   A. Chiclidae
   B. Tilapia
   C. Oreochromis
   D. Sarotherodon

5. Tilapias cannot be cultured on commercial basis under temperatures below

   A. 14°C
   B. 10°C
   C. 16°C
   D. 20°C

6. The required temperature for tilapia production should be between the ranges.

   A. 15°C to 20°C
   B. 17°C to 28°C
   C. 15°C to 25°C
   D. 25°C to 36°C

7. The environmental parameters which are necessary for tilapia production included the following except?

   A. Temperature
   B. Humidity
   C. pH Scale
   D. Turbidity

8. Commercial tilapia production in Ghana take place in the following water bodies except

   A. Lake Bosumtwi
   B. Weija Lake

C. Volta river

D. Tano River

9. The following are part of the tilapia value chain expect?

A. Tilapia farmers

B. Teachers

C. Feed producers

D. Consumers

10. Tilapia can be cultures through the following techniques except?

A. Open sea culture

B. Concrete tanks

C. Earthen pond

D. Cage culture

11. The pH scale required for tilapia production is?

A. 4.5 to 7.5

B. 6.5 to 9.0

C. 7.5 to 9.5

D. 5.0-8.5

12. Which of among these is the feeding technique used in tilapia production?

A. Supply-base technique

B. Electronic-Supply systems

C. Demand feeding technique

D. Dilute technique

13. The size of tilapia pond should be between the range of?

A. 20 x 45 meters

B. 10 x 45 meters

C. 15 x 45 meters

D. None of the above

14. Which of among these is the most commercially cultured tilapia?

A. Nile Tilapia

B. Africa Tilapia

C. Oreochromis

D. None of the above

15. The depth of tilapia pond should be?

A. 1 meter

B. 1.25 meters

C. 1.5 meters

D. None of the above

16. Tilapia must be feed at least?

A. Once a day

B. Twice a day

C. Thrice a day

D. None of the above

Part 2: True or False (1 mark)

INSTRUCTION: Indicate whether the following are true or false by circling the corresponding letter in the following questions.

17. Male tilapias are not different from female tilapias.

A. True

B. False

18. Male tilapias are bigger than female tilapias.

A. True

B. False

19. Females key the fry in their mouth.

A. True

B. False

20. Tilapia cannot survive under temperatures below 10°C.

A. True

B. False

21. Water quality is not necessary for tilapia production.

A. True

B. False

22. Regulating pH scale is very important for tilapia production.

A. True

B. False

23. Regular draining of tilapia pond in very important.

A. True

B. False

24. Tilapia production is not economically profitable.

A. True

B. False

25. Tilapia production serve as source of employment.

A. True

B. False

APPENDIX B

MARKING SCHEME FOR PRE-TEST ONE

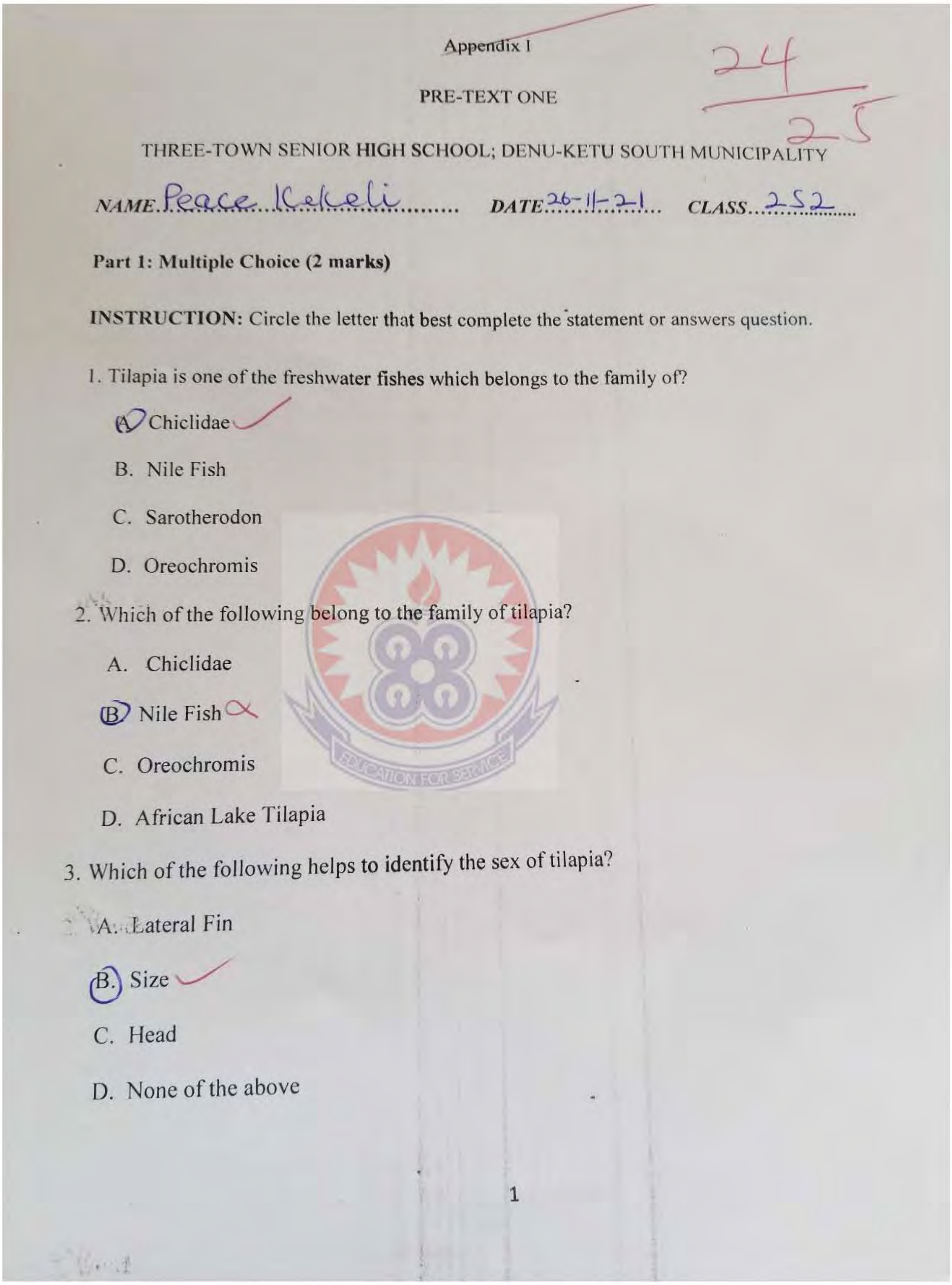
1. **A**
2. **C**
3. **B**
4. **A**
5. **C**
6. **D**
7. **B**
8. **D**
9. **B**
10. **A**
11. **B**
12. **C**
13. **D**
14. **D**
15. **D**
16. **B**
17. **B**
18. **B**
19. **A**
20. **A**
21. **B**
22. **A**
23. **A**

24. B

25. A

APPENDIX C

SAMPLE SCORE 1 OF PRE-TEST ONE



Appendix I

PRE-TEXT ONE

24/25

THREE-TOWN SENIOR HIGH SCHOOL; DENU-KETU SOUTH MUNICIPALITY

NAME.Peace Kekeli......... *DATE*26-11-21.. *CLASS*..2S2......

Part 1: Multiple Choice (2 marks)

INSTRUCTION: Circle the letter that best complete the statement or answers question.

1. Tilapia is one of the freshwater fishes which belongs to the family of?

[✓ A.] Chiclidae ✓

B. Nile Fish

C. Sarotherodon

D. Oreochromis

2. Which of the following belong to the family of tilapia?

A. Chiclidae

[✓ B.] Nile Fish ✗

C. Oreochromis

D. African Lake Tilapia

3. Which of the following helps to identify the sex of tilapia?

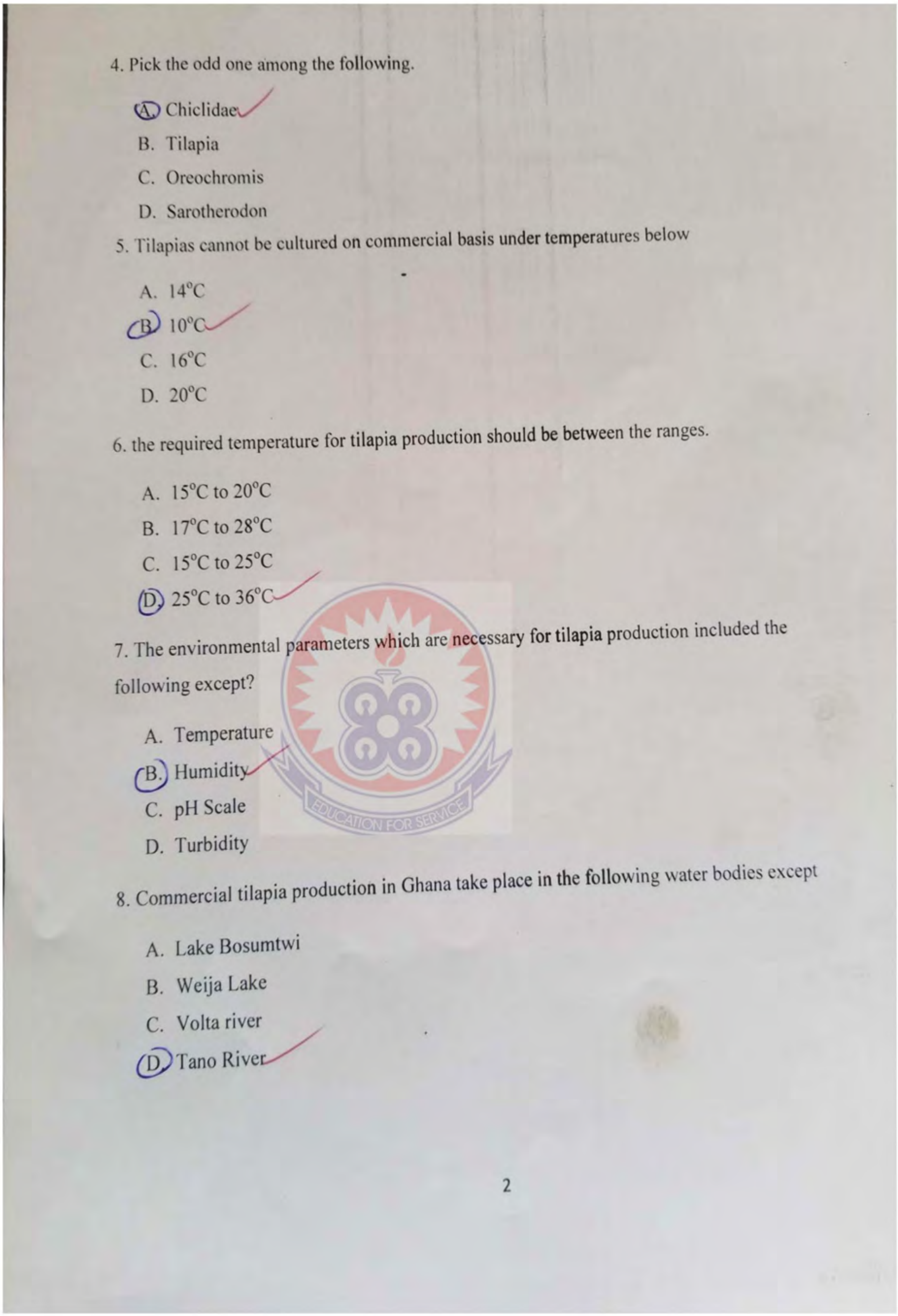
A. Lateral Fin

[✓ B.] Size ✓

C. Head

D. None of the above

1



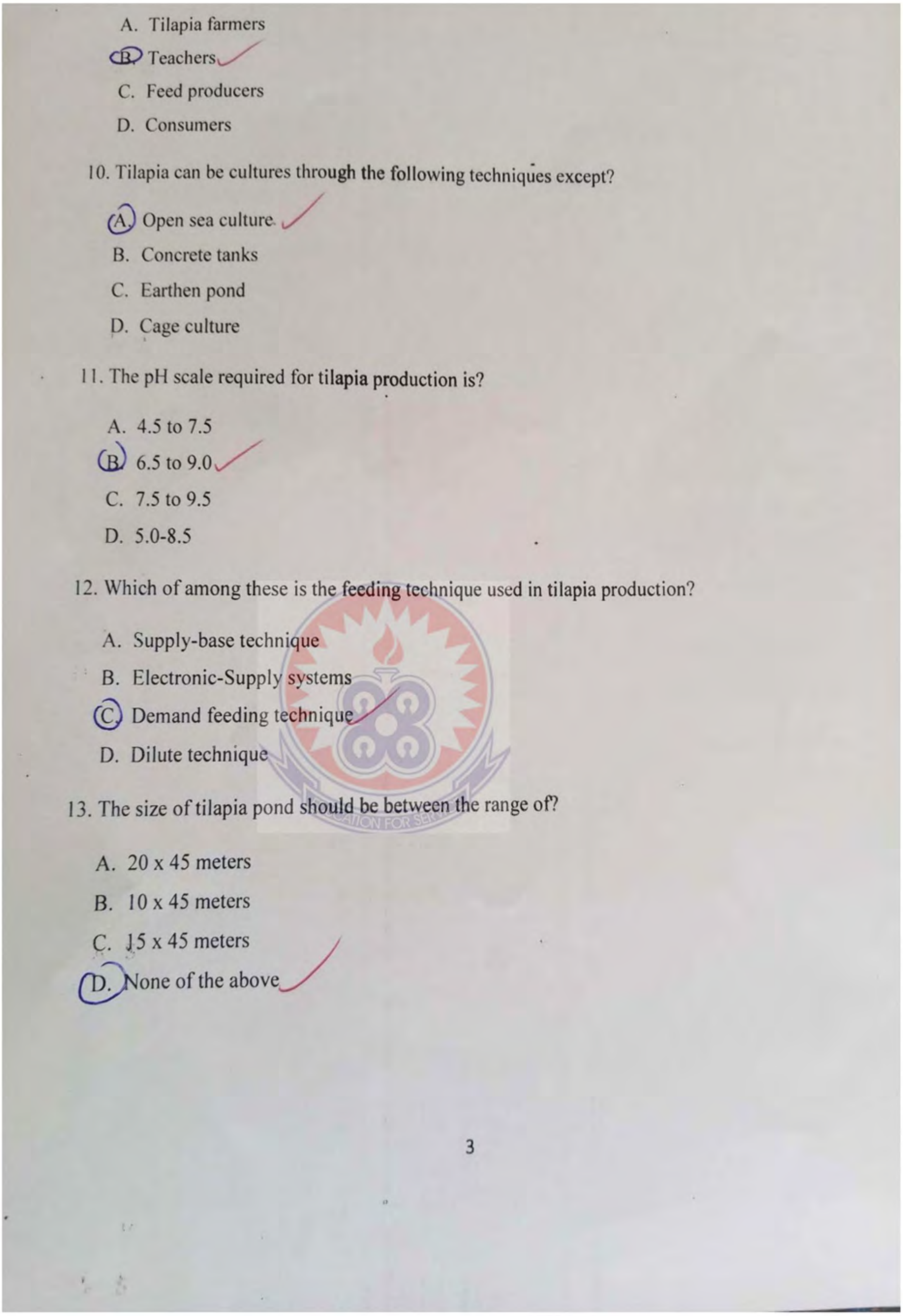
4. Pick the odd one among the following.
   - [✓ A. Chiclidae]
   - B. Tilapia
   - C. Oreochromis
   - D. Sarotherodon

5. Tilapias cannot be cultured on commercial basis under temperatures below
   - A. 14°C
   - [✓ B. 10°C]
   - C. 16°C
   - D. 20°C

6. the required temperature for tilapia production should be between the ranges.
   - A. 15°C to 20°C
   - B. 17°C to 28°C
   - C. 15°C to 25°C
   - [✓ D. 25°C to 36°C]

7. The environmental parameters which are necessary for tilapia production included the following except?
   - A. Temperature
   - [✓ B. Humidity]
   - C. pH Scale
   - D. Turbidity

8. Commercial tilapia production in Ghana take place in the following water bodies except
   - A. Lake Bosumtwi
   - B. Weija Lake
   - C. Volta river
   - [✓ D. Tano River]



A. Tilapia farmers
[✓ B. Teachers]
C. Feed producers
D. Consumers

10. Tilapia can be cultures through the following techniques except?

[✓ A. Open sea culture]
B. Concrete tanks
C. Earthen pond
D. Cage culture

11. The pH scale required for tilapia production is?

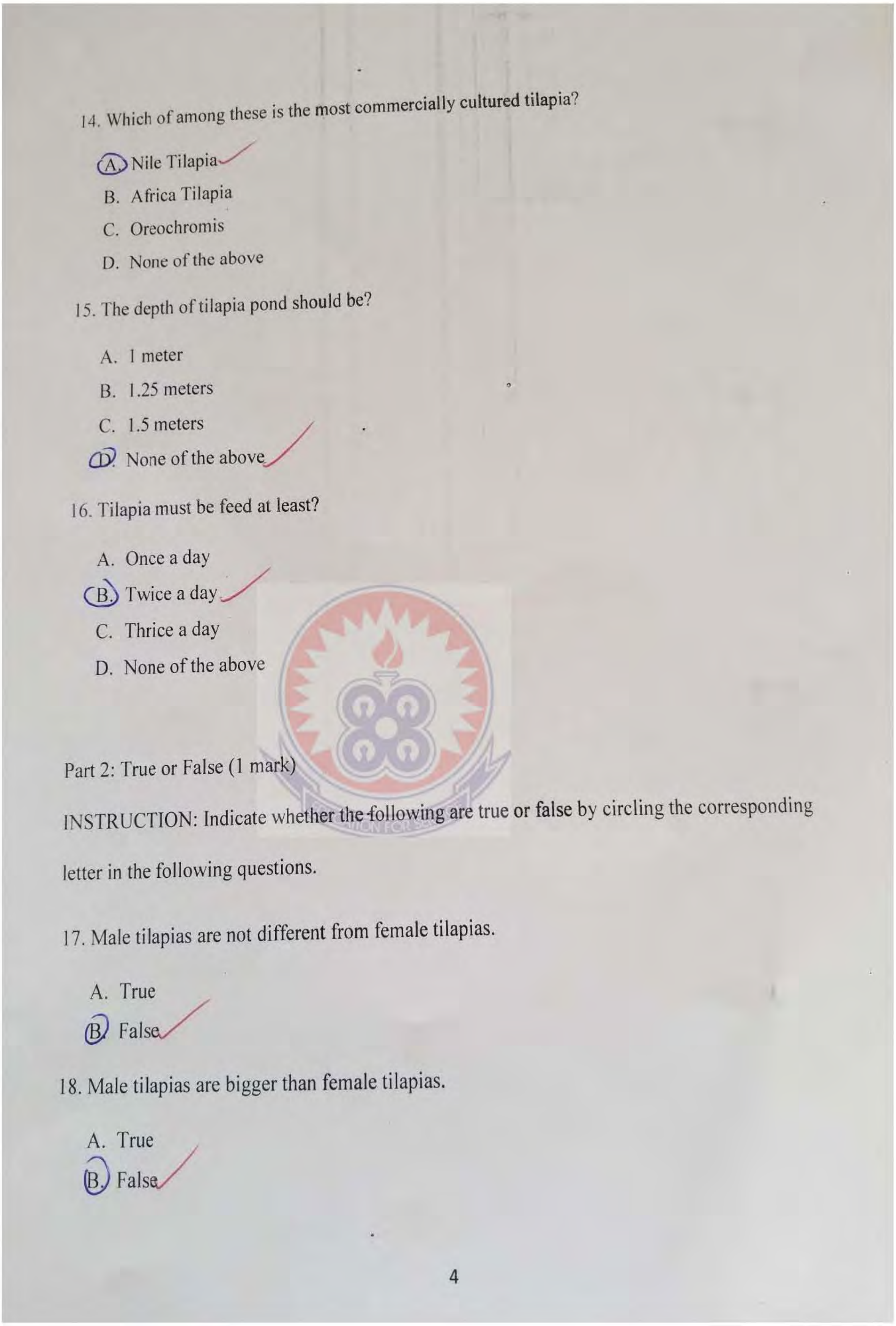
A. 4.5 to 7.5
[✓ B. 6.5 to 9.0]
C. 7.5 to 9.5
D. 5.0-8.5

12. Which of among these is the feeding technique used in tilapia production?

A. Supply-base technique
B. Electronic-Supply systems
[✓ C. Demand feeding technique]
D. Dilute technique

13. The size of tilapia pond should be between the range of?

A. 20 x 45 meters
B. 10 x 45 meters
C. 15 x 45 meters
[✓ D. None of the above]



14. Which of among these is the most commercially cultured tilapia?

[✓ A.] Nile Tilapia
B. Africa Tilapia
C. Oreochromis
D. None of the above

15. The depth of tilapia pond should be?

A. 1 meter
B. 1.25 meters
C. 1.5 meters
[✓ D.] None of the above

16. Tilapia must be feed at least?

A. Once a day
[✓ B.] Twice a day
C. Thrice a day
D. None of the above

Part 2: True or False (1 mark)

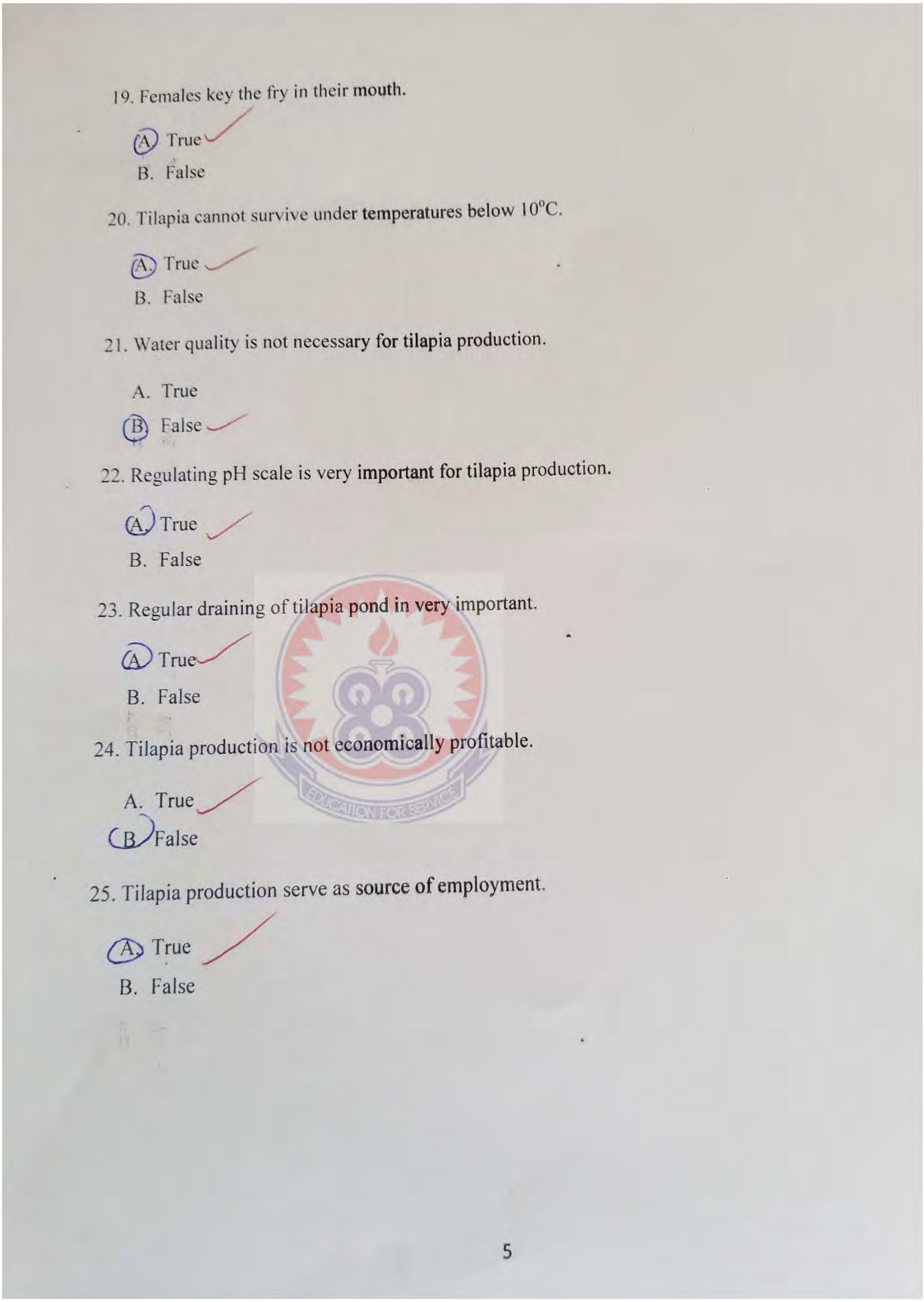
INSTRUCTION: Indicate whether the following are true or false by circling the corresponding letter in the following questions.

17. Male tilapias are not different from female tilapias.

A. True
[✓ B.] False

18. Male tilapias are bigger than female tilapias.

A. True
[✓ B.] False



19. Females key the fry in their mouth.

[✓ A. True] ✓

B. False

20. Tilapia cannot survive under temperatures below 10°C.

[✓ A. True] ✓

B. False

21. Water quality is not necessary for tilapia production.

A. True

[✓ B. False] ✓

22. Regulating pH scale is very important for tilapia production.

[✓ A. True] ✓

B. False

23. Regular draining of tilapia pond in very important.

[✓ A. True] ✓

B. False

24. Tilapia production is not economically profitable.

A. True ✓

[✓ B. False]

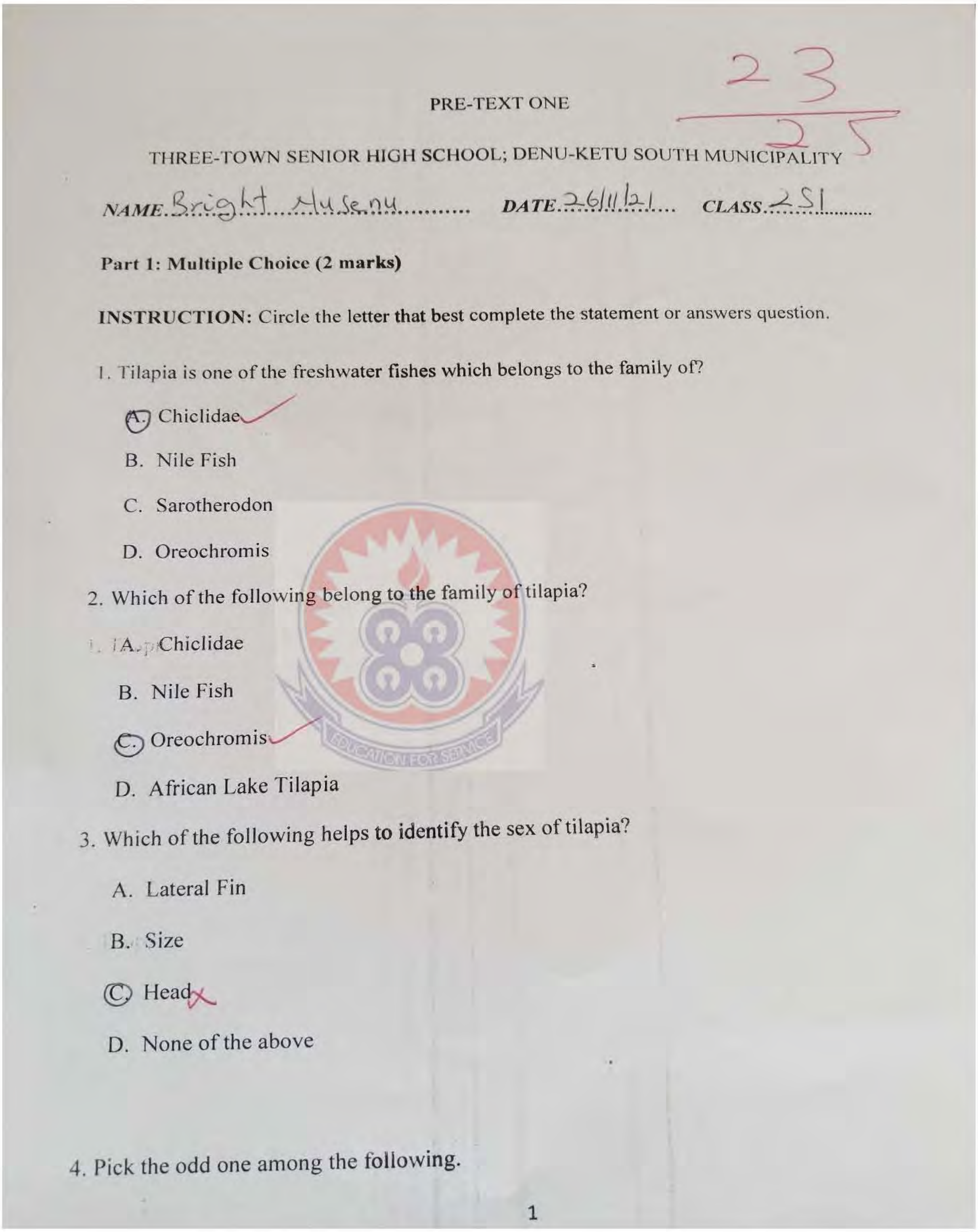
25. Tilapia production serve as source of employment.

[✓ A. True] ✓

B. False

APPENDIX D

SAMPLE SCORE 2 OF PRE-TEST ONE



23/25

PRE-TEXT ONE

THREE-TOWN SENIOR HIGH SCHOOL; DENU-KETU SOUTH MUNICIPALITY

NAME.Bright Huseny.......... *DATE*.26/11/21.... *CLASS*.2S1..........

Part 1: Multiple Choice (2 marks)

INSTRUCTION: Circle the letter that best complete the statement or answers question.

1. Tilapia is one of the freshwater fishes which belongs to the family of?

[✓ A.] Chiclidae ✓

B. Nile Fish

C. Sarotherodon

D. Oreochromis

2. Which of the following belong to the family of tilapia?

A. Chiclidae

B. Nile Fish

[✓ C.] Oreochromis ✓

D. African Lake Tilapia

3. Which of the following helps to identify the sex of tilapia?

A. Lateral Fin

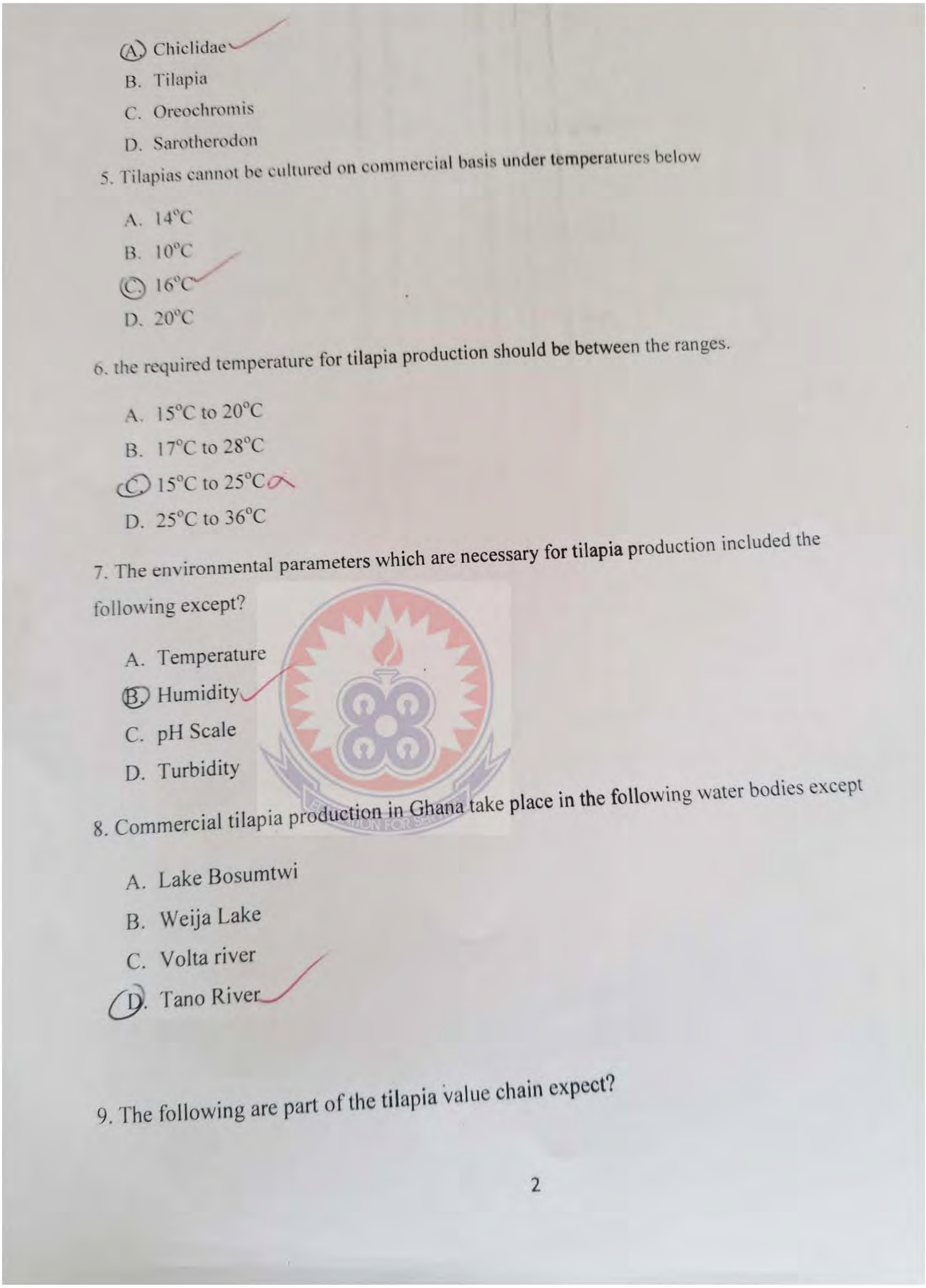
B. Size

[✓ C.] Head ✗

D. None of the above

4. Pick the odd one among the following.

1



- [✓ A. Chiclidae]
- B. Tilapia
- C. Oreochromis
- D. Sarotherodon

5. Tilapias cannot be cultured on commercial basis under temperatures below

- A. 14°C
- B. 10°C
- [✓ C. 16°C]
- D. 20°C

6. the required temperature for tilapia production should be between the ranges.

- A. 15°C to 20°C
- B. 17°C to 28°C
- [✓ C. 15°C to 25°C]
- D. 25°C to 36°C

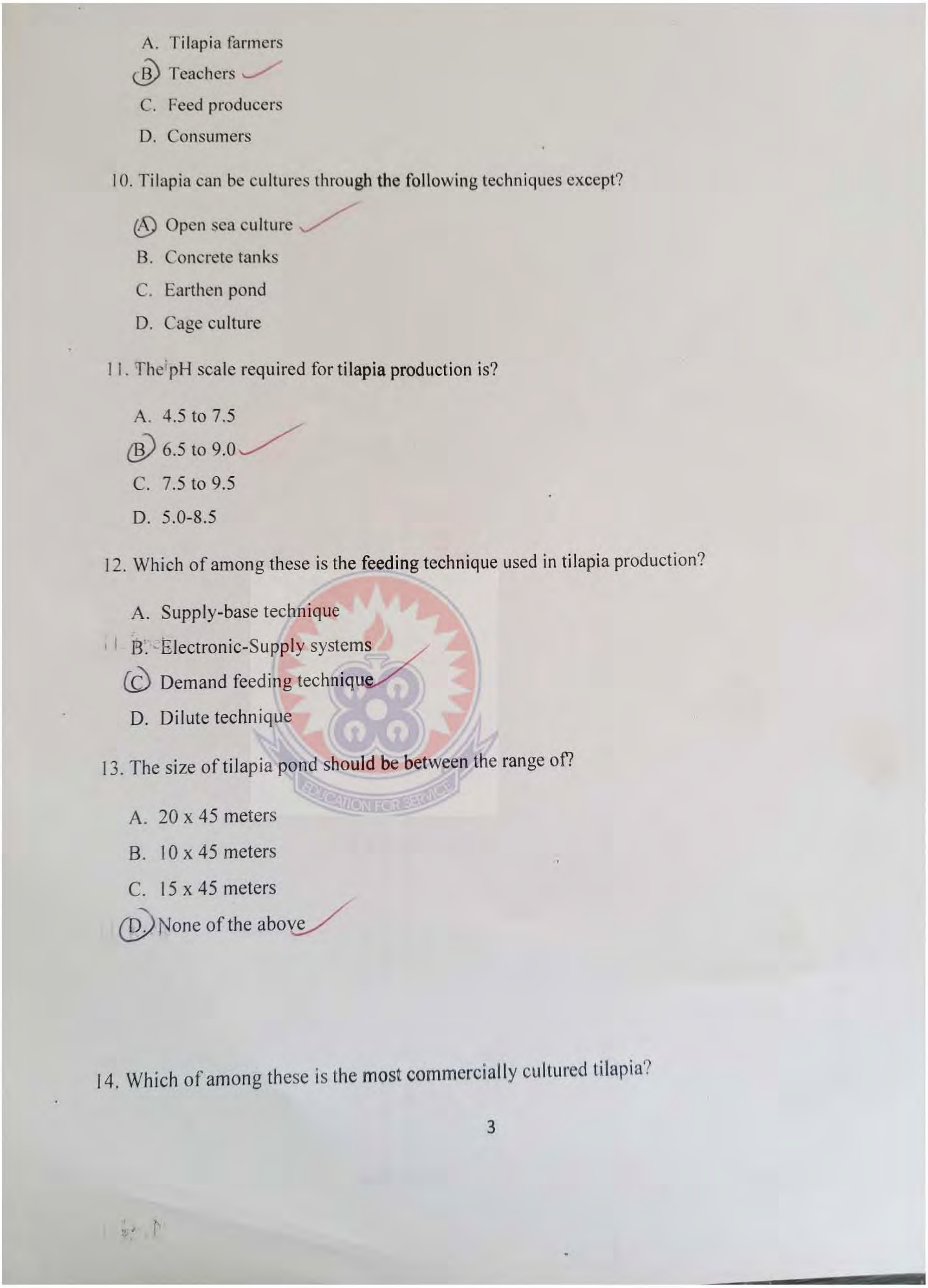
7. The environmental parameters which are necessary for tilapia production included the following except?

- A. Temperature
- [✓ B. Humidity]
- C. pH Scale
- D. Turbidity

8. Commercial tilapia production in Ghana take place in the following water bodies except

- A. Lake Bosumtwi
- B. Weija Lake
- C. Volta river
- [✓ D. Tano River]

9. The following are part of the tilapia value chain expect?



A. Tilapia farmers
[✓ B. Teachers]
C. Feed producers
D. Consumers

10. Tilapia can be cultures through the following techniques except?

[✓ A. Open sea culture]
B. Concrete tanks
C. Earthen pond
D. Cage culture

11. The pH scale required for tilapia production is?

A. 4.5 to 7.5
[✓ B. 6.5 to 9.0]
C. 7.5 to 9.5
D. 5.0-8.5

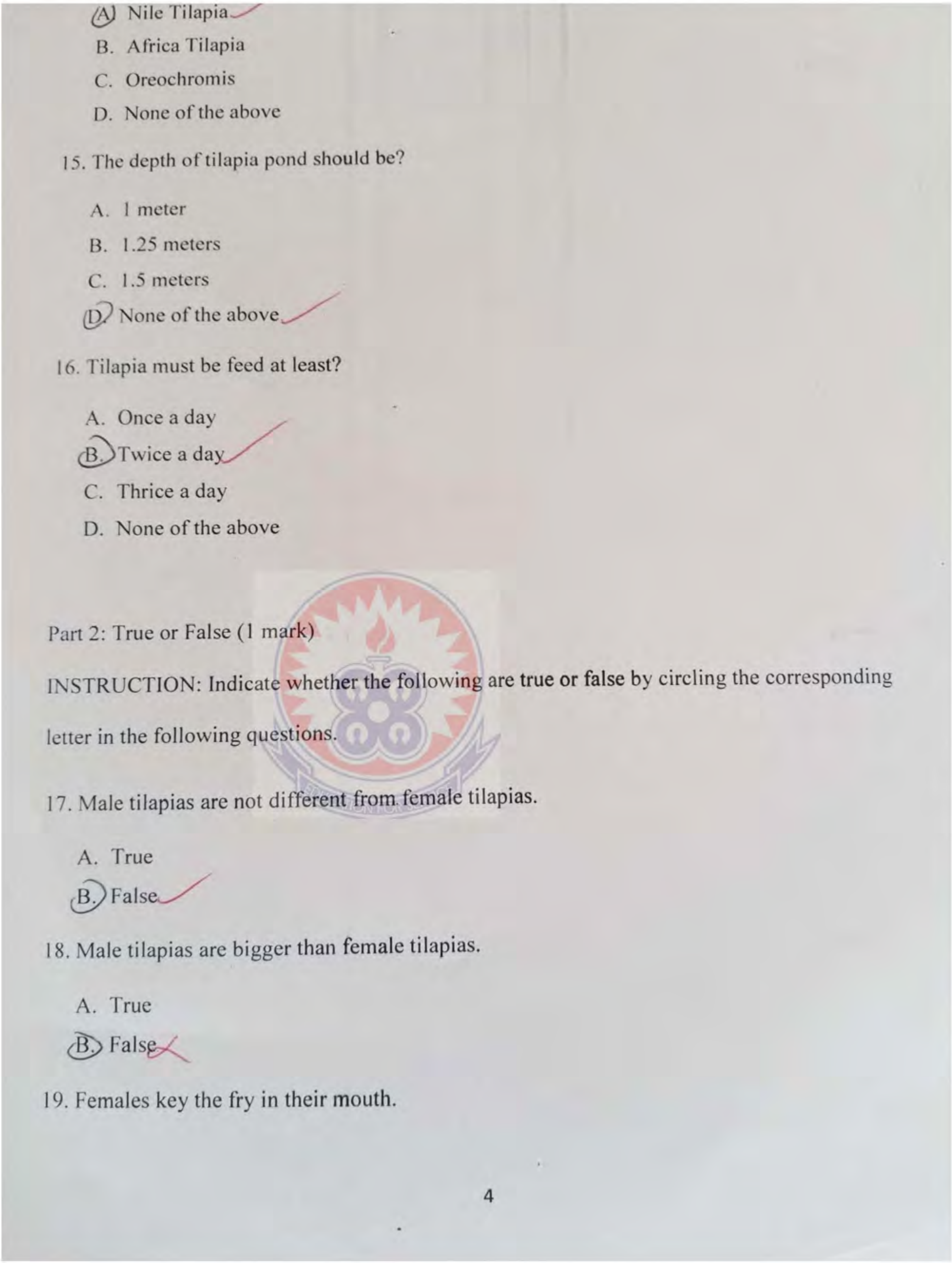
12. Which of among these is the feeding technique used in tilapia production?

A. Supply-base technique
B. Electronic-Supply systems
[✓ C. Demand feeding technique]
D. Dilute technique

13. The size of tilapia pond should be between the range of?

A. 20 x 45 meters
B. 10 x 45 meters
C. 15 x 45 meters
[✓ D. None of the above]

14. Which of among these is the most commercially cultured tilapia?



[✓ A. Nile Tilapia]

B. Africa Tilapia

C. Oreochromis

D. None of the above

15. The depth of tilapia pond should be?

A. 1 meter

B. 1.25 meters

C. 1.5 meters

[✓ D. None of the above]

16. Tilapia must be feed at least?

A. Once a day

[✓ B. Twice a day]

C. Thrice a day

D. None of the above

Part 2: True or False (1 mark)

INSTRUCTION: Indicate whether the following are true or false by circling the corresponding letter in the following questions.

17. Male tilapias are not different from female tilapias.

A. True

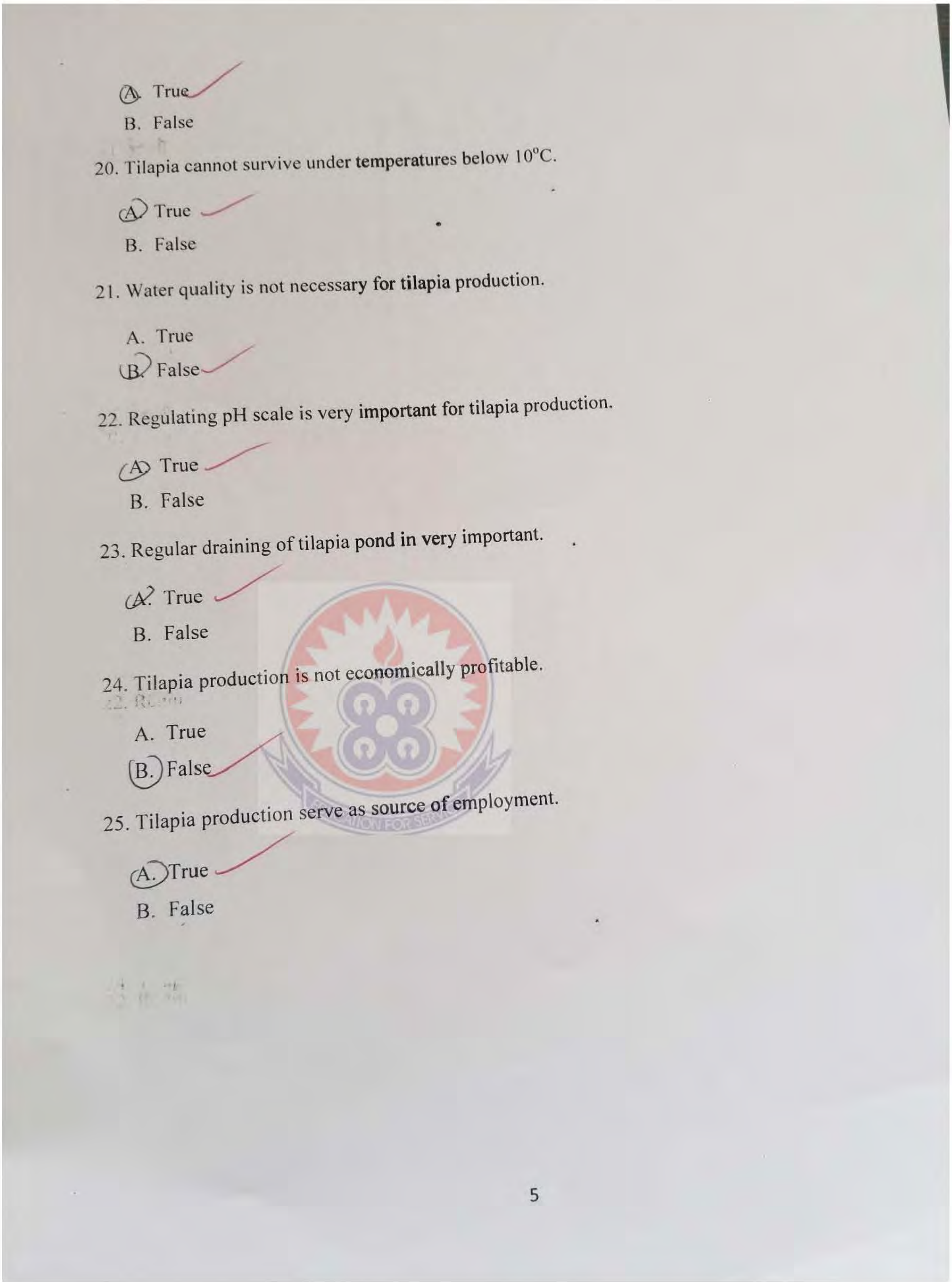
[✓ B. False]

18. Male tilapias are bigger than female tilapias.

A. True

[✓ B. False]

19. Females key the fry in their mouth.



[✓ A. True]

B. False

20. Tilapia cannot survive under temperatures below 10°C.

[✓ A. True]

B. False

21. Water quality is not necessary for tilapia production.

A. True

[✓ B. False]

22. Regulating pH scale is very important for tilapia production.

[✓ A. True]

B. False

23. Regular draining of tilapia pond in very important.

[✓ A. True]

B. False

24. Tilapia production is not economically profitable.

A. True

[✓ B. False]

25. Tilapia production serve as source of employment.

[✓ A. True]

B. False

APPENDIX E

POST-TEST

THREE-TOWN SENIOR HIGH SCHOOL; DENU-KETU SOUTH MUNICIPALITY

NAME…………………………………….……………… ***DATE………………***

CLASS…….............

AGE…………………… YEARS

SECTION ONE A: *KNOWLEDGE OF STUDENTS ON THE BIOLOGY OF TILAPIA*

This section is to assess your knowledge on sex identification of tilapia. The section seeks to investigate whether you can identify male tilapia from the female tilapia. In effect you are required to indicate whether the following statement are TRUE or FALSE.

1. The males are usually smaller in size than the females

   A. True

   B. False

2. The males have tapered shape below the anus whilst females have rounded shape below the anus

   A. True

   B. False

3. The females are more aggressive than the females

   A. True

   B. False

4. The males typically dig nest and defend it whilst females tend to hide unless they are spawning

A. True

B. False

5. Name four species of tilapia that can be cultured in commercial fish farming

A. …………………………………………

B. …………………………………………

C. …………………………………………

D. …………………………………………

SECTION ONE B: BREEDING CONDITIONS OF TILAPIA

This section seeks to examine whether you understand the breeding conditions of tilapia. You are required to indicate whether the following statements are TRUE or FALSE.

6. The males become extremely aggressive when sprawling is due

A. True

B. False

7. The female display darkened eye colour and lead the female to the nesting area

A. True

B. False

8. The females male collect the eggs in their mouth to maintain them until hatching

A. True

B. False

9. The fry are maintained in the mouth of the mother for several days until they are ready to feed

A. True

B. False

10. List **Four (4)** economic and social importance of tilapia production.

A. ……………………………………………………………………………………

B. ……………………………………………………………………………………

C. ……………………………………………………………………………………

D. ……………………………………………………………………………………

SECTION TWO: Conditions for tilapia productions

The table below shows the physical conditions which are required for tilapia production. You are required to complete the table by indicating the right range or condition required for each of the outlined conditions.

Number	Condition	Requirement
11	Temperature	
12	pH scale	
13	Dissolved oxygen	
14	Turbidity	
15	Water quality	
16	Temperature	

17. List and briefly explain the conditions which must be considered during site selection for the construction of tilapia pond.

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

APPENDIX F

MARKING SCHEME FOR POST-TEST

Multiple Choice

1. B	**6. A**
2. A	**7. B**
3. B	**8. B**
4. A	**9. A**

QUESTION 5: Four species of tilapia that can be cultured in commercial fish farming

Species	**Mark**
Nile tilapia **(Oreochromis niloticus)**	**1**
Redbreast tilapia (**Tilapia rendalli)**	**1**
Redbelly tilapia (**Tilapia Zilli)**	**1**
Blue tilapia (**Oreochromis aereus)**	**1**

QUESTION 10. Four (4) economic and social importance of tilapia production.

Species	**Mark**
Source of income to tilapia farmers and sellers	**1**
Source of employment for tilapia farmers and sellers	**1**
Source of food	**1**
Source of entertainment and recreation	**1**

SECTION 2: Conditions for tilapia productions

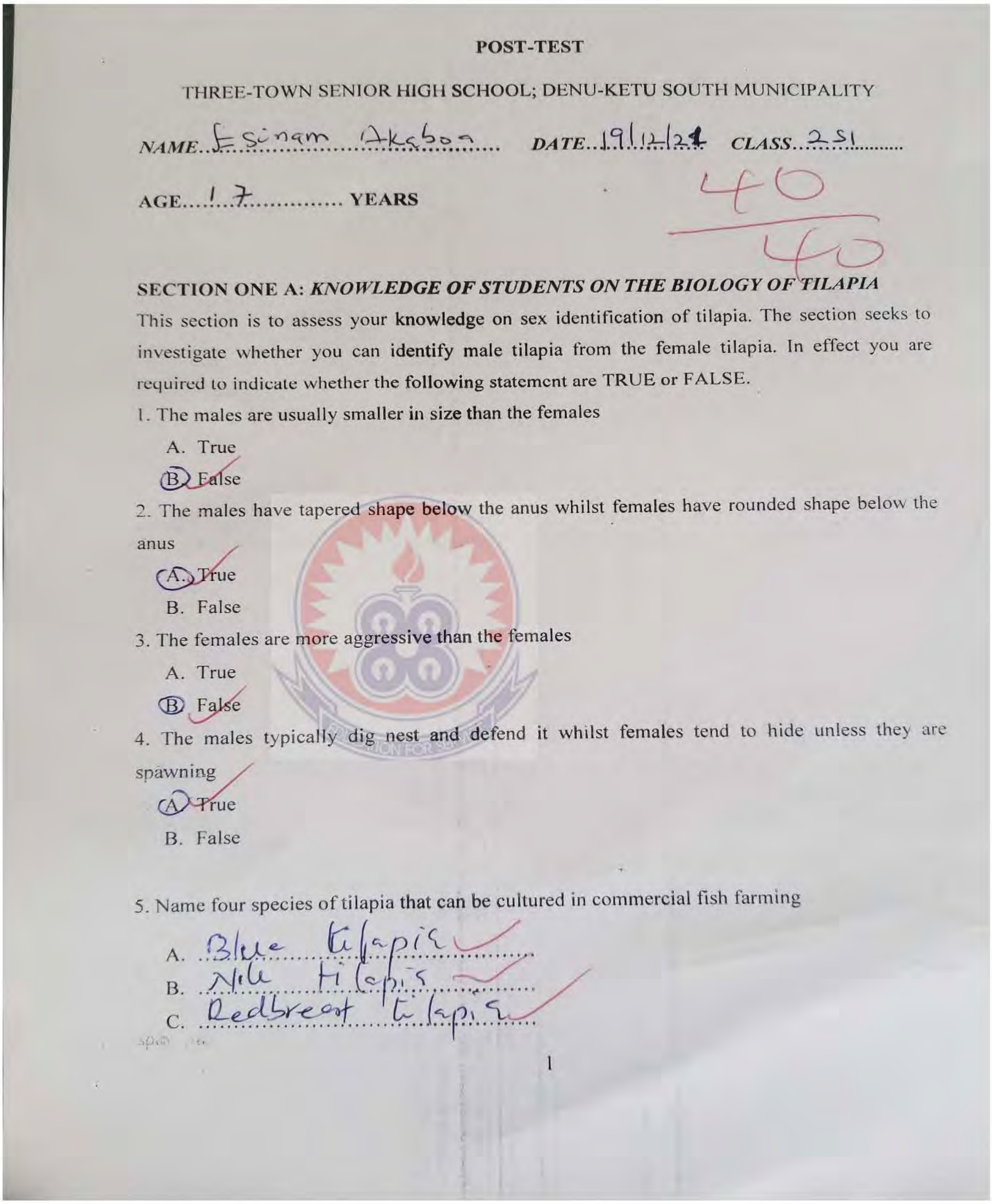
Question	Condition	Requirement	Mark
11	Temperature	27 °C	**2**
12	pH scale	6.9	**2**
13	Dissolved oxygen	13ppm DO	**2**
14	Turbidity	Less mud, less phytoplankton and less suspended organic and inorganic matter	**2**
15	Water quality	Clean and non-muddy water, light green water colour	**2**

QUESTION 17: List and briefly explain the conditions which must be considered during site selection for the construction of tilapia pond.

Factors	Requirement	Reason	Mark
Water source	Close water source	For reliable supply of water	**3**
Topography	Flat land	To prevent overflowing of the water bank in times of flooding.	**3**
Soil type	Clay dominant	To prevent breaking of the walls	**3**
Vegetation cover	Less shaded site	For constant penetration of sunlight into the pond	**3**
Predators	Security guard, nets	To prevent theft and exposure of the pond to predators such as snakes and birds.	**3**

APPENDIX G

SAMPLE SCORE 1 OF POST TEST



POST-TEST

THREE-TOWN SENIOR HIGH SCHOOL; DENU-KETU SOUTH MUNICIPALITY

NAME.. Esinam Akaboa ***DATE***.. 19/12/21 ***CLASS***.. 2S1

AGE.. 17 .. **YEARS**

$\frac{40}{40}$

SECTION ONE A: ***KNOWLEDGE OF STUDENTS ON THE BIOLOGY OF TILAPIA***

This section is to assess your knowledge on sex identification of tilapia. The section seeks to investigate whether you can identify male tilapia from the female tilapia. In effect you are required to indicate whether the following statement are TRUE or FALSE.

1. The males are usually smaller in size than the females

   A. True

   [✓ B. False] ✓

2. The males have tapered shape below the anus whilst females have rounded shape below the anus

   [✓ A. True] ✓

   B. False

3. The females are more aggressive than the females

   A. True

   [✓ B. False] ✓

4. The males typically dig nest and defend it whilst females tend to hide unless they are spawning

   [✓ A. True] ✓

   B. False

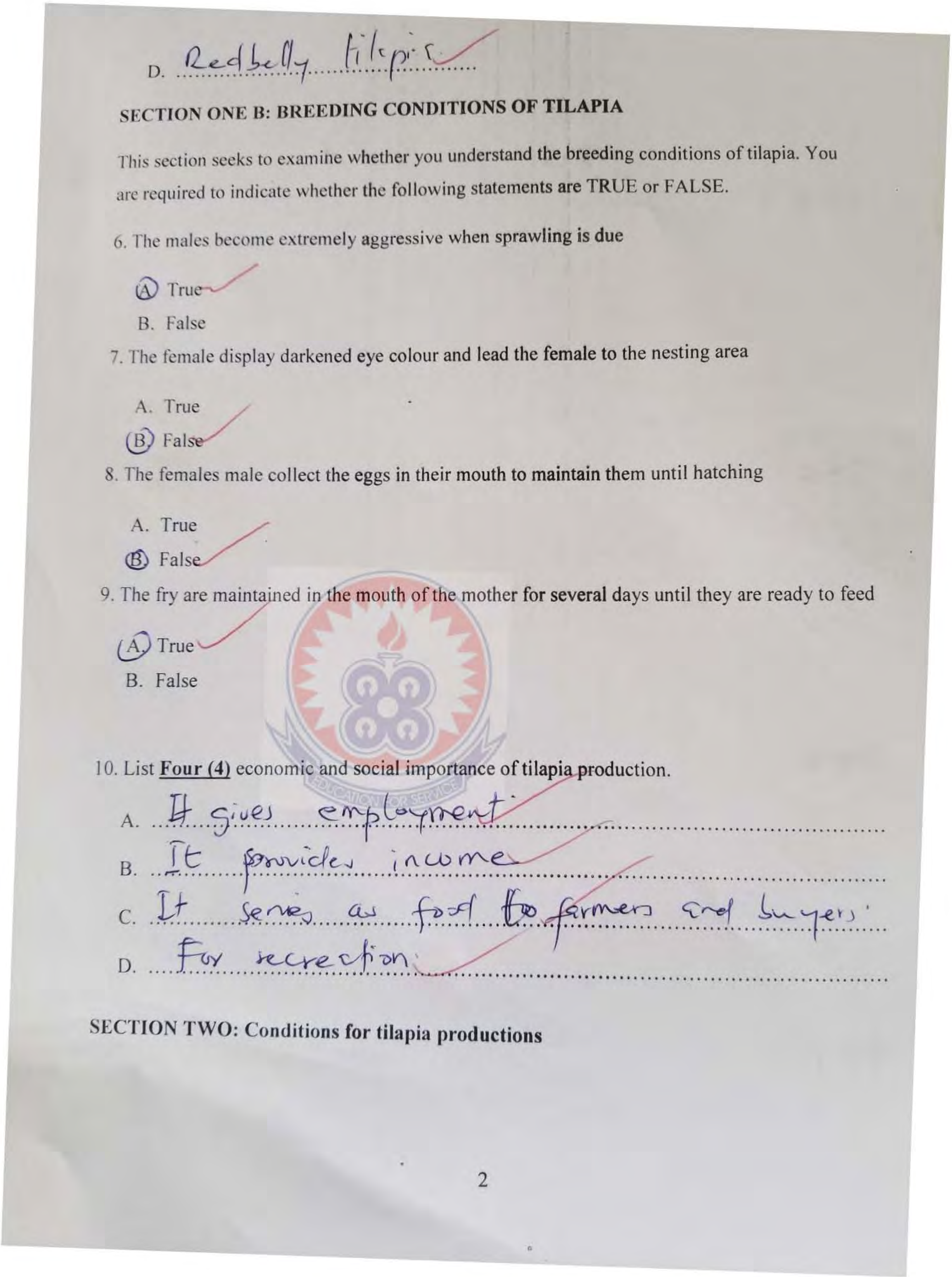
5. Name four species of tilapia that can be cultured in commercial fish farming

   A. Blue tilapia ✓

   B. Nile tilapia ✓

   C. Redbreast tilapia ✓

1



D. Redbelly tilapia

SECTION ONE B: BREEDING CONDITIONS OF TILAPIA

This section seeks to examine whether you understand the breeding conditions of tilapia. You are required to indicate whether the following statements are TRUE or FALSE.

6. The males become extremely aggressive when sprawling is due

[✓ A.] True
B. False

7. The female display darkened eye colour and lead the female to the nesting area

A. True
[✓ B.] False

8. The females male collect the eggs in their mouth to maintain them until hatching

A. True
[✓ B.] False

9. The fry are maintained in the mouth of the mother for several days until they are ready to feed

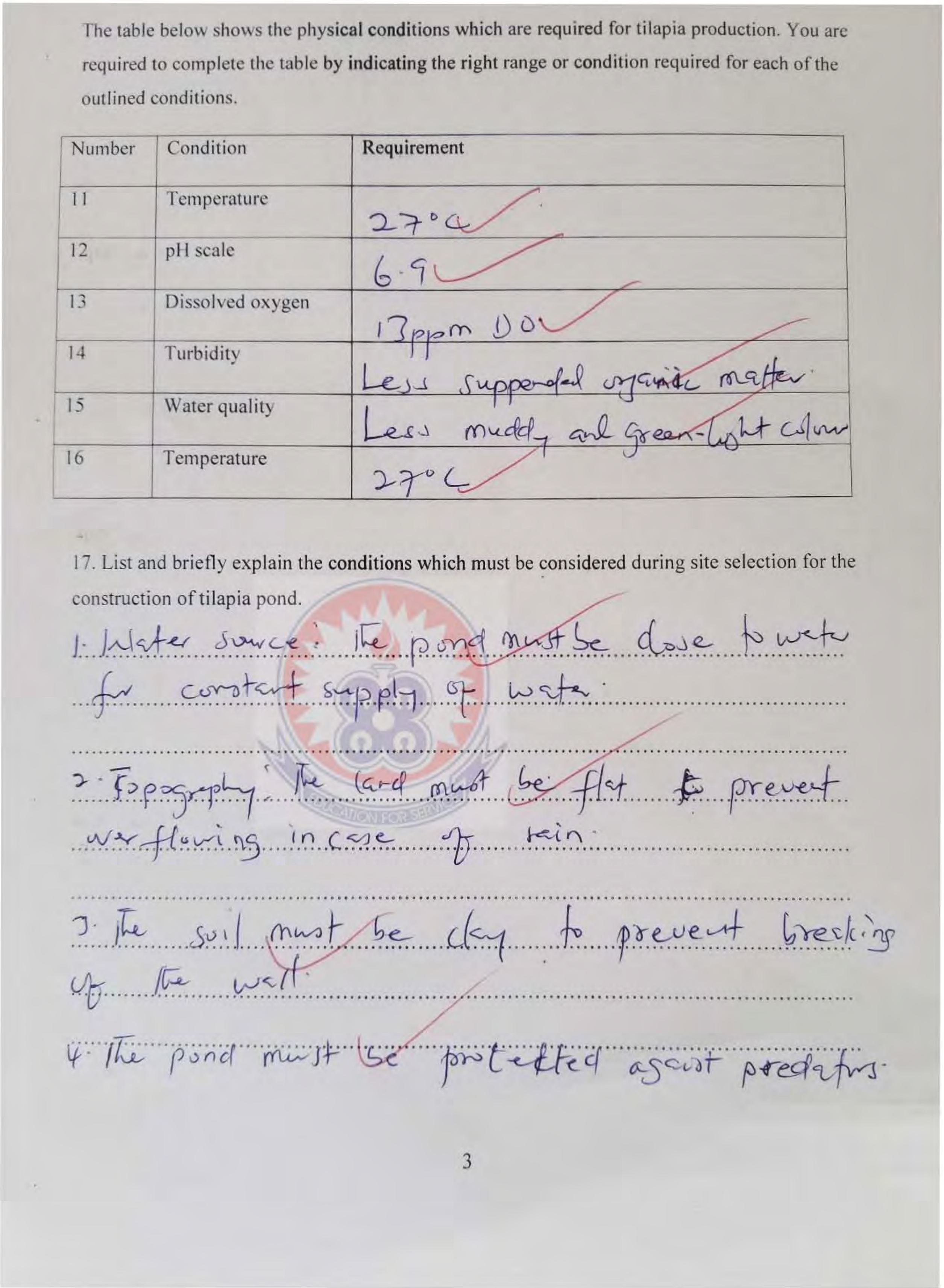
[✓ A.] True
B. False

10. List **Four (4)** economic and social importance of tilapia production.

A. It gives employment
B. It provides income
C. It serves as food to farmers and buyers
D. For recreation

SECTION TWO: Conditions for tilapia productions

2



The table below shows the physical conditions which are required for tilapia production. You are required to complete the table by indicating the right range or condition required for each of the outlined conditions.

Number	Condition	Requirement
11	Temperature	27°C
12	pH scale	6.9
13	Dissolved oxygen	13ppm DO
14	Turbidity	Less suppended organic matter.
15	Water quality	Less muddy and green-light colour
16	Temperature	27°C

17. List and briefly explain the conditions which must be considered during site selection for the construction of tilapia pond.

1. Water source: The pond must be close to water for constant supply of water.

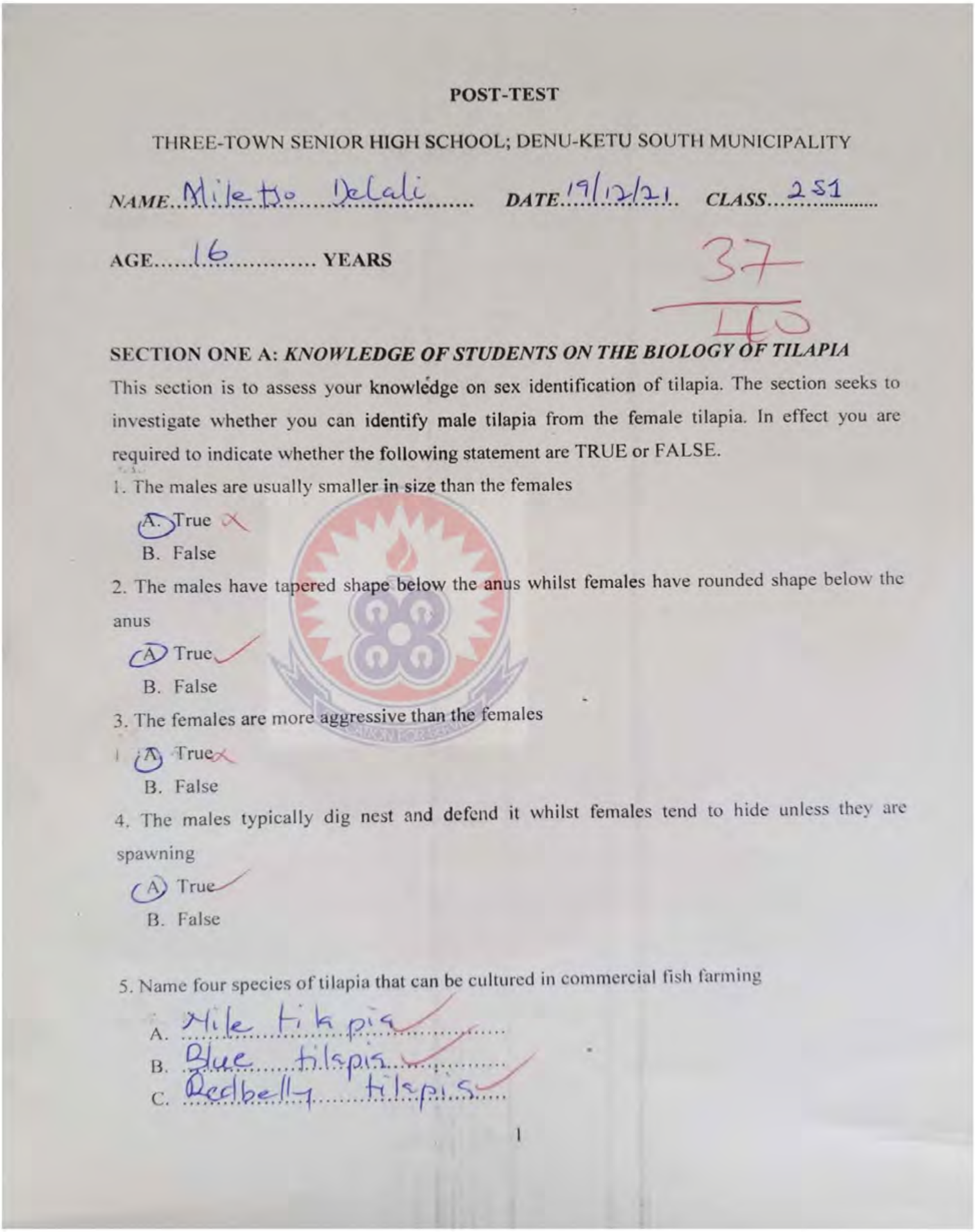
2. Topography: The land must be flat ~~to~~ prevent overflowing in case of rain.

3. The soil must be clay to prevent breaking of the wall.

4. The pond must be protected against predators.

APPENDIX H

SAMPLE SCORE 2 OF POST TEST



POST-TEST

THREE-TOWN SENIOR HIGH SCHOOL; DENU-KETU SOUTH MUNICIPALITY

NAME Miletso Delali DATE 19/12/21 CLASS 2S1

AGE 16 YEARS

37/40

SECTION ONE A: *KNOWLEDGE OF STUDENTS ON THE BIOLOGY OF TILAPIA*

This section is to assess your knowledge on sex identification of tilapia. The section seeks to investigate whether you can identify male tilapia from the female tilapia. In effect you are required to indicate whether the following statement are TRUE or FALSE.

1. The males are usually smaller in size than the females

   [✓ A. True] ✗
   B. False

2. The males have tapered shape below the anus whilst females have rounded shape below the anus

   [✓ A. True] ✓
   B. False

3. The females are more aggressive than the females

   [✓ A. True] ✗
   B. False

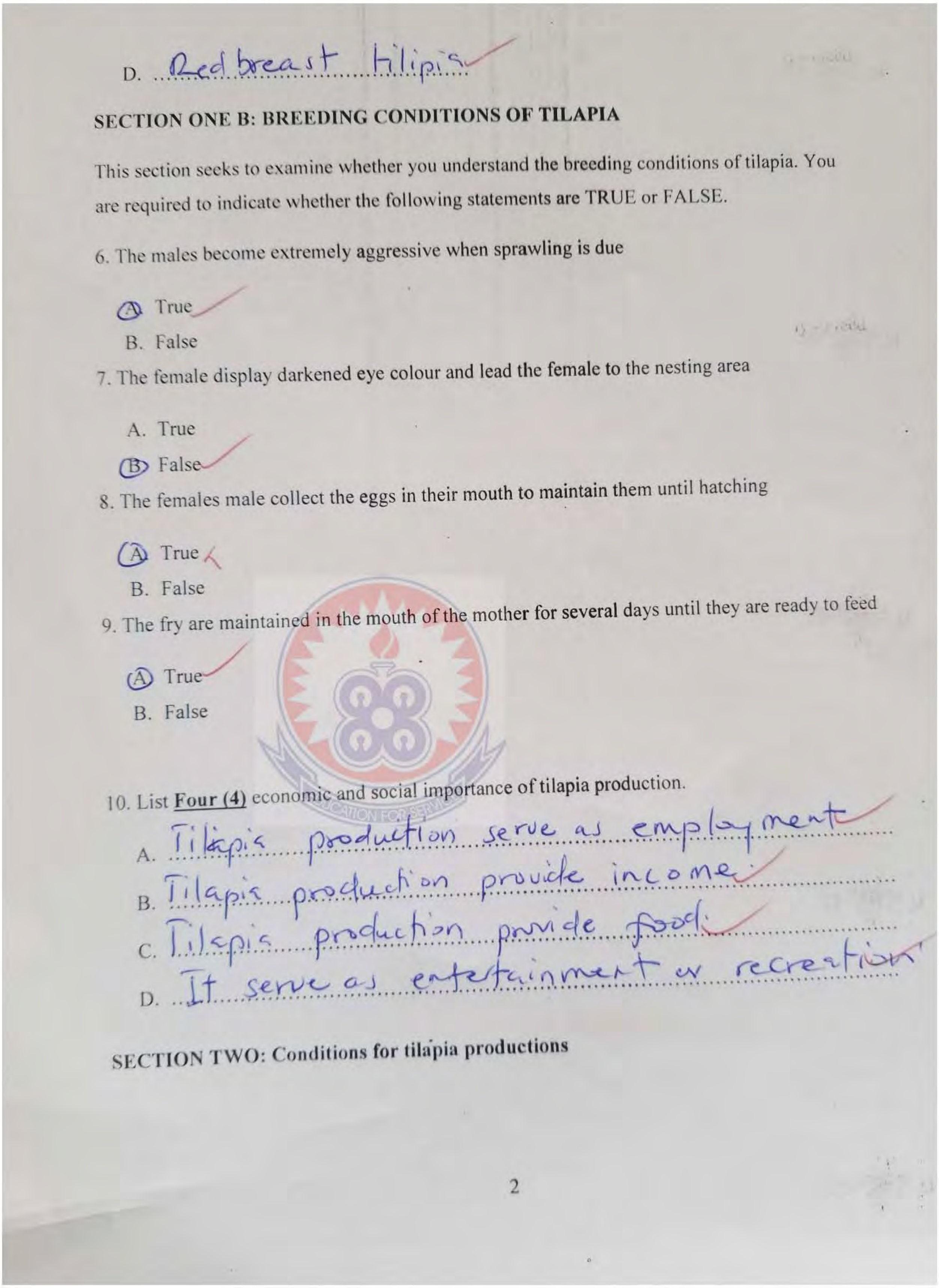
4. The males typically dig nest and defend it whilst females tend to hide unless they are spawning

   [✓ A. True] ✓
   B. False

5. Name four species of tilapia that can be cultured in commercial fish farming

   A. Nile tilapia ✓
   B. Blue tilapia ✓
   C. Redbelly tilapia ✓

1



D. Red breast tilipis

SECTION ONE B: BREEDING CONDITIONS OF TILAPIA

This section seeks to examine whether you understand the breeding conditions of tilapia. You are required to indicate whether the following statements are TRUE or FALSE.

6. The males become extremely aggressive when sprawling is due

[✓ A. True]
B. False

7. The female display darkened eye colour and lead the female to the nesting area

A. True
[✓ B. False]

8. The females male collect the eggs in their mouth to maintain them until hatching

[✓ A. True]
B. False

9. The fry are maintained in the mouth of the mother for several days until they are ready to feed

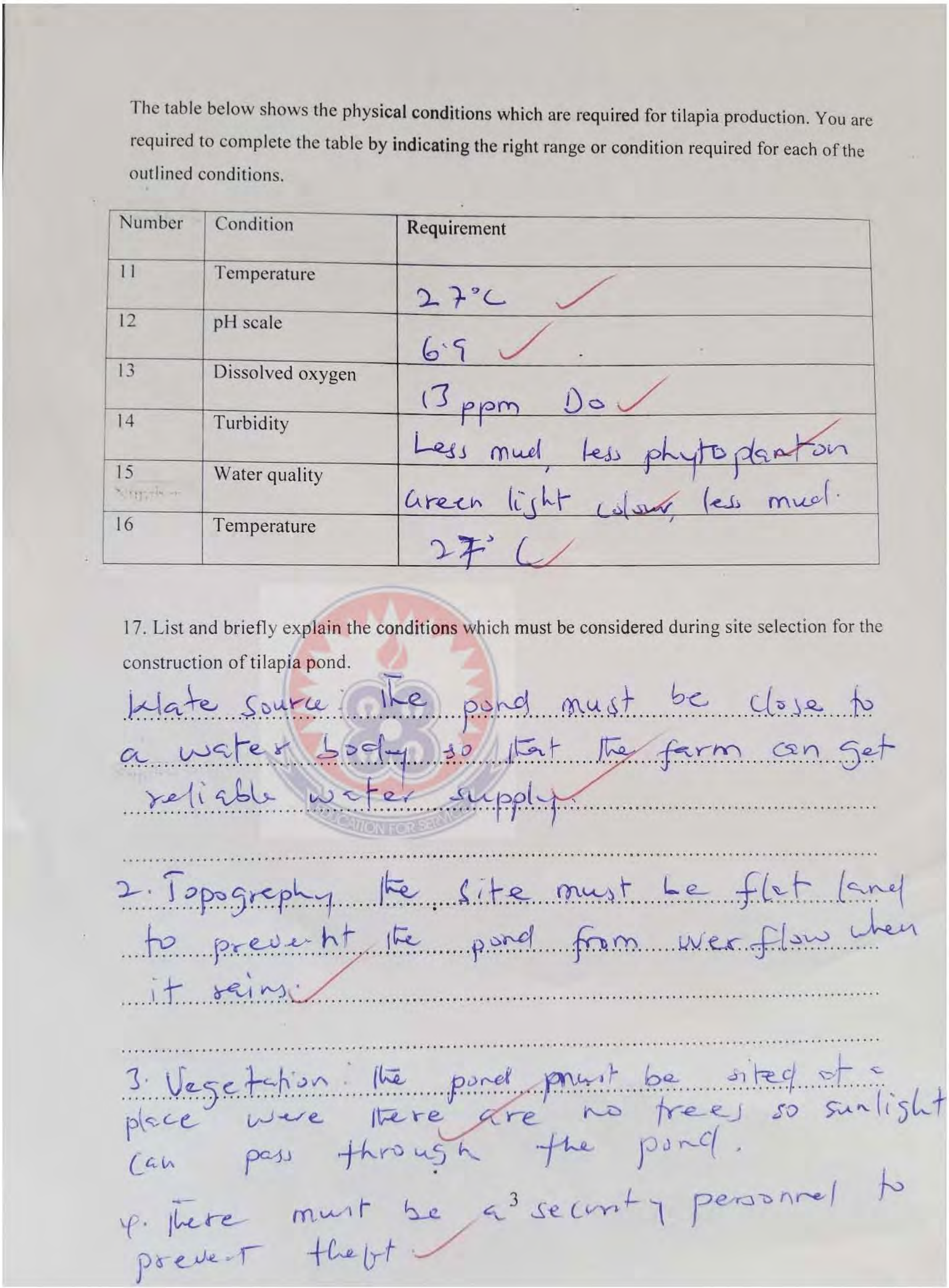
[✓ A. True]
B. False

10. List **Four (4)** economic and social importance of tilapia production.

A. Tilapis production serve as employment
B. Tilapis production provide income
C. Tilapis production provide food
D. It serve as entertainment or recreation

SECTION TWO: Conditions for tilapia productions

2



The table below shows the physical conditions which are required for tilapia production. You are required to complete the table by indicating the right range or condition required for each of the outlined conditions.

Number	Condition	Requirement
11	Temperature	27°C ✓
12	pH scale	6.9 ✓
13	Dissolved oxygen	13 ppm Do ✓
14	Turbidity	Less mud, less phytoplanton ✓
15	Water quality	Green light colour, ✓ less mud.
16	Temperature	27° C ✓

17. List and briefly explain the conditions which must be considered during site selection for the construction of tilapia pond.

Wate source: The pond must be close to a water body so that the farm can get reliable water supply ✓

2. Topogrephy the site must be flet land to prevent the pond from werflow when it rains ✓

3. Vegetation: the pond must be sited at a place were there are no trees so sunlight can pass through the pond. ✓

4. there must be a 3 security personnel to prevent theft ✓