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CHARACTERISATION OF TILAPIINE SPECIES FROM SELECTED RESERVOIRS AND RIVERS IN THE NORTHERN REGION OF GHANA

BY

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DECLARATION

I hereby declare that this thesis is the result of my own original work and that no part of it has been presented for another degree in this university or elsewhere.

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ABSTRACT

A study was carried out in selected water bodies in the Tolon, Kumbungu and West Mamprusi districts in the Northern Region of Ghana to distinguish between tilapiine species. Eighteen (18) morphometric characters were taken using calipers and a measuring board and eight (8) meristic counts were conducted using visual observation. Discriminant function analysis was employed to discriminate between the tilapiine species using the morphometric characters. AOAC procedures for analyzing proximate composition was used to obtain crude protein, dry matter, fat and ash content of the tilapiine species. Physico-chemical characteristics analysed included pH, temperature, nitrate, phosphorus, DO and chlorophyll 'a' concentration of water bodies. Three (3) tilapiine species; *Oreochromis niloticus, Tilapia zillii* and *Sarotherodon galilaeus* were identified. Meristic characteristics among the tilapiine species observed were not significantly different ($P>0.05$) for all meristic features considered except pectoral fin rays and pelvic fin rays and spines. Pectoral fin length, caudal fin length, head depth, and body depth were the morphometric characters that discriminated between the tilapiine species using the discriminant function analysis. The length-weight relationship for *O. niloticus* (2.288), *T. zillii* (2.287) and *S. galilaeus* (2.065) exhibited a negative allometric growth. Physico-chemical variables were similar for the water bodies. The crude protein levels for *O. niloticus* (48.14±2.26) was significantly higher compared to *T. zillii* (37.75±1.96) and *S. galilaeus* (38.76±3.12). There was significant difference in the dry matter and fat content of *T. zillii* (19.12±0.31; 2.31±0.59) and *S. galilaeus* (18.10±0.39; 1.46±0.53) respectively but no significant difference between the aforementioned species and *O. niloticus* (18.46±0.37; 2.00±0.39). Differences in colorations, length-weight relationship, pectoral fin length, caudal fin length, head depth, body depth and all the meristic characteristics considered

except pelvic fin rays and spines were able to differentiate between the tilapiine species harvested from the selected rivers and reservoirs. Conducting a genotypic characterisation is recommended.

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DEDICATION

I dedicate this work to my entire family, especially to my children Saha and Bangaham Salifu.

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LIST OF ABBREVIATIONS

WHO	World Health Organisation
GDP	Gross Domestic Product
FAO	Food and Agriculture Organization of the United Nations
Ghagov	Ghana Government
GMA	Ghana Maritime Authority
GSS	Ghana Statistical Service
IDA	Irrigation Development Authority
APHA	American Public Health Association
ANZECC	Australia and New Zealand Environment and Conservation Council
AOAC	Association of Official Analytical Chemists
EPA	Environmental Protection Agency
DENR	Department of Environment and Natural Resources
DAO	DENR Administrative Order
NPCC	National Pollution Control Commission
ORSANCO	Ohio River Valley Water Sanitation Commission

CHAPTER ONE

1.0 INTRODUCTION

Growth of the world's population is estimated to reach 9.8 billion by 2050. This increase presents major challenges to ensuring food security in the face of an expanding demand for food and against a background of climate change impacts (FAO, 2019). Aquaculture, the world's fastest growing food production sector, is slated to play a vital role in supplying food from marine and inland waters while alleviating pressure on wild stocks (FAO, 2018). Hundreds of millions of people around the world are dependent on fisheries and aquaculture for livelihood and nourishment. According to FAO (2016 a), fish contributed 17 percent of protein sourced from animals and 6.7 percent of the protein ingested worldwide in 2013 alone. Additionally, a total of 3.1 billion of the world's population achieved about 20 percent of their average per capita animal protein requirements by consuming fish. It is the preferred protein source because it contains easily digestible, high-quality protein with all the essential amino acids. It also provides omega-3 fatty acids, vitamins and minerals essential for growth and development (FAO, 2019). Consumption of fish is associated with health benefits such as protection against cardiovascular diseases and is paramount in the developmental process of the brain and nervous system of foetuses and infants (FAO/WHO, 2011). Fish is the cheapest source of proteins for immune compromised, malnourished, pregnant women, nursing mothers and communities who do not consume red meat. In some densely populated countries, fish has a higher preference and is incorporated into local and traditional recipes (Jim *et al*., 2017). For instance, FAO (2016 a) reported that, fish contributes or exceeds 50 percent of total animal protein intake in some small island developing states, as well as in Ghana.

Fish provides an enormous economic value through fisheries and aquaculture operations by offering employment, recreation, market and economic empowerment for individuals involved in the fisheries industry. According to the FAO (2016), the fisheries sector in Ghana is based on resources from the marine and inland (Freshwater) sectors and coastal lagoons with 298,000 tonnes of fisheries being captured in 2013. Out of this, 90,000 tonnes were harvested from inland fisheries mainly from Lake Volta. In 2016, fishing contributed Gh¢1,793,000 to GDP which translates into 1.1 percent of the 18.9 percent contributed by Agriculture in Ghana (GSS, 2017).

In Ghana, fisheries contribute significantly to the socio-economic development which leads to poverty reduction, food security and sustainable livelihoods (FAO, 2017; Jim *et al*., 2017). Fish farming has grown rapidly from 1,200 tonnes in 2005 to 38,500 tonnes in 2014 as a result of rising prices of tilapia. Tilapia constitute over 90 percent of aquaculture production (FAO, 2016). Tilapia play a major role in the sustenance of fish farming for several generations in parts of Africa and the Middle East but in the recent past, its prominence for aquaculture as well as an exotic or staple food has soared (Gupta and Acosta, 2004). Tilapia is one of the most desirable species for aquaculture besides its enormous impact on inland water fisheries in Africa (Ayotunde *et al.*, 2011). Currently, over 85 countries farm tilapia globally (Al Zaidy, 2013). Numerous species of *Oreochromis*, *Sarotherodon*, and *Tilapia* are preferred for aquaculture due to their high protein content and consumer acceptability. Their rapid growth and attainable large sizes make them desirable in most aquaculture production systems (Samaradivakara *et al*., 2012; FAO, 2016; Azua *et al*., 2017).

Grimes *et al*. (1987) has indicated that effective management of fisheries can only be worthwhile if the stock structure of a species, fishing effort and mortality distribution are understood. The concept of geographical structure in fish population is fundamental for population dynamics and management of fisheries Bailey (1997), to the point that identification of geographical ranges of each stock unit becomes essential to the debate (Ihssen *et al*., 1981). The quantification of specific characteristics of an individual or a group of individuals can indicate the level of speciation resulting from biotic or abiotic factors and further contribute to the definition of different stock of species (Ambily, 2016).

The morphometric study of fish is a powerful tool for characterising strains and /or stocks of the same species which involves the detection of subtle variation in shape irrespective of size (Gonzalez *et al.*, 2016). Meristic characters have been used as a tool for stock discrimination for centuries due to ease of observing and counting of these features. For instance, Manimegalai *et al*. (2010) observed different variations in fish species of *Etroplus maculatus* with the help of morphometric analysis. Langer *et al*. (2013) conducted a study on the morphometric and meristic characters of golden mahseer (*Tor putitora*) from a stream in India and reported an isometric growth pattern in all specimen in their natural habitat. Despite the availability of techniques that directly examine biochemical or molecular genetic variation, the morphometric or meristic method continually play an important role in stock identification (Swain and Foote, 1999).

1.1 Problem statement

Some of the major fishing countries in Africa (the United Republic of Tanzania, Egypt and the Democratic Republic of the Congo), Europe/Asia (the Russian Federation) and South America

(Brazil) have reported reduced catches in inland waters FAO (2016 a). This is buttressed by reports from Ofori-Danson *et al*., (2012); Alhassan *et al*. (2014) and MoFAD, (2015) in Ghana. These reductions in catches are attributed to environmental degradation (mining, pollution etc.) and climate change which has resulted in limited habitats for fish species leading to over fishing (Rurangwa *et al*., 2015, FAO, 2019). According to Entsua - Mensah *et al*. (2000), over fishing causes changes in the size structure as well as the species composition which could result in genetic erosion.

Aquaculture, the world's fastest growing food production sector, is slated to play a vital role in supplying food from marine and inland waters while alleviating pressure on wild stocks (FAO, 2018). Aquaculture has grown rapidly from about 1,200 tonnes in 2005 to about 38,500 tonnes in 2014 due to rising prices of tilapia and currently constitutes over 90 percent of aquaculture harvest in Ghana (FAO, 2016). Kassam (2014) and Amenyogbe *et al*. (2018) have reported that insufficient availability and quality of fingerlings for stocking and feed are key hindrances identified by MoFAD to the development of Ghana's aquaculture. Reports from FAO (2019) also indicates that some aquaculture systems still rely on the wild relative as seed for stocking. There is therefore the need to characterise the wild stock populations and institute proper management strategies such as selective breeding of resilient species that have evolved and adapted to their changing environment.

1.2 Justification

Characterisation of animal genetic resources for food and agriculture (AnGR) involves three types of information: phenotypic, genetic and historical. The information provided by characterisation studies is essential for planning the management of AnGR at local, national, regional and global levels. Phenotypic characterisation of AnGR is the process of identifying distinct breed populations and describing their external and production characteristics in a given environment and under given management, taking into account the social and economic factors that affect them FAO (2012). It is, therefore, imperative that farmers and scientists know the difference between and within the tilapia species to better inform them of requirements such as nutrition, physical and chemical compositions of their environment. Furthermore, knowledge of such characteristics will enable proper planning and management of fish in the areas of breeding, production and conservation of fish genetic resources.

According to Turan (1999) morphometric and meristic characterisation can thus be a starting point for the investigation of stock structure of a species. Previous studies adopted this method for fish stock identification in fish species such as *Trachurus mediterraneus*, *Sebastes mentalla* and *Megalspis cordyla* by Turan (2004), Sajina *et al*. (2011) and Trella *et al*. (2013), respectively. Kolher *et al*. (1995) stated that length-weight relationships are standard and useful result of fish sampling programs where morphometry is employed. This relationship can be used to predict morphological and physiological aspects such as growth rates, length and age structures as well as significant variables in fish population dynamics. Some researchers such as Quarcoopome *et al*. (2008); Kwarfo-Apegyah and Ofori-Danso, (2010); Alhassan *et al*. (2014, 2015) have conducted fish stock assessment in some of the reservoirs in Northern region but data on characterisation on fish species dates back to the 1990's (Dankwa *et al*., 1999). This study, therefore, sought to phenotypically characterise the tilapiine species found in selected rivers and reservoirs in the northern region of Ghana with their morphometric and meristic characteristics.

1.3 Objectives

1.3.1 Main objective

To determine the phenotypic characteristics of the tilapiine species as well as the management and the quality features of the selected reservoirs and rivers.

1.3.2 Specific objectives

To ascertain the differences in the management of the selected water bodies and its' resources.

To ascertain the morphometric and meristic characteristics of tilapiine species from the selected water bodies.

To assess the nutritional composition of the tilapiine species from the selected water bodies.

To determine the physico-chemical parameters of the selected water bodies.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Overview of tilapiine species

Tilapia is a name given to the species of fish in the Cichlidae family and order Perciformes. Tilapiines are clustered into a tribe within the family Cichlidae, one of the four main families. These families Cichlidae, Embiotocidae, Pomacentridae and Labridae were included in the suborder Larbroidae by Kaufman and Liem (1982) and it includes about 5 – 10 percent of all known fish species (Beveridge and McAndrew, 2000). Trewavas (1982) reported that 'tilapia' is derived from the African Bushman word which means 'fish'. According to Philippart and Ruwet (1982), Tilapias are a group of freshwater fish originating exclusively from Africa (minus Madagascar) and from Palestine in the Jordan Valley and coastal rivers. McAndrew (2000) indicated that *Tilapia* as well as *Sarotherodon* species are generally found in the Western parts of Africa while the *Oreochromis* tends to be common in the Central and Eastern African water bodies. However, species such as *Tilapia zillii*, *Sarotherodon galilaeus* and *Oreochromis niloticus* have an overlapping and much larger distribution termed as a Nilo-Sudanian distribution. This wide spread presence over Africa is courtesy of the interconnected major river system namely rivers Nile, Chad and Niger in the northern parts of Africa.

Most tilapia species of the tribe Tilapiine being used in aquaculture were grouped initially into one genus, Tilapia. The species within this genus were later classified according to their mode of reproduction (Trewavas, 1983). According to Popma and Masser (1999), all tilapia species are nest builders with brooding parents guarding the fertilized eggs in their nest. The substrate spawners that guard their eggs were classified under the genus *Tilapia* while mouthbrooding species were classed into the new species *Sarotherodon*. *Sarotherodon* and *Oreochromis* are known to be mouthbrooders (Arrignon, 1998). Fertilization of eggs takes place in the nest and brood parents instantly take the eggs in their mouth and keep it in their buccal cavity throughout incubation and for a number of days after hatching. Females of *Oreochromis* species normally brood in their mouth but in *Sarotherodon* species both males and females or the males are mouth brooders (Popma and Masser, 1999). The classification of the genus *Oreochromis* was based on the difference in their reproduction, feeding habits, and biogeography. Genus *Oreochromis* (*O*) includes Nile tilapia (*O. niloticus*), Mozambique tilapia (*O. mossambicus*) and Blue tilapia (*O. aureus*) which are the most commercially important species (Wohlfarth *et al*., 1990).

Ten of about 16 *tilapiine* species are used for commercial aquaculture (FAO, 2004). The general morphology of tilapia is a rectangular body-shaped fish with ctenoid or cycloid scales Al Zaidy (2013), they are laterally compressed and deep-bodied with a lengthy dorsal fin. The anterior dorsal fins have spines which are webbed together with the posterior soft rays. They can be identified by the discontinues lateral line which is a distinct characteristic of the cichlid family (Popma and Masser, 1999; Al Zaidy, 2013). Tilapias are herbivorous and possess two types of teeth, jaws with bicuspid and tricuspid teeth and small but sharp pharyngeal teeth which enable them to break down some portions of their feed before reaching the stomach. They also have long and coiled intestines that could be up to fourteen times their body length (Trewavas, 1982). El-Sayeed (2006) reported that daily and seasonal changes affects the efficiency and feeding habits of tilapia. Tilapia tends to feed intensively during early morning and late afternoon but feed very little mid-day and nights.

El-Sayeed (2006) described tilapia bodies to be characterised by distinct vertical bars, with relatively subdued colours and with little contrast over the body colours which provides the fish with the ability to change its colours, in response to stress, by controlling skin chromatophores. Tilapias have well-developed sense organs. This is seen in prominent nares and a clearly visible lateral line. The eyes are also relatively large, providing the fish with an excellent visual capability. Tilapia is a warm water fish which is found mostly in Africa, it is generally considered as a freshwater species but will tolerate brackish conditions. Some species can survive salinity levels of about 15ppt to 20ppt (Popma and Masser, 1999). Tilapias are quite tolerant of unfavorable changes in the environment. They can withstand high levels of turbidity, low oxygen and water quality (Arrignon, 1998). They are able to tolerate temperatures ranging from 11°C – 36°C and at extreme temperatures of 8 °C – 42 °C (Philippart and Ruwet, 1982; Zenebe, 1998). Tilapias are plastic animals whose development is greatly influenced by the environment (Nehemia *et al*., 2012), they could be misidentified based on their body color alone since their environment, sexual maturity and available food also contributes to intensity of body coloration (Popma and Masser, 1999).

Oreochromis niloticus (Nile tilapia) is a day active fish that feeds chiefly on phytoplankton, benthic algae, and plants (Azua *et al*., 2017). It is a surface breeder and omnivorous in nature. Its females hold eggs in their mouth until fry is old enough to be released. Anterior dorsal fins have spines which are not separated from 13 posterior soft rays with no spines (Al Zaidy, 2013). *Oreochromis niloticus* (Nile tilapia) can be characterised by distinguishable dark bands of stripes on the body, these bands are prominent in mature fishes (Marx *et al*., 2014). According to Trewavas (1983), it has dark brown vertical stripes on the caudal fin with a light grey background.

The pectoral rays are red to light brown and the flanks may have 7 – 8 vertical bars. The anal fin has 9 –11 soft rays while the spines are 3. Sexual maturity is reached at 10 – 30 cm total length and is related to the maximum size attained in a given population and condition, which in turn is determined by food availability and temperature.

Tilapia zillii (Redbelly tilapia) can be found in freshwater, brackish and are benthopelagic. They survive in pH ranges of 6 – 9 at depth ranges of 7 – 1 m and temperatures of 11 °C – 36 °C (Eccles, 1992; Riede, 2004). According to Bailey (1994), they are substrate spawners that occasionally swim in a school which is formed diurnally and they prefer shallow vegetated areas of their environment. They are herbivorous and feed on water plants, epiphyton and some invertebrates such as insects (Eccles, 1992; Bailey, 1994 and Atindana *et al*., 2014). They have dorsal spines ranging from 13 – 16, dorsal soft rays 10 – 14, anal spines 3, anal soft rays 8 – 10 and 8- 11 lower gill rakers (Teugels and van den Audenaerde, 1991). Nobah *et al*. (2006) reported that, *Tilapia zillii* of standard length (SL) below 14 cm have completely yellowish or greyish caudal fins without spots but tend to develop a greyish caudal fin with spots as they mature. van Oijen (1995) and Teugels and van den Audenaerde (2003) described them to have pinkish chests with dorsal, anal and caudal fins appearing as brownish-olivaceous with yellow spots. According to Zouakth *et al*. (2016) the length at first maturity is about 10 cm in both sexes, however, van Oijen (1995) reported their common SL to be 30 cm and a maximum of 40 cm in males and unsexed *Tilapia zillii*.

Sarotherodon galilaeus (St. Peter's fish or Mango tilapia) is a dominant, endemic, and economically important tropical fresh water fish species, which belongs to the Cichlidae family.

Sarotherodon galilaeus has been known to thrive in waters with temperatures of 9 °C. They occasionally form schools with adults preferring open waters, juveniles and breeding adults, however, remain inshore (Teugels and van den Audenaerde, 1991). They are often associated with beds of submerged vegetation in Sudd lakes and feed on algae and fine organic debris. They form temporary pair bonds which are dissolved as soon as the eggs are in the parental mouth, mouthbrooding is reportedly biparental (Stiassny *et al*., 2008). Bailey (1994) and Stiassny *et al*. (2008) have described *Sarotherodon galilaeus* to have fins ranging from 15 - 17 dorsal spines;12-13 dorsal soft rays; 3 anal spines and 9 – 11 anal soft rays. Reproductive fishes are greyish in the dorsal region and silvery in the ventral parts with a pinkish margin of caudal and dorsal fins. In adults, the sides and fins are light silver to grey with a white belly. In the young ones, however, fins are grey with upper margins of especially the dorsal fin being rosy red. The body has the signature grey – slivery coloration with narrow black crossbars on the sides (Teugels *et al.*, 2003; Stiassny *et al.*, 2008).

2.2 Morphometric Characteristics

Morphometrics is the use of external measurements to quantify the variations in an organism's morphology. The purpose of morphometrics is to describe and quantify the size and shape of organisms with statistical methods. Morphometric analyses can be used to analyse developmental changes, interactions between the environmental factors and form of an organism as well as for predicting quantifiable genetic parameters of shape, (Rohlf and Marcus, 1993 and Webster, 2006).

Morphometric studies are essential to understanding the taxonomy of a species. However, variation in its features may be associated with habits and the habitat among the variants in a particular species (Cavalcanti *et al.*,1999). To discriminate between a species, the examination of their body shape, the proportion of body part to its total length, pattern of arrangements of fins, the position of mouth, coloration, and number of fin rays is essential. Furthermore, these characteristics are used to measure intra specific variations among the species (Ambily, 2016).

Morphometric parameters of a fish species have a major role to ensure whether there is any disparity between same species of different geographic region (Naeem *et al*., 2012). There are phenotypic variations in morphometric and meristic characters between fishes of the same species, due to variations resulting from sex, food availability, predator-prey interactions, physical parameters and environmental condition (Dasgupta, 1991). Both morphometric and meristic characters respond to changes in environmental factors, their response is different in some situations and can differ from species to species and therefore morphometric variation among stocks may be applicable for studying short-term environmentally induced variations (Gonzalez *et al*., 2016). Herath *et al*. (2014) considered some morphological characteristics in *Oreochromis mossambicus* in 3 brackish water systems in Sri Lanka and discovered significant variation in the both anterior and posterior body parts of the fish as well as differences in the morphological characters of fish from the different locations. Differences were associated with environmental differences such as salinity, temperature, hardness as well as genetic influence capable of morphological variation.

2.2.1 Meristic Characteristics

Meristic characters are a series of countable structures on fish such as fins (spines and rays), lateral lines and scales. Fin spines are solid unbranched and undivided fin rays whereas fin rays are soft, branched, divided and flexible fin rays (FAO, 2013). A most specific feature of fish is the fins. There are two types of fins, median fins (dorsal, anal, adipose and caudal) and paired fins (pectoral and pelvic) respectively (Ambily, 2016). Nowadays, the term is used for any countable structure such as scales and gill rakers as opposed to its traditional reference to body segments such as the number of vertebrae or fin rays (Helfman *et al*., 1997; Waldman, 2005). According to Chase (2014) meristic features are clearly defined and quantifiable which makes it useful in comparison of characters in a species of several strains. It is also useful for describing or identifying species (Gogoi and Goswami, 2015). Several researchers have illustrated the significance of using morphometric and meristic characters of different species of fish to determine variations between and among them. Herath *et al*. (2014) determined morphological variations between three (3) *Oreochromis mossambicus* populations in three brackish water systems of southern Sri Lanka using morphometric measurements. Gonzalez *et al*. (2016) characterised wild and cultured *Cichlasoma festae* species with their morphometric and meristic traits. The study recorded a significant difference between populations in some twenty-one standardized morphometric measurements out of twenty-six with univariate analysis. According to El-zaeem *et al*. (2012), morphometric and meristic character indices were used to group *Oreochromis niloticus* into groups of wild and cultured and further grouped into phenotypically similar groups using hierarchical cluster analysis.

The importance of morphometric and meristic in examining phenotypic population structure and shape variations has further been emphasised by various researchers Salam and Naeem (2004), El-Zaeem *et al*. (2012), Samaradivakara *et al*. (2012), Kosai *et al*. (2014), Ramli *et al*. (2016), Azua *et al*. (2017) and Ahammad *et al*. (2018). They have all established that using both meristic and morphometric characteristics is the simplest way to identify and group species.

2.2.2 Length-Weight Relationship

The length-weight relationship is a simple method that provides crucial data on the biology of fish and is instrumental in fishery assessment, management of populations (Pervin and Morzatu, 2008) and enables prediction of weight from length in yield assessment (Pauly, 1987). The growth pattern of fish is influenced by the availability of food, stock density and physico-chemical parameters of its habitat and biological factors viz, size, gender, age and reproductive status (Le Cren, 1951). The relationship between length and weight exhibited in animals during growth serves as a tool for assessment such as well-being of fish (Kuriakose, 2014; Marx *et al.*, 2014). It can be expressed as a mathematical relationship which is helpful in estimating biomass from various length class of any given fish species (Beyer, 1987, Kuriakose, 2014). The mathematical relationship between length and weight takes a non-linear form which requires logarithmic transformation to establish a linear equation since growth in length and weight of fish is not proportionate (Ricker, 1975 and Kuriakose, 2014). According to Kuriakose (2014) the length - weight relationship of fish is in the form $W=aL^b$. The parameters a and b are calculated from length and weight data collected from fish, a is a scaling coefficient for weight at length of the fish species whiles b is a shape parameter for the body form of the fish species. Logarithmic transformation is needed to linearize the length and weight relationship $W=aL^b$ into $In\ (W) = In\ (a) + b\ In\ (L)$ or $A + bX$. This enables estimation of either growth parameter using simple linear regression. Several researchers Marx *et al.* (2013), Herath *et al.* (2014), Alhassan e*t al.* (2015) and Azua *et al.* (2017) have all estimated length-weight relationships of cichlids in different geographical locations to express their growth pattern. They reported a value of b>3 as positive allometric growth, b<3 as negative allometric growth and b=3 as isometric growth in their studies. Growth of the body parts is proportional to the growth of the total length, therefore, morphometric measurement of fishes and statistical relationship among and between them are crucial to the taxonomic study of a species (Tandon *et al.*, 1993).

2.2.3 Discriminant Function Analysis

Discriminant analysis is a common tool used in the identification of populations (Maric *et al*., 2004). According to Ayogu *et al.* (2014) discriminant analysis is an essential statistical technique used in the classification of an observation into one or more a priori groups that is dependent on the characteristics of the individual. To distinguish between the groups, the researcher selects a collection of discriminating variables that measure characteristics on which the groups are expected to differ. In discriminant analysis, the independent variables are the predictors and the dependent variables are the groups. Brown and Tinsley (1983) explained that to employ discriminant analysis, treatments should be identified and grouped based on distinct characteristics. These are termed as groups; each treatment is designated to a group based on existing knowledge and a minimum of two groups is required. For the predictor variables, its efficient use can be achieved based on its significance as a discriminator. Each variable represents a unique characteristic on which groups are expected to differ. Multiple data on variables must be available for each treatment within the various groups (Ayogu *et al*., 2010). New variables computed from linear combinations of the original discriminant variables are then termed discriminant functions (Brown and Tinsley, 1983).

According to Brown and Tinsley (1983), numerous statisticians recommend using chi-square and Wilks' lambda to determine the importance of functions. The Wilks' lambda statistic is an inverse measure of the discriminating characteristics peculiar to each of the discriminator variables. A larger Wilks' lambda value means less information remains in the discriminator variables which is systematically related to group differences. According to the pair, a chi-square test based on Wilks' lambda is usually associated with the summary statistic to report the statistical significance of any remaining information among the discriminator variables. There are two methods known for discriminating variables, the direct and stepwise selection methods. According to Ayogu *et al.* (2014), the direct method includes all independent variables irrespective of their discriminating power whereas in the stepwise method, inclusion in the analysis is based on the discriminating power of the independent variables.

Simon *et al.* (2010) employed stepwise discriminant function analysis to obtain 14 morphometric characters out of 31 morphometric characteristics as the discriminating characters for differentiating *Toxotes chatareus* and *Toxotes jaculatrix*. The results indicated that *T. chatareus* can be distinguished from *T. jaculatrix* by having a higher number of lateral line scales, less pectoral fin rays, and more anal fin rays using their meristic characteristics. The morphometric differentiation was evident in the lengths of the dorsal and anal spines with *T. chatareus* having shorter dorsal and longer anal spines than *T. jaculatrix.* The essence of discriminant analysis is to investigate difference among and between groups, observe if classified groups are correctly predicted and to determine percentage variance in the dependent variable explained by the independent variables (Ayogu *et al*., 2014). According to Herath *et al*. (2014), discriminant function analysis was able to distinguish between three (3) populations of *Oreochromis* *mossambicus* from three (3) different brackish water systems in Southern Sri Lanka. In this study, the discriminant functions computed successfully classified individuals into their a priori groups at a 94.4% success rate. Authors Samaradivakara *et al*. (2012), Gonzalez *et al*. (2016) and Ahammad *et al*. (2018) have respectively used discriminant function analysis to successfully group four (4) tilapia populations in selected reservoirs in Sri Lanka, populations of wild and cultured *Cichlasoma festae* in tropical Ecuadorian rivers and wild populations of *Laboe ariza* for conservation in Bangladesh. The discriminant functions used in these studies were derived from data on morphometric and meristic features of the different fish species considered for each research.

2.3 Proximate Analysis

The chemical composition of fish varies greatly from species to species and an individual to another depending on gender, age, environment and seasonal variability (Huss, 1988). The aforementioned factors therefore allow a substantial normal variation to be observed for the various constituents of fish muscle (Yeannes and Almandos, 2003). Biochemical composition of fish flesh is a credible indicator of fish quality as well as physiological state of the fish and its environment (Hernandez *et al*., 2001; Aberoumad and Pourshafi, 2010; Shamsan and Ansari, 2010; Ravichandran *et al*., 2011). Pearson and Cox (1976) and Olagunju *et al*. (2012) have reported that fish generally contains very high moisture content and this differs from one fish species to another. The moisture content ranges between 60 – 80 % whereas protein falls between 15 – 26 %, fat on the other hand is between 2 – 13 % of the bodyweight of the fish.

Mineral composition of fish is influenced by the mineral content of the water it inhabits (Shearer, 1994; Morris, 2001). Ash is the measure of the mineral component (inorganic residue) after the organic constituent has been burnt off (Olagunju *et al.,* 2012). For fish to meet these nutritional qualities, factors such as feed composition and availability, level of dietary intake and growth should be right (Svàsand *et al.*, 1998; Favalora *et al.*, 2002; and Flos *et al.*, 2002).

According to Ackman (1989), fish can be grouped into four categories according to their fat content: lean fish (less than 2 %), low fat (2 – 4 %), medium fat (4 – 8%), and high fat (greater than 8%). The body fat content of fish is related to the food and feeding habits of the fish (Love, 1957). The amount of protein in fish species depends on sex and age of the fish, its feeding habits and fat and moisture contents. Protein in fish is made up of amino acids and it also contains minerals such as calcium and phosphorus and vitamins such as vitamin A, B and D (FAO, 2016). The knowledge of the proximate composition of fishery species has fundamental importance in the application of different technological processes Stansby (1967), Connell (1975) and Huss (1988), it is also important as an aspect of grading quality of raw material, sensory attributes and storage stability in the fisheries processing industry (Sikorski, 1990).

The significance of proximate composition in tilapiine species has been investigated by several researchers. Edea *et al*. (2018) reported proximate composition in cultured *Oreochromis niloticus* of body weight ranging between 100 – 200 g and 300 – 500 g as crude protein (78.76 % and 84.11 %), ash (5.42 % and 5.22 %) and dry matter (23.95 % and 25.04 %) respectively. According to Fawole *et al*. (2007), fresh water *Oreochromis niloticus* had mean percentage crude protein of 38.40, ash of 4.55, dry matter of 92.50 and fat of 3.50. *Sarotherodon galilaeus* on the other hand was reported to have mean percentage crude protein of 41.28, ash of 4.76, dry matter of 94.20 and fat of 4.15. *Tilapia zillii* found in Iraqi waters were reported to have crude protein of 19.10 %, fat of 5.77 %, ash of 1.58 % and moisture content of 73.03 % (Saleh *et al*., 2014).

2.4 Water Quality

Water quality characteristics refer to the suitability of water for purposes such as drinking, industrial use, and fisheries. It is therefore necessary that the water meet the standard requirements for such purposes. Water quality is usually termed as physico-chemical characteristics or properties. Quality characteristics of aquatic environment result from a host of physical, chemical and biological interactions (Ugwu and Wakawa, 2012); These physico-chemical properties of natural waters such as temperature, pH, turbidity, salinity, hardness, dissolved oxygen, elements and nutrients affect the growth and health of fishes. Limited ranges and concentrations are therefore required for optimal productivity, hence testing source water for its physico-chemical properties is essential in assessing the source water suitability for aquaculture (Zweig *et al*., 1999). It is also useful for determining the contribution and impact of harvest water on productivity of its inhabitants. According to Popma and Masser (1999), Tilapias are more tolerant to high salinity, high water temperature, low dissolved oxygen, and high ammonia concentrations.

2.4.1 pH

This is a measure of H^+ concentrations. It is an indicator of relative acidity or alkalinity of a water body. Fish is said to have an optimal pH that ranges from 6.5 to 8.5. pH values below 5 will likely cause mortality in fish although some fish species may survive at a pH of between 4-10 (ORSANCO, 1955; FAO, 1993). According to Lloyd (1992) and Akintomide *et al*. (2010), several fish species survive and produce at their optimum level within pH ranges from 6.5 to 9.5 since slow growth and salt imbalance sets in at pH levels below 6.5. Ukwe and Abu (2016) also reported that pH is a factor that impacts hatchability and fertility of fish eggs. Popma and Masser (1999) however stated that, tilapia can survive in pH ranging from 5 to 10 but do best in a pH range of 6 to 9. Water source found to have pH levels lower than 6.5 should be treated with lime according to Boyd (1990).

2.4.2 Nutrients and Chlorophyll '*a*'

According to EPA (2001) nitrate found in natural waters is mostly originates from organic and inorganic sources, only a minute fraction is of mineral origin. The organic source mainly being waste discharges and the latter contributed by artificial fertilisers. On the other hand, nitrite is present in very low concentrations because the nitrogen tends to exist in the more reduced (ammonia; NH_3) or more oxidised (nitrate; NO_3) forms. Nitrate is the least toxic of the major inorganic soluble nitrogen compounds, it is formed as the end product of the nitrification process and concentrations are generally higher than both ammonia and nitrite (Zweig *et al.*,1999). Levels of nitrite in unpolluted water are usually low (< 0.03 mg/L). However, values greater than this indicate sewage pollution (EPA, 2001). High levels of nitrate can affect osmoregulation and oxygen transport, but toxic concentrations are much higher than for ammonia and nitrites (Lawson, 1995). Nitrite is toxic to many fish since it reduces capacity of haemoglobin to transport oxygen; chloride ions are effective at neutralising its toxicity. Santhosh and Singh (2007) recommended that nitrite concentration in water should not exceed 0.5 mg/L. According to Popma and Masser, (1999), Tilapias are more tolerant of nitrite than many cultured freshwater fish species, Santhosh and Singh (2007) have however suggested the favourable range in water for fish culture should fall between 0.1 to 4.0 mg/L. According to Bhatnagar *et al*. (2004), nitrate concentrations of 0.02

– 1.0 mg/L is lethal to many fish species; > 1.0 mg/L is lethal for many warm water fishes and < 0.02 mg/L is acceptable.

Phosphorus is commonly found in plants, in micro-organisms, in animal wastes etc. It is generally used as an agricultural fertiliser and as a major constituent of detergents, especially those used for domestic purposes. Run-off and sewage discharges are therefore a major contributor of phosphorus to surface waters. Phosphorus (phosphate) entering such water bodies, along with nitrogen as nitrate, promotes the growth of algae and other plants leading to blooms and diurnal dissolved oxygen fluctuations (EPA, 2001). According to Stone and Thomforde (2004) the phosphate level of 0.06 mg/L is desirable for fish culture, meanwhile, Bhatnagar *et al*. (2004) have also suggested that 0.05 - 0.07 mg/L is optimum for productivity.

Chlorophyll is a green pigment which appears naturally in algae, cyanobacteria, plants, and vegetation. Its content is affected by factors such as nutrients (phosphate and nitrite), pH, water flow and temperature of the water. Phosphorus (phosphate) tends to enrich chlorophyll whiles nitrogen (nitrite) degrades them (EPA, 2001; Herbold, 2003). Chlorophyll is essential to the existence of phytoplankton. Phytoplankton can be used as an indicator organism for the health of a particular body of water.

Monitoring chlorophyll levels is a direct way of tracking algal growth. Surface waters that have high chlorophyll conditions are typically high in nutrients, generally phosphorus and nitrogen (EPA, 2001). These nutrients cause the algae to grow or bloom. When algae populations bloom, then crash and die in response to changing environmental conditions, they deplete dissolved oxygen levels which is a primary cause of most fish kills, Adam and Keith (2012) have also reported that run offs from farm lands and dumpsites can also cause fish kills. High levels of nitrogen and phosphorus can be indicators of pollution from man-made sources, such as septic system leakage, poorly functioning wastewater treatment plants, or fertilizer runoff. Thus, chlorophyll measurement can be utilized as an indirect indicator of nutrient levels.

2.4.3 Temperature

Fishes are poikilothermic animals. Their body temperature changing with changes in the environmental temperature. It is between 0.5 and 1 °C above or below the temperatures of their microclimate (FAO, 1993). Temperature is one of the most important factors among the external factors that influence fish production (Huet, 1986). The effect of temperature, especially fluctuations in temperature, on living organisms can be critical and complex. It applies to a wide range of factors and activities. Where biochemical reactions such as in the uptake of oxygen by bacteria are involved, a rise of 10 °C in temperature leads to an approximate doubling of the rate of reaction. On the other hand, such reactions are retarded by cooling, hence the recommendation that water samples be cooled to 4 °C in the interval between sampling and analysis (FAO, 1993; EPA, 2001)

2.4.4 Dissolved oxygen

Dissolved oxygen is the volume of oxygen contained in water. It is a measure of the amount of gaseous oxygen dissolved in an aqueous solution that plays a vital role in the biology of aquatic organisms (Dhawan and Karu, 2002; Ehiagbonare and Ogundiran, 2010). Gases dissolved in water provide oxygen for metabolic processes of fish. Solubility of oxygen in water is however directly impacted by rising temperature and salinity (Herbold, 2003). Every fish species has a different requirement for dissolved oxygen concentration limits but at least a concentration of 5 mg/L is ideal for all types of fish (FAO, 1993, PHILMINAQ, 2019). Tilapias survive routine dawn dissolved oxygen (DO) concentrations of less than 0.3 mg/L, however, tilapia ponds ought to be managed to maintain DO concentrations above 1 mg/L since productivity and disease resistance decreases with decreasing DO level over an extended period of time (Popma and Masser, 1999). Riche and Garling (2003), have also reported that the preferred DO for optimum growth of tilapia is above 5 mg/L.

CHAPTER THREE

3.0 METHODOLOGY

3.1 Study Location

The study was carried out in and around selected water bodies in the Tolon, Kumbungu and West Mamprusi districts in the Northern Region of Ghana. The research period spanned from January to April 2018. The water bodies included Nasia river, Nawuni river, Golinga reservoir and Botanga reservoir. The Northern Region lies within the Guinea savannah agro-ecological zone and its vegetation is mainly made of short trees with grass under growths and drought-resistant trees such as *Acacia* and Neem. The area experiences a unimodal rainfall regime with an annual average rainfall of between 950mm – 1100m. The rainy season begins around April and peaks in August whiles the dry season begins in late October and is characterised by the harmattan winds. The temperature is at its lowest at about 15 °C in the night and its highest at about 42 °C during the day especially in March and April (Quarcoopome *et al*., 2008, Alhassan *et al*., 2015, Ghagov, 2019).

The Nasia River lies within latitude 10° 09' 27.33" N and longitude 0° 48' 13.52" W in the West Mamprusi District. The Nasia River is a tributary of the White Volta which originates from Burkina Faso. The White Volta flows southwards upon entry into Ghana, it turns west to be joined by the Red Volta and continues to flow westwards through the Upper East Region before turning south again to be joined by the Nasia River (GMA, 2019). The White Volta at Nawuni is located within latitude 9° 40' 15'.87" N and longitude1°02' 08.78" W. The White Volta flows southwards from its tributaries such as the Sissili and Nasia Rivers through Nawuni which then flows westwards to Daboya and turns to the south again to be joined by the Mole River to eventually empty into the Volta Basin (GMA, 2019).

Golinga Reservoir is situated in the Tolon District, and lies within latitude 9°21' 31.43" N and 0°57' 23.42" W. Its construction was started in 1917 and completed in 1976. It has a height and length of embankment of 4.5 m and 700 m respectively. The dugout has an area of about 18 hectares and also has a maximum storage capacity of 1.23 (10^6 m^3). It has a catchment area of 165 km^2, a mean depth of 2.7 m and a maximum depth of 4.95 m. (Alhassan *et al*., 2015; Adongo *et al*., 2017; Abobi *et al*., 2019).

Botanga Reservoir is located within latitude 9° 34' 18.58" N and longitude 1° 01' 06.98" W in the Kumbungu District. The construction of this reservoir started in 1980 and was completed in 1986. It has a height and length of embankment of 12 m and 1900 m respectively. It has a surface area of 770 hectares at maximum height and a maximum storage capacity of 25 (10^6 m^3). It also has a mean depth of 5.9 m and a maximum depth of 9.7 m. The reservoir was constructed for irrigation purposes but currently presents a flourishing fishery and an opportunity for aquaculture (IDA, 1986; Quarcoopome *et al*., 2008; Adongo *et al*., 2017; Abobi *et al*., 2019).

Plate 1: Map of water bodies

3.2 Sampling Procedures and Laboratory Analysis

The research comprised four different experiments. These included (i) interviews on management systems of the selected water bodies and their resources, (ii) morphometric measurements and meristic counts of fish samples (iii) proximate analysis on tilapiine species and (iv) physico-chemical analysis of water bodies.

3.2.1 Management of water bodies and its resources

Group and individual interviews guided by a semi structured questionnaire (checklist) was conducted for fishermen who operate in the selected water bodies. A total of 50 purposively sampled respondents were interviewed with 12, 14, 14 and 10 of the respondents coming from Botanga, Golinga, Nasia and Nawuni respectively. These interviews were recorded electronically using a voice recording device and some responses manually written in a notepad.

3.2.2 Morphometric and Meristic Characterization Study

The descriptions of the morphometric and meristic characteristics are detailed in table 1. Some pictures of how the measurements were taken are displayed in Plate 2 – 11.

Morphometric measurements and meristic counts were taken on ninety-one (91) specimens of *Oreochromis niloticus*, *Tilapia zillii* and *Sarotherodon galilaeus*. This includes thirty-nine (39) *O. niloticus*, fifteen (15) *T. zillii* and thirty-seven (37) *S. galilaeus*. These samples were collected from fishermen at landing sites at the selected water bodies. The specimen numbers are unequal because some species were unavailable during days of sampling.

Twenty-six (26) morphometric and meristic measurements of samples were taken. Eighteen (18) morphometric measurements were taken with a digital caliper, divider and measuring board. The readings were recorded in centimeters. Eight (8) meristic count of fins and spines was done and recorded as counts. Measurements were taken using the descriptions by Simon *et al.* (2010), Herath *et al*. (2014), Gonzalez *et al*. (2016) and Gholami and Shapoori, (2017).

Fin spines and rays (also known as fin formulae) were counted and recorded as counts. Fin spines in this study are solid unbranched and undivided fin rays whereas fin rays are soft, branched, divided and flexible fin rays as described by FAO (2013).

The abbreviations such as D, A, Pc, C, P were used for Dorsal fin, Anal fin, Pectoral fin, Caudal fin, and Pelvic fin respectively.

Table 1: Description of morphometric measurements and meristic counts taken on tilapiine species

Morphometric measurements	**Description**
Total length (TL)	Tip of the snout to the longest tip of the caudal fin (Plate 2)
Standard length (SL)	Tip of the snout to the base of the caudal fin
Body weight (BdyW)	Weight of fish
Body depth (BdyDpth)	The maximum vertical distance of the body (Plate 9)
Head depth (HdDpth)	The vertical distance along the opercula margin in between the dorsal head margin and ventral head margin (Plate 8)
Body width (BdyWth)	The largest width just above the gill opening (Plate 3)
Eye diameter (Eye D)	The diameter of the eye (Plate 7)
Snout length (SnL)	Tip of the snout to the front margin of the orbit
Head length (HdL)	Tip of the snout to the posterior point of the opercular membrane

Pre-dorsal length (PreDor L)	Tip of the snout to the origin of the dorsal fin
Pre-pectoral length (PrePec L)	Tip of the snout to the origin of pectoral fin
Pre-pelvic length (PrePelv L)	Tip of the snout to the origin of pelvic fin
Pre-anal length (PreAnaL)	Tip of the snout to the origin of the anal opening
Dorsal fin length (DorFin L)	Tip of the snout to the origin of the dorsal fin (Plate 6)
Pectoral fin length (PecFin L)	Length of base of the pectoral fin to the longest tip (Plate 5)
Pelvic fin length (PelvFin L)	Length of base of the pelvic fin to the longest tip
Anal fin length (AnalFin L)	Length of base of the anal fin to the longest tip
Caudal fin length (CaudFin L)	Length of base of the caudal fin to the longest tip (Plate 4)

Meristic counts	**Description**
Dorsal fin rays (DorFRay Count)	Number of dorsal fin rays
Dorsal fin spines (DorFSp Count)	Number of dorsal fin spine
Pectoral fin rays (PecFRay Count)	Number of pectoral fin rays
Caudal fin rays (CaudFRay Count)	Number of caudal fin rays
Pelvic fin spines (PelvFSp Count)	Number of pelvic fin spines (Plate 10)
Pelvic fin rays (PelvFRay Count)	Number of pelvic fin rays (Plate 10)
Anal fin rays (AnalFRay Count)	Number of anal fin rays (Plate 11)
Anal fin spines (AnalFSp Count)	Number of anal fin spines (Plate 11)

Plate 2 - Total length

Plate 3 – Body width

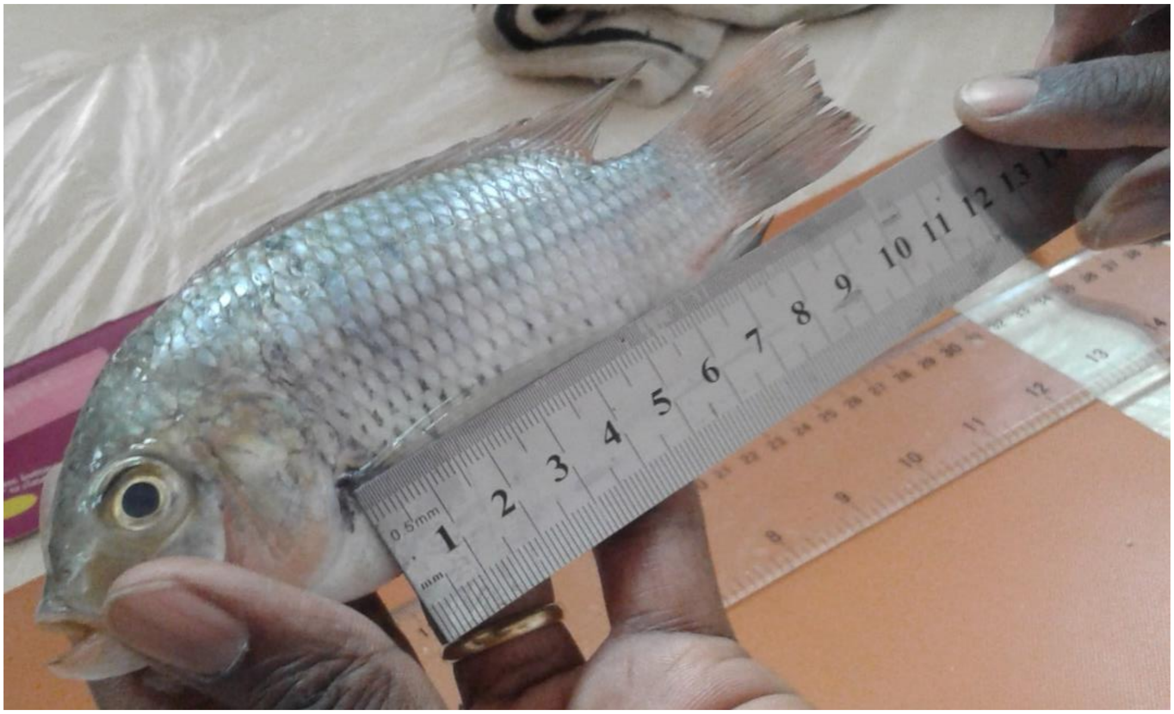

Plate 4 – Caudal fin Length

Plate 5 – Pectoral fin Length

Plate 6 – Dorsal fin Length

Plate 7 – Eye Diameter

Plate 8 – Head Depth

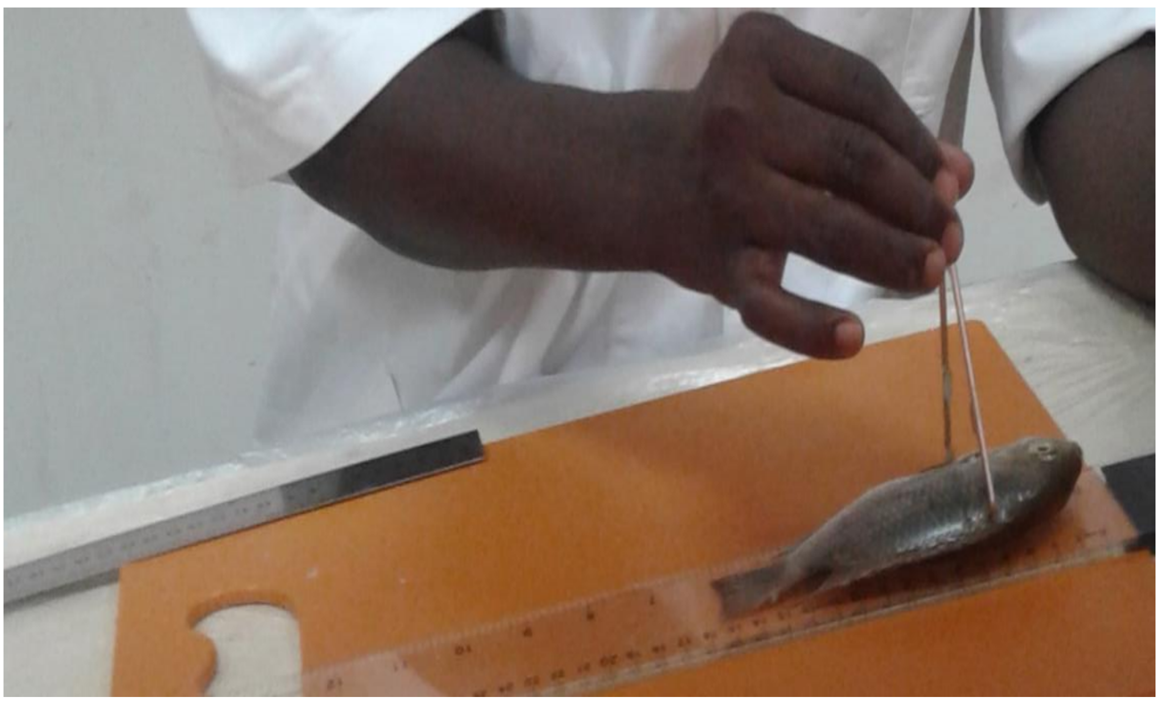

Plate 9 – Body depth

Plate 10 – Pelvic fin Counts

Plate 11 – Anal fin Length

3.2.3 Proximate Analysis of tilapiine Species

Proximate analysis of samples was performed at the University for Development Studies (UDS) Spanish Laboratory, Nyankpala and the Savannah Agricultural Research Institute (SARI) Soil Science Laboratory, Nyankpala to enhance the declaration of the nutritional composition of the tilapiine species found in the selected water bodies. The parameters determined included, crude protein, ash, fat and moisture content. A sample of each tilapiine species (*O. niloticus*, *T. zillii*, *S. galilaeus*) was filleted. The filleted fish sample was oven-dried for moisture and thoroughly mixed into a homogenous mixture.

3.2.3.1 Moisture Content Analysis

AOAC (2000) analytical method was employed to determine the moisture content of the fish sample in duplicates. After oven drying at a temperature of 105°C, the weight was taken gravimetrically until a constant weight was determined. The loss in weight was computed in percentage as indicated in the equation below:

$$\text{Moisture content} = \frac{\text{Weight of wet sample - Weight of dried sample}}{\text{Weight of wet sample}} \times 100$$

3.2.3.2 Protein Content Analysis

Kjeldahl method of protein analysis as prescribed by the AOAC (2000) was used to obtain the percentage nitrogen content of the homogenized tilapia samples. The percentage nitrogen (N) calculated was then multiplied by the 6.25 factor to estimate the crude protein content of the fish.

$$\% \text{ Crude protein} = \frac{[(\text{titre vol sample} - \text{titre vol blank}) \times 0.014 \times 0.1 \times 6.25]}{\text{Weight of sample}} \times 100$$

3.2.3.3 Fat Content Analysis

Homogenized filleted fish sample was used to determine fat content with a Soxhlet apparatus according to AOAC (2000) procedure.

Percentage fat content was computed as follows:

$$\% \text{ Fat} = \frac{\text{Weight of fat}}{\text{Weight of sample}} \times 100$$

3.2.3.4 Ash Content Analysis

Pre- weighed crucible containing homogenous tilapia sample was put into a furnace and heated at 550°C until its content was ash and grey. The grey content together with crucible was weighed and the percentage ash calculated according to AOAC (2000) procedure as indicated in the below:

$$\% \text{ Ash} = \frac{\text{Weight of ash}}{\text{Weight of sample}} \times 100$$

3.2.4 Physico-Chemical Analysis of Water bodies

Water samples were taken three (3) times from each of the water bodies in one (1) liter and 300 ml BOD bottles between 8:30 to 10:00 am on each sampling day. A total of seventy- two (72) water samples were collected from the four (4) selected water bodies. Six (6) water samples were taken per collection period (February to April) for each selected water body. In all the water samples were collected over three collection periods from each water body making a total of 18 water samples per water body. These were used to determine its physico-chemical characteristics of the water body. Out of the six samples per waterbody, two (2) samples were collected in glass biological oxygen demand (BOD) bottles whiles the other four (4) was collected in plain one (1) liter plastic bottle for nutrients and chlorophyll 'a' tests. The set of three samples each were obtained from both up and down streams of the selected water bodies. Water quality parameters that were considered for this study were temperature, pH, dissolved oxygen (DO), chlorophyll 'a' and some nutrients (phosphate - phosphorus and nitrate-nitrogen).

pH meter and a thermometer were used to measure pH and temperature respectively. The DO was fixed using the Winkler's method of azide modification Amankwaah *et al.* (2014). The chlorophyll 'a' was extracted using 90% acetone solution and the concentrations of chlorophyll 'a' was estimated spectrophotometrically as described by Amankwaah *et al.* (2014). Nutrients analyses followed standard procedures described by APHA (1998), hydrazine reduction method was used for nitrate whiles the stannous chloride method was used for phosphorus.

3.3 Data management and Statistical Analysis

All data collected were collated using Excel in Microsoft Office Home and Student 2016. Data from interviews on management of water bodies was analysed in Excel and depicted in percentages, charts and graphs. Genstat Eighteenth (18^{th}) Edition statistical package was used in analyzing data gathered for all experiments namely; morphometric characteristics, meristic characteristics, physico-chemical properties and proximate composition. Data gathered on water bodies and resources management was presented in tables, charts and a qualitative form whiles phenotypic descriptions of tilapiine species was presented in a qualitative form in a table. The alpha level used was $\alpha = 0.05$

3.3.1. Analysis of Morphometric and Meristic characteristics

The morphometric data was transformed using *natural log with base e* to establish a linear relationship between length (TL) and weight (W) with the formula below using linear regression as described by Kuriakose (2014).

$$W = aL^b \quad In \text{ transformed into } In\,(W) = In\,(a) + b\, In\,(L) \text{ or } Y = A + b\,X$$

Where *a* is the intercept, *b* is the slope or regression coefficient, *L* is the length and *W* is the weight. A regression of all morphometric characteristics on total length was estimated to determine the linear relationship between all morphometric characters and total length. The linear relationship was established based on the formula below.

$$Y = bX + a,$$

where

Y is the morphometric characters,

X is the total length (TL),

a is a constant value which is the intercept and

b is the regression coefficient (slope). The regression of body weight on total length is an expression of the length-weight relationship.

3.3.2 Characterisation of the tilapiine species using discriminant analysis

Characterization was done using the stepwise discriminant analysis in the multivariate analysis, in GenStat. The selection criterion was by Wilk's lambda whereas the error rate method was bootstrapping since this combination yielded the highest result of correctly assigning tilapiine species to a priori groups with the least error percentage. The chi-square test indicates whether the groups are significantly different in the measured characteristics. The eigen value of a discriminant function (DF) shows the proportion of the variance explained by that function and so a large eigen value indicates a strong or a powerful function.

In general form, the formula for a discriminant function is:

$$Y = (B_1)(X_1) + (B_2)(X_2) + \ldots + (B_p)(X_p)$$

where:

Y = The discriminant score,

p = The number of discriminator variables,

$B_1 \bullet\bullet\bullet B_p$ - The standardized (or unstandardized) discriminant function coefficients (i.e., weights) for variables 1 through p, and

$X_1 \bullet\bullet\bullet X_p$ = The individual's scores on variables 1 through p.

3.3.3 Analysis of proximate composition of the tilapiine species

The proximate composition parameters were also analyzed using General Analysis of Variance, means separation was done by Tukey's range test.

The factor *T* is Tilapinii species and the factor *N* is proximate composition. Statistical model for proximate composition of Tilapinii species is depicted below:

$$y_{ijk} = \mu + T_i + N_j + (TN)_{ij} + \varepsilon_{ijk}$$

where:

y_{ijk} = observation *k* in level *i* of factor *T* and level *j* of factor *N*

μ = the overall mean

T_i = the effect of level i of factor T

N_j = the effect of level j of factor N

$(TN)_{ij}$ = the effect of the interaction of level i of factor T with level j of factor N

ε_{ijk} = random error

3.3.4 Analysis of Physico-Chemical characteristics of waterbodies

Physico - chemical parameters were analyzed using the General Analysis of Variance in Genstat. The factor W is water bodies and P is physico-chemical parameters. Statistical model for physico-chemical analysis is indicated below:

$$y_{ijk} = \mu + W_i + P_j + \mathcal{E}_{ijk}$$

Where:

y_{ijk} = observation k in level i of factor W and level j of factor P

μ = the overall mean

W_i = the effect of level i of factor W

P_j = the effect of level j of factor P

ε_{ijk} = random error

CHAPTER FOUR

4.0 RESULTS

4.1.1 Background information on respondents

Majority of the respondents (56%) were from Golinga and Nasia while the least number of respondents came from Nawuni (Table 2). The study also revealed that 40 % of the respondent had primary education, 16 % had junior high education, 10 % had senior high education, 10 % had tertiary education and 20 % had no education.

A considerable number of the respondents (90 %) had between 6 and 40 years of experience with only 10 % having less than 5 years of experience (Figure 1). The age ranges of the respondents indicate that 94 % of the respondent were within the age range of 21 to 59 whiles only 6 % were 60 years and above (Figure 2).

Table 2: Percentage distribution of respondents

Communities	No of respondents	Percentage (%) distribution
Botanga	12	24
Golinga	14	28
Nasia	14	28
Nawuni	10	20
Total	**50**	**100**

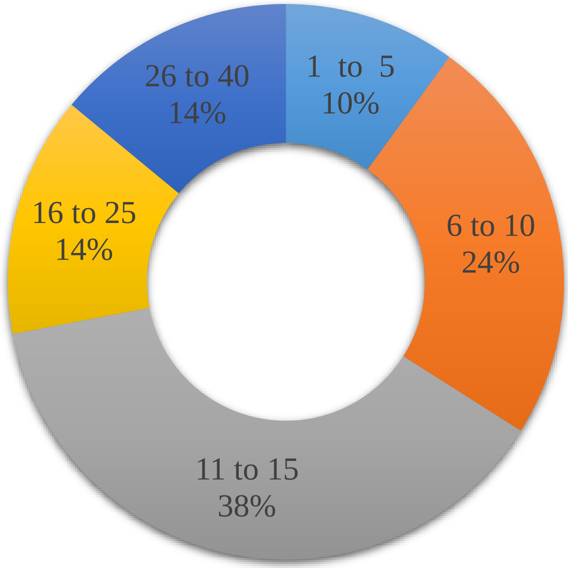

Figure 1: Years of experience of respondents and their percentage distribution

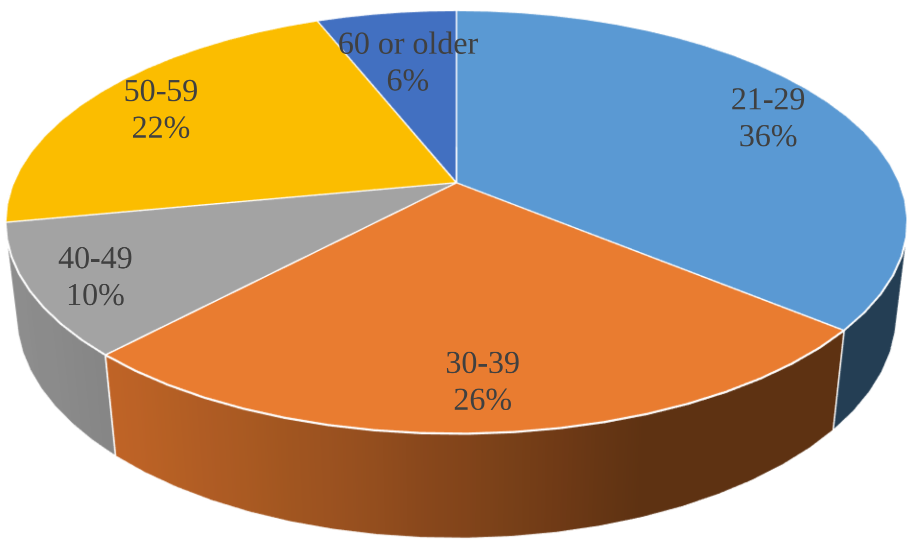

Figure 2: Age ranges of respondents and percentage their distribution

4.1.2 Fishing activities and its related practices and challenges

According to the respondents, fishing periods in the rainy season is between June and September whereas in the dry season it is between October and May. Even though fishing is done all year round, reasons such as reduction in catches, flooding or droughts and sale of fishing rights to an individual obstructs fishing activities in the study locations.

The net types commonly used in the water bodies in the study area ranged from gill nets, cast nets to woven cane or wire traps. The net sizes used in these water bodies ranges from 3 – 7 cm. The gill nets are set in the evenings and checked after 12 hours. Time of arrival at the landing sites in all water bodies was between 6:30 and 9:30am.

Some of the challenges facing fisher folks in these fishing communities are unavailability and access to inputs, cost of inputs such as nets and wood for carving canoes. Other challenges revealed during the study was reduction in fish catches generally and reduction in stock populations of the reservoirs.

4.2 Phenotypic descriptions of tilapiine species from the selected water bodies

Table 3 shows the phenotypic description of the tilapiine species identified from the selected water bodies. In all the tilapiine species, bands were usually prominent in the young ones. In the *S. galilaeus*, there were some that had no bands and others with very distinct bands. Bands on the *T. zillii* were not discernible due to their natural coloration. Bands on *O. niloticus* appeared to be continues with the dark stripes in the tail.

Table 3: Phenotypic descriptions of tilapiine species from selected water bodies

Tilapiine species	Phenotypic description	Local name
O. niloticus	The fish has a dark appearance with discernable black striations (bands) on the body. The black bands are quite obvious underwater and in live fishes. The bands on the fish are 6 - 9 on the average. They have dark stripes on the caudal, dorsal and anal fins. The ventral part from the head to the caudal fin is reddish in color. The dorsal part of the fish is dark grey but the middle towards the ventral part of the fish is lighter grey with an obvious reddish coloration at the ventral area in some (Golinga). It has reddish opercula bones. Some of the caudal and pectoral fins are reddish in color. The pectoral fin webs have a dark coloration whereas the pelvic fins take on the reddish color of the ventral areas of the fish. In some locations (Nasia) they are pale to light pink with light-red fin margins. Pictures *of O. niloticus* can be seen in Plate 12 a - c.	Akpanuhe (Nawuni Ewe) Akpanwowui (Nawuni Ewe) Akpa-logo (Nasia Ewe) Pipaa sabinli (Dagbanli)
T. zillii	Fins have a combination of dark green to yellow and reddish colorations. All the fins have yellow spots. The tail is also yellowish with reddish horizontal stripes towards the tips. Dorsal and anal fins have yellowish fins with red highlights and yellow spots. The body has a green to yellowish	Akpa chui (Dagbanli) Akpa siella or sinlla (Ewe

	coloration with a reddish belly from the lower part of the snout all the way to the caudal fin. The head has a wide mouth which is a bit raised up. Pictures of *T. zillii* can be seen in Plate 14 a - d	Nawuni and Nasia)
S. galilaeus	This fish is grey with greenish appearance, especially in the dorsal and caudal fins. They are grey in color, almost white. There are no visible stripes in the fins. The pectoral fins have some black patches and sometimes there are scattered black patches on the body as well. The end of the tail has a pinkish color with the ventral area of the body being whitish with light red highlights. The head has a grey to white color with a light red color on the operculum. They have very faint bands in dead fish but prominent bands in live and younger fish. There are obvious dark bands on the body of some of this fish. An average of 5 bands was counted on the front side when the fish is positioned on its pelvic fins with the head towards the left and the tail on the right. Pictures of *S. galilaeus* can be seen in Plate 13 a - c	Akpayi or Akpay3 (Nasia and Nawuni Ewe) Pipaa pielli (Dagbanli)

Plate 12 a: Snapshot of *O. niloticus* (Nawuni)

Plate 12 b: Snapshot of *O. niloticus* (Golinga)

Plate 12 c: Snapshot of *O. niloticus* (Nasia)

Plate 12: Pictures of *O. niloticus* from selected water bodies

Plate 13 a: Snapshots of *S. galilaeus* (Golinga)

Plate 13 b: Snapshots of *S. galilaeus* (Nawuni)

Plate 13 c: Snapshots of *S. galilaeus* (Nasia)

Plate 13: Pictures of *S. galilaeus* from selected water bodies

Plate 14 a: Snapshots of *T. Zillii* (Nawuni)

Plate 14 b: Snapshots of *T. Zillii* showing redbelly (Nawuni)

Plate 14 c: Snapshots of *T. Zillii* (Golinga)

Plate 14 d: Snapshots of *T. Zillii* (Botanga)

Plate 14: Pictures of *T. Zillii* from selected water bodies

4.3 Morphometric characteristics of tilapiine species

Descriptive statistics of morphometric measurements are presented in Table 4. *O. niloticus* used in the study had body weight ranging from of 52 – 112 g, total length ranging from 13.95 – 19.00 cm and standard length ranging from 10.70 – 14.80 cm. Body depth and body width of this species ranged from 2.25 – 4.50 cm and 1.76 – 2.33 cm respectively. *S. galilaeus* in the study had body weight ranging from 52 – 91 g, total length ranging from 14.30 – 18.00 cm and standard length ranging from 10.80 – 13.90 cm. The body depth and body width ranged from 4.30 – 6.10 cm and 1.54 – 2.19 cm respectively. *T. zillii* considered in the study had body weight ranging from 51 – 95 g, total length ranging from 14.40 – 18.30 cm and standard length ranging from 11.30 – 14.40 cm. The body depth and body width ranged from 4.00 – 5.60 cm and 1.67 – 2.40 cm respectively.

Table 4:Descriptive statistics of morphometric characteristics of tilapiine species

Morphometric characteristics	Tilapinii species	No. of observation	Mean ± SE	Minimum	Maximum
Bdy W/g	*O. niloticus*	39	72.44±2.01	52.00	112.00
	T. zillii	15	73.87±3.61	51.00	95.00
	S. galilaeus	37	70.27±1.70	52.00	91.00
TL/cm	*O. niloticus*	39	16.02±0.16	13.95	19.00
	T. zillii	15	16.04±0.30	14.40	18.30
	S. galilaeus	37	15.99±0.15	14.30	18.00
SL/cm	*O. niloticus*	39	12.51±0.13	10.70	14.80
	T. zillii	15	12.5±0.23	11.30	14.40
	S. galilaeus	37	12.29±0.12	10.80	13.90

BdyDpth/cm	*O. niloticus*	39	4.83±0.05	4.25	5.50
	T. zillii	15	4.82±0.10	4.00	5.60
	S. galilaeus	37	5.03±0.07	4.30	6.10
HdDpth/cm	*O. niloticus*	39	2.85±0.04	2.21	3.26
	T. zillii	15	2.86±0.05	2.56	3.38
	S. galilaeus	37	3.01±0.04	2.55	3.40
BdyWth/cm	*O. niloticus*	39	2.02±0.03	1.76	2.33
	T. zillii	15	2.05±0.06	1.67	2.40
	S. galilaeus	37	1.95±0.02	1.54	2.19
Eye D/cm	*O. niloticus*	39	1.19±0.02	1.04	1.45
	T. zillii	15	1.11±0.02	1.00	1.24
	S. galilaeus	37	1.22±0.01	1.06	1.44
SnL/cm	*O. niloticus*	39	1.01±0.03	0.73	1.42
	T. zillii	15	1.10±0.04	0.85	1.36
	S. galilaeus	37	1.01±0.02	0.75	1.47
HdL/cm	*O. niloticus*	39	4.28±0.05	3.60	5.00
	T. zillii	15	4.11±0.10	3.40	5.00
	S. galilaeus	37	4.27±0.06	3.75	5.70
Dorfin L/cm	*O. niloticus*	39	9.87±0.14	8.15	13.00
	T. zillii	15	10.18±0.25	8.70	12.40
	S. galilaeus	37	9.42±0.12	7.80	11.00
Pecfin L/cm	*O. niloticus*	39	5.24±0.07	4.65	6.90
	T. zillii	15	4.69±0.16	3.35	5.50

	S. galilaeus	37	5.58±0.08	4.50	6.90
Pelvfin L/cm	*O. niloticus*	39	3.98±0.06	3.00	4.80
	T. zillii	15	4.02±0.13	3.20	4.90
	S. galilaeus	37	3.99±0.05	3.35	4.60
Analfin L/cm	*O. niloticus*	39	4.47±0.08	3.65	6.50
	T. zillii	15	4.50±0.14	3.85	5.80
	S. galilaeus	37	4.43±0.06	3.70	5.50
Caudalfin L/cm	*O. niloticus*	39	3.63±0.06	3.10	5.20
	T. zillii	15	3.70±0.09	3.15	4.40
	S. galilaeus	37	3.85±0.04	3.45	4.45
PreDor L/cm	*O. niloticus*	39	3.89±0.05	3.25	4.60
	T. zillii	15	3.81±0.10	3.30	4.50
	S. galilaeus	37	3.99±0.07	3.30	5.10
PrePec L/cm	*O. niloticus*	39	4.24±0.06	3.65	5.15
	T. zillii	15	4.07±0.06	3.65	4.35
	S. galilaeus	37	4.21±0.05	3.60	4.85
PrePelv L/cm	*O. niloticus*	39	4.80±0.06	4.00	5.70
	T. zillii	15	4.66±0.09	4.10	5.20
	S. galilaeus	37	4.72±0.05	4.20	5.65
PreAnal L/cm	*O. niloticus*	39	8.30±0.08	7.30	9.80
	T. zillii	15	8.28±0.17	7.55	9.55
	S. galilaeus	37	7.98±0.08	7.05	9.30

NB: SE=Standard Error.

4.3.1 Morphometric characteristics among tilapiine species within the selected water bodies

A Table (Table 16) of descriptive statistics of morphometric characteristics within the selected water bodies is in Appendix 2. Fish samples collected from Botanga had weights that ranged from 51 – 87 g, total lengths from 13.95 – 17 cm and standard lengths from 10.70 – 13.20 cm. Tilapiine species from Golinga had a maximum weight of 112 g and a minimum of 54 g. These samples had total and standard lengths ranging from 14.30 – 19 cm and 14.80 – 10.80 cm respectively. Weights of samples from Nasia and Nawuni rivers ranged from 54 – 94 g and 57 – 95 g respectively. The maximum and minimum standard and total lengths recorded for Nasia and Nawuni were 14.90 – 18 cm and 15 – 17.90 cm respectively.

4.3.2 Regression of morphometric characteristics of tilapiine species on total length

Morphometric characteristics with the strongest positive correlation to the total length in *O. niloticus* and *S. galilaeus* are standard length (R = 0.964; R = 0.963) and dorsal fin length (R = 0.922; R = 0.908) respectively. *T. zillii* had a strong correlation with only standard length (R = 0.991). On the other hand, *S. galilaeus* had a weak positive correlation to body width (R = 0.525) whiles *O. niloticus* (R = 0.464) and *T. zillii* (R = 0.486) had a weak positive correlation to eye diameter.

The regression equations for morphometric characteristics against total length of *O. niloticus* is shown in Table 5. In *O. niloticus*, b = 2.288. The regression coefficient was significant ($P<0.05$) for all the morphometric characters expressed as a function of total length. The SL had the highest correlation (r = 0.976) to total length whereas Eye D had the lowest correlation (r = 0.464) to the total length.

Regression equations of *T. zillii* can be found in Table 6. *T. zillii* samples used in the study had b = 2.287. Except Eye D, all the regression coefficients for *T. zillii* were significant ($P<0.05$). The morphometric characters with the highest and lowest correlation to total length are SL (r = 0.991) and Eye D (r = 0.486) respectively.

Table 7 contains the regression equations. Somatic growth in *S. galilaeus* can be represented by the equation Y= 2.065TL -1.478, where b = 2.065, also indicating a negative allometric growth pattern. The highest correlated morphometric character with total length in *S. galilaeus* is also SL (r = 0.963) but the least correlated one is Bdy Wth (r = 0.525). The slope for the various morphometric characters of *S. galilaeus* expressed as a function of total length were significant (P = 0.01). The regression lines depicting these observations are presented in the figure 1,2 and 3 in Appendix 3.

Table 5: Regression of morphometric characteristics as a function of total length *(O. niloticus*)

Morphometric characteristics	a	b	R	R^2	Y= bX + a
Bdy W	-2.075	2.288	0.862	0.743	Y= 2.288TL – 2.075
SL	-0.181	0.976	0.964	0.929	Y= 0.976TL – 0.181
BdyDpth	-0.405	0.713	0.716	0.513	Y= 0.713TL – 0.405
HdDpth	-1.303	0.846	0.626	0.392	Y= 0.846TL – 1.303
BdyWth	-1.564	0.816	0.646	0.417	Y= 0.816TL – 1.564
Eye D	-1.438	0.582	0.464	0.215	Y= 0.582TL – 1.438
SnL	-3.550	1.281	0.526	0.276	Y= 1.281TL – 3.550
HdL	-1.050	0.902	0.751	0.564	Y= 0.902TL – 1.050
Dorfin L	-1.311	1.297	0.922	0.850	Y= 1.297TL – 1.311
Pecfin L	-0.330	0.716	0.568	0.323	Y= 0.716TL – 0.330
Pelvfin L	-2.399	1.362	0.844	0.713	Y= 1.362TL – 2.399
Analfin L	-2.446	1.421	0.853	0.728	Y= 1.421TL – 2.446
CaudFin L	-2.183	1.250	0.782	0.612	Y= 1.250TL – 2.183
PreDor L	-0.903	0.814	0.626	0.392	Y= 0.814TL -0.903
PrePec L	-1.160	0.938	0.705	0.498	Y= 0.938TL – 1.160
PrePelv L	-1.120	0.968	0.745	0.555	Y= 0.968TL – 1.120
PreAnal L	-0.219	0.842	0.892	0.797	Y= 0.842TL – 0.219

NB: a = Intercept; b = Slope; R^2 = coefficient of determination; R = correlation coefficient (r); X = Total length

Table 6: Regression of morphometric characteristics as a function of total length (*T. zillii*)

Morphometric characteristics	a	b	R	R^2	Y= bX + a
Bdy W	-2.055	2.287	0.832	0.693	Y= 2.287TL – 2.055
SL	-0.241	0.998	0.991	0.982	Y= 0.998TL – 0.241
BdyDpth	-0.859	0.876	0.761	0.579	Y= 0.876TL – 0.859
HdDpth	-1.066	0.762	0.746	0.557	Y= 0.762TL – 1.066
BdyWth	-2.392	1.119	0.719	0.517	Y= 1.119TL – 2.392
Eye D	-1.035	0.410	0.486	0.237	Y= 0.410TL – 1.035
SnL	-3.292	1.218	0.582	0.339	Y= 1.218TL – 3.292
HdL	-1.571	1.075	0.853	0.728	Y= 1.075TL – 1.571
Dorfin L	-0.904	1.161	0.891	0.793	Y= 1.161TL – 0.904
Pecfin L	-1.971	1.265	0.617	0.381	Y= 1.265TL – 1.971
Pelvfin L	-1.683	1.106	0.615	0.379	Y= 1.106TL – 1.683
Analfin L	-2.050	1.279	0.803	0.645	Y= 1.279TL – 2.050
CaudFin L	-1.448	0.993	0.781	0.610	Y= 0.993TL – 1.448
PreDor L	-1.849	1.148	0.854	0.729	Y= 1.148TL – 1.849
PrePec L	-0.305	0.616	0.781	0.611	Y= 0.616TL – 0.305
PrePelv L	-0.501	0.735	0.694	0.481	Y= 0.735TL – 0.501
PreAnal L	-0.129	0.808	0.734	0.538	Y= 0.808TL – 0.129

NB: a = Intercept; b = Slope; R^2 = coefficient of determination; R = correlation coefficient (r); X = Total length

Table 7: Regression of morphometric characteristics as a function of total length (*S. galilaeus)*

Morphometric characteristics	a	b	R	R^2	Y= bX + a
Bdy W	-1.478	2.065	0.830	0.689	Y= 2.065TL – 1.478
SL	-0.174	0.968	0.963	0.928	Y= 0.968TL – 0.174
BdyDpth	-0.051	0.961	0.702	0.493	Y= 0.961TL – 0.051
HdDpth	-1.891	1.080	0.748	0.559	Y= 1.080TL – 1.891
BdyWth	-1.037	0.614	0.525	0.276	Y= 0.614TL – 1.037
Eye D	-2.425	0.945	0.757	0.573	Y= 0.945TL – 2.425
SnL	-3.754	1.379	0.591	0.349	Y= 1.379TL – 3.754
HdL	-2.175	1.308	0.893	0.797	Y= 1.308TL – 2.175
Dorfin L	-1.149	1.223	0.908	0.824	Y= 1.223TL – 1.149
Pecfin L	-1.444	1.409	0.803	0.646	Y= 1.409TL – 1.444
Pelvfin L	-1.403	1.005	0.697	0.486	Y= 1.005TL – 1.403
Analfin L	-2.025	1.266	0.823	0.678	Y= 1.266TL – 2.025
CaudFin L	-1.239	0.933	0.850	0.723	Y= 0.933TL – 1.239
PreDor L	-1.438	1.017	0.602	0.362	Y= 1.017TL – 1.438
PrePec L	-1.296	0.986	0.766	0.587	Y= 0.986TL – 1.296
PrePelv L	-1.028	0.931	0.818	0.669	Y= 0.931TL – 1.028
PreAnal L	-0.460	0.915	0.894	0.799	Y= 0.915TL – 0.460

NB: a = Intercept; b = Slope; R^2 = coefficient of determination; R = correlation coefficient (r); X = Total length

4.3.3 Characterisation of tilapiine species using morphometric characteristics

Table 8 shows summary statistics of discriminant analysis. Stepwise discriminant analysis revealed that DF (Discriminant Function) 1 correctly explained 89 % of the total variance in the data while the DF 2 explained 11 %. Both functions were statistically significant for discriminating the samples but the chi-square and eigen values were higher in the DF 1 than DF 2. The morphometric characteristics used to discriminate the tilapiine species were pectoral fin length, dorsal fin length, caudal fin length, head depth, pre anal length, body depth, eye diameter, and body width.

Percentage allocation of samples to their original groups revealed that 13 out of 15 of *T. zillii* representing 74 % were correctly assigned and 26 % was wrongly allocated to *O. niloticus*. For *O. niloticus*, 32 out of 39 representing 78 % was accurately assigned, 5 (16 %) was wrongly allocated to *T. zillii* and 2 (6 %) was wrongly allocated to *S. galilaeus*. 37 (98 %) out of the 37 samples were correctly identified as *S. galilaeus* but 2 (2 %) of *O. niloticus* was wrongly assigned to this group.

Table 8: Summary statistics of discriminant analysis and test significance in canonical variate analysis

Function	Eigen value	% Variance	Chi-square	df	Significance (Pr.)
1	3.301	89	152.15	16	<0.001
2	0.408	11	28.88	7	<0.001

NB: df = Degrees of Freedom. Pr. = Probability

4.4 Meristic characteristics of tilapiine species

Table 9 depicts the descriptive statistics of the meristic characters of the tilapiine species collected for the study. Meristic characteristics of *O. niloticus* indicated its dorsal fin to have 15 – 18 spines and 11- 14 rays, anal fin had 3 spines and 8 -11 rays, pectoral fin had 13 -14, the caudal fin had 15 -18 rays and pelvic fin had 1 spine and 4 – 5 rays. The fin formula can be written as D: 15–18, 11 – 14; A: 3,8 – 11; Pc: 13 – 14; C: 15 – 18; P: 1, 4 – 5.

T. zillii meristic features indicated that the dorsal fin had 15 – 17 spines and 11 – 12 rays, anal fin has 3 spines and 8 – 12 rays, pectoral fin had 12 – 15 rays, caudal fin had 15 – 17 rays and pelvic fin had 1 spine and 5 rays. Its fin formula can therefore be given as D: 15 – 17, 11 – 14; A: 3,8 – 12; Pc: 12 – 15; C: 15 – 17; P: 1,5.

S. galilaeus samples examined indicated the dorsal fin had 15 – 16 spines and 12 – 14 rays, the anal fin had 3 spines and 9 – 12 rays, the pectoral fin had 12 – 14 rays, the caudal fin had 14 – 17 rays and pelvic fin had 1 – 3 spines and 3 – 5 rays. This translates in a fin formula of D: 15 – 16,12 – 14; A: 3,9 – 12; Pc: 12 – 14; C: 14 – 17; P:1 – 3, 3 – 5.

Table 9: Descriptive statistics of meristic characteristics among tilapiine species

Meristic characteristics	Tilapiine species	No of observations	Minimum	Maximum
Anal fin rays	*O. niloticus*	39	8	11
	T. zillii	15	8	12
	S. galilaeus	37	9	12

Anal fin spines	*O. niloticus*	39	3	3
	T. zillii	15	3	3
	S. galilaeus	37	3	3
Caudal fin rays	*O. niloticus*	39	15	18
	T. zillii	15	15	17
	S. galilaeus	37	14	17
Dorsal fin rays	*O. niloticus*	39	11	14
	T. zillii	15	11	13
	S. galilaeus	37	12	14
Dorsal fin spines	*O. niloticus*	39	15	18
	T. zillii	15	15	17
	S. galilaeus	37	15	16
Pectoral fin rays	*O. niloticus*	39	13	14
	T. zillii	15	12	15
	S. galilaeus	37	12	14
Pelvic fin rays	*O. niloticus*	39	4	5
	T. zillii	15	5	5
	S. galilaeus	37	3	5
Pelvic fin spines	*O. niloticus*	39	1	1
	T. zillii	15	1	1
	S. galilaeus	37	1	3

4.4.1 Meristic characteristics of tilapiine species within the selected water bodies

Table 10 shows the meristic characteristics of tilapiine species within the selected water bodies. Anal fin rays of fish from the reservoirs ranged from 8 – 12 and 9 – 12 for the rivers, the anal fin spines were, however, the same (3) for fish from both reservoirs and rivers. Caudal fin rays of tilapiine species from the rivers had a minimum of 15 and a maximum of 17 fins. Those from the reservoirs, on the other hand, had a minimum of 14 and a maximum of 18 fins. Dorsal fin rays of fish species from both rivers and reservoirs ranged from 11 – 14 but the spines of those from the reservoirs had a minimum of 15 and a maximum of 17 whereas the ones from the rivers had a minimum of 15 and a maximum of 18 dorsal fin spines. Pectoral fin rays of fish species from the reservoirs ranged from 12 – 14 and the fin rays of those from the rivers ranged from 12 – 15. Pelvic fin rays and spines for the tilapiine species from the reservoirs were in the ranges of 4 – 5 and 1respectively whiles that of those from the rivers was 3 – 5 and 1 – 3 respectively.

Table 10: Descriptive statistics of meristic characteristics of tilapiine species collected from the selected water bodies in Northern Region

Meristic characteristics	Water bodies	No of observations	Minimum	Maximum
Anal fin rays	Botanga reservoir	30	8	12
	Golinga reservoir	27	8	12
	Nasia river	15	8	12
	Nawuni river	19	9	12
Anal fin spines	Botanga reservoir	30	3	3
	Golinga reservoir	27	3	3

	Nasia river	15	3	3
	Nawuni river	19	3	3
Caudal fin rays	Botanga reservoir	30	15	16
	Golinga reservoir	27	14	18
	Nasia river	15	15	17
	Nawuni river	19	15	17
Dorsal fin rays	Botanga reservoir	30	11	14
	Golinga reservoir	27	11	13
	Nasia river	15	11	13
	Nawuni river	19	11	14
Dorsal fin spines	Botanga reservoir	30	15	17
	Golinga reservoir	27	15	17
	Nasia river	15	15	17
	Nawuni river	19	15	18
Pectoral fin rays	Botanga reservoir	30	12	14
	Golinga reservoir	27	12	14
	Nasia river	15	12	15
	Nawuni river	19	13	14
Pelvic fin rays	Botanga reservoir	30	4	5
	Golinga reservoir	27	5	5
	Nasia river	15	3	5
	Nawuni river	19	5	5
Pelvic fin spines	Botanga reservoir	30	1	1

Golinga reservoir	27	1	1
Nasia river	15	1	3
Nawuni river	19	1	1

4.4.2 Meristic characteristics among tilapiine species within selected water bodies

Table 11 depicts interaction of meristic characteristics between tilapiine species and the selected water bodies. Meristic characteristics of the tilapiine species among the selected water bodies studied were significantly different ($P<0.05$) for all the meristic features considered except pelvic fin rays and spines. There were differences among meristic features of tilapiine species within the selected water bodies. There was a significant difference ($P<0.05$) in the pelvic fin spines, pelvic fin rays, and pectoral fin rays, however, there were no significant difference ($P>0.05$) among all the other meristic features considered for this study. Interaction between the tilapiine species and the water bodies they were harvested from is significantly different ($P>0.05$) for all the meristic characteristics except anal fin spines which were the same for all tilapiine species from both rivers and reservoirs.

Table 11: Interaction of meristic characteristics among tilapiine species and selected water bodies

Meristic characteristics	Tilapiine species		Water bodies		Interactions	
	P- value	SED	P- value	SED	P- value	SED
Anal fin rays	<0.001	0.224	0.345	0.232	0.010	0.462
Anal fin spines	-	0	-	0	-	0
Caudal fin rays	0.003	0.183	0.255	0.190	0.010	0.379
Dorsal fin rays	0.001	0.184	0.676	0.191	0.009	0.381
Dorsal fin spines	<0.001	0.166	0.646	0.171	<0.001	0.342
Pectoral fin rays	<0.001	0.168	0.016	0.174	0.031	0.347
Pelvic fin rays	0.156	0.088	0.003	0.091	0.004	0.182
Pelvic fin spines	0.060	0.081	<0.001	0.084	0.002	0.168

NB: SED-Standard Error of Differences.

4.5 Proximate composition of tilapiine species collected from selected water bodies

Table 12 shows the results of the proximate analysis of tilapiine species collected from the water bodies. The ash content of the tilapiine species from the water bodies was not significantly different (P> 0.05). The crude protein content of the various species *O. niloticus*, *T. zillii* and *S. galilaeus* from the water bodies were significantly different (P<0.05). Dry matter and fat content of tilapiine species were also similar (P = 0.0037 and P = 0.0465). Dry matter and fat content of *O. niloticus* were not significantly different from *T. zillii* and *S. galilaeus* but there was a significant difference in that of *T. zillii* and *S. galilaeus*.

Table 12: Proximate composition of tilapiine species collected from selected water bodies

	Tilapiine species			
	O. niloticus	*T. zillii*	*S. galilaeus*	
Parameter	**Mean ± SE**	**Mean ± SE**	**Mean ± SE**	**P-value**
Ash%	5.47±0.27^{a}	5.60±0.42^{a}	5.98±0.19^{a}	0.2729
Crude protein %	48.14±2.26^{a}	37.75±1.96^{b}	38.76± 3.12^{c}	<0.0001
Dry matter%	18.64±0.37^{ab}	19.12± 0.31^{a}	18.10± 0.39^{b}	0.0037
Fat%	2.00±0.39^{ab}	2.31± 0.59^{a}	1.46± 0.53^{b}	0.0465

NB: Means with the same letter in a row are not significantly different; SE- Standard Error.

4.5.1 Proximate composition of tilapiine species within the selected water bodies

Table 13 shows the proximate composition of tilapiine species from the selected water bodies. Proximate composition of tilapiine species was significantly different (P<0.05) for all tilapiine species obtained from the selected water bodies. Percentage ash content of tilapiine species from Botanga were significantly different (P<0.05) from those from Nasia and Nawuni but not significantly different (P>0.05) from those found in Golinga. The crude protein content of fish samples from Nawuni and Golinga were similar (P>0.05) however, those from Botanga and Nasia were different (P<0.05). Dry matter content of fish from all the water bodies were similar (P>0.05) but those from Botanga and Golinga were significantly different (P<0.05). Percentage fat content of tilapiine species from Nawuni, Nasia and Golinga were not significantly different (P>0.05) however, Botanga differed significantly from tilapiine species from all water bodies except Nasia.

Table 13: Proximate composition of tilapiine species from selected water bodies

Proximate composition	Reservoirs		Rivers		P-value
	Botanga	Golinga	Nasia	Nawuni	
	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	
Ash (%)	4.98±0.37[b]	5.46±0.35[ba]	6.29±0.21[a]	6.00±0.25[a]	0.0151
Crude protein (%)	47.71±4.81[a]	39.97±2.32[b]	38.57±2.38[c]	39.95±2.80[b]	<0.0001
Dry matter (%)	18.82±0.39[b]	19.71±0.16[a]	18.16±0.28[cb]	17.79±0.39[c]	<0.0001
Fat (%)	3.16±0.40[a]	1.67±0.36[b]	2.45±0.58[ba]	1.67±0.33[b]	0.0009

NB: Means with the same letter in a row are not significantly different; SE-Standard Error.

4.5.2 Interaction between proximate composition of tilapiine species and selected water bodies

Interaction between the tilapiine species and the water bodies they were collected from was not significantly different ($P = 0.104$) for percentage ash content. Percentage crude protein, dry matter and fat however were significantly different at P - values of ($P = 0.001$, $P = 0.016$ and $P = 0.010$) respectively.

4.6 Physico-chemical characteristics of selected water bodies

Table 14 shows means and standard error of physico-chemical water quality parameters of the water bodies in the study area. The water quality parameters of the water bodies were similar ($P>0.05$). Botanga recorded the highest pH (7.68) whiles Nawuni recorded the lowest (7.61). Temperature, dissolved oxygen and nitrate levels were higher in Nasia than Golinga and Nawuni, however, Botanga recorded the lowest values respectively. All water bodies low chlorophyll 'a' concentration < 0.001μg/L

Table 14: Physico-chemical parameters of water bodies

Physico-chemical parameters	Water bodies				P-value
	Botanga	Golinga	Nasia	Nawuni	
	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	
pH	7.68±0.20	7.62±0.07	7.39±0.10	7.61±0.13	0.500
Temperature (°C)	27.42±0.76	28.19±1.57	29.85±2.10	28.94±0.79	0.839
Dissolved oxygen (mg/L)	3.47±0.21	3.62±0.28	3.81±0.10	3.65±0.11	0.719
Nitrate (mg/L)	0.28±0.07	0.43±0.18	0.47±0.26	0.29±0.04	0.616
Phosphorus (mg/L)	0.00±0.00	0.16±0.13	0.01±0.01	0.00±0.00	0.249
Chlorophyll 'a' (μg/L)	<0.001	<0.001	<0.001	<0.001	*

NB: SE- standard Error

4.6.1 Comparison of the physico-chemical parameters of water bodies

Table 15 shows a comparison of the physico-chemical parameters of the rivers and reservoirs. The results revealed that the physico-chemical characteristics of rivers were not significantly different (P>0.05) from those of the reservoirs. The reservoirs had the highest pH and phosphate levels of 7.65 and 0.083, respectively, while the rivers recorded the highest temperature (29.40 °C), dissolved oxygen (3.73) and nitrate (0.38) values. All water bodies had a chlorophyll 'a' concentration of <0.001μg/L.

Table 15: Comparison between the Physico-chemical parameters of Reservoirs and Rivers

	Water bodies		
	Reservoirs	Rivers	
Physico – chemical parameters	**Mean ± SE**	**Mean ± SE**	**P-value**
pH	7.65±0.10	7.50±0.09	0.300
Temperature (°C)	27.81±0.82	29.40±1.05	0.283
Dissolved oxygen (mg/L)	3.54±0.16	3.73±0.08	0.339
Nitrate (mg/L)	0.36±0.09	0.38±0.13	0.885
Phosphorus (mg/L)	0.083±0.07	0.004±0.00	0.251
Chlorophyll ‘a’ (µg/L)	0.001±0.00	0.001±0.00	*

NB: SE- standard Error

CHAPTER FIVE

5.0 DISCUSSION

5.1 Management system of water bodies and their resources

This study recorded 14 respondents from Golinga and 12 respondents from Botanga, however, according to a survey conducted between July 2016 and June 2017 by Abobi *et al*. (2019), Botanga and Golinga had 96 and 18 active fishermen respectively. This could be because full-time fishermen in Botanga and Nasia move to the Black Volta at Buipe and the Red Volta (Pwalugu) and other nearby towns respectively to ply their trade when catches in the water bodies in their communities are low. In Nasia particularly, the chief sells the fishing rights to the river to individuals and this unfortunate situation results in migration of some fishermen and economic losses because this river falls within the flood plains and is likely to be restocked during the rainy season. Quarcopoome *et al*. (2008) reported that the high number in fish species in Libga reservoir in contrast to Botanga could be attributed to restocking during the flooding in the rainy season.

In Nasia and Golinga, fish is brought to the landing site twice in a day (5:30 – 7:00 am; 3:00 – 4:00 pm) and (7:00am – 9:00 am; 1:00 – 3:00 pm) for Golinga and Nasia respectively. Conversely fish is only available in Botanga and Nawuni only in the mornings between 7:00 – 9:00 am. Some of the fishermen fish full time whiles others engage in carpentry, school or farm in the rainy season when water levels make it difficult for fishing in their small canoes. Gill nets are set in the evening around 4:00 pm and checked about 12 hours later in the early hours of the day in all the study areas; Abobi *et al*. (2019) reiterated that gill nets are set at 4.00 pm and removed before 11.00 am the next day. In Nasia and Nawuni however, traps made of wire gauzes and woven cane baskets are also used respectively in the dry seasons. In Nasia, these traps are used when the water levels have reduced but in Nawuni, the traps are used in the Oxbow lake.

In Botanga, the reservoir is managed by Irrigation Development Authority (IDA). When fishermen find an alarming number of dead fish in the reservoir IDA intervenes with the farmers to minimize losses. Runoffs from farms, dumpsites, and urban centers can alter the water quality of water bodies which can result in fish kills (Rao, 2011; Adam and Keith, 2012 and Amankwaah *et al.*, 2014). With the other communities, the water bodies fall under the custody of the chiefs, Nawuni and Golinga fishermen pay homage to the chief before the onset of fishing but in Nawuni, an additional sacrifice is offered to the river gods. In the case of Nasia, the chief sometimes sells fishing rights to an individual for a period of time and within that period other fishermen are banned from fishing in the river. A deliberate attempt will have to be made at restocking the Golinga and Botanga reservoirs since restocking from the main rivers are unlikely. Neither the fishermen nor any organization has re-stocked the reservoirs. Botanga however, may have some species being introduced into it since some public universities and research institutions in the country run experiments in the reservoir.

Both Golinga and Nasia mostly rely on water bodies for all domestic activities. Golinga has rules in place to prevent the pollution of the water and this includes entering the water barefoot, watering animals at a particular point, an area reserved for washing and on rare occasions ban on fishing. On the other hand, the rules governing the use of the Nasia river were not adhered to, animals were observed drinking inside the river, children doing dishes and laundry in the river and donkey with cart fetching water for domestic use all in very close proximity. Amankwaah *et al.*

(2014) agreed that certain activities contributed to the pollution of water bodies; EPA (2001) has also indicated that pollution may lessen the utility of water bodies for use as public water supply.

The fishermen in all the communities also complained about the dwindling nature of sizes and number of catches compared to previous years and attributed it to temperature, the pattern and amount of rainfall. Bimal *et al.* (2010) implicated erratic changes in climate due to the sensitive nature of the habitat of fishes to the variations in climate conditions. Abobi *et al*. (2019) reiterated that for the past 20 years catches from reservoirs in northern Ghana have been reported by (Abban *et al*., 2002; Amevenku and Quarcoopome, 2006) to be dwindling and could be attributed to overexploitation of stocks, environmental degradation and low water levels which impact fish productivity negatively.

5.2 Morphometric characteristics and characterisation of tilapiine species within the selected water bodies

Morphometric characteristics observed for growth pattern in conjunction with total length exhibited a linear relationship as reported by Brraich and Akhter (2015), Ambily (2016), Fagbuaro *et al.* (2016) in *Crossocheilus latius latius and Garra goytla goytla* in separate experiments, *Arius subrostratus* and *O. niloticus and T. zillii* in reservoirs in Nigeria respectively. For all the tilapiine species observed, there was a very strong relationship between the standard length and total length. Over 90 % of the variation in standard length can be explained by total length for *O. niloticus* (R^2= 0.929), *T. zillii* (R^2 = 0.982) and *S.galilaeus* (R^2 = 0.928), however, the weakest links in the model is body width for *S.galilaeus* and eye diameter for *O. niloticus* and *T. zillii*. Only 27.6 %, 21.5% and 23.7% of their respective values fit in the model. Fagbuaro *et al.* (2016) demonstrated a relationship between the standard length and total length of *O. niloticus* and *T. zillii* in reservoirs in Southwestern Nigeria. Morphometric and meristic characteristics of fishes reveal crucial information on the geographic allocation and stock structures (Fagbuaro *et al.*, 2016). According to Tandon *et al.* (1993) the growth of all other body parts is proportionate to total length; however, standard length is a measurement of total length minus the tail, hence the strong positive correlation between TL and SL. The variations observed in morphological characters among and between the same species highlights the alteration of the usual environmental condition of their habitat. These variations could be due to genetic and environmental influence such as unavailability of food and pollution. (Allendorf *et al.*,1987; Wimberger, 1992; Ambily, 2016).

Bhatt *et al*. (1997) also observed eye diameter to have the weakest correlation to the total length in a study of T*or putitora* in river Ganga. The other morphometric characters that had positive correlation to total length are pelvic fin length, anal fin length and pre anal fin length for *O. niloticus*. *T. zillii* recorded high correlation in head length, dorsal fin length, anal fin length and pre dorsal length whiles *S. galilaeus* highly correlated with head length, pectoral fin length, anal fin length, caudal fin length, pre pelvic and pre pectoral lengths. These findings conform with Johal *et al*. (1994) and Bhatt *et al*. (1997) who also found the standard length to have a very strong correlation to the total length in *Tor putitora* from a reservoir and a river respectively. Head length also had a high correlation in *T. zillii* and *S. galilaeus* for this study and in *Nandus nandus* as reported by Goswami and Dasgupta (2007). Even though anal fin length is one of the least correlated in the abovementioned study, it was among one of the highly correlated body parts in all tilapiine species observed in this study.

Length-weight values recorded for *O. niloticus*, *T. zillii* and *S. galilaeus* was 2.288, 2.287 and 2.065 respectively. These values were less than 3 and therefore indicated negative allometric growth. This could mean that, in small-sized samples, the specimen had a better nutritional provision during the sampling period (Kuriakose, 2014). The average weight of the tilapiine species used in this study ranged from 70.27 ± 1.70 g – 73.87 ± 3.61 g and recorded a (b) value ranging from 2.065 – 2.288 whereas Fagbuaro *et al.* (2016) reported b values ranging from 2.5 – 3.5 in different sexes of *O. niloticus* and *T. zillii* of weights ranging from 162.2 ± 33.24 g – 170.2 ± 31.84 g respectively.

Imam *et al*. (2010) also reported b values of 1.5 and 2.5 (negative allometry) in *T. zillii* for wet and dry seasons respectively in Wasai reservoir in Kano, Nigeria. It also exhibited negative allometry in freshwater but positive allometry in 35ppt salinity water in a research by Nehemia *et al*. (2012). Mossad, (1990) and Ibrahim *et al*. (2008) also reported a negative allometric growth in *T. zillii* in brackish water indicating that habitat (ecosystem) and salinity could influence growth pattern of fish. Olufeagba *et al*. (2015) reported negative allometric growth in *O. niloticus* (2.29) and *S. galilaeus* (2.47) whereas Alhassan *et al*. (2015) reported an isometric growth in *O. niloticus* (3.07), negative allometry in *T. zillii* (2.75) and *S. galilaeus* (2.91) from Golinga reservoir in Ghana.

It is opined that fish with thin elongated bodies tend to have values of $b<3$, implying fish become slenderer with an increase in weight whiles thick-bodied fish tend to have $b>3$, implying fish become deeper-bodied with increasing length (Riede *et al*., 2007; Kuriakose, 2014). Growth of the body parts is proportional to the growth of the total length. Therefore, morphometric measurement of fishes and statistical relationship among and between them are crucial to the taxonomic study of a species (Tandon *et al.*,1993).

The variables that played an important role in discriminating between the tilapiine species considered for this study are pectoral fin length, caudal fin length, head depth and body depth for DF1. Eighty-nine percent (89 %) of the between-groups variation was accounted for by DF1, the eigen value of the DF1 was higher than that of DF2 indicating that DF1 had a higher discriminating ability than DF2. According to Samaradivakara *et al*. (2012) the function with the larger eigen value explains more of the variance in the dependent variable. One of the discriminating variables in that study also included body depth. Body depth as an influential predictor variable has been reported by authors Gonzalez *et al*. (2016) and Ahammad *et al*. (2018) in studies on *cichlosoma festae* and *Labeo azaria* respectively. In Herath *et al*. (2014) caudal fin length and body depth were reported among the discriminating characters in *Oreochromis mossambicus.*

5.3 Meristic and phenotypic characteristics of tilapiine species

Dorsal and anal fin spines and ray counts reported in this study for *O. niloticus* are similar to counts reported by Trewavas (1983), Akel (1989), Bakhoum (2002) and Genner *et al*. (2018). Pectoral fin ray counts for *O. niloticus* reported by Bakhoum (2002) was 12 – 15 rays whereas the count recorded for this study ranges from 13 – 14. Number of Anal fin (12 – 14 rays), dorsal fin (14 – 17 spines, 9 – 13 rays) and pectoral fin (12 – 14 rays) counts for *T. zillii* recorded is similar to counts published by Akel (1989), Abdalla (1995), Anene (1999), Teugels *et al*. (2003) and Genner *et al.* (2018). *S. galilaeus* counts for dorsal and anal fin spines and rays are similar to the counts observed by (Teugels *et al*., 2003; Stiassny *et al*., 2008). According to Barlow (1961) variations in meristic counts are attributed to genetics and environment. Meristic characters are generally determined during early development. Evidently, the serial element is determined by developmental rate where larger developmental periods eventually results in higher meristic structures. Tanning (1952) has associated variations in species characteristics to temperature, implying a high correlation between environments with lower temperatures to higher meristic counts.

According to van Oijen (1995) and Teugels *et al.* (2003), *T. zillii* have a brownish to olivaceous dorsal, anal and caudal fins with yellow spots and a dorsal fin outlined by a narrow orange band. They are said to have a pinkish chest with no bifurcated dark vertical bars on the flanks and the dorsal and caudal fins may or may not be feebly blotched. This description fits what was observed in this study except for the narrow orange band outlining the dorsal fin. On the contrary, Williams *et al.* (2008) reported there were black spots outlined in yellow on their caudal fins but yellowish spots were observed on the caudal, anal and posterior portions of the dorsal fins. The chest or ventral region was observed as reddish in this study instead of pink. These differences could be due to the environment and the geographic locations. Moyle (1976) also observed that in a non-breeding one, the sides have an iridescent sheen with 6 – 7 poorly defined vertical bars with yellow spots on the entire fin and in the breeding one, the fish has a shiny dark green on the back and sides with red and black on the throat and belly with distinct vertical bands. This demonstrates that age, season and reproductive stages in the fish could also influence its appearance.

In *S. galilaeus*, reproductive fishes are greyish in the dorsal region and silvery in the ventral parts with a pinkish margin of caudal and dorsal fins. In adults, the sides and fins are light silver to grey with a white belly. In the young ones, however, fins are grey with upper margins of especially dorsal fin being rosy red. The body has the signature grey – slivery coloration with narrow black crossbars on the sides (Teugels *et al.*, 2003; Stiassny *et al.*, 2008). This indicates that most of the fish caught during the course of this study were between the young and juvenile stages. The most distinct characteristic of the *O. niloticus* is the vertical stripes throughout the depth of the caudal fin. Eccles (1992), Teugels *et al.* (2003) and Genner *et al.* (2018) reiterated that the vertical stripes are present at all life stages and this corroborates the observation in this current study. Trewavas (1983) described the breeding male to have a dusky grey color around the throat, chest, and belly whiles females and young ones have a pale slate-grey body and white chest, belly and pelvic fins as was observed in some samples in this study.

There was a significant difference of interaction between the water bodies and tilapiine species in respect to only 3 meristic features (pectoral fin rays, pelvic fin spines, and pelvic fin rays), all the others were not significantly different ($P>0.05$). This could be attributed to the insignificant differences in the water quality parameters of the water bodies discussed earlier. Barlow (1961) has indicated that variations in habitats have an enormous influence on meristic characteristics. On the other hand, except for pelvic fin spines and rays that were not significantly different ($P>0.05$), all other meristic characters among the tilapiine species were significantly different ($P<0.05$). This is to be expected because they merely belong to the same tribe (tilapiine species) but *T. zillii*, *S. galilaeus* and *O. niloticus* belong to the genus *Tilapia*, *Sarotherodon* and *Oreochromis* respectively, albeit being cichlids (Trewavas, 1983). These differences make them susceptible to variations in their morphometric and meristic characteristics due to variations resulting from internal and external environmental conditions, gender, type of food and its availability and predator-prey interactions as highlighted by Dasgupta (1991). Goswami and

Dasgupta (2007) also mentioned that the environment affects morphometric characters of fish and these environmentally stimulated phenotypic variations offer superiority in the fish stock structure.

5.4 Proximate composition of tilapiine species collected from selected water bodies

The proximate composition of tilapiine species *O. niloticus, T. zillii,* and *S. galilaeus* in this study had percentage ash content ranging from 5.47 – 5.98 %, this was similar to reports by Edea *et al*. (2018) who reported ash content in *O. niloticus* to range from between 5.22±0.04 – 5.42±0.20 %. Daniel *et al*. (2016) and Akongyuure *et al*. (2015) also reported an ash content of 6.17±0.28 – 7.20 ±1.67 % and 6.33±0.21 % respectively. Several other authors, Job *et al.* (2015), Mohammed *et al.* (2016) and Jim *et al.* (2017) reported ash content values lower than the values recorded in this current study. *T. zillii* from the selected water bodies recorded an ash content of 5.60±0.42% which is higher than that of Olagunju *et al.* (2012), Taşbozan *et al*. (2013), Saleh *et al.* (2014) and Adewumi *et al.* (2014) who recorded lower ash content ranging from 0.43 –1.58 % in *T. zillii* from different water bodies. The percentage ash content of 5.98±0.19 was recorded for *S. galilaeus*. Ash content ranging from 4.70 - 5.80 % and 4.76 % was recorded by Sadiku (1988) and Fawole *et al.* (2007) respectively. However, Bombata-Fashina *et al*. (2013) recorded lower values such as 1.75 %. These high percentage ash content indicate that the tilapiine species from the selected water bodies are high in minerals which could be a result of the high mineral content of the water bodies from which the fishes were harvested.

Higher percentage crude protein values ranging from 55.88 – 84.11 % were however reported by El-Zaeem *et al.* (2012), Akongyuure *et al.* (2015) and Edea *et al*. (2018) respectively for *O. niloticus*. On the other hand, Mohammed *et al.* (2016) reported crude protein content of

30.33±0.55 – 32.77±0.37 % which were lower than the value recorded for the present study. Crude protein percentage of 55.80 – 67.70 % and 41.28 % was recorded by Sadiku, (1988) and Fawole *et al.* (2007) for *S. galilaeus* in contrast to the 38.76±3.12 % recorded in this current study. Contrary to these, Bombata-Fashina *et al*. (2013) and Adewumi *et al.* (2014) reported lower values for this species. *T. zillii* has been reported to have lower protein content than the value recorded in this study. Olagunju *et al.* (2012), Adewumi *et al.* (2014) and Saleh *et al*. (2014) have all recorded percentage crude protein values lower than 37.75±1.96 %. High protein content observed in the tilapiine species is an indicator that tilapias are proteinaceous and have the potential to provide a cheap source of protein to communities where the selected water bodies are found.

Water constituting 80 – 85 % of total weight of fish (Vinogradvo, 1953) is the most appropriate opening to the discussion of the dry matter content of the tilapiine species considered for this study. The percentage dry matter content for the species analyzed ranged from 18.10±0.39 – 19.12±0.31 % which translates into 80.88 – 81.90 % moisture. Dry matter for *O. niloticus* for this study is18.64±0.37% but other researchers, Mohammed *et al.* (2016), Jim *et al.* (2017) and Edea *et al.* (2018) have recorded values ranging between 19.18 – 24.70 %, 23.00±0.89 – 28.66±1.96 % and 23.95±0.19 – 25.04±0.51 % respectively. Akongyuure *et al.* (2015) and Job *et al.* (2015) reported the moisture content to be 77.83±0.601 and 80.90 % in wild *O. niloticus* respectively. Dry matter content recorded by *T. zillii* in the present study is 19.12±0.31 % but (Taşbozan *et al.*, 2013) reported a dry matter content of 26.03±0.61 % for this same species. *S. galilaeus* recorded a dry matter content of 18.10±0.39 % which translates into 81.90 % moisture content in this study whiles Fawole *et al.* (2007) reported 94.20 % moisture content and Bombata-Fashina *et al*. (2013) reported 79.33 % in *S. galilaeus*. The percentage dry matter and its corresponding moisture content corroborate statement that fish contains very high moisture content and in most fish species the moisture content is between 60 ‑ 80 % even though on some occasions some extreme values are reported (Pearson and Cox, 1976, Olagunju *et al*., 2012).

S. galilaeus recorded the least percentage crude fat (1.46±0.53). This is similar to the range of values reported by Adewumi *et al.* (2014) and slightly lower than the values observed by Bombata-Fashina *et al.* (2013). *O. niloticus* recorded the second least percentage fat content (2.00±0.39) in this present study. It however, falls within the range of 1.73 - 3.17 % reported by Jim *et al.* (2017). Akongyuure *et al.* (2015) reported a lower value whereas Fawole *et al.* (2007) reported a higher value than the one presently reported.

T. zillii contained the highest percentage crude fat (2.31±0.59%) among the tilapiine species observed for this study, several authors Olagunju *et al*. (2012), Taşbozan *et al*. (2013), Saleh *et al*. (2014) and Adewumi *et al.* (2014) have all recorded percentage crude fat values higher than the value being reported for this study. According to Sadiku (1988), lipid accumulation being a function of depth is highlighted in this study. The fat content observed in these tilapiine species indicates that fishes from different longitudinal and vertical locations vary in lipid content since *T. zillii* which is known to be an opportunistic bottom feeder (Akinwunmi, 2003) also had the highest fat content. Benson and Lee (1957) observed that in deep waters, teleost adapted to cold temperatures by storing high amounts of unsaturated fat as compared to their counterparts in shallow and warmer surface waters.

5.4.1 Proximate composition of tilapiine species within and between the selected water bodies

Interaction of the proximate composition parameters measured among Tilapinii species within the selected water bodies recorded values which were not significantly different (P>0.05) in the ash content of all tilapiine species. There was significant difference among the crude protein, dry matter and fat contents of the tilapiine species within the selected water bodies. Within the selected water bodies, ash content of tilapiine species from rivers was significantly different (P<0.05) from those from reservoirs. However, ash content of tilapiine species from Golinga (reservoir) were not similar to the ash content of tilapiine species from the rivers. The mean ash content of tilapiine species from the rivers was 6.00±0.25 % and 6.29±0.21 % and that of reservoirs was 4.98±0.37 % and 5.46±0.35 %. Ash content of 6.33±0.211 has been reported in wild *O. niloticus* by Akongyuure *et al.* (2015) whereas values such as 1.20 and 1.42 – 1.88 % have been reported for *O. niloticus* and *T. zillii* from rivers respectively by Isah *et al.* (2014) and Job *et al.* (2015). In the reservoirs, Fawole *et al*. (2007) reported an ash content of 4.55 in *O. niloticus* and 4.76 in *S. galilaeus*. Ash content of the tilapiine samples collected from the selected rivers and reservoirs is high and this could be due to the natural mineral content of these water bodies. Jim *et al.* (2017) has opined that, the concentration of minerals in harvest waters influences the minerals preserves in fishes inhabiting it, the type of muscle used for the analysis can also influence the ash content (Sadiku, 1988).

Percentage crude protein content of tilapiine species from Botanga (reservoir) and Nasia (river) was significantly different from each other but not for Golinga (reservoir) and Nawuni (river), this was the case in percentage fat content as well. Studies by Mohammed *et al.* (2016) in Sudanese reservoirs in summer produced crude protein ranging from 30.22±0.55 – 32.77±0.37 %

and crude fat content ranging from 7.00± 0.23 – 7.53±0.10 % in *O. niloticus*. Taşbozan *et al*. (2013) in a river in Turkey reported crude protein of 18.75±0.01 % and crude fat of 2.64±0.07 % in Tilapia spp. Lastly, Sadiku (1988) reported crude protein ranging from 55.80 – 67.70 % and crude fat ranging from 15.90 – 22.80 % in *S. galilaeus*. These values corroborate the values reported in this study. The high protein and fat content values reported could be as a result of high aquatic plant activities during the dry season leading to an abundance of food for the fish in the water. Love (1957) documented high protein and lipid content in tissue muscle occurring slightly in protein but rapidly in lipids during the food abundant period in summer and food deficit period in winter in the temperate region. Efficiency with which tilapias harvest and use food in their natural environment according to Popma and Masser (1999) could also be a reason for the high protein content registered in the tilapiine species from these selected reservoirs and rivers.

Percentage dry matter of fish amounts to 15 – 20 % of its body weight (Love, 1957), the dry matter content of the tilapiine species obtained from the selected water bodies ranged between 18.10±0.39 – 19.12±0.31 %. These values are within the range reported by Love (1957). All fish from both rivers and reservoirs had high moisture content which increases their susceptibility to microbial spoilage, degradation by oxidation reaction of its fatty acids and an overall decrease in the quality of the fish due to extended periods needed for preservation (Omorola and Omotayo, 2008; Olagunju *et al.,* 2012). Several experimenters Bombata-Fashina *et al.* (2013), Taşbozan *et al*., (2013), Adewumi *et al.* (2014) and Job *et al.* (2015) have also reported similar percentage dry matter and moisture content values for tilapiine species from both rivers and reservoirs.

5.5 Physico – chemical characteristics of the water bodies

The pH recorded ranged between 7.39 and 7.68, Popma and Masser (1999) reported that tilapia generally performs at their optimum at pH ranges of 6 to 9. pH of water bodies during the sampling period fell within the recommended range suitable for fish growth and survival Davis (1993). Tepe *et al.* (2005) and Amankwaah *et al.* (2014) have recorded similar values ranging from 7.6 to 7.9 and 7.7 to 8.7 respectively. Fish species experience slow growth and their capacity to maintain salt balance is reduced at a pH below 6.5 (Lloyd, 1992; Akintomide *et al.*, 2010). pH is considered as an integral contributor to fertility and hatchability of fish egg (Ukwe and Abu, 2016), therefore the selected water bodies meeting these recommended limits makes them adequate for aquaculture.

Temperatures in this study ranged from 27.42 °C to 29.85 °C. These values are within the optimum range (20 – 30 °C) reported by Boyd (1990) and the FAO (2006) recommended temperature range (25 – 30 °C) for optimum yield in aquaculture. Temperatures recorded for both rivers and reservoirs in the study are within the desirable ranges recommended for fish production. Temperatures are generally climatologically influenced and February to April is a period with high temperatures. Alhassan *et al.* (2015) indicated that the areas in the same ecological zone as the Botanga, Golinga, Nasia and Nawuni recorded maximum temperatures of 42 °C in March and April. Similarly, Tepe *et al.* (2005) recorded temperatures as high as 29.1°C in Yarseli lake in Turkey and (Amankwaah *et al.,* 2014) recorded temperatures ranging from 22.1 to 27.38°C for Asuofia stream and 23.9 to 29.2°C for pond samples at Nkawie in Ghana. Contrastingly, Ezeanya *et al.* (2015) recorded a temperature of 26.9°C in Otamiri river in Nigeria.

DO levels in the water bodies during the study period ranged from a mean of 3.47 – 3.81 mg/L. Lloyd (1992) indicated that the tolerable level of DO for tilapia is 3 – 4 mg/L but the preferred level is >5 mg/L. DO levels ranging from 2.8 - 6.0 mg/L has been reported by Keremah *et al.* (2014) for pond water in fresh water areas in Bayelsa State, Nigeria. The importance of DO is directly connected to aquatic life as it is needed for respiration and metabolic activities. The critical concern with oxygen solubility is that it has an inverse relationship with temperature and therefore high temperatures will result in lower DO levels (EPA, 2001). DO levels in the selected water bodies did not differ statistically but DO level in the rivers was slightly higher than that of the reservoirs albeit the former recorded the highest temperature. Daily fluctuations of DO levels in impounded waters is much higher than those in running waters, with low levels often occurring around dawn to early hours of the day and high levels occurring in the late afternoons (Boyd,1990).

Nitrate levels recorded in this study ranged between (0.28 and 0.47 mg/L) and were within the optimum range (< 0.5mg/L) for freshwater fish as indicated by Swann (1993). Amankwaah *et al.* (2014) and Ezeanya *et al.* (2015) recorded a mean nitrate level of 0.015mg/L and 5 – 7.57 mg/L respectively which is higher than the mean nitrate level recorded in this study. These values were however within the 16.9 mg/L maximum limit indicated by Schwartz and Boyd (1994). High levels of nitrate can cause eutrophication, algal bloom, osmoregulation and oxygen transport (Lawson, 1995). Nitrate is found as the end product of the nitrification process, and high levels of nitrate affect osmoregulation and oxygen transport (Lawson, 1995). According Oboh and Egun (2017) the mean nitrate concentrations of 0.15 mg/L which is considered the permissible concentration of nitrate in aquaculture is less than 3 mg/L. Several researchers have also recorded values that corroborate values recorded in this study (Meade,1989; Zweig *et al.*,1999; Akintomide *et al.*, 2010).

For lakes or reservoirs, phosphate concentration should not exceed an average of 0.05 mg/L nor a maximum of 0.1 mg/L (DAO, 1990). Phosphorus levels recorded were on average, lowest of 0.00 mg/L to highest of 0.16 mg/L. Phosphate levels of <0.01 mg/L has been reported as acceptable by ANZECC (2000) whiles in the Philippines, an average range of < 0.05 to 0.1 mg/L was recommended as acceptable by PMNQ (2019). Amankwaah *et al*. (2014) recorded a mean level of 0.64 mg/L in ponds which is higher than the values recorded in this study and a lower mean level of 0.07 - 0.09 mg/L in streams which is within the range recorded in this study. Oboh and Egun (2017) also reported a mean of 0.09 – 0.46 mg/L when they tested the suitability of groundwater for aquaculture in Agbor, Delta State in Nigeria. (EPA, 2001).

Both reservoirs and rivers had phosphorus levels that were not significantly different but the reservoirs had relatively higher phosphorus levels (0.083 mg/L) than that of the rivers (0.004 mg/L). Phosphorus is also a major constituent of detergents, particularly the ones used for domestic activities (PMNQ, 2019). According to EPA (2001) phosphorus widely occurs in plants, animal waste, and micro-organism, however, run-offs and sewage discharges are a major contributor to phosphorus in surface water and is key to the phenomenon of eutrophication which is basically over-enrichment of lakes and rivers. Phosphorus gains access to these water bodies, along with nitrogen as nitrate and promotes the growth of algae and other plants resulting in blooms. This is the case for the water bodies that were observed in this study. They were surrounded by farmlands and so runoffs from these farms end up in these water bodies which resulted in the growth of some aquatic plant in the impoundments during the sampling period.

Chlorophyll 'a' concentration in all selected water bodies was < 0.001µg/L and can therefore be considered to be oligotrophic. Chlorophyll is one of the most important parameters in the assessment of the water quality of lakes with regards to their trophic quality (ANZECC, 2000; EPA, 2001). The trophic quality is a measure of the degree at which a water body is enriched due to the presence of nutrients such as phosphorus and nitrate as nitrogen. According to Jones and Lee (1982) the amount of chlorophyll extracted from algae is dependent on the age and nutritional status of the cell, specific algae present, the solvent used and the efficiency of the extraction method. Measuring chlorophyll is hampered by large amounts of suspended solids which absorb the extracted chlorophyll resulting in erroneously low readings (Jones and Lee, 1982). The low readings from this study could be attributed to the abovementioned reason since the period of sample collection fell within the rainy season. In the rainy season, the water levels rise due to precipitation and run offs which carry debris into the water bodies. The concentration of these debris in the water bodies increase as the water levels reduce in the dry season.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The study revealed that the waterbodies are governed by different management systems and the reduction in fish catches is ubiquitous. Majority of the fishermen are young and could be trained in aquaculture production to reduce pressure on the wild species.

The tilapiine species observed in this study all had values of $b<3$, indicating a negative allometric growth pattern which also means fish became slender with increasing weight. The study revealed that morphometric and meristic characteristics can be used to discriminate tilapiine species. The meristic characteristics considered in the tilapiine species were all significantly different ($P<0.05$) except for pelvic fin rays and spines and those considered within the selected water bodies were also significantly different ($P<0.05$) with the exception of pelvic fin rays and spines and pectoral fin rays. The morphometric characters that were pivotal in the distinguishing between the tilapiine species were pectoral fin length, caudal fin length, head depth, and body depth.

The regression coefficient for all the tilapiine species was significantly different except for eye diameter in *T.zillii*. Correlation between total length and the standard length was the highest whereas the correlation between the eye diameter was lowest for *O. niloticus* and *T. zillii* and body width *for S. galilaeus*. The coefficient of determination showed a strong relationship between total length and standard length in all the tilapiine species.

The proximate composition of the tilapiine species was significantly different (P<0.05) for all the fish sampled from the rivers and reservoirs. The ash content which ranged from (4.98 – 6.00) for the tilapine species was not significantly different (P>0.05). There was a significant difference in the crude protein content that ranged from (48.14 – 37.75) for all the tilapiine species with *O. niloticus* having the highest protein content. Fat and dry matter content which ranged from (1.46 – 2.31) and (18.10 – 19.12) respectively for *T. zilli* was significantly different from *S. galilaeus* but not from *O. niloticus*.

The study also revealed that there was no significant difference (P>0.05) in the physico-chemical properties of the selected water bodies. There was evidence of sedimentation and some level of pollution in the Nasia river but the rest of the water bodies Nawuni river, Botanga and Golinga reservoirs showed little evidence of pollution.

6.2 Recommendation

Genotypic characterisation of the tilapiine species should be explored to provide further information on the variations in the tilapiine species.

The Botanga and Golinga reservoirs should be restocked and the Ministry of Fisheries and Aquaculture Development should train the fishermen in aquaculture production and provide the resources in the existing waterbodies to reduce pressure on the wild fisheries stock.

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APPENDICES

Appendix 1: Checklist

1. Demographic data of Fishermen:

Name:

Age:

Level of education:

Years of fishing:

Water body type:

Has there been any changes in the fishing activities due to changes in weather patterns?

What are they?

2. Which period do you consider as your fishing season?

Rainy season: which months in the rainy season –

Dry season: which months in the dry season –

3. When do you not go fishing?
4. What species of fish do you catch?
5. What species of fish do you catch most?
6. Do you catch tilapia when you go fishing?
7. What is the indigenous name for tilapia here?
8. Is there any difference/s in the tilapias that you catch?

If there is, what are the difference?

And do you have different names for the different tilapias?

9. What sizes of tilapia fish do you normally catch?
10. Can I get up to 5 big ones of the same size every month from now to April?

11. Are you able to determine upstream, midstream and downstream of the water body in which you fish?
12. Is it possible to collect water samples from these various points every month from now to April?

How about in the rainy season?

13. What months in the rainy season does the water rise very high and makes it unsafe to go fishing?
14. Do you have ponds here?
15. What is management systems for water bodies and its resources?
16. Do you use cages or net? Do you have parts of the water allocated to people?
17. Do you need to introduce fry into the water? Do you treat the water in a particular way for the benefit of the fish? What do you do?
18. What is the size of the gill nets you use for fishing?
19. Do you have oxbow lakes? Can we harvest fish from these lakes?
20. What species of fish do you catch from the oxbow lake?

Appendix 2: Descriptive statistics of morphometric characteristics of tilapiine species within selected water bodies

Table 16: Descriptive statistics of morphometric characteristics of tilapiine species within selected water bodies

Morphometric characteristics	Water bodies	No. of observation	Mean ± SE	Maximum	Minimum
Bdy W/g	Botanga reservoir	30	65.60±1.50	87.00	51.00
	Golinga reservoir	27	77.00±2.37	112.00	54.00
	Nasia river	15	73.67±3.76	94.00	54.00
	Nawuni river	19	72.68±2.36	95.00	57.00
TL/cm	Botanga reservoir	30	15.55±0.15	17.00	13.95
	Golinga reservoir	27	16.18±0.21	19.00	14.30
	Nasia river	15	16.35±0.27	18.00	14.90
	Nawuni river	19	16.25±0.19	17.90	15.00
SL/cm	Botanga reservoir	30	12.13±0.12	13.20	10.70
	Golinga reservoir	27	12.50±0.18	14.80	10.80
	Nasia river	15	12.65±0.21	13.90	11.70
	Nawuni river	19	12.58±0.15	13.60	11.70
BdyDpth/cm	Botanga reservoir	30	4.74±0.05	5.20	4.00
	Golinga reservoir	27	4.95±0.05	5.60	4.60
	Nasia river	15	5.26±0.12	6.10	4.60
	Nawuni river	19	4.83±0.07	5.40	4.30
HdDpth/cm	Botanga reservoir	30	2.84±0.05	3.39	2.21

	Golinga reservoir	27	2.93±0.04	3.38	2.86
	Nasia river	15	3.00±0.08	3.39	2.51
	Nawuni river	19	2.96±0.05	3.28	2.49
BdyWth/cm	Botanga reservoir	30	1.97±0.03	2.33	1.77
	Golinga reservoir	27	2.06±0.03	2.40	1.71
	Nasia river	15	1.97±0.06	2.28	1.54
	Nawuni river	19	1.95±0.03	2.23	1.76
Eye D/cm	Botanga reservoir	30	1.17±0.02	1.38	1.02
	Golinga reservoir	27	1.13±1.01	1.27	1.00
	Nasia river	15	1.25±0.02	1.42	1.13
	Nawuni river	19	1.25±0.02	1.45	1.08
SnL/cm	Botanga reservoir	30	0.98±0.02	1.25	0.73
	Golinga reservoir	27	1.03±0.03	1.42	0.85
	Nasia river	15	1.22±0.03	1.47	0.91
	Nawuni river	19	1.08±0.03	1.34	0.85
HdL/cm	Botanga reservoir	30	4.14±0.06	4.80	3.40
	Golinga reservoir	27	4.21±0.06	5.00	3.75
	Nasia river	15	4.45±0.12	5.70	3.70
	Nawuni river	19	4.32±0.06	5.00	3.95
Dorfin L/cm	Botanga reservoir	30	9.25±0.11	10.55	7.90
	Golinga reservoir	27	10.09±0.22	13.00	7.80
	Nasia river	15	9.90±0.17	11.00	8.80
	Nawuni river	19	9.90±0.15	11.40	8.65

Pecfin L/cm	Botanga reservoir	30	5.20±0.12	6.00	3.35
	Golinga reservoir	27	5.20±0.06	6.00	4.50
	Nasia river	15	5.57±0.22	6.90	4.20
	Nawuni river	19	5.35±0.10	6.00	4.65
Pelvfin L/cm	Botanga reservoir	30	3.77±0.06	4.50	3.00
	Golinga reservoir	27	4.06±0.08	4.90	3.35
	Nasia river	15	4.02±0.10	4.60	3.50
	Nawuni river	19	4.21±0.06	4.80	3.75
Analfin L/cm	Botanga reservoir	30	4.24±0.06	5.00	3.65
	Golinga reservoir	27	4.51±0.12	6.50	3.70
	Nasia river	15	4.52±0.10	5.00	3.90
	Nawuni river	19	4.67±0.07	5.50	4.15
Caudalfin L/cm	Botanga reservoir	30	3.56±0.05	3.95	3.10
	Golinga reservoir	27	3.78±0.06	4.45	3.15
	Nasia river	15	3.87±0.12	5.20	3.20
	Nawuni river	19	3.83±0.06	4.40	3.40
PreDor L/cm	Botanga reservoir	30	3.87±0.06	4.50	3.25
	Golinga reservoir	27	3.90±0.07	4.60	3.30
	Nasia river	15	4.16±0.13	5.10	3.50
	Nawuni river	19	3.82±0.05	4.10	3.30
PrePec L/cm	Botanga reservoir	30	4.12±0.06	5.00	3.60
	Golinga reservoir	27	4.15±0.05	4.65	3.65
	Nasia river	15	4.34±0.08	4.80	3.85

	Nawuni river	19	4.28±0.07	5.15	3.75
PrePelv L/cm	Botanga reservoir	30	4.66±0.06	5.35	4.00
	Golinga reservoir	27	4.67±0.07	5.35	4.10
	Nasia river	15	4.81±0.10	5.65	4.30
	Nawuni river	19	4.93±0.08	5.70	4.60
PreAnal L/cm	Botanga reservoir	30	7.99±0.07	8.75	7.05
	Golinga reservoir	27	8.29±0.12	9.80	7.45
	Nasia river	15	8.34±0.15	9.40	7.65
	Nawuni river	19	8.16±0.12	9.20	7.45

NB: SE-Standard Error

Appendix 3: Regression graphs of morphometric characteristics of tilapiine species

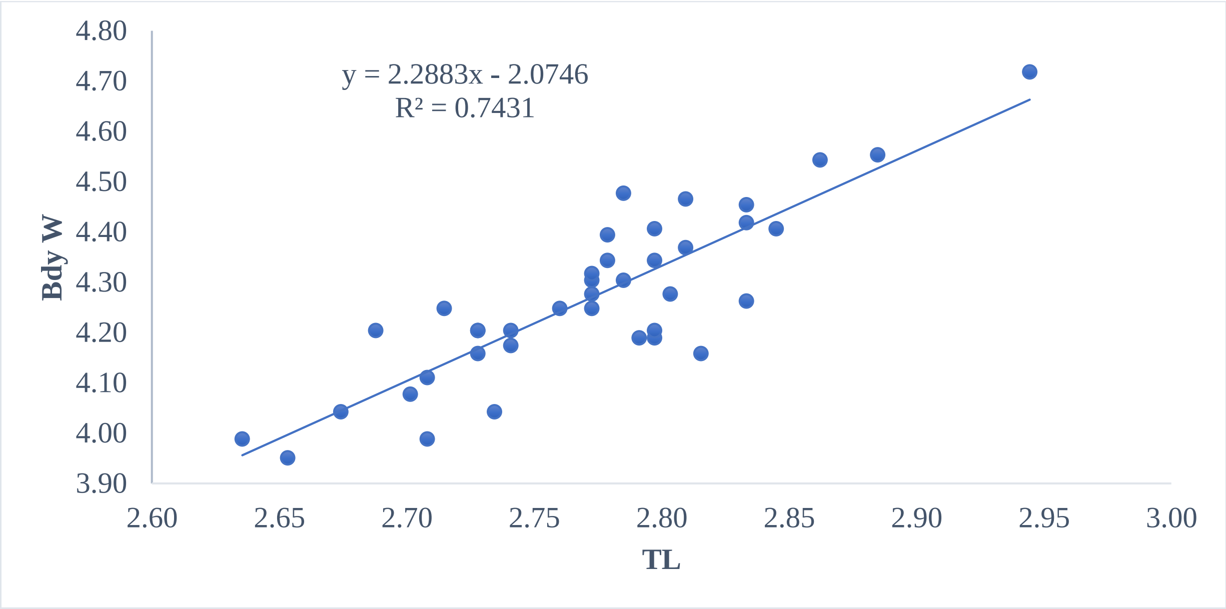

Figure 3: Regression graph of body weight on the total length of *O. niloticus*

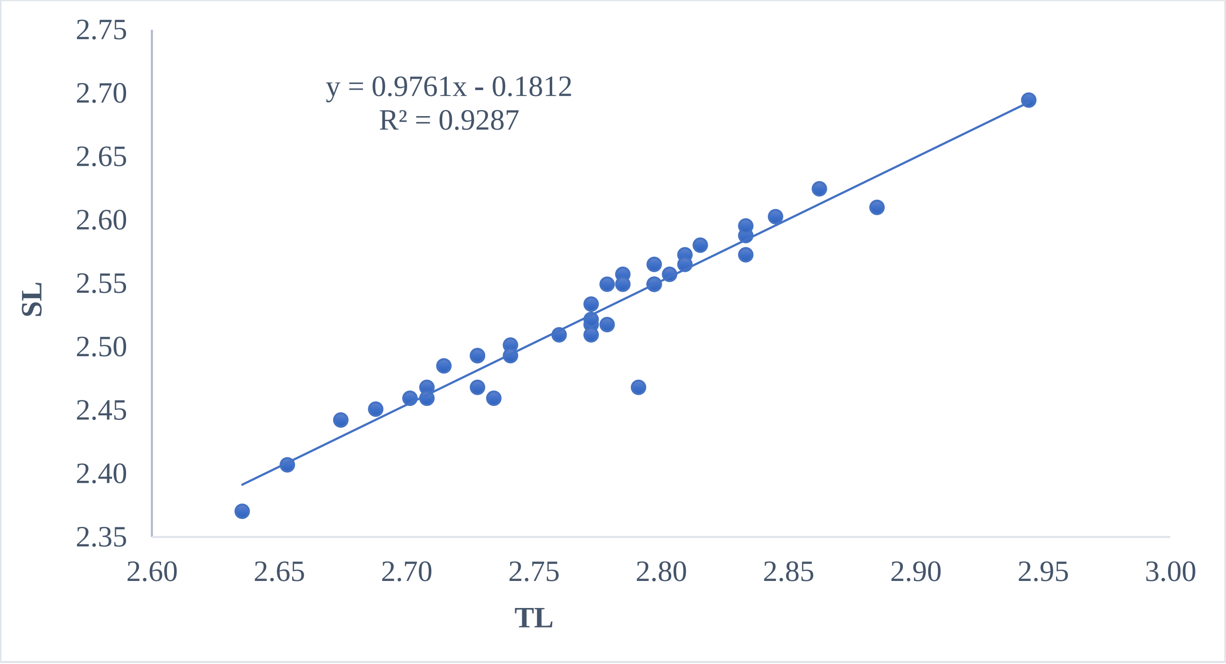

Figure 4: Regression graph of standard length on the total length of *O. niloticus*

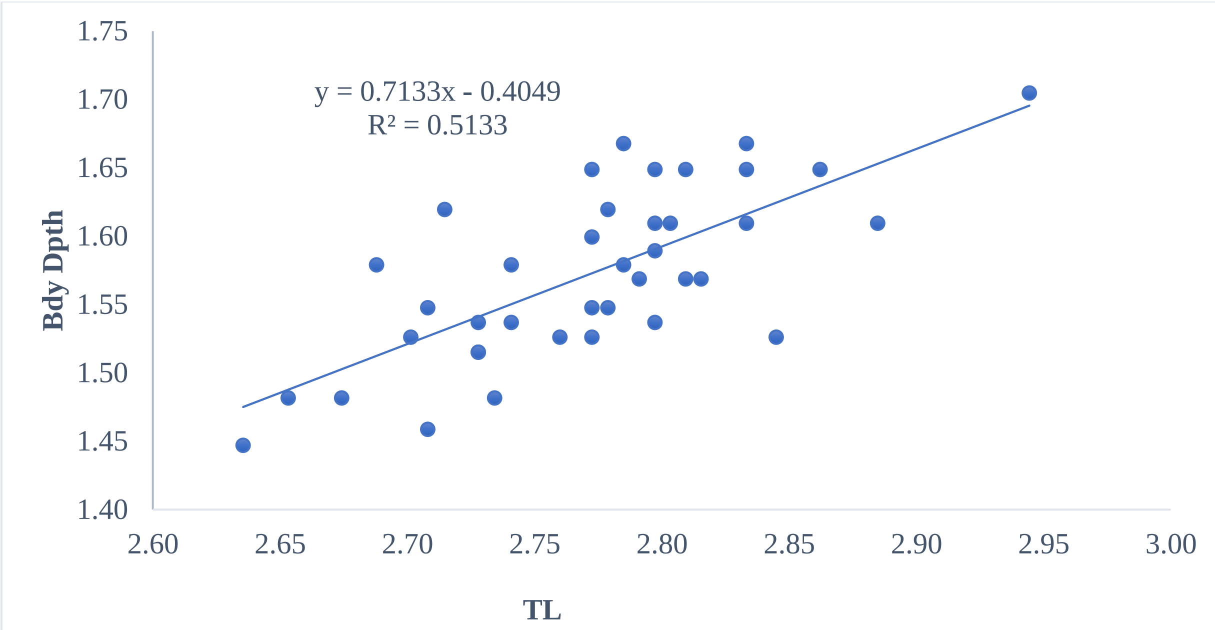

Figure 5 :Regression graph of body depth on the total length of *O. niloticus*

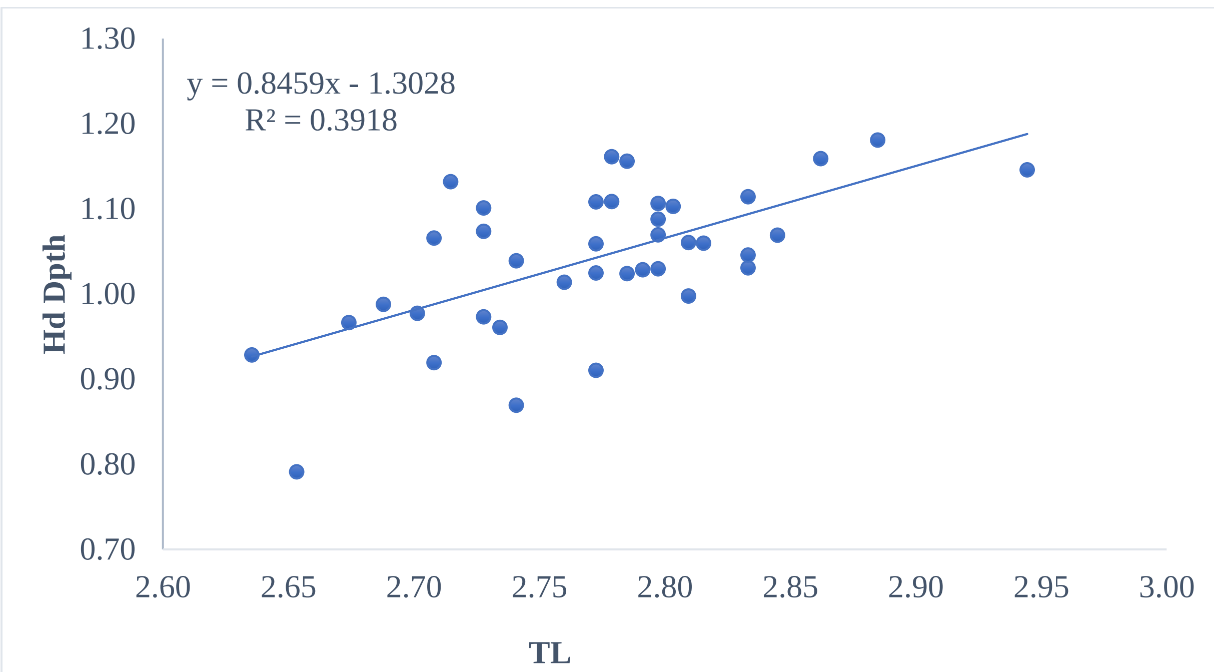

Figure 6: Regression graph of head depth on the total length of *O. niloticus*

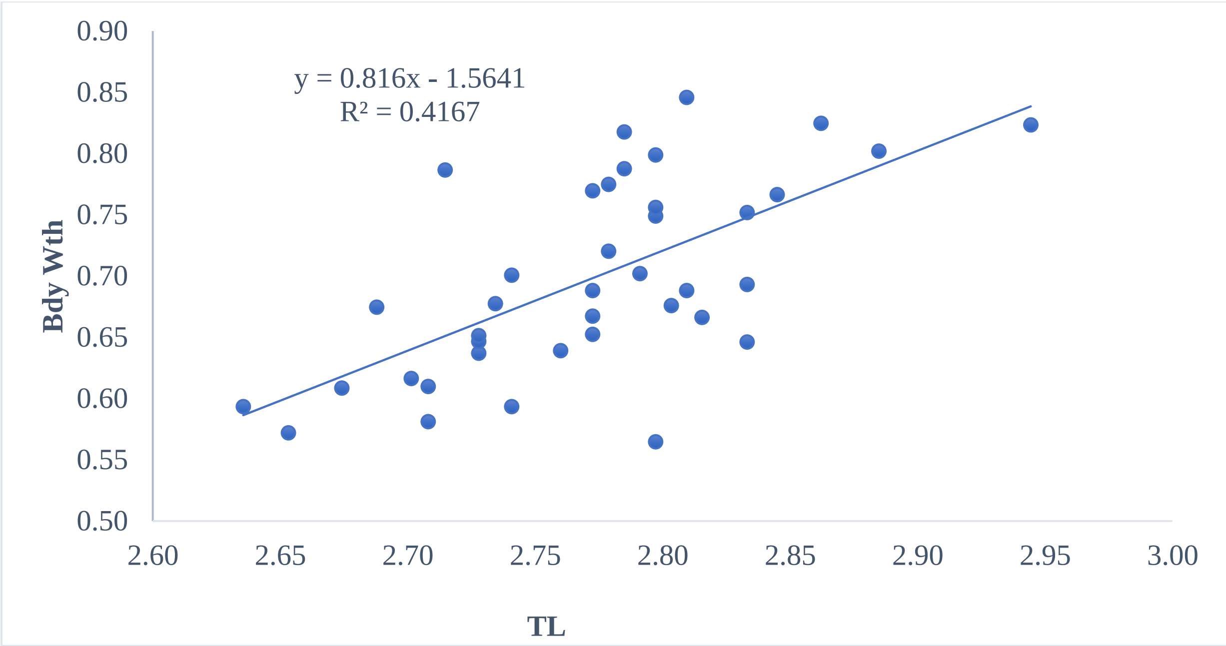

Figure 7: Regression graph of body width on the total length of *O. niloticus*

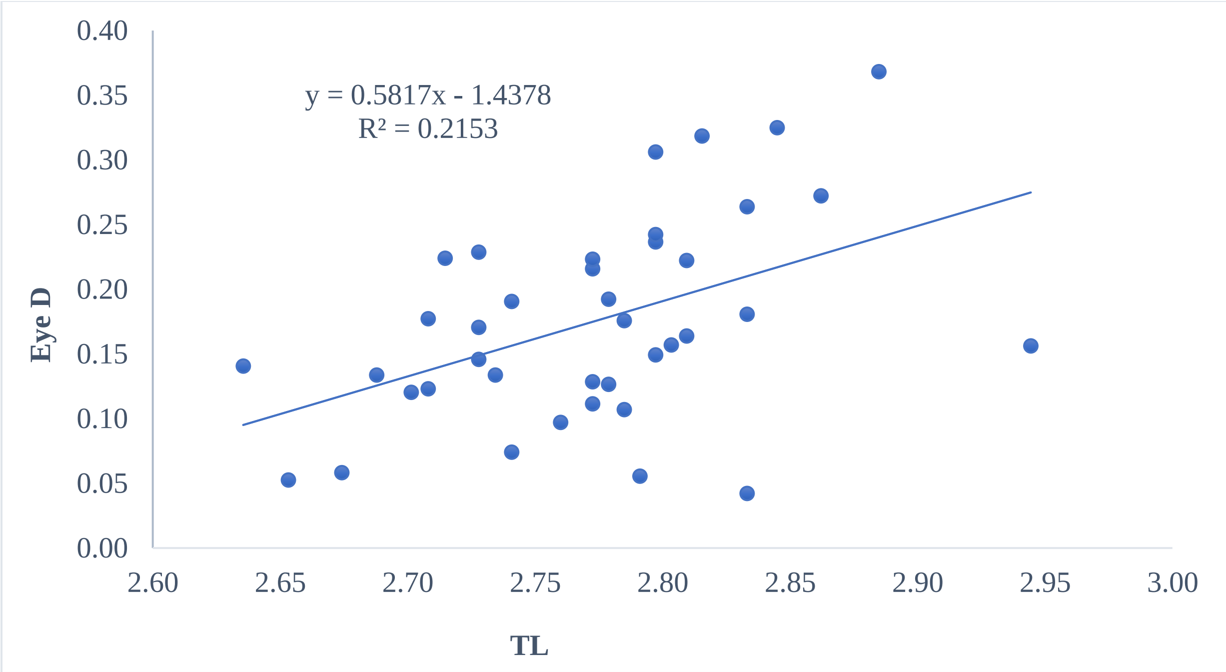

Figure 8: Regression graph of eye diameter on the total length of *O. niloticus*

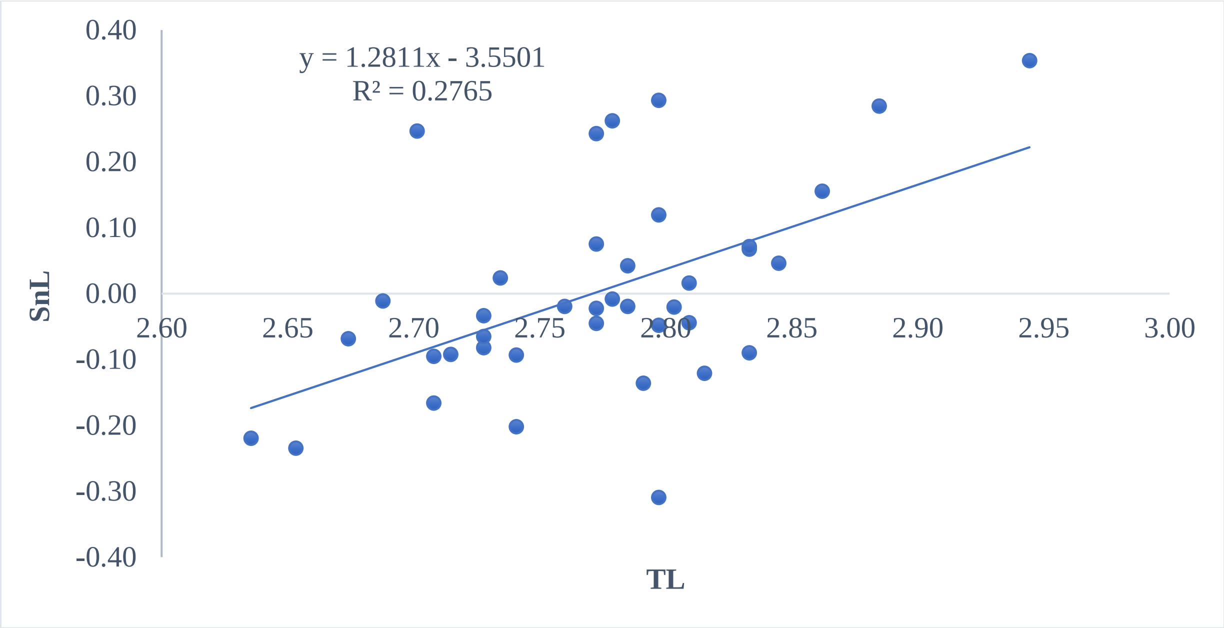

Figure 9: Regression graph of snout length on the total length of *O. niloticus*

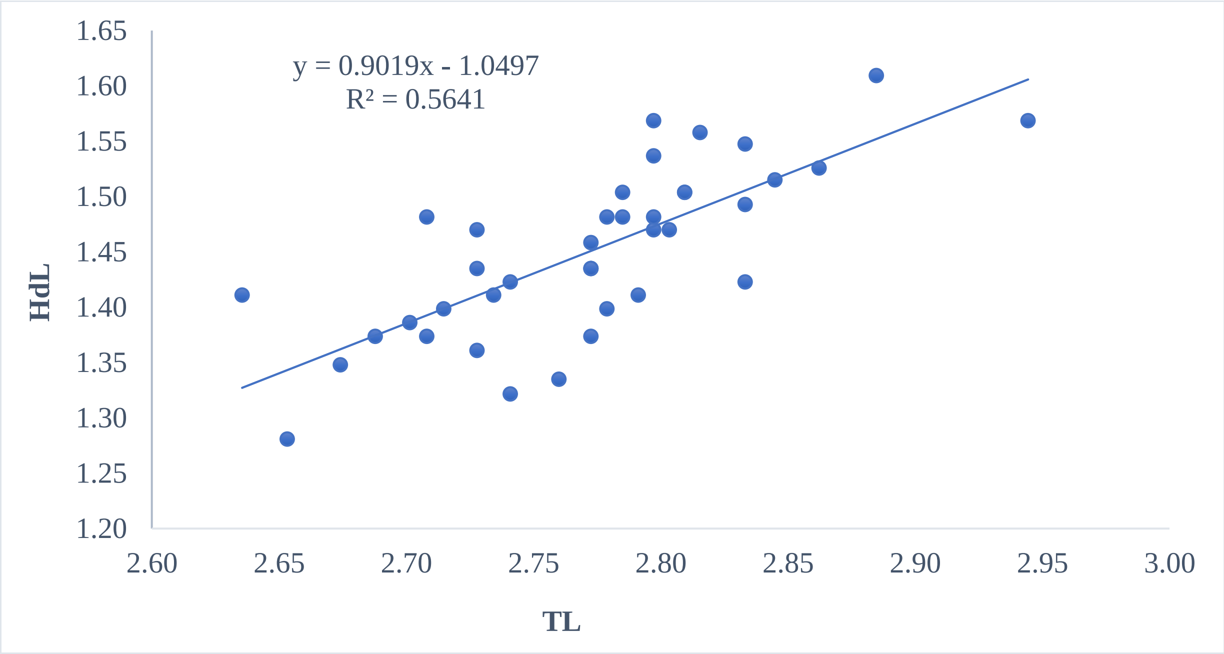

Figure 10: Regression graph of head length on the total length of *O. niloticus*

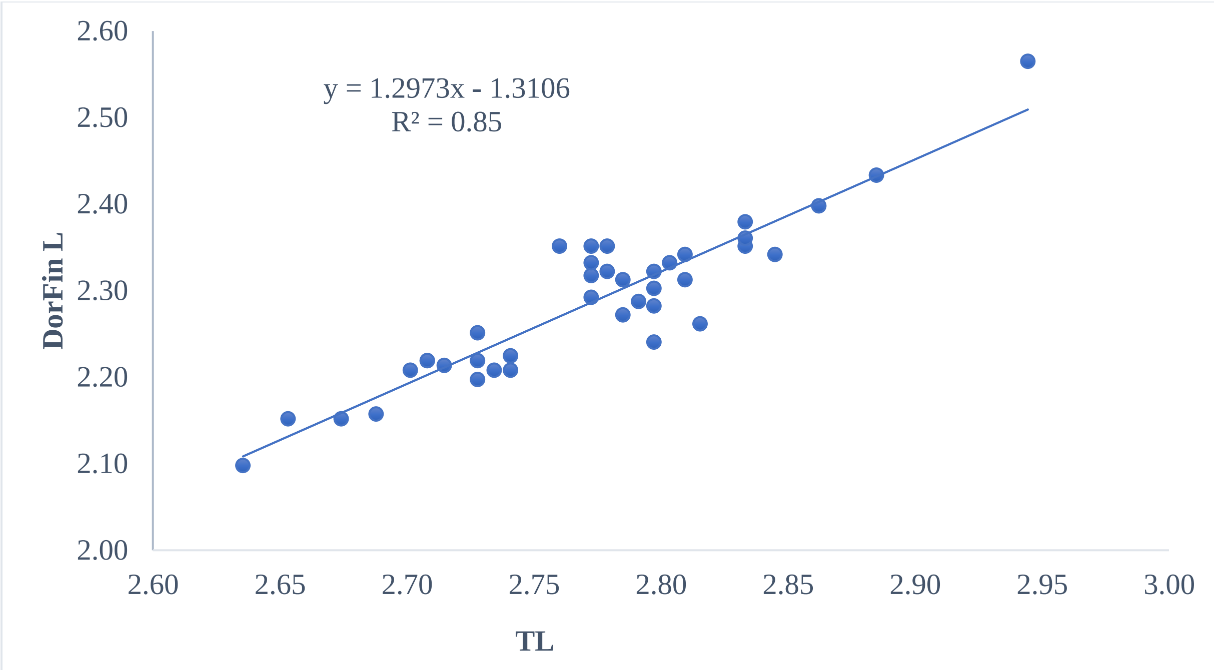

Figure 11: Regression graph of dorsal fin length on the total length of *O. niloticus*

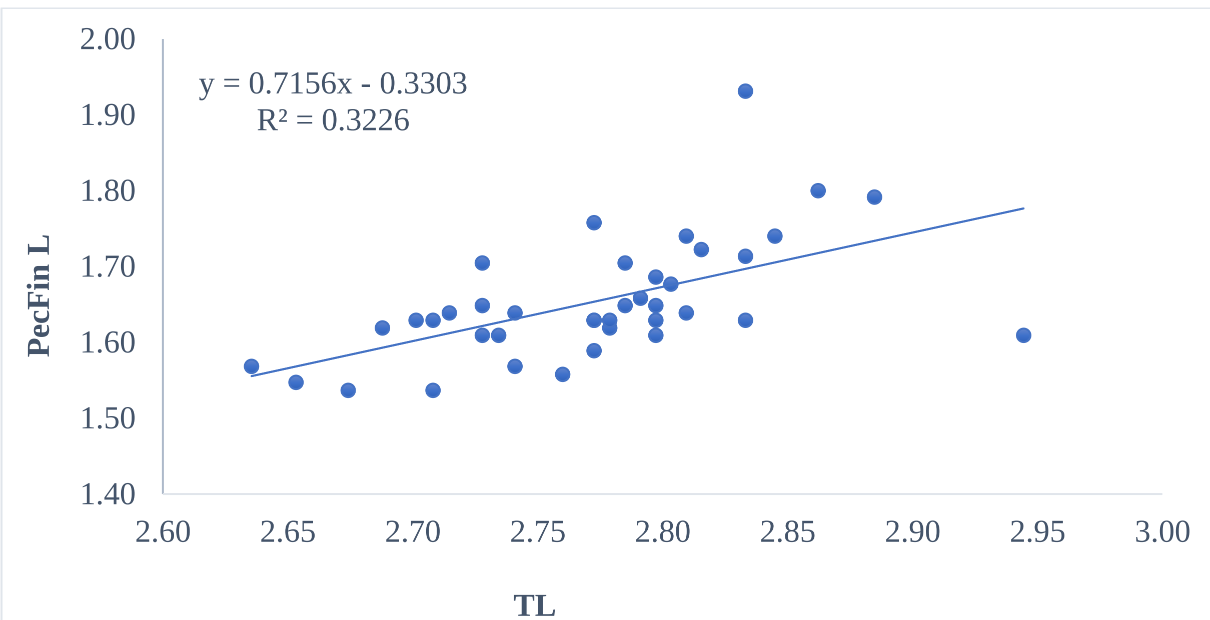

Figure 12: Regression graph of pectoral fin length on the total length of *O. niloticus*

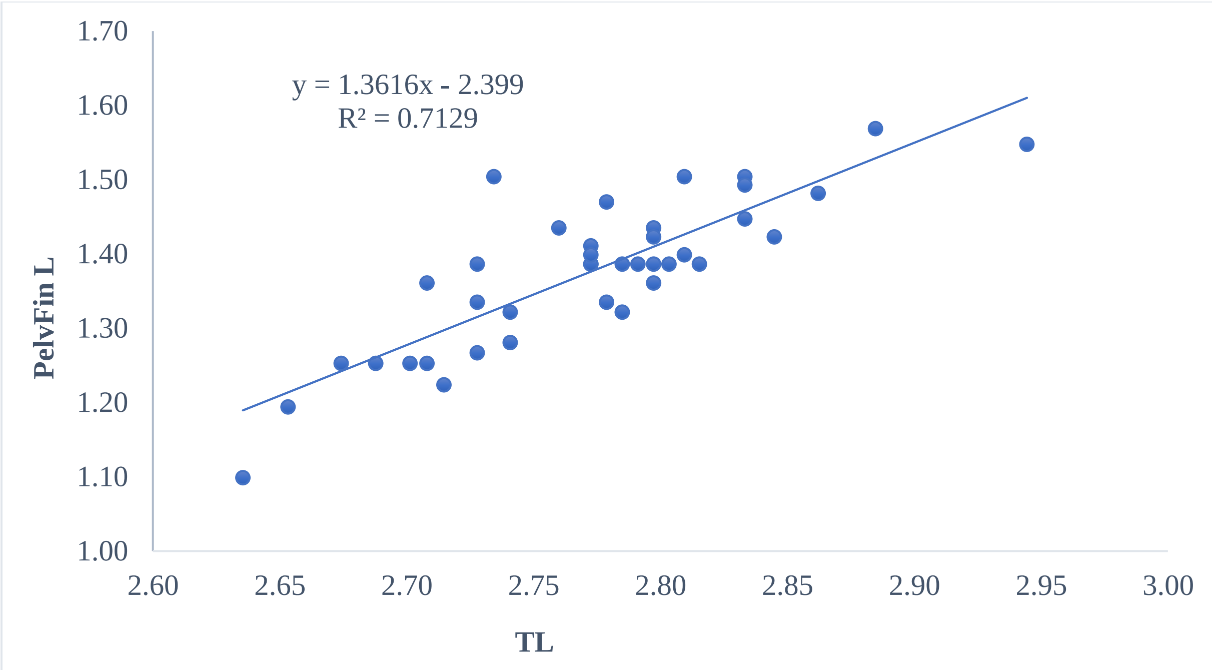

Figure 13: Regression graph of pelvic fin length on the total length of *O. niloticus*

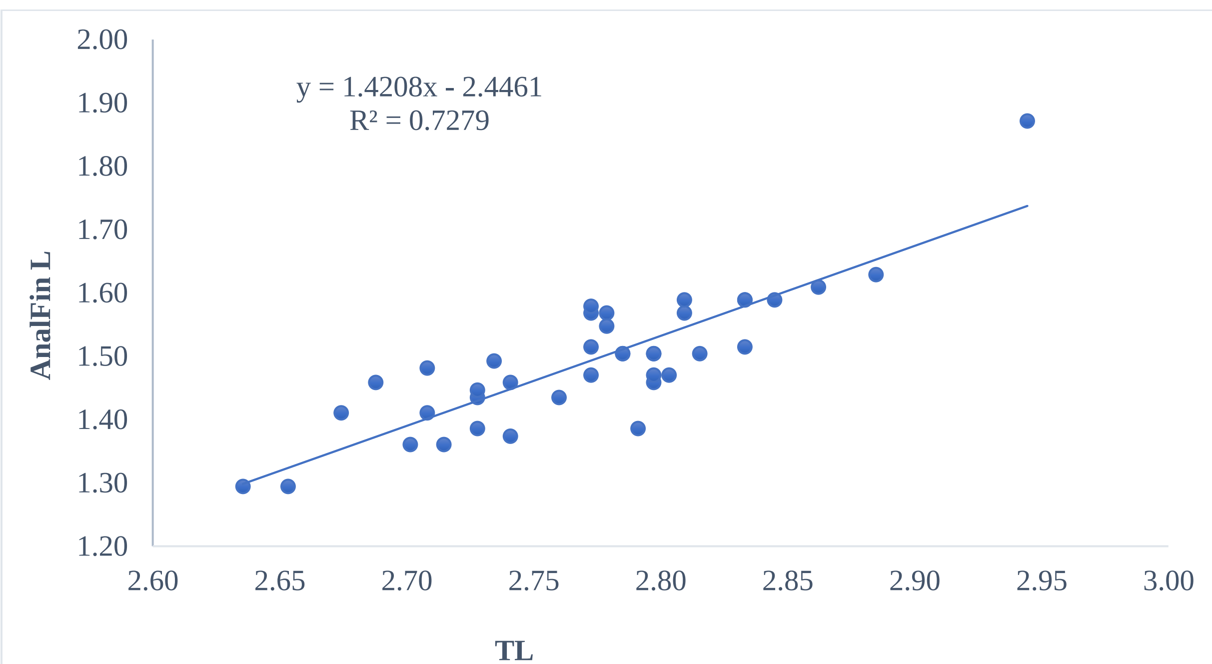

Figure 14: Regression graph of pelvic fin length on the total length of *O. niloticus*

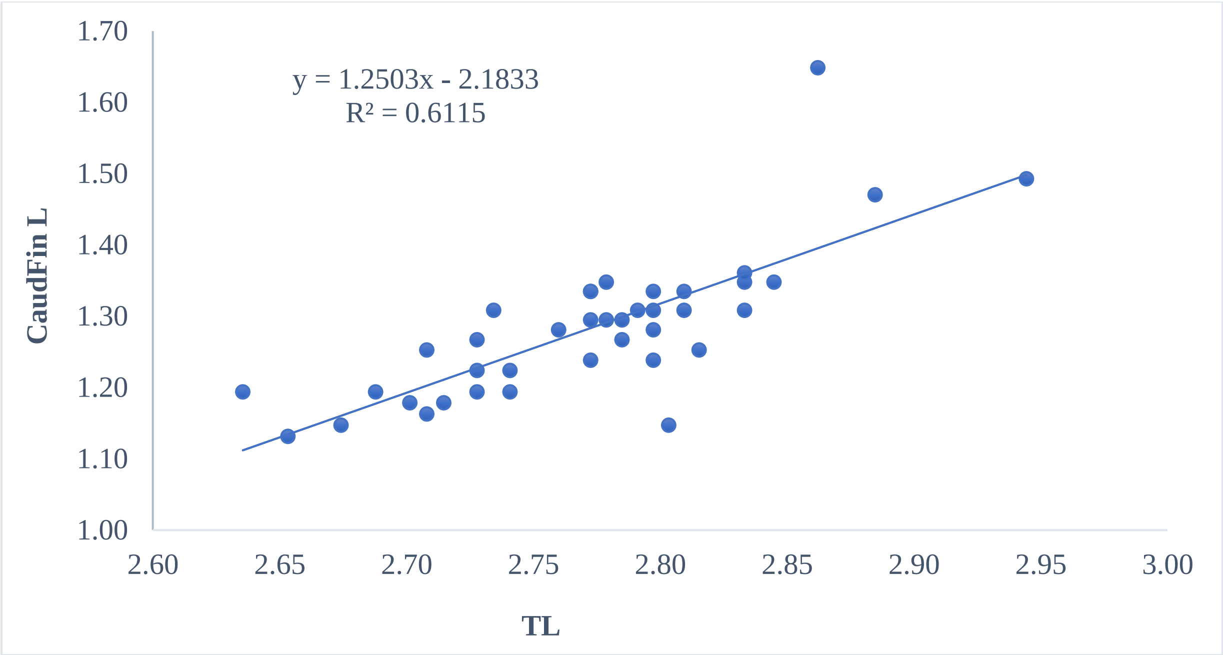

Figure 15: Regression graph of caudal fin length on the total length of *O. niloticus*

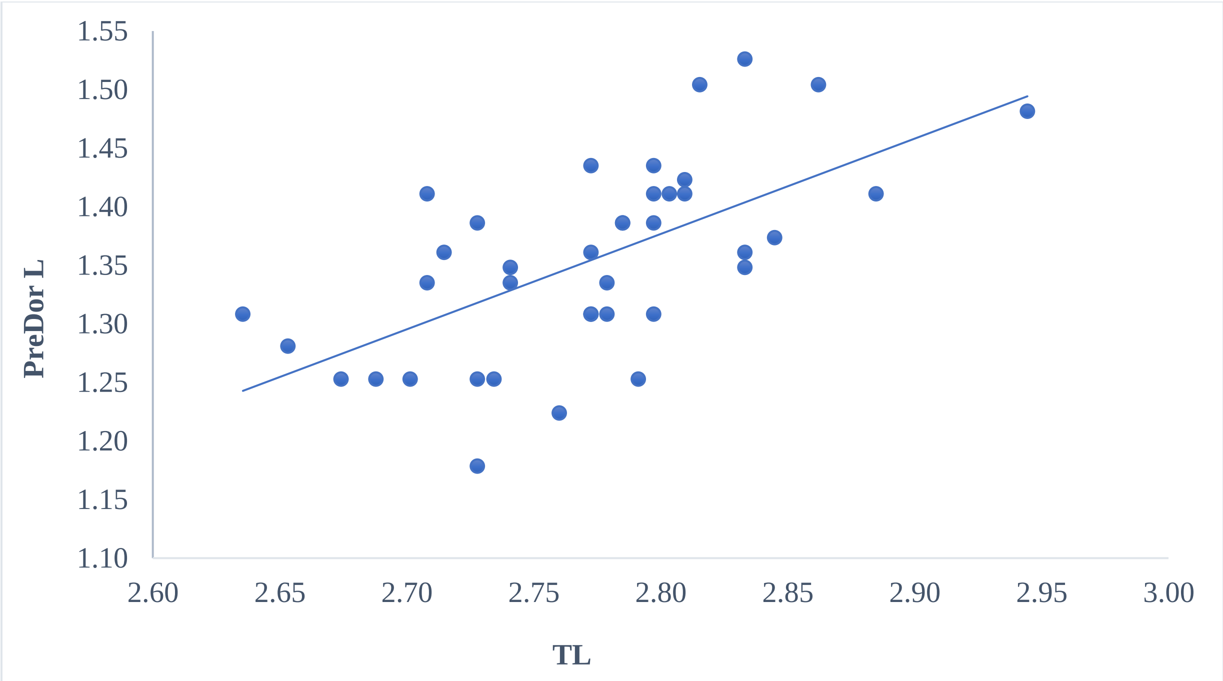

Figure 16: Regression graph of pre dorsal length on the total length of *O. niloticus*

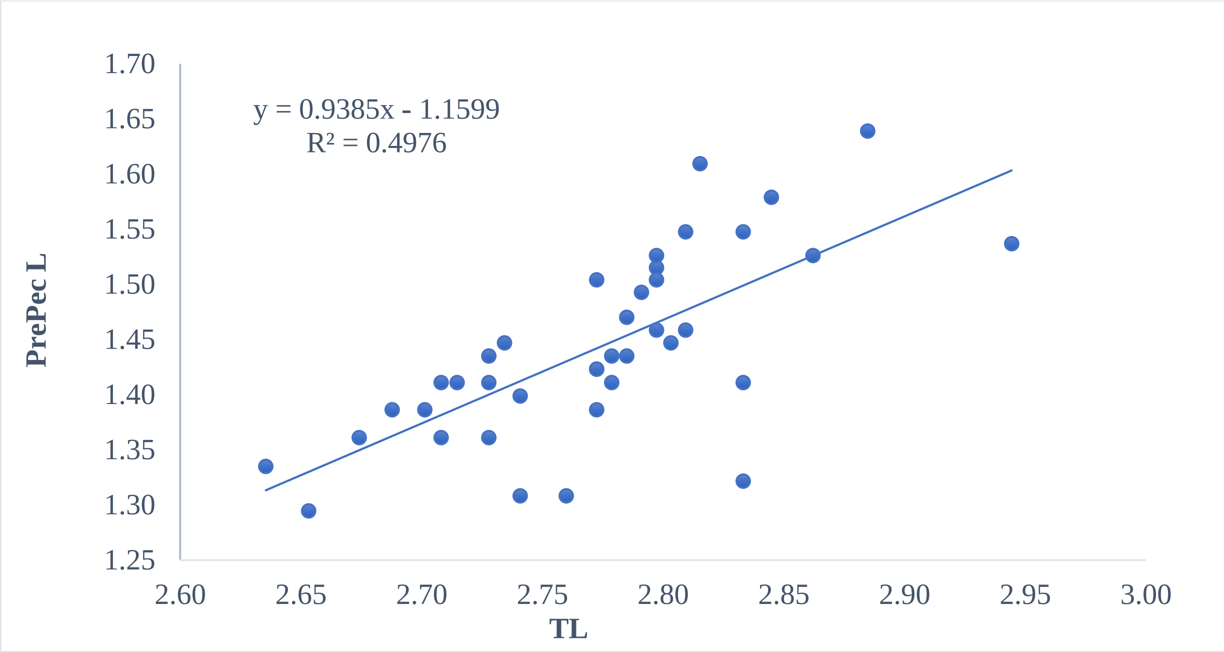

Figure 17: Regression graph of pre pectoral length on the total length of *O. niloticus*

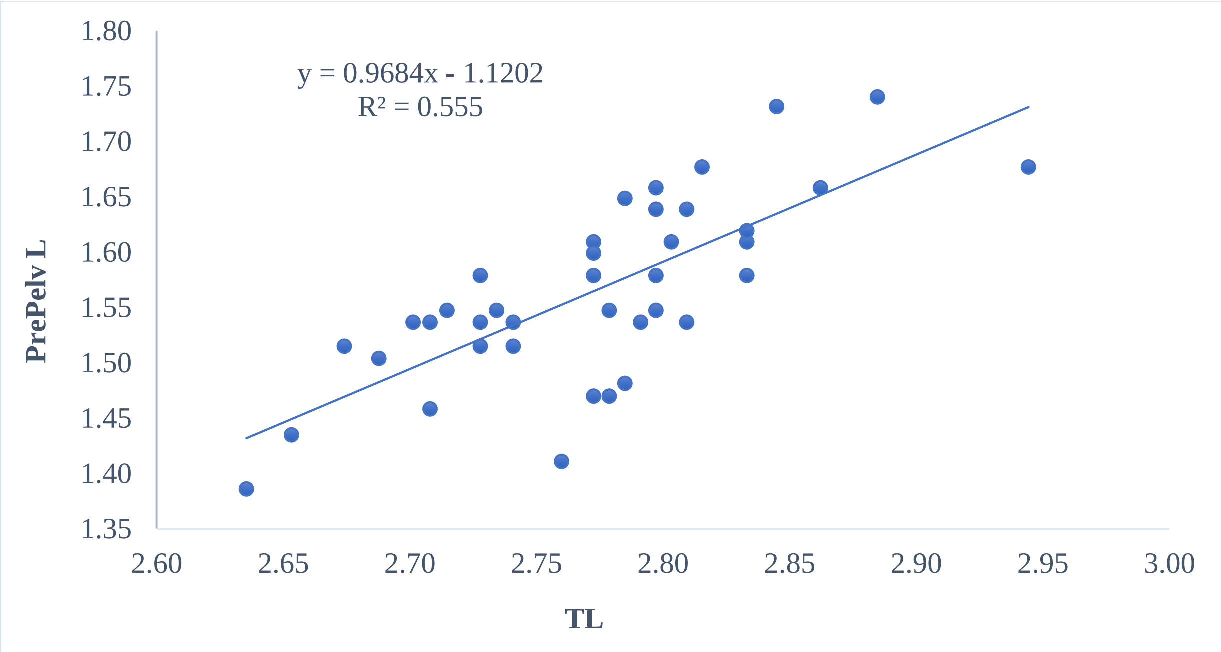

Figure 18: Regression graph of pre pelvic length on the total length of *O. niloticus*

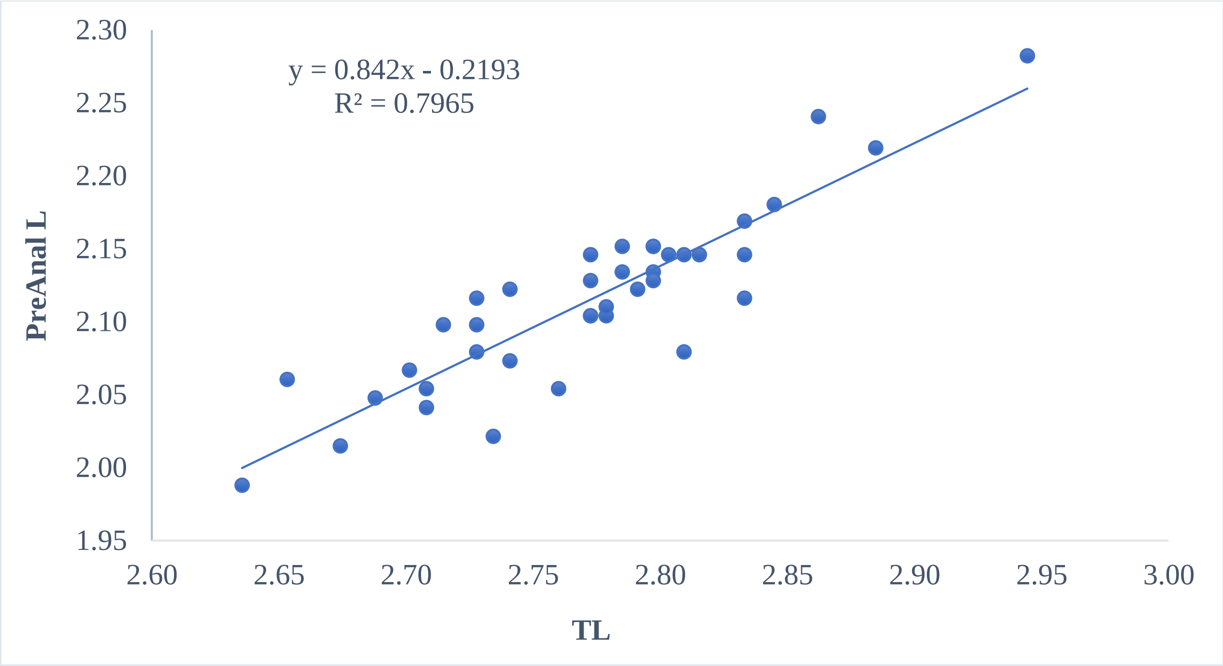

Figure 19: Regression graph of pre anal length on the total length of *O. niloticus*

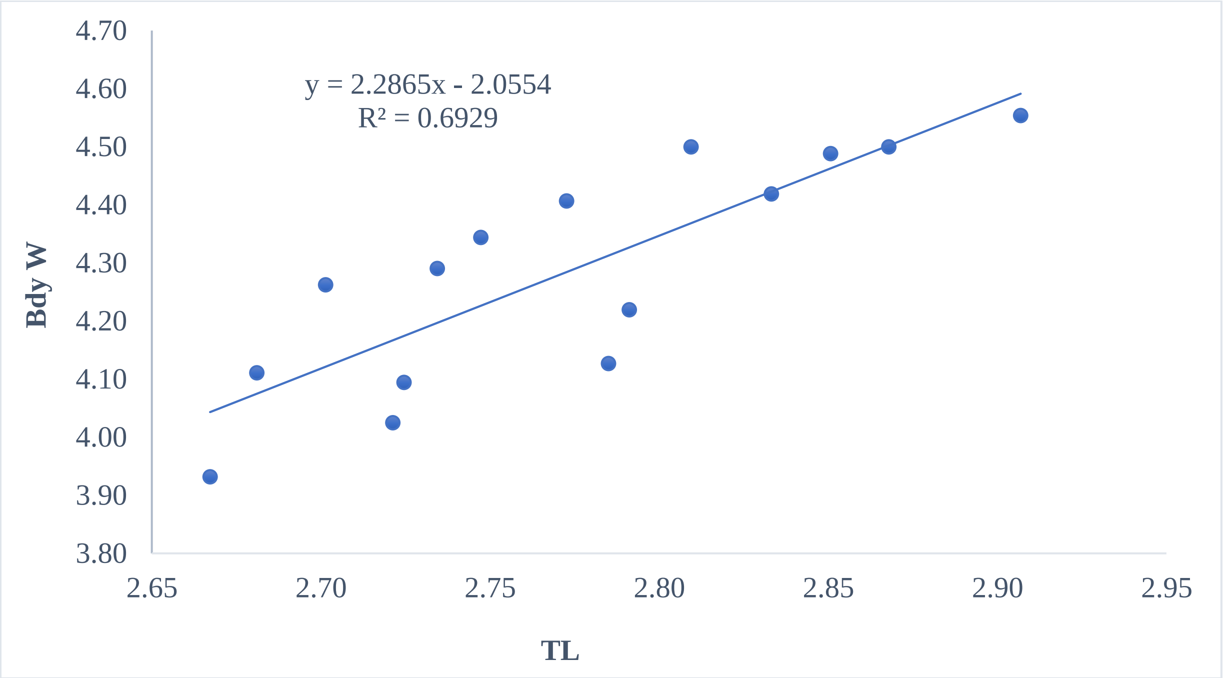

Figure 20: Regression graph of body weight on the total length of *T. zillii*

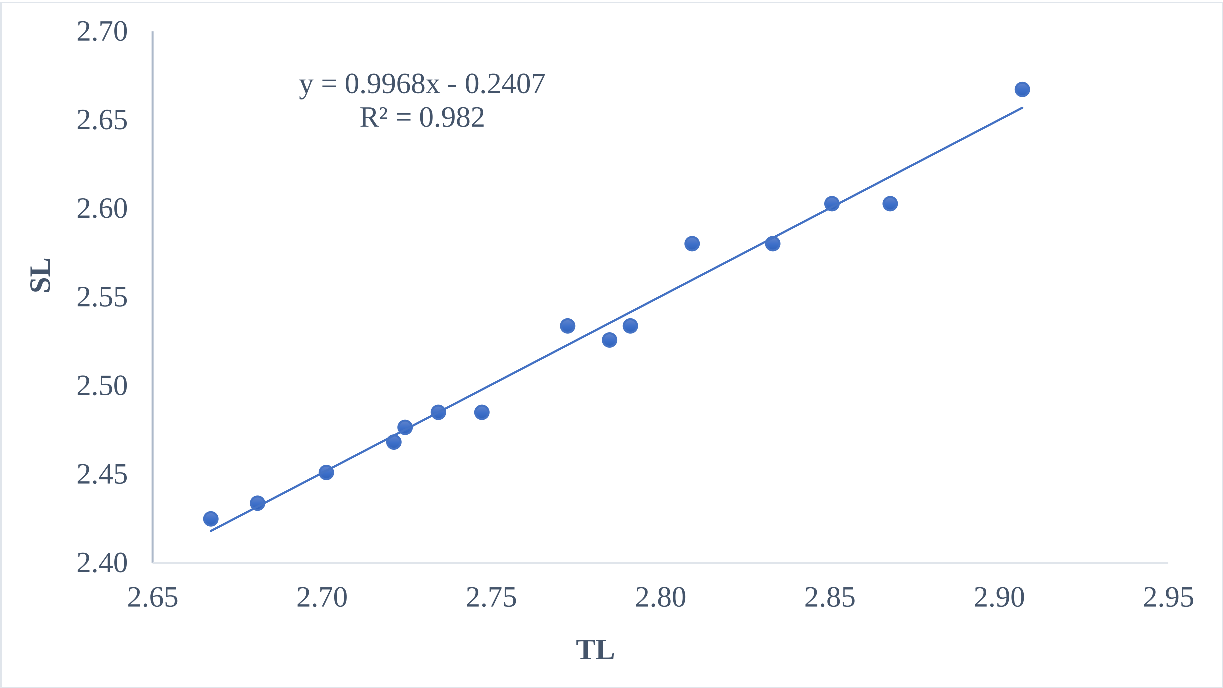

Figure 21: Regression graph of standard length on the total length of *T. zillii*

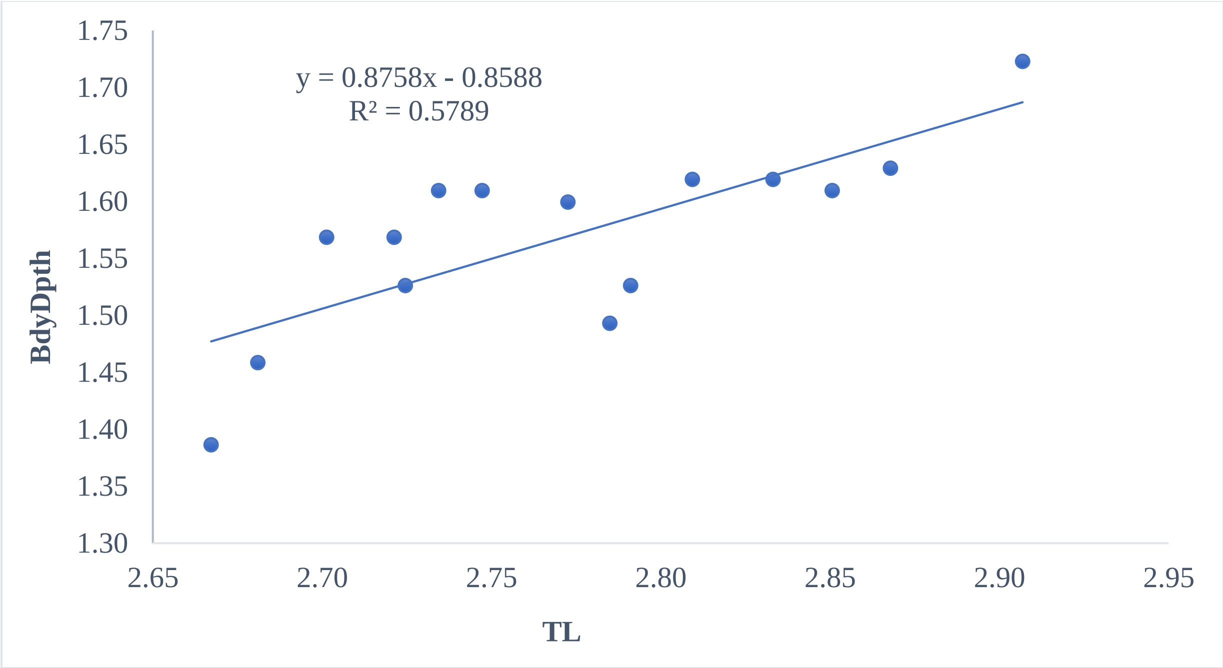

Figure 22: Regression graph of body depth on total length of *T. zillii*

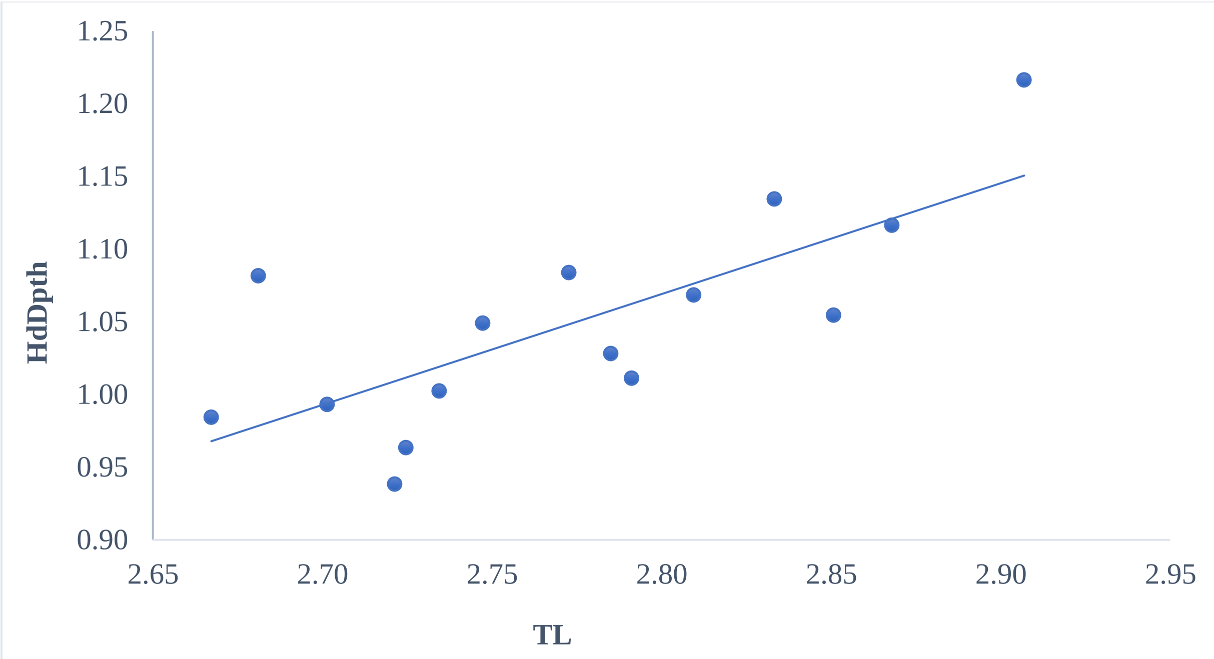

Figure 23: Regression graph of head depth on the total length of *T. zillii*

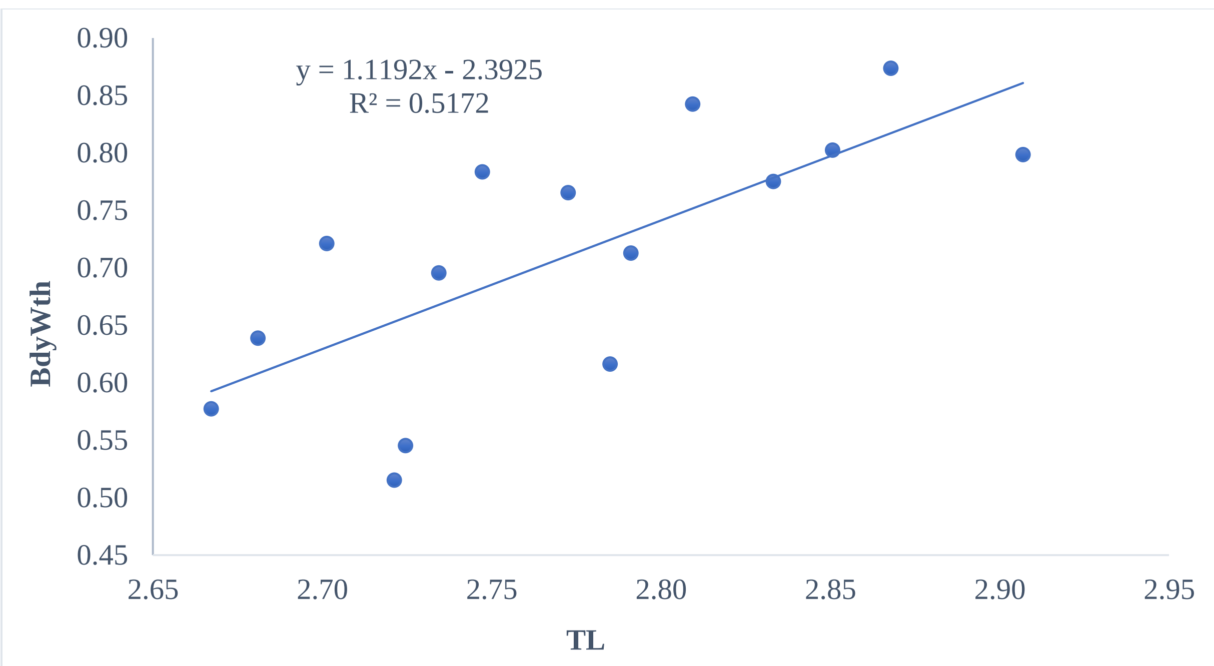

Figure 24: Regression graph of body width on the total length of *T. zillii*

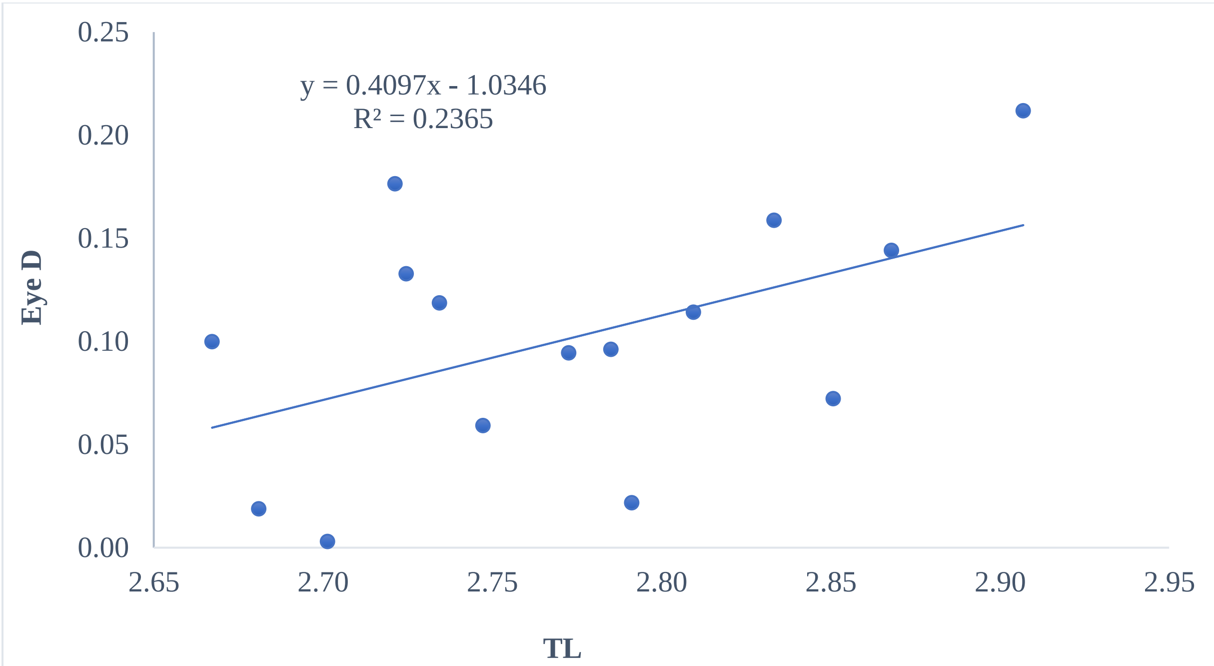

Figure 25: Regression graph of eye diameter on the total length of *T. zillii*

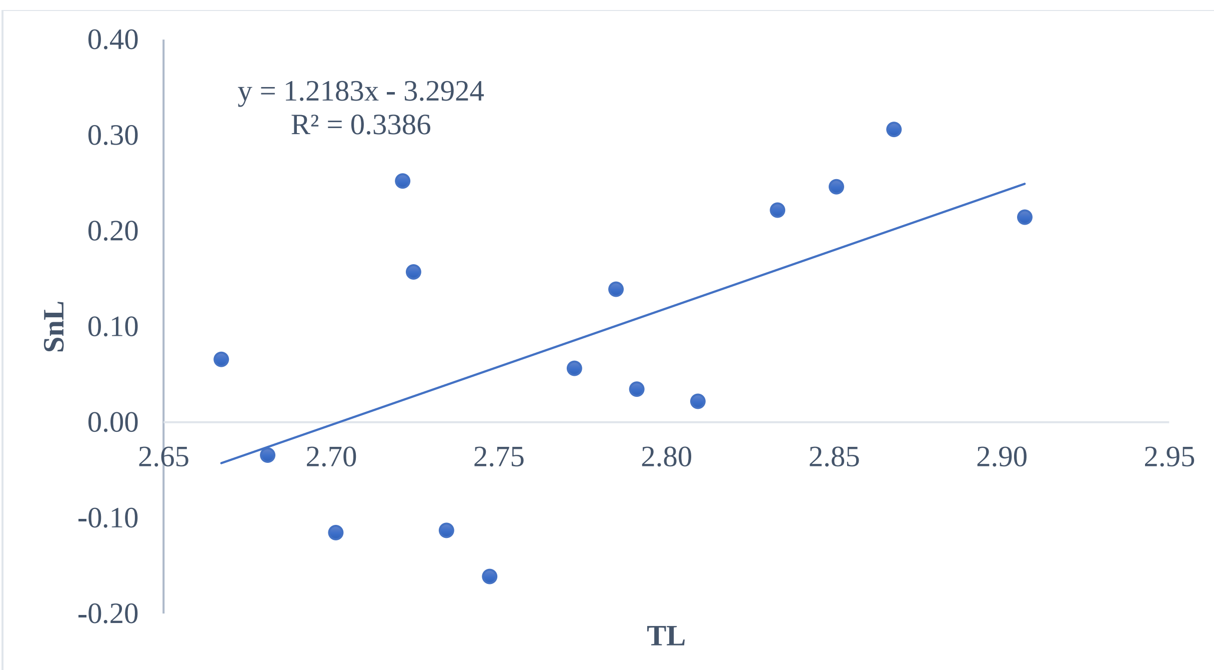

Figure 26: Regression graph of snout length on the total length of *T. zillii*

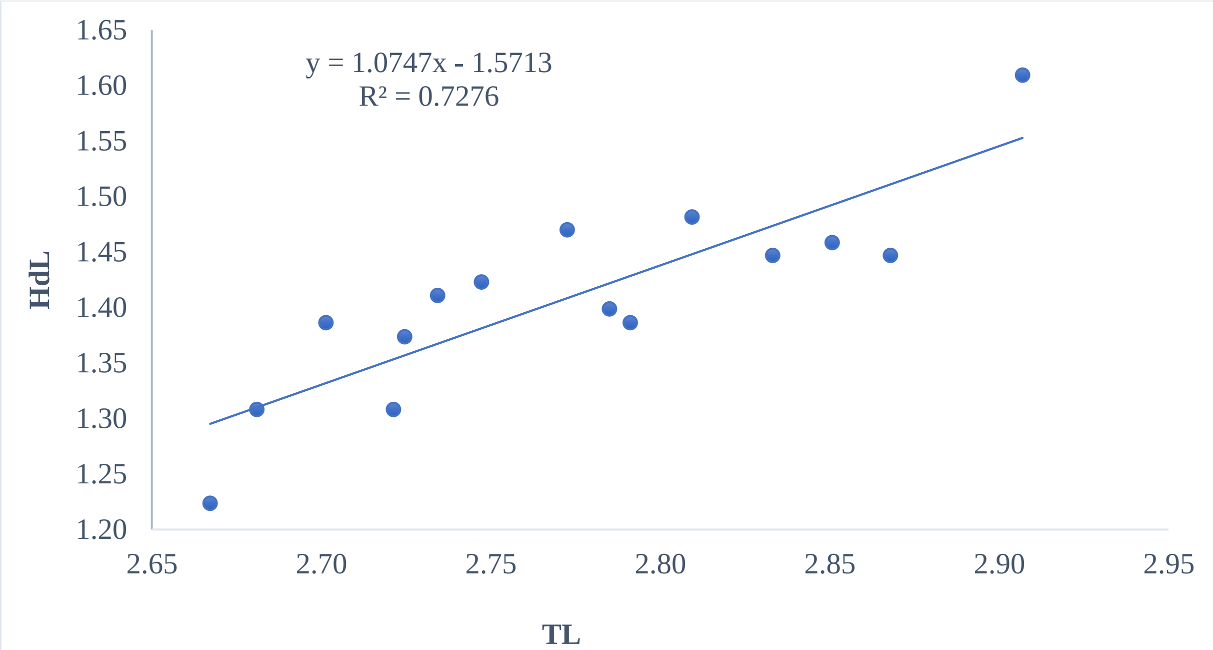

Figure 27: Regression graph of head length on the total length of *T. zillii*

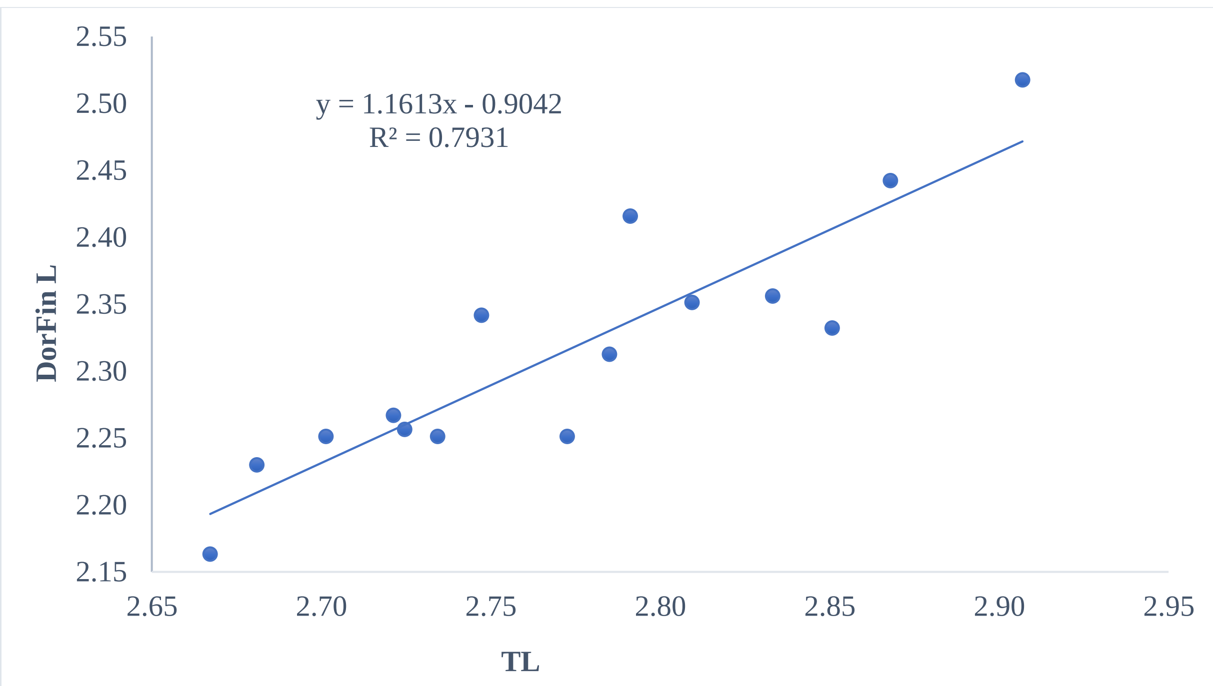

Figure 28: Regression graph of dorsal fin length on the total length of *T. zillii*

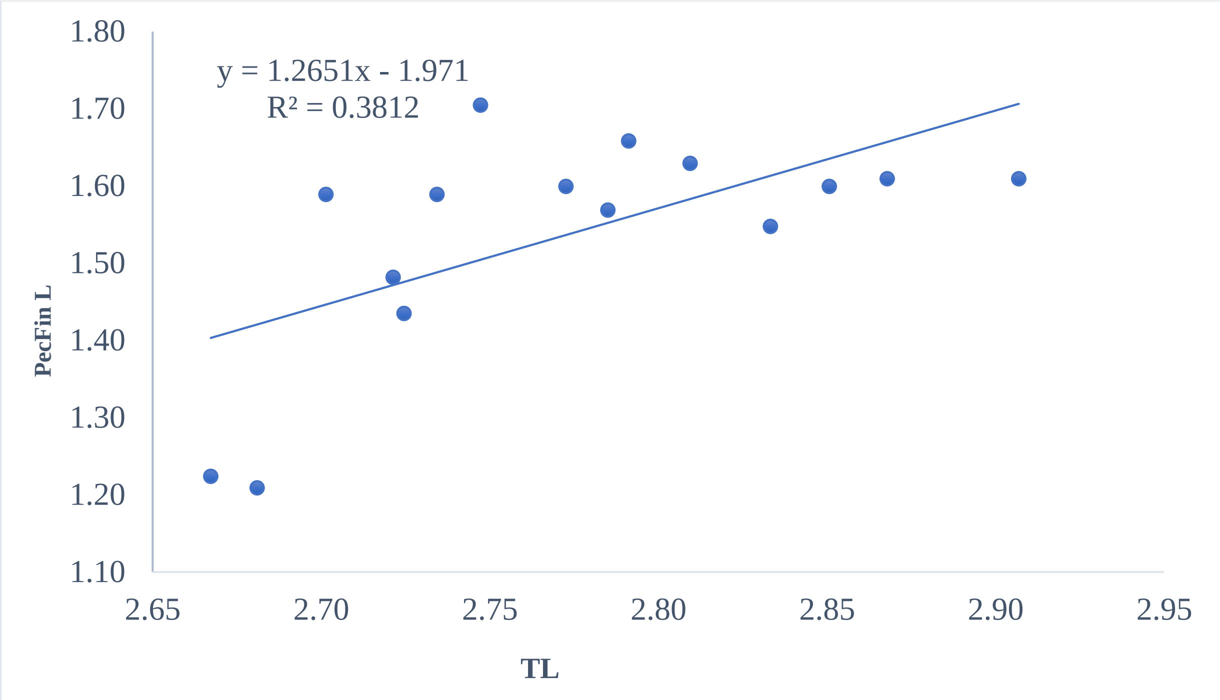

Figure 29: Regression graph of pectoral fin length on the total length of *T. zillii*

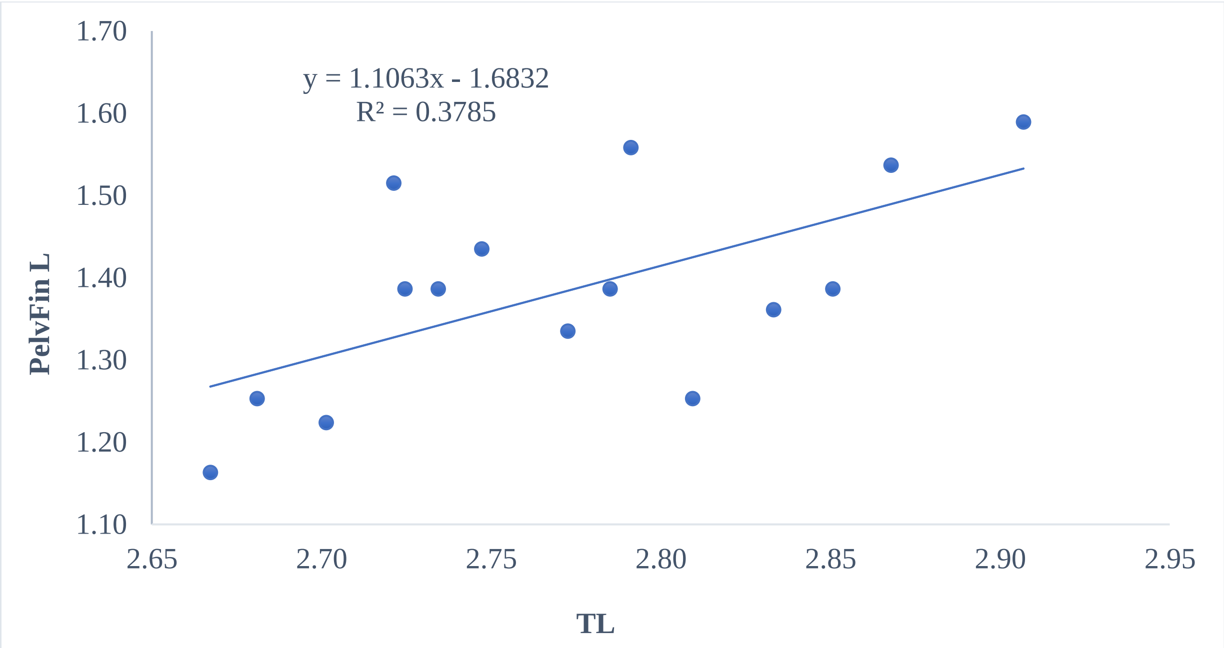

Figure 30: Regression graph of pelvic fin length on the total length of *T. zillii*

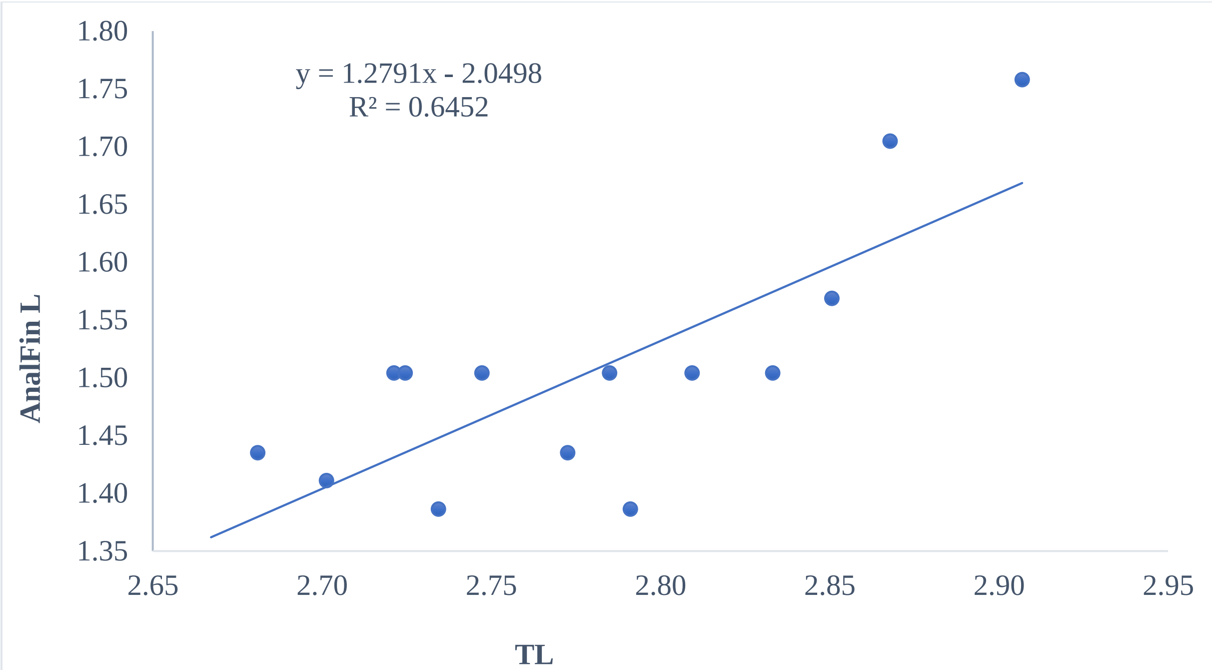

Figure 31: Regression graph of anal fin length on the total length of *T. zillii*

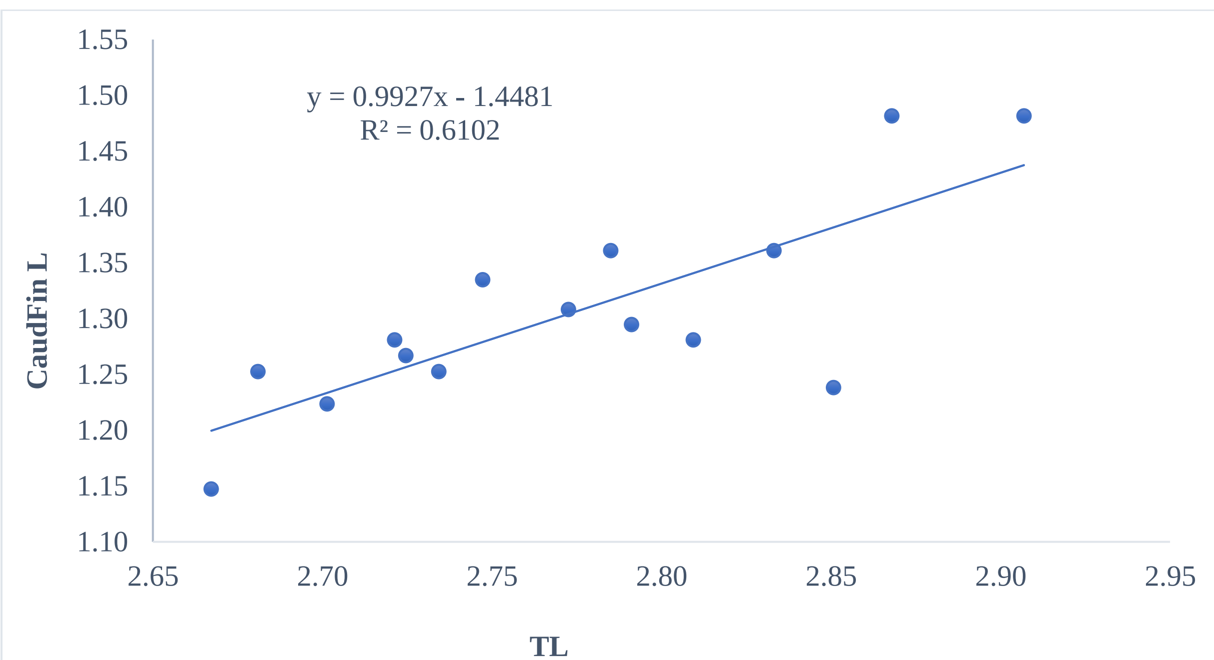

Figure 32: Regression graph of caudal fin length on the total length of *T. zillii*

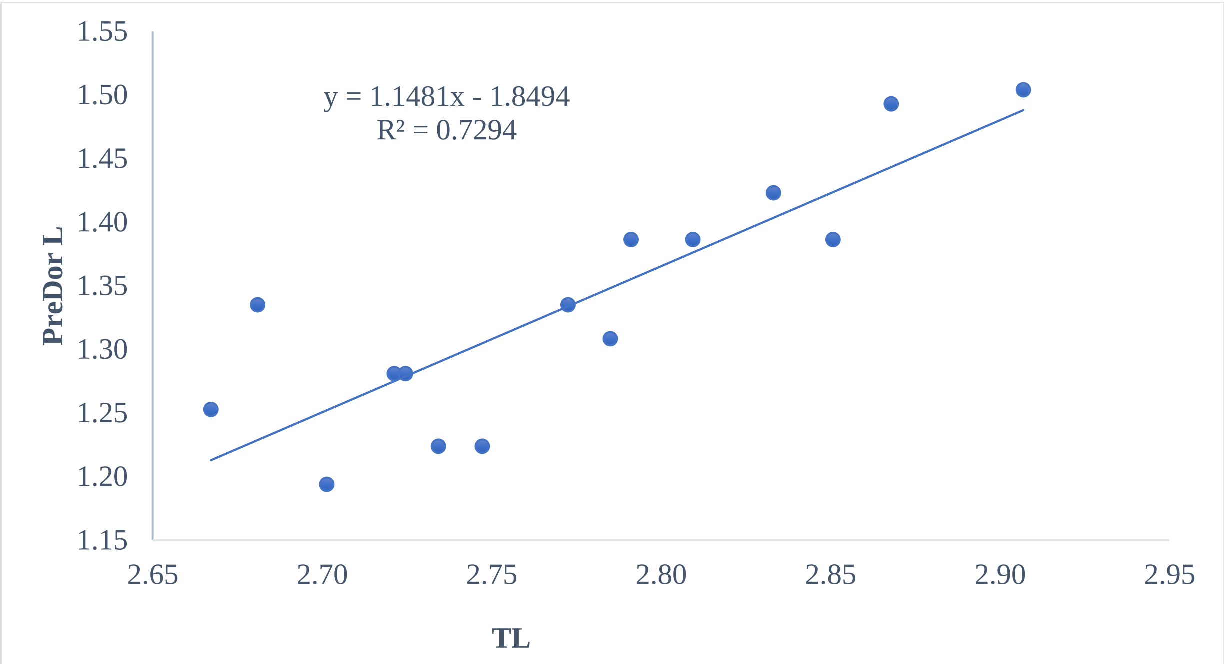

Figure 33: Regression graph of pre dorsal length on the total length of *T. zillii*

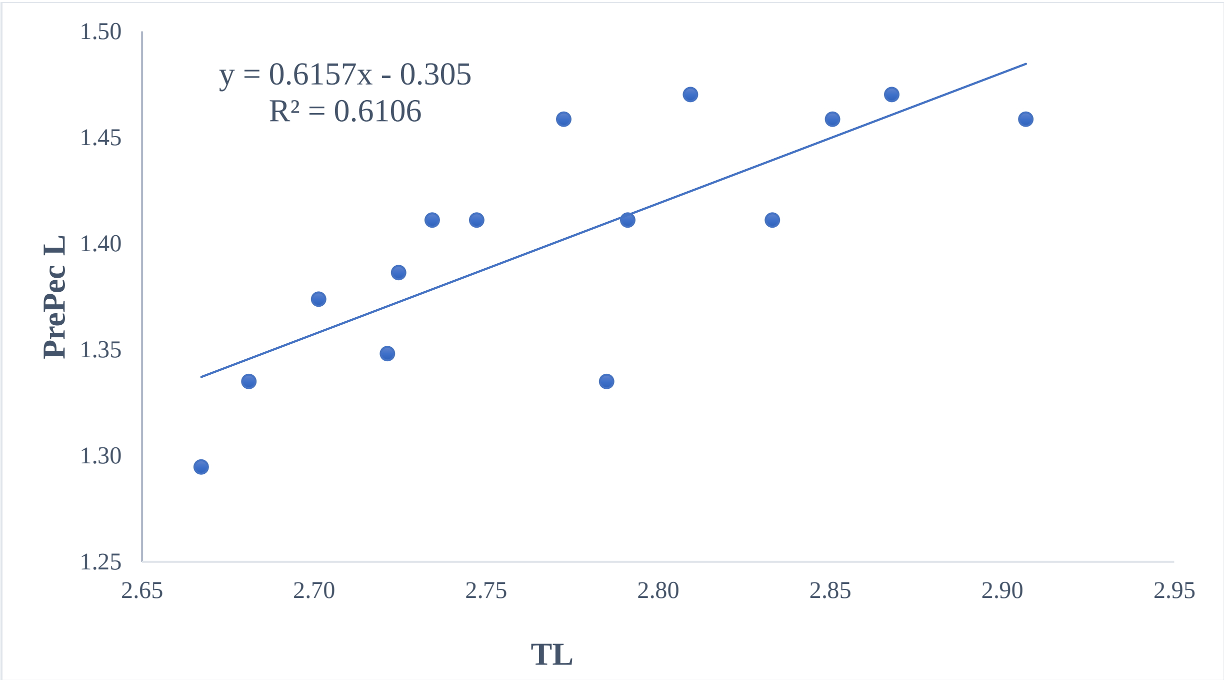

Figure 34: Regression graph of pre pectoral length on the total length of *T. zillii*

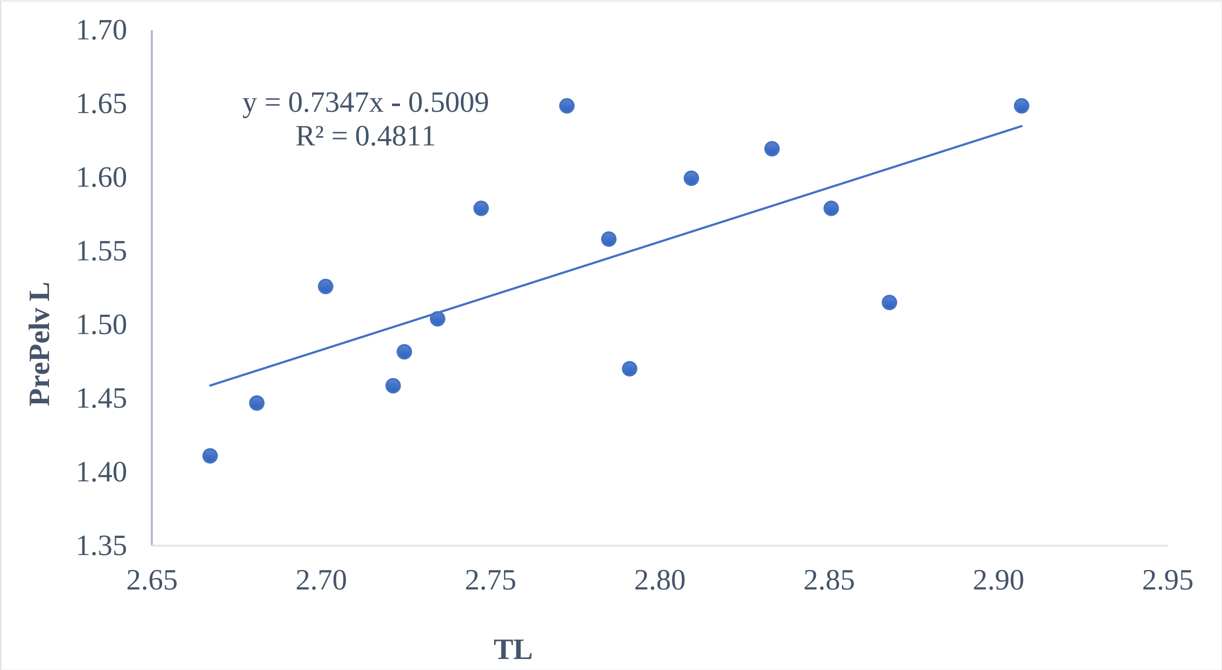

Figure 35: Regression graph of pre pelvic length on the total length of *T. zillii*

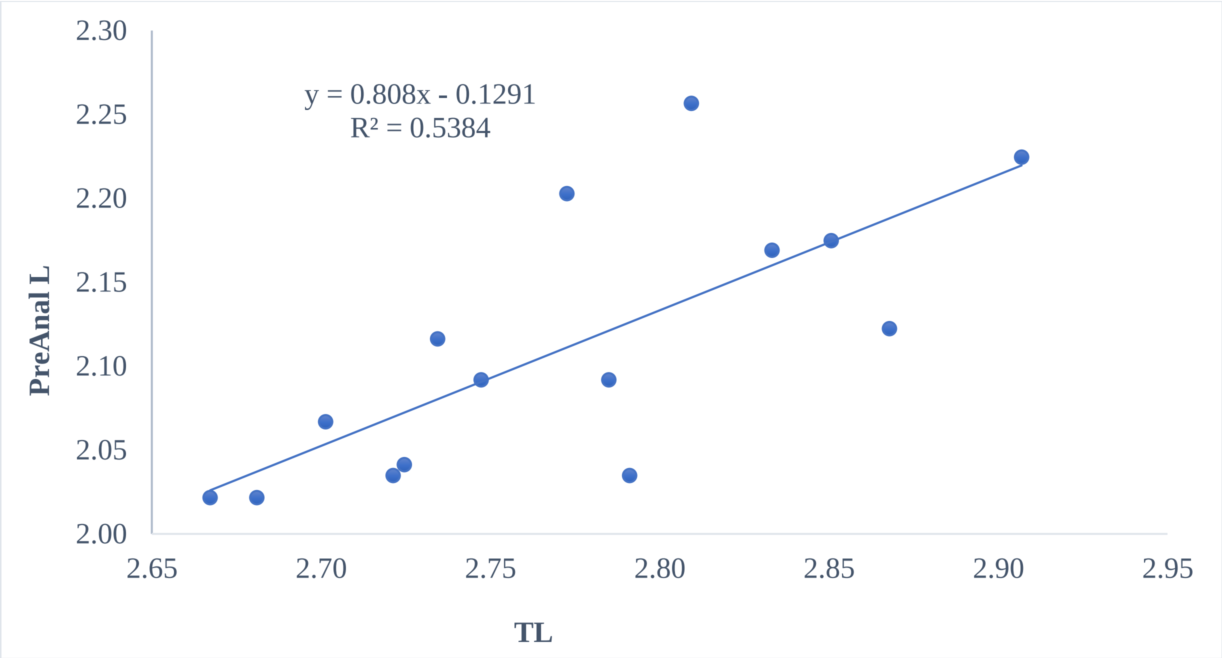

Figure 36: Regression graph of pre anal length on the total length of *T. zillii*

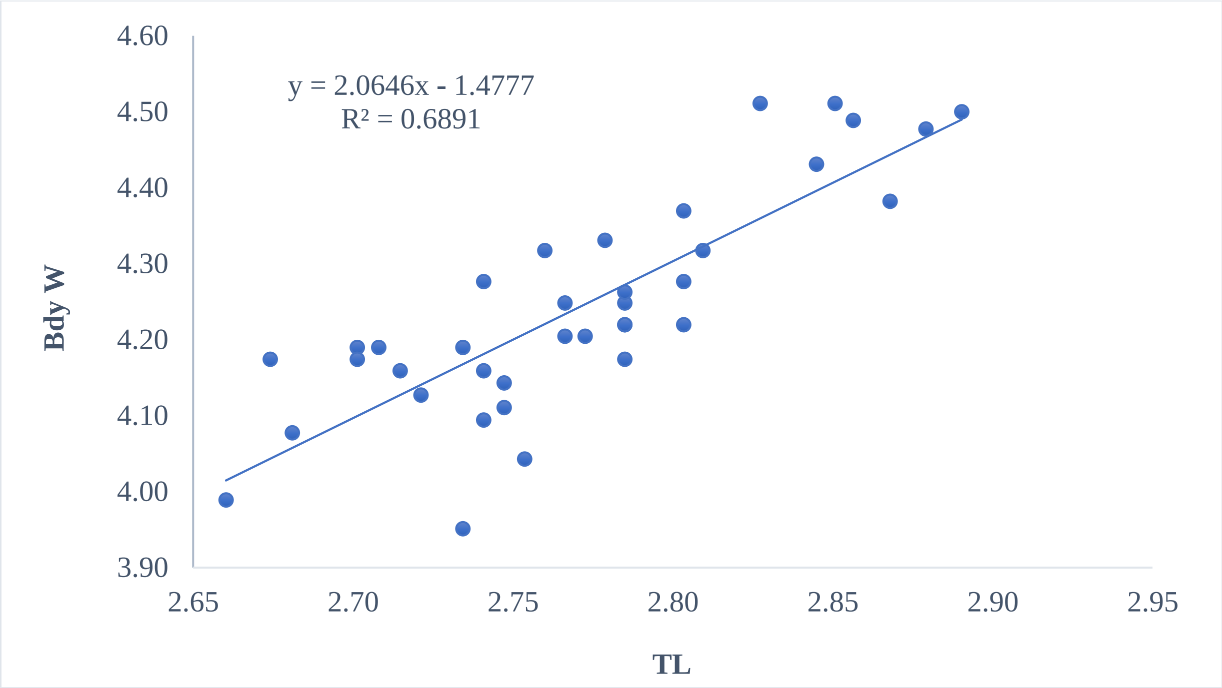

Figure 37: Regression graph of body weight on the total length of *S. galilaeus*

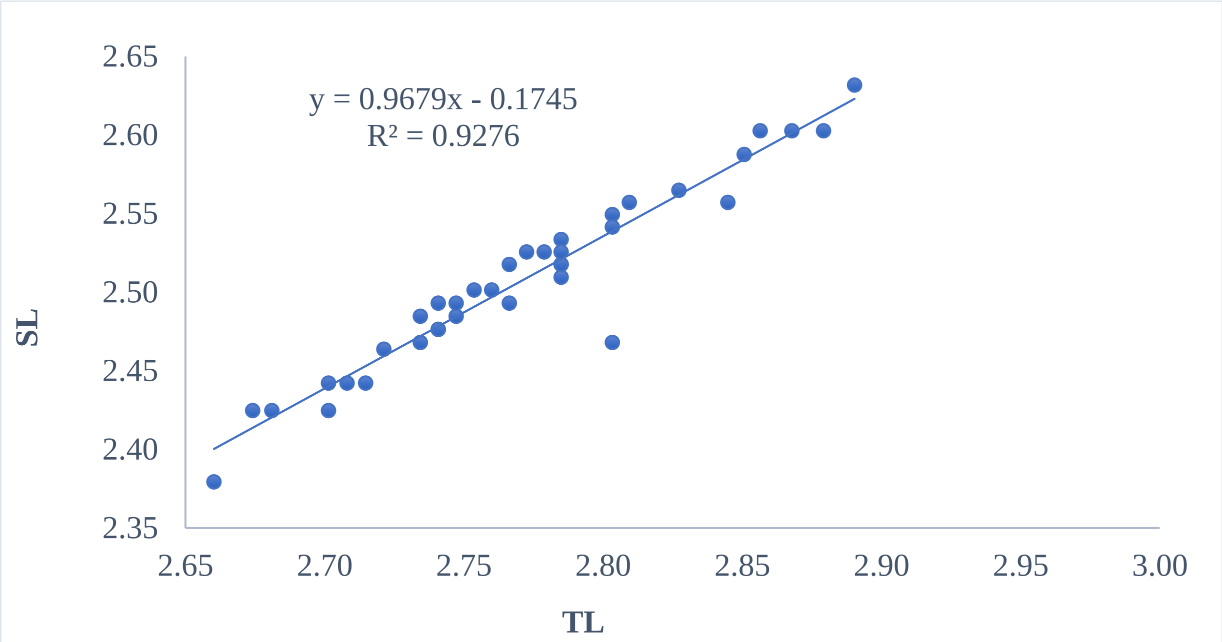

Figure 38: Regression graph of standard length on the total length of *S. galilaeus*

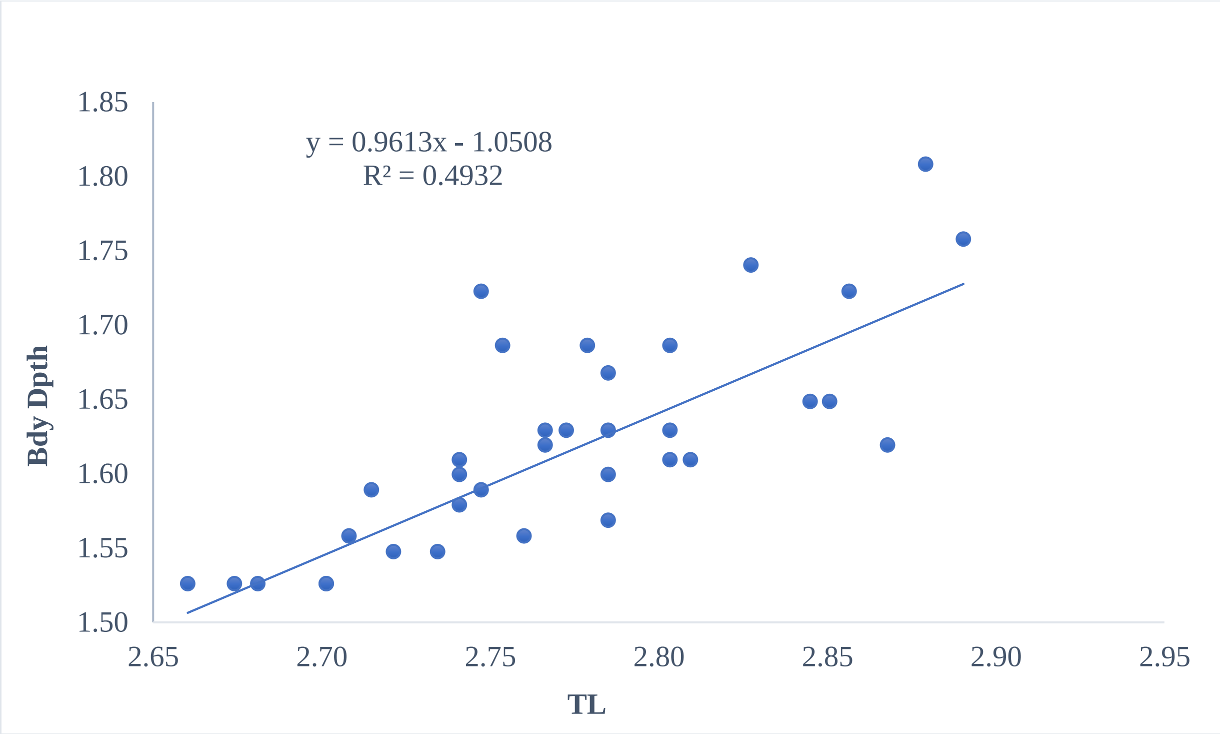

Figure 39: Regression graph of body depth on the total length of *S. galilaeus*

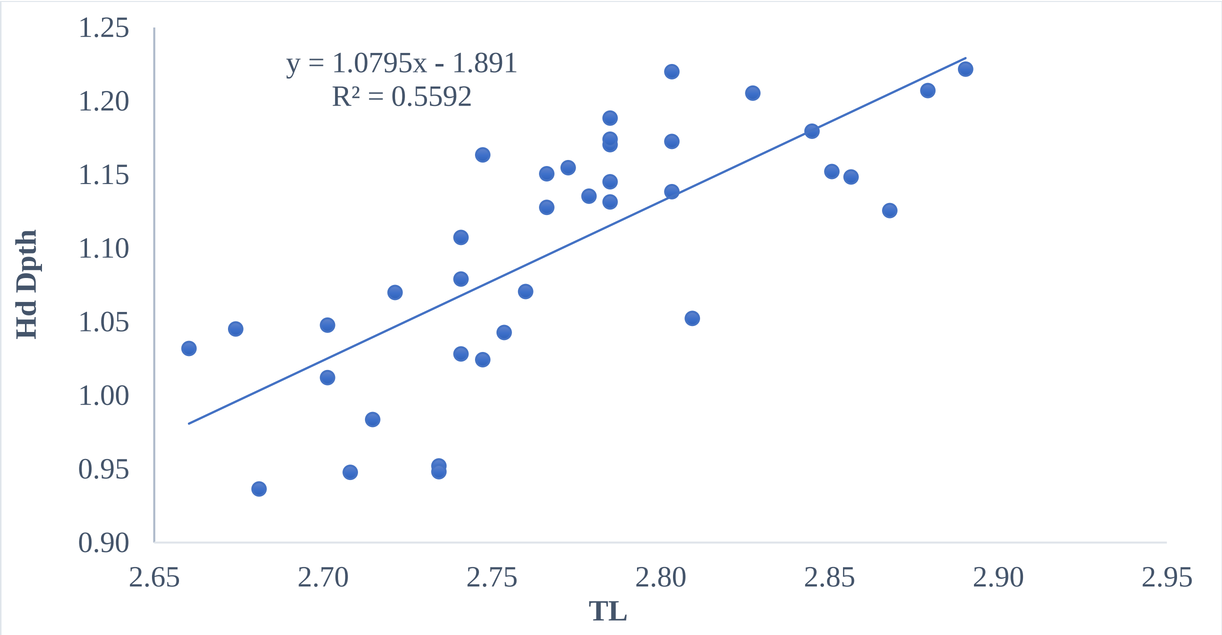

Figure 40: Regression graph of head depth on the total length of *S. galilaeus*

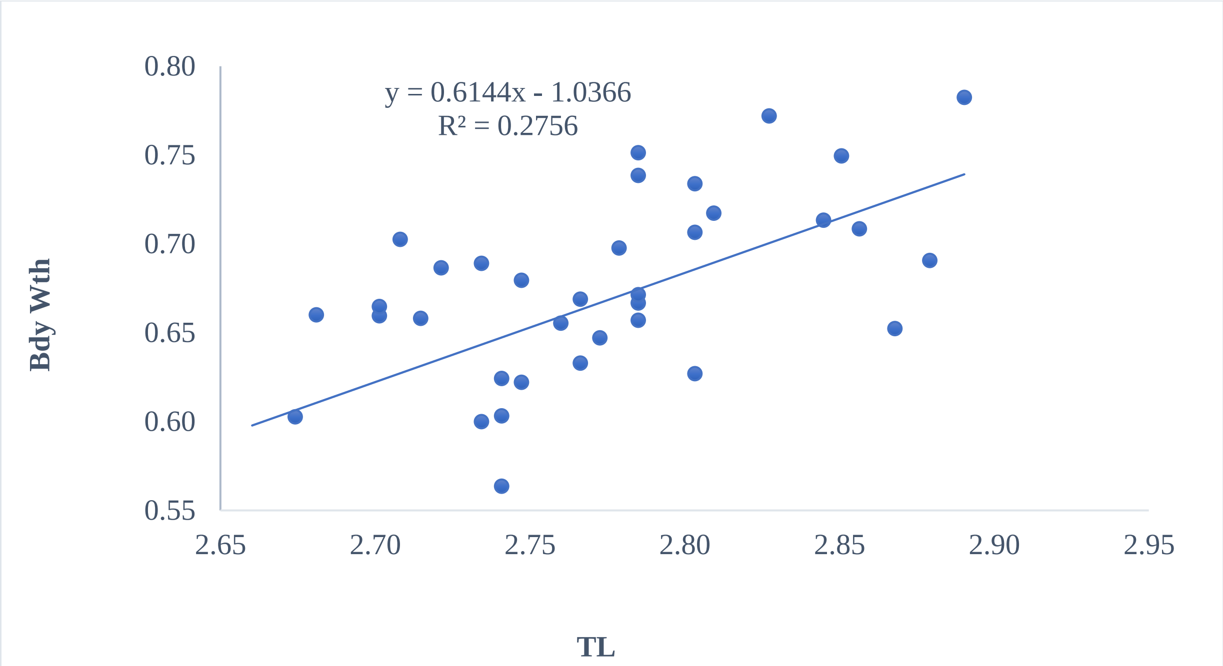

Figure 41: Regression graph of body width on the total length of *S. galilaeus*

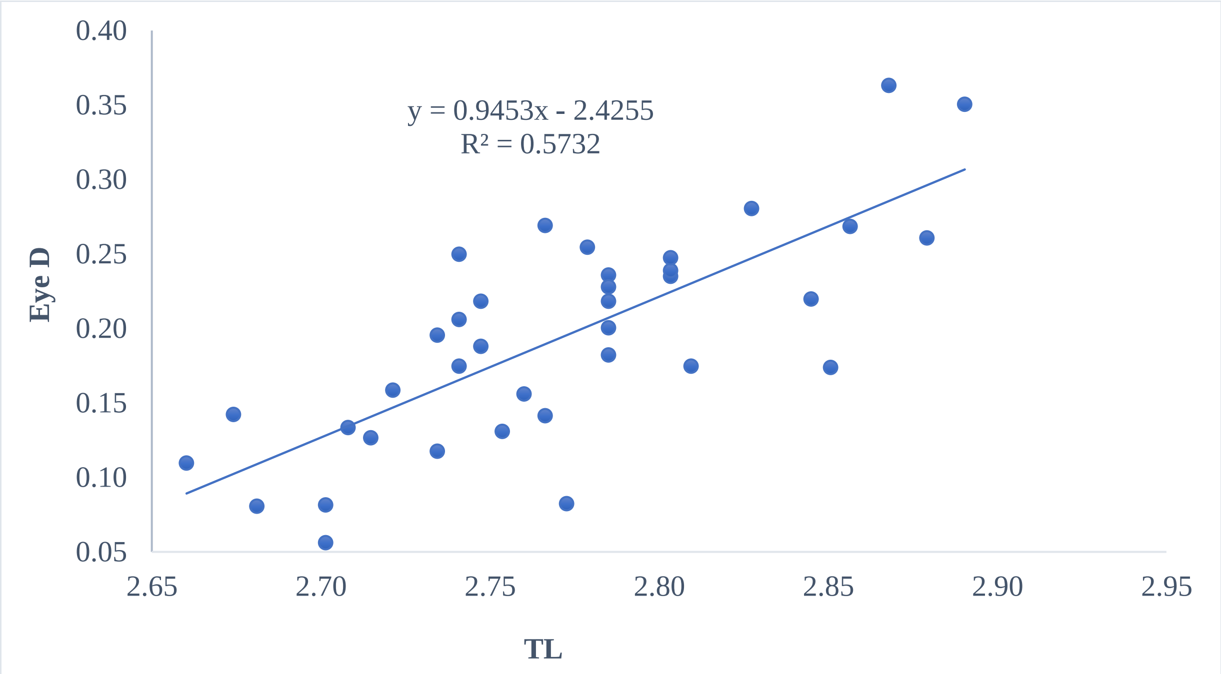

Figure 42: Regression graph of eye diameter on the total length of *S. galilaeus*

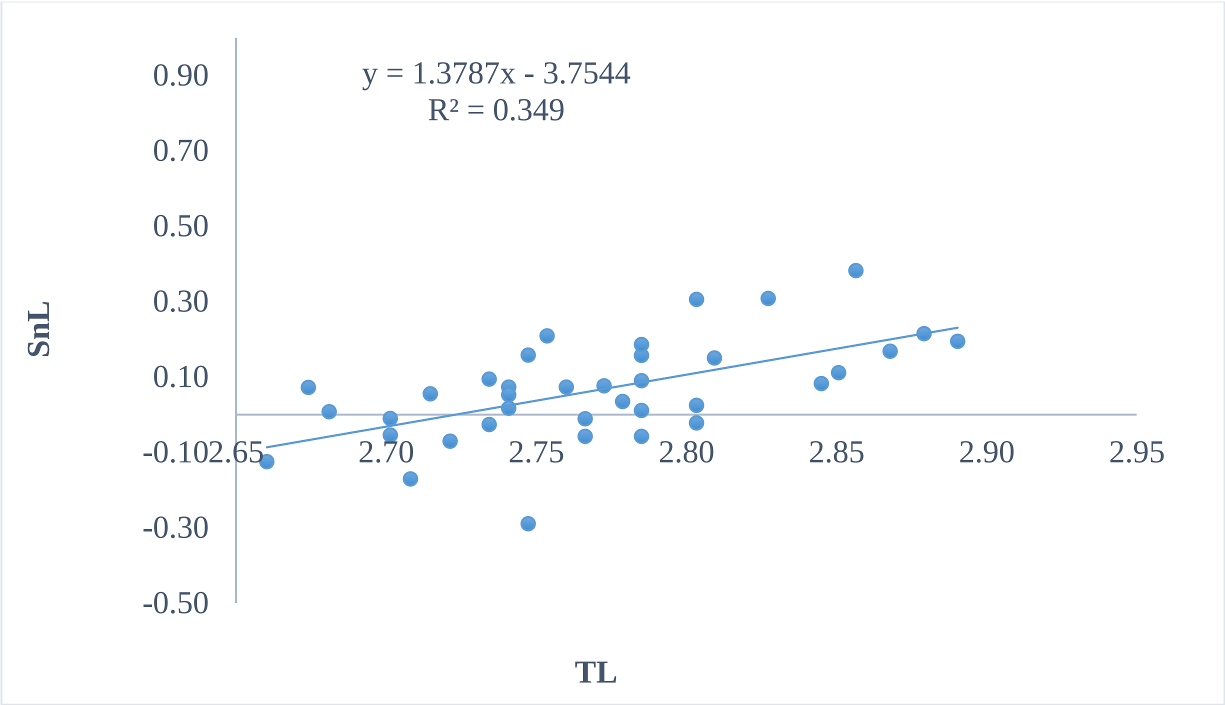

Figure 43: Regression graph of snout length on the total length of *S. galilaeus*

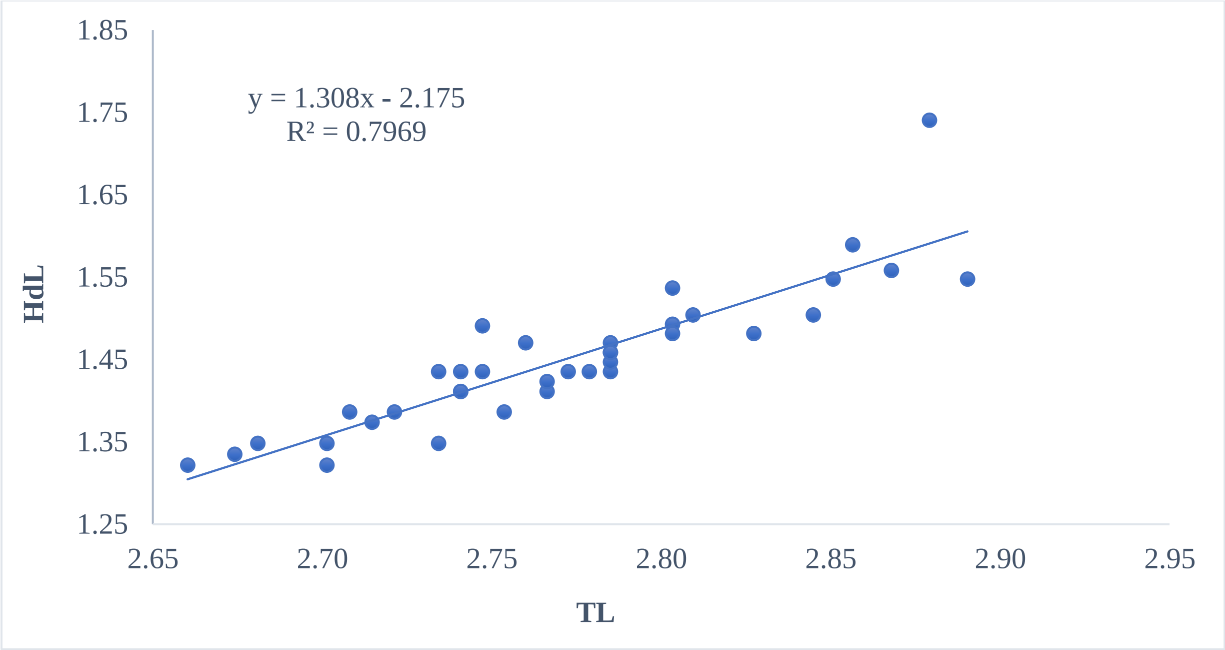

Figure 44: Regression graph of head length on the total length of *S. galilaeus*

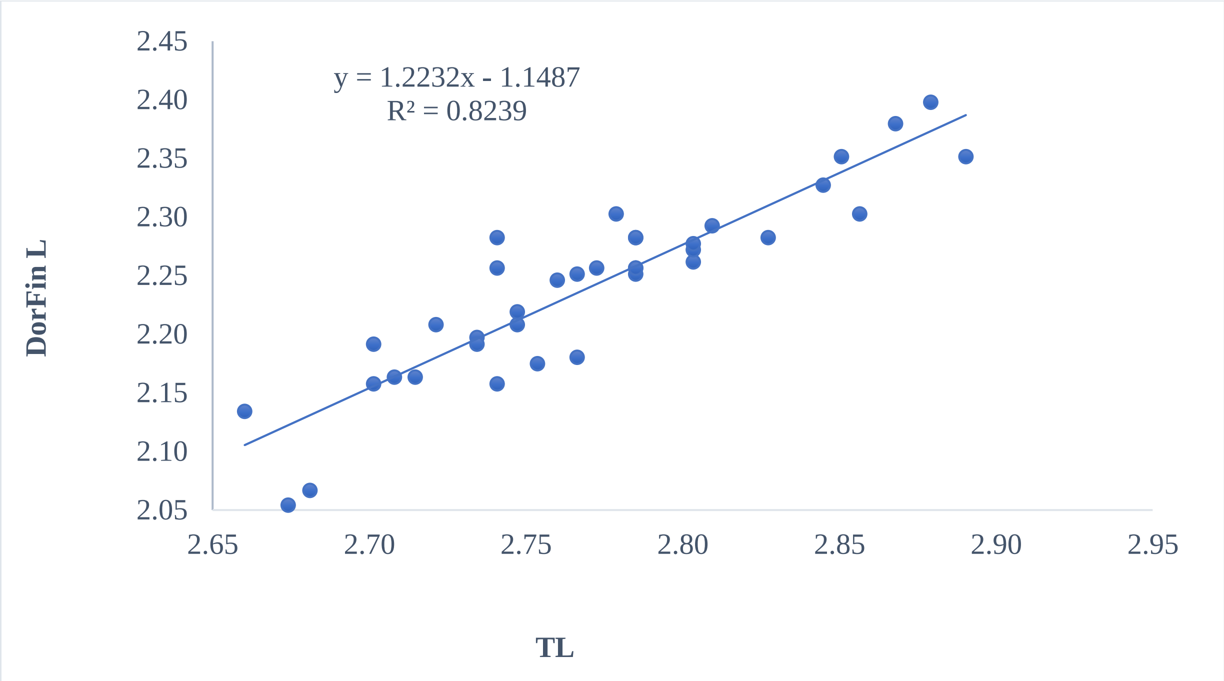

Figure 45: Regression graph of dorsal fin length on the total length of *S. galilaeus*

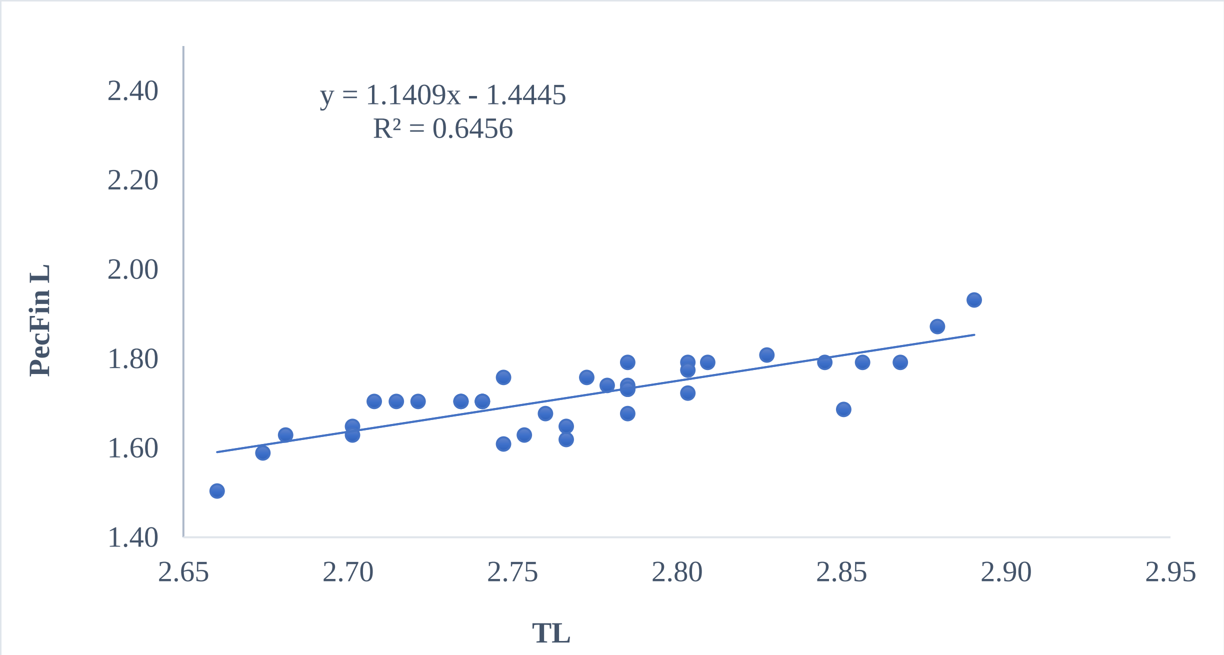

Figure 46: Regression graph of pectoral fin length on the total length of *S. galilaeus*

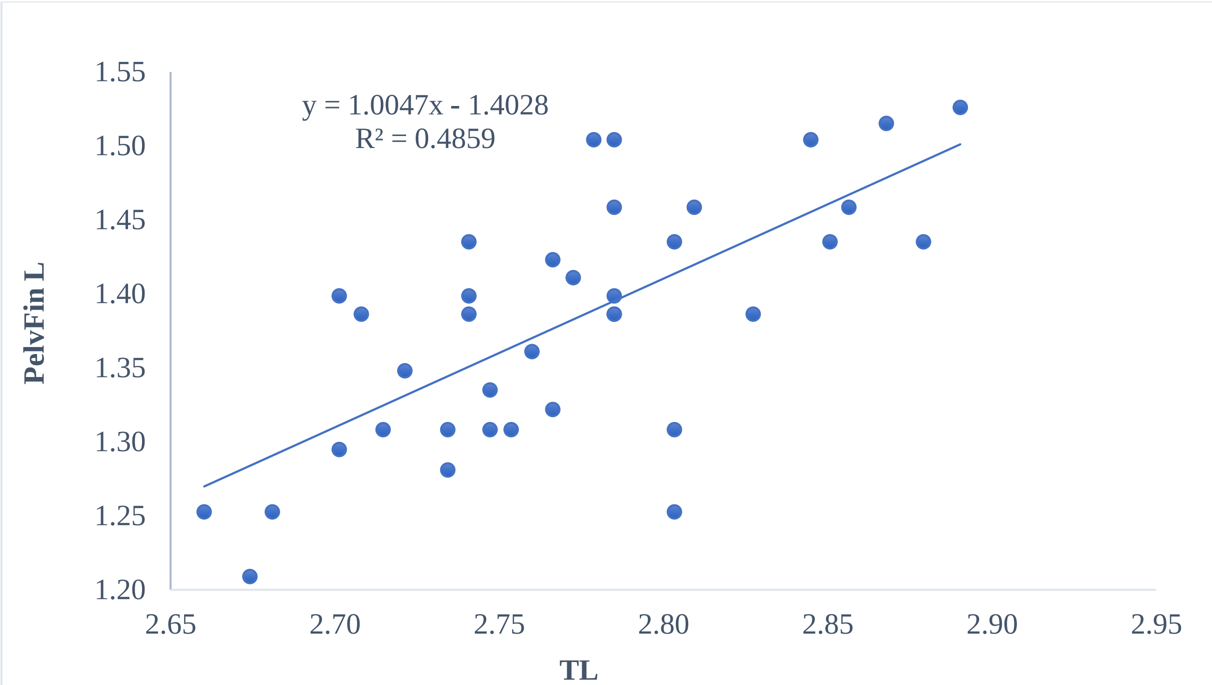

Figure 47: Regression graph of pelvic fin length on the total length of *S. galilaeus*

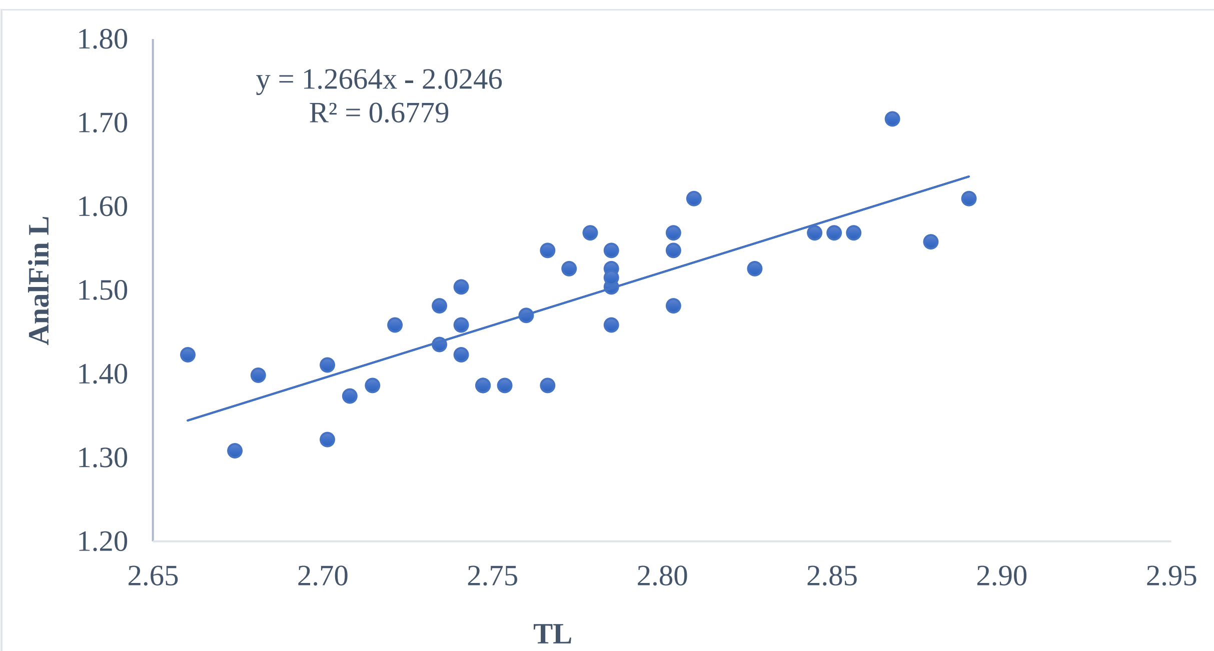

Figure 48: Regression graph of anal fin length on the total length of *S. galilaeus*

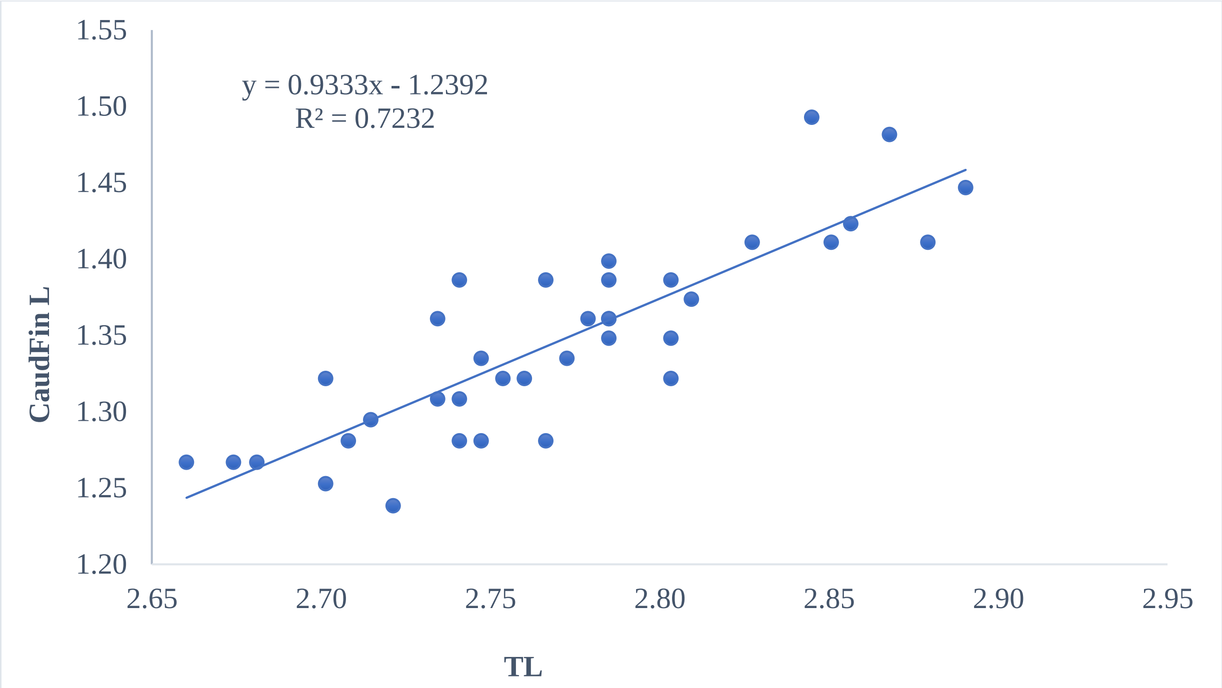

Figure 49: Regression graph of caudal fin length on the total length of *S. galilaeus*

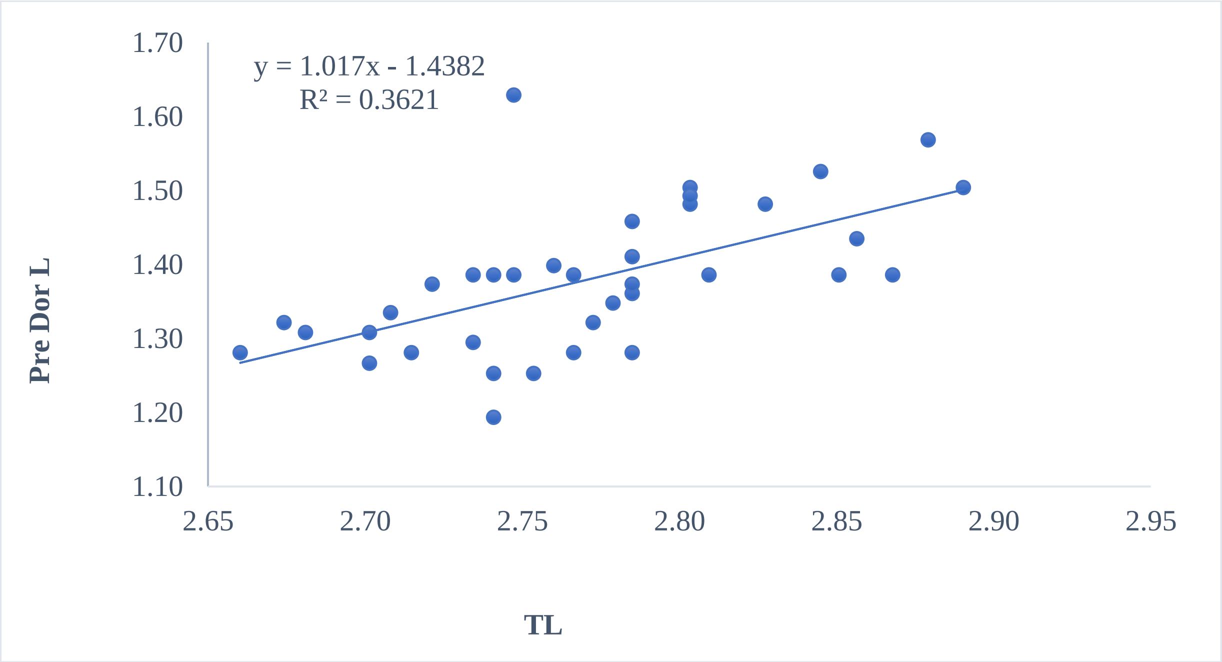

Figure 50: Regression graph of pre dorsal fin length on the total length of *S. galilaeus*

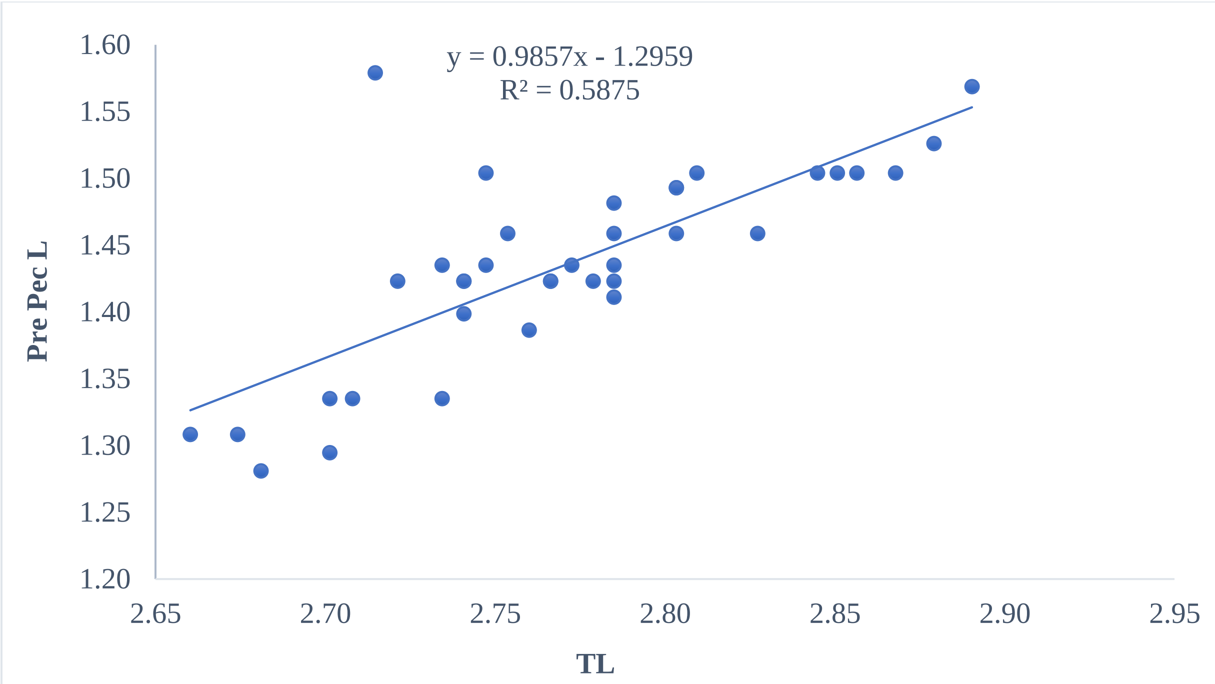

Figure 51: Regression graph of pre pectoral fin length on the total length of *S. galilaeus*

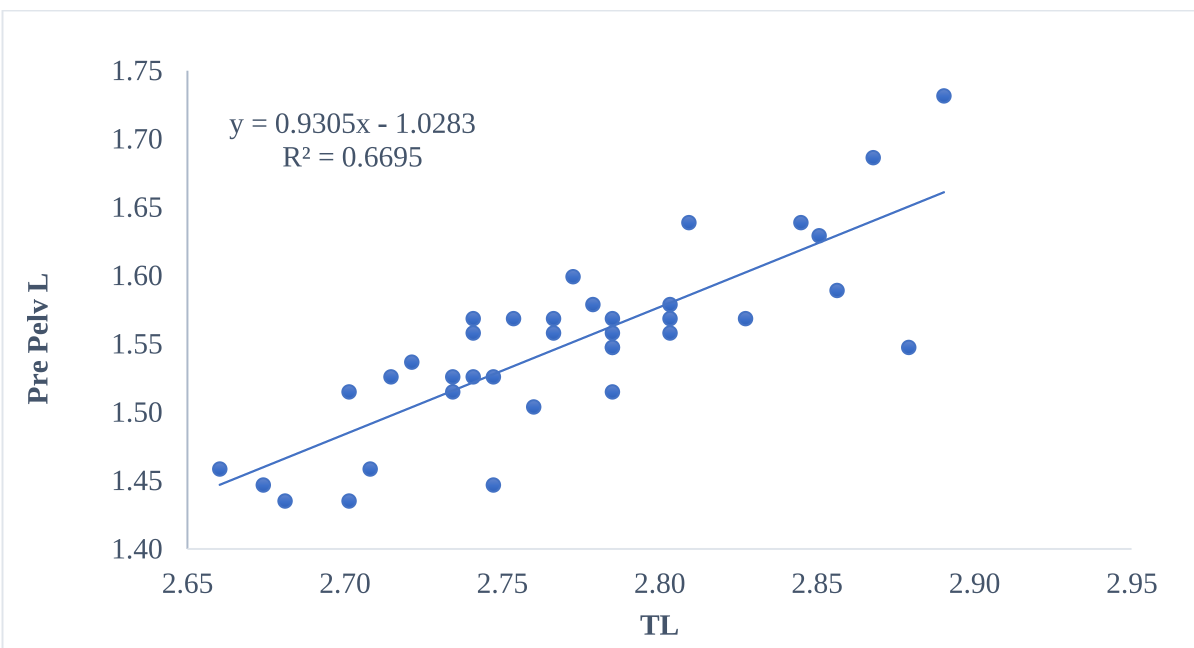

Figure 52: Regression graph of pre pelvic fin length on the total length of *S. galilaeus*

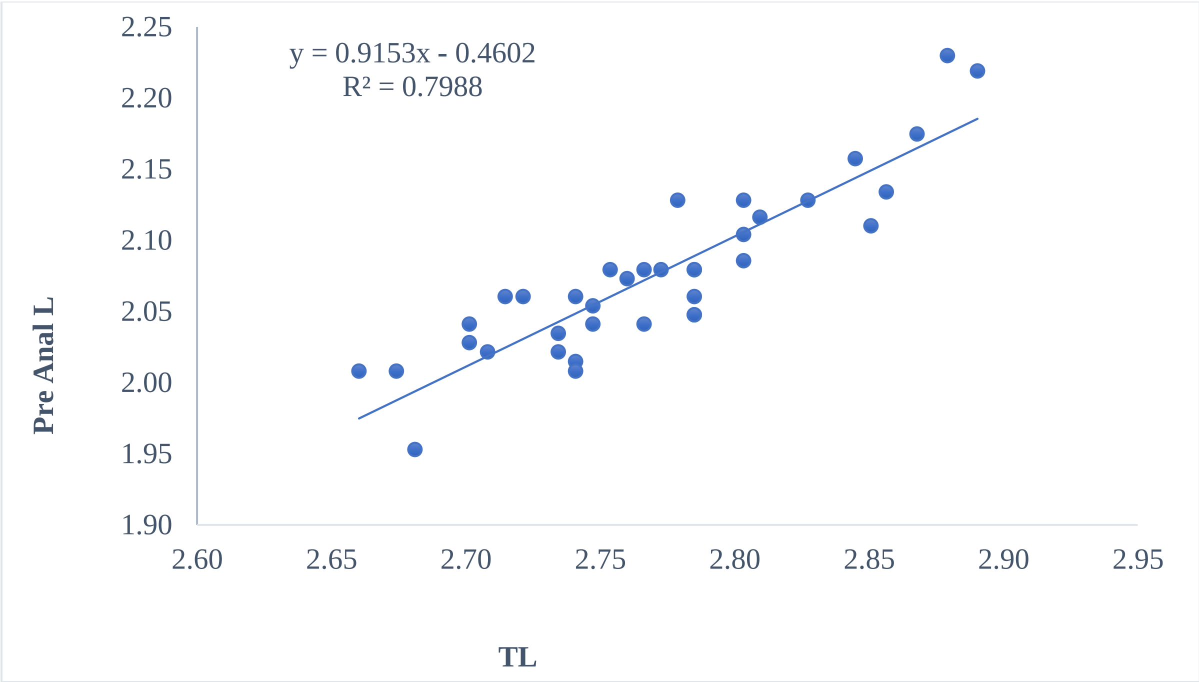

Figure 53: Regression graph of pre anal fin length on total length of *S. galilaeus*