UNIVERSITY OF CAPE COAST

ASPECTS OF THE BIOLOGY AND POPULATION DYNAMICS OF SPHYRAENA SPHYRAENA (LINNAEUS, 1758), APSILUS FUSCUS (VALENCIENNES, 1830) AND CYNOGLOSSUS SENEGALENSIS (KAUP, 1858) IN GHANAIAN WATERS

DIVINE WORLANYO HOTOR

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BY

DIVINE WORLANYO HOTOR

Thesis submitted to the Department of Fisheries and Aquatic Sciences of the School of Biological Sciences, College of Agricultural and Natural Sciences, University of Cape Coast, in partial fulfillment of the requirements for the award of Master of Philosophy degree in Fisheries Science

JULY, 2020

DECLARATION

Candidate's Declaration

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

Candidate's Signature:... Date:...........................

Name: Divine Worlanyo Hotor

Supervisors' Declaration

We hereby declare that the preparation and presentation of the thesis were supervised in accordance with the guidelines on supervision of thesis laid down by the University of Cape Coast.

Principal Supervisor's Signature:.................................... Date:.........................

Name: Prof. Joseph Aggrey-Fynn

Co-Supervisor's Signature: .... Date:.........................

Name: Prof. John Blay

ABSTRACT

Despite the commercial relevance of the *S. sphyraena*, *A. fuscus* and *C. senegalensis* to the Ghanaian fisheries there is paucity of information on the growth, population dynamics and exploitation rates of the three stocks, as such making it nearly impossible to sustainably exploit these species in Ghana. Therefore it was reasonable to investigate aspects of the biology and population dynamics of these species as the findings would help boost management measures. A total of 420, 423 and 562 specimens of *Sphyraena sphyraena, Apsilus fuscus and Cynoglossus senegalensis* respectively were studied. Total length (TL) ranged from 12.5 cm to 66.5 cm for *S. sphyraena*, 20.3 cm to 50.9 cm for *A. fuscus* and 11.0 cm to 56.4 cm for *C. senegalensis.* A significant relationship and a strong correlation between total length (TL) and body weight (BW) was exhibited by the three species. The growth of *S. sphyraena* and *A. fuscus* were allometric (b = 2.75 ±0.11; $P<0.05$ for *S. sphyraena* and b = 2.84 ±0.12; $P<0.05$ for *A. fuscus*) while *C. senegalensis* showed an isometric growth pattern (b = 3.08 ±0.11; $P>0.05$). Condition factor range for pooled specimens of *S. sphyraena* was 0.41 (±0.03) to 0.60 (±0.02), 0.37 to 0.72 for males and 0.38 (±0.04) to 0.54 for females. For *A. fuscus,* condition factor for pooled specimens ranged from 0.93 to 1.09 (±0.03), 0.94 to 1.09 and 0.94 to 1.08 (±0.03) for females. The condition factor ranged from 0.39 to 0.68 for pooled specimens of *C. senegalensis*. The exploitation rate were estimated at 0.62 for *S. sphyraena*, 0.56 for *A. fuscus,* and 0.52 for *C. senegalensis*. In conclusion, all three species exhibited exponential growth and the condition factor recorded was higher in smaller size groups than in the larger size groups.

KEY WORDS

Asymptotic length

Condition factor

Growth

Mortality

Total length

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DEDICATION

To Mr. Frederick Ekow Jonah and the Department of Fisheries and Aquatic Sciences of the University of Cape Coast, Ghana.

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LIST OF ABBREVIATIONS

COPACE	Fisheries Committee for East Central Atlantic
EEZ	Exclusive Economic Zone
ELEFAN	Electronic Length Frequency Analysis
FAO	Food and Agriculture Organization of the United Nations
FiSAT	Fisheries Stock Assessment Tool
GDP	Gross Domestic Product
ICFG	Integrated Coastal and Fisheries Governance
ICLARM	International Centre for Living Aquatic Resources Management
ISO	International Standards Organization
MoFA	Ministry of Food and Agriculture
MoFAD	Ministry of Fisheries and Aquaculture Development
SIAP	Statistical Institute for Asia and the Pacific
UCC	University of Cape Coast
USAID	United States Agency for International Development

CHAPTER ONE

INTRODUCTION

The dwindling production in Ghana’s marine fisheries is particularly dramatic for economically important species, critical for coastal livelihoods and food security. Sustaining fishery resources is essential to fishermen and the economy's survival and prosperity, as the industry continues to make a significant contribution to Ghana's GDP (Nunoo & Asiedu, 2013). *Sphyraena sphyraena* (Appendix A), *Apsilus fuscus* (Appendix B) *and Cynoglossus senegalensis* (Appendix C) form part of Ghana’s high-priced fishes, yet there is a deficiency in specific management measures due to the paucity of biological and population dynamics information of these stocks. It was therefore reasonable to investigate aspects of the biology and conduct stock assessment for these stocks in order to come up with recommendations that would lead to sustainable utilization of these fisheries resources. Studies on these fish stocks would provide information on their current state and inform policies that would ensure efficient management of their fishery.

Age and growth studies of bony fish are important bases for stock assessment (Gayanilo, Sparre & Pauly, 2005). Length is an alternative non-linear measure of time that can be used as a proxy for age (Mason, 1997). Length-based stock assessment is often seen as a last resort approach to stock assessment as it is the only practical method available in tropical waters (Fournier, Sibert, Majkowski & Hampton, 1990). This comes with the development of the length-based stock assessment methodologies, which makes it possible to investigate population dynamics of fish stocks in tropical waters using the von Bertalanffy growth function of fish stocks in tropical waters (Pauly & Munro 1984; Pauly & Morgan, 1987).

Background to the Study

Ghana has a coastline of about 550 km (Nunoo, Asiedu, Olauson & Intsiful, 2015), a continental shelf area of 23,700 km^2 and an exclusive economic zone (EEZ) of 200 nm covering an area of 235,349 km^2 (Aggrey-Fynn, 2008). The coastal upwelling system drives the productivity of Ghana's marine fisheries. This seasonal upwelling occurs between December/January to February (minor upwelling) and again between July to September (major upwelling) (Mensah, 1995; Food and Agriculture Organization [FAO], 2016). These are periods where high economic returns occur especially in the artisanal sector (Sarpong, Quaatey & Harvey, 2005; Ghana Statistical Service [GSS], 2010). According to "The State of World Fisheries and Aquaculture 2018" by FAO (2018), fish contributed more than 50% of total animal protein intake in Ghana. It is estimated that about 75% of total domestic fish production is consumed locally, accounting for about 22.4% of household food expenditures. The annual per capita consumption is estimated at about 25kg which is greater than the global the annual per capita consumption of 19kg. Total fish production from inland, marine and aquaculture is estimated at 440,000T over the last five to six years (Ministry of Fisheries and Aquaculture Development [MoFAD], 2013 & 2014; FAO, 2014). The fisheries resources in Ghana have long been a pillar of the national economy, contributing significantly to her socio-economic development. The fisheries sector generates over US$1 billion in revenue each year and accounts for at least 4.5% of Ghana's Gross Domestic Product (GDP). The sector also provides livelihood for an estimated 10% of the population representing about 2.5million people who are employed directly or indirectly including their dependents according to MoFAD (2014).

The Ghanaian fishery is operated in about 24,300 km^2 of marine continental shelf area and approximately 11,000 km^2 inland waters (Bannerman & Cowx, 2002; MoFA, 2012). The marine fishery is the backbone of the fishery sector and has been a significant non-traditional export commodity since the introduction of the Economic Recovery Program in 1984 (Quaatey, 1996). The marine fisheries sector is categorized into three main subsectors namely industrial, semi-industrial and artisanal fisheries according to Quaatey. The artisanal fisheries subsector is the most important with respect to landed weight of fish, contributing about 70% of the total annual landings of the marine fishery (MoFA, 2012) and employment (Amador, Bannerman, Quartey & Ashong, 2006). The Ghanaian fishing industry, including marine and inland fisheries, has over the last two decades contributed between 4.2% and 0.5% respectively to the nation's GDP, 2% to 7% of agricultural GDP (Sarpong et al., 2005; GSS, 2010). FAO (2005) defines artisanal fisheries as traditional fisheries involving fishing households (as opposed to commercial companies) using relatively small amount of capital and energy and relatively small fishing vessels (if any) making short fishing trips close to shore mainly for local consumption. The Ghanaian fishery is characterized by the use of several gears like purse seine net, beach seine net, drifting gillnet and hook and line which are mainly operated from dug-out canoes, powered by outboard motors with engines up to 40hp (Amador et al., 2006). MoFA (1995) reiterates the relevance of the artisanal and inshore fisheries as they provide Ghanaians with fish both for domestic use and export, whilst industrial fishery is export-oriented.

The most important pelagic fish species exploited in the Ghanaian coastal fisheries are the sardinellas (*Sardinella aurita* and *Sadinella mederensis*), which are important in the entire Gulf of Guinea. The major upwelling is thought to be more important than the minor upwelling, apparently because more sardinellas are caught during the major upwelling period, nonetheless, it is important to note that the minor upwelling is as important as the major upwelling to the recruitment of sardinella in the Ivorian-Ghanaian ecosystem (Koranteng, 1989; Nunoo, Asiedu, Amador, Belhabib & Pauly, 2014). Other pelagic fishes exploited by Ghanaian fleets belong to the Sphyraenidae, Scombridae, Carangidae, Lutjanidae, Clupeidae and Thunnidae. The most important of these to the coastal fishery are the Atlantic chub mackerel (*Scomber colias*), often found in association with sardinellas. Generally, small pelagic fish catches constitute about 65% of total landings (Nunoo et al., 2014). A number of fish species contribute to the demersal fishery in Ghana. The most important of these are Sparidae or porgies (mainly red pandora *Pagellus bellottii,* Canary dentex *Dentex canariensis* and bluespotted seabream *Pagrus caeruleostictus*), Haemulidae or grunts and Sciaenidae or croakers. Others are Mullidae or mullets, Cynoglossidae or tongue soles, Serranidae or groupers and Polynemidae or threadfins, Penaeidae or shrimps (Nunoo et al.,).

Nunoo, Asiedu, Olauson and Intsiful, (2015) reveals that sustaining fishery resources is crucial to the survival and wealth of artisanal fishers in Ghana. The artisanal fisheries sector of Ghana provides food, employment, livelihood support and socio-economic benefits to the Ghanaian economy. Fishery resources of Ghana are under stress from population pressure, increasing demand of fish, fishery products and open-access regime. A study by Koranteng, Nmashie and Baddoo (1994) echoes the immense significance of the artisanal fisheries sector when the study revealed that each artisanal fisher had between one and five wives and three to 26 other dependents, which indicates that about 94,000 fishers in the 1990s supported about 1.5 million wives, children and other relatives.

There is a worldwide perception that modern fisheries management strategies are failing to address the overexploitation of fishery resources. Stocks that are managed by both modern and traditional fisheries are improving globally. Fisheries experts now recognize that a fishery cannot be managed effectively without the cooperation of fishers to make laws and regulations work. There is inadequate understanding of traditional fisheries management practices in Ghana by both the formal managers, scientists, researchers, and the general populace. This has resulted in formulation of unsustainable and ineffective policies and management plans which sometimes lead to conflicts and mistrust between fisheries officers, fishers and fishing communities (Kuperan & Abdullah, 1994; Hilborn & Ovando, 2014)

Ghana's marine fisheries landings of all stocks have declined dramatically over the last decade, while official national statistics indicate a 30% decline from a high of 492,776MT in 1999 to 333,524MT in 2011 (FAO, 2014). The shrinking harvest is particularly dramatic for the small pelagics, sardine-like *Sardinella* species, by far the most critical for coastal livelihoods and food security. Catches have declined by some 66% and this has occurred at a time of dramatic increase in fishing effort. Worse still, the *Sardinella* catch for the all-important canoe fleet, is now around 20,000MT, down from a peak of approximately 140,000MT in 1992 (Integrated Coastal and Fisheries Governance [ICFG], 2013).

Fisheries provide a critical source of food and livelihood for millions of people. When managed properly, fisheries can augment the ecological, social, and economic goods and services that nations rely upon. However, while many countries are moving towards sustainable approaches to fisheries management, challenges still exist (Costello, 2012). Several crucial concerns that emasculate the development of the fisheries sector in Ghana include; consistent decline in national output and dwindling stock levels of aquatic resources, increasing national fish consumption deficit resulting in higher level of importation of fish and fishery products, over exploitation of fish stocks on all water bodies, weak enforcement of fisheries laws and regulations, inadequate fishing infrastructure, lack of national aquaculture suitability map (zonation), weak collaboration with communities in the management of fisheries resources, inadequate supply of fishery inputs, inadequate skilled labour in the fisheries industry and weak institutional capacity to implement government policy initiatives in the fisheries sector among varied others. The above listed problems can further be categorized under a few headings as: Low levels of protection for marine biodiversity; excessive fishing effort exerted in all aspects of the fishery; inadequate regulations and weak enforcement of existing regulations; inappropriate procedures in certifying fish for export and inadequate information on fisheries biology and stocks. In the Fisheries Management Plan of Ghana, (MoFAD, 2014), Ghana seeks to use major strategic responses to address the above outlined key issues by: Protecting marine habitats to conserve biodiversity, reducing the current levels of fishing effort and fishing capacity, ensuring product certification and reducing post-harvest losses, effective enforcement of fisheries legislation and improving information on fisheries biology and stock assessment to support a stock.

Wallace and Fletcher (2001) point out that renewable resources like finfish and shellfish are living things that replenish themselves naturally and can be harvested, within limits, on a continuing basis without being eliminated. The scientific principles behind this renewability are well known and provide the basis for fish and wildlife management. Sound knowledge basis of the biological potentials of fisheries resources are essential to ensure sustainable management of the said resources. This scientific knowledge informs and guides any management strategies to allow sustainable exploitation based on defined objectives. The goal of the management plan is to rebuild fish stocks to enhance the socio-economic conditions of fishing communities, create employment within national and international frameworks and standards and improve food security as well as contribute to GDP and foreign exchange earnings. For this reason, management is to provide a strategic framework for reversing the declining trend of fish resources and establish a sound management regime to ensure that fish stocks are exploited sustainably in an enhanced environment (MoFAD, 2014). Cooper (2006) reiterates the importance of scientific knowledge of every fishery by stating that, stock assessment provides decision makers with much of the information necessary to make reasoned choices. The most important reason to conduct fisheries stock assessments is to be able to evaluate the consequences of alternative management actions that is, to conduct a decision analysis (Punt & Hilborn, 1997).

Gayanilo and Pauly (1997) described a stock as a sub-set of one species having the same growth and mortality parameters, for which the geographical limits can be determined. Cushing (1995) defines a stock as a subset of a species with a single spawning group which the adults join year after year. Larkin (1972) defines a stock as "a population of organisms which, sharing a common gene pool, is sufficiently discrete to warrant consideration as a self-perpetuating system which can be managed", while Ihssen et al. (1981) define a stock as "a temporal or spatial integrity". Ricker (1975) defines a fish stock as "the part of a fish population which is under consideration from the point of view of actual or potential utilization". This definition reflects a different view of the stock concept. Gulland (1983), conceivably offers a more suitable definition by stating that, for fisheries management purposes, the definition of a unit stock is an operational matter, that is, a subgroup of a species can be treated as a stock if differences within the group and interchanges with other groups can be ignored without making invalid the conclusions reached in the course of an assessment.

Gayanilo and Pauly (1997) explained that, it will be preferable to initiate stock assessments over the entire area of distribution of a species, as long as there are no indications that separate unit stocks exist in that area if it becomes clear that the growth and mortality parameters differ significantly in various parts of that area, it will be necessary to perform the assessment on a stock basis. This implies that it will commonly be appropriate to initiate stock assessments over the entire area of distribution of a species, as long as there are no indications that, separate unit stocks exist in that area. If it becomes clear that the growth and mortality parameters differ significantly in various parts of that area, it will be necessary to perform the assessment on a stock basis. It is easier to identify a stock for species showing little migratory behavior (mainly demersal species) than for highly migratory species such as tunas. According to Sparre and Venema (1992), a prerequisite for the identification of stocks is the ability to distinguish between different species, and because of the great number of different, but often similar, species observed in tropical fisheries their identification can be problematic. The fishery scientist, however, must master the techniques of species identification if any meaningful fish stock assessment is to come out of the data collected. According to King (1995), the principal objective of fish stock assessment is to establish the status of the stock and to determine the intensities at which it could be exploited sustainably. That is, fish stock assessment brings forth the exploitation level which in the long run gives the maximum yield in weight from the fishery. After stock assessment has been carried out, enough basis are provided to inform the optimum exploitation of aquatic living resources such as fish and shrimp. Cooper (2006) explains that, stock assessment describes a range of life history characteristics for a species, such as information (derived from other studies) about age, growth, natural mortality, sexual maturity and reproduction; the geographical boundaries of the population and the stock; critical environmental factors affecting the stock; feeding habits; and habitat preferences. Drawing on the knowledge of both fishermen and scientists, stock assessments give qualitative and quantitative descriptions of the fishery for a species, past and present.

In tropical and subtropical waters, it is not possible to determine age by counting rings in hard parts of the fish, such as otoliths or scales. The lack of strong seasonality makes the distinction of seasonal rings and year-rings problematic for tropical species (Konan, Joanny, Sylla, Lianthuam & Kumar, 2015). However, with the development of the length based stock assessment methodologies, it is possible to investigate population dynamics of fish stocks in tropical waters (Pauly & Munro, 1984; Pauly & Morgan, 1987). Studies on the population dynamics of fish stocks involves the estimation of stock abundance, determination of growth and mortality parameters, analysis of catch and effort data, determination of yield, reproductive activities and recruitment patterns.

According to Wallace and Selman (1981), most tropical teleosts undergo continuous growth and reproduction. This makes the application of the conventional stock assessment procedures to tropical fisheries difficult (Bagenal & Tesch, 1978; Pauly, 1979; Gayanilo et al., 2005). Nonetheless, the development of modified methods of length-based procedures makes it easier and possible to assess tropical fish stocks (Gayanilo, Soriano & Pauly, 1988;

Sparre, 1990). Most fish stock assessment procedures are computer-based (including Length-based Fish Stock Assessment [LFSA], Electronic Length Frequency Analysis [ELEFAN], Fisheries Stock Assessment Tool [FiSAT]) which are used in analyzing periodic collection of length or weight-based data (Pauly & Morgan, 1987; Sparre &Venema, 1992). Researchers in Ghana have used length-based data by the use of ELEFAN I (FiSAT) in estimating the exploitation rates and determining suitable levels of exploitation as well as growth and mortality parameters (Blay & Asabere-Ameyaw, 1993; Blay, 1998; Kwafo-Apegyah, Ofori-Danson & Nunoo, 2008; Ofori-Danson & Kwarfo-Apegyah, 2008).

Problem Statement and Justification

Sphyraena sphyraena (European Barracuda), *Apsilus fuscus* (African fork tail) and *Cynoglossus senegalensis* (Senegalese tongue sole) are important fish resources in Ghana (Koranteng, 2001a; Nunoo et al., 2014). Aggrey-Fynn and Sackey-Mensah, (2012) revealed a relative abundance of about 7.4% for all three fish species out of a total of 56 marine fish species studied. Nunoo et al. (2015) spelt out that, sustaining fishery resources is crucial to the survival and wealth of artisanal fishers in Ghana. As part of Ghana's Fisheries Management Plan (2015-2019), Ghana seeks to use major strategic responses to address the current situation by improving information on fisheries biology and stock assessment to support management of the stocks (MoFAD, 2014). Despite the commercial relevance of the *S. sphyraena, A. fuscus* and *C. senegalensis* to the Ghanaian fisheries there is paucity of information on the growth, population dynamics and exploitation rates of the three stocks, as such making it nearly impossible to sustainably exploit these species in Ghana.

Purpose of the study

It is reasonable to investigate the aspects of the growth, population dynamics and exploitation rates of these three commercially important species (*S. sphyraena, A. fuscus* and *C. senegalensis*) as these would help close the knowledge gap on these species. Again, the study would provide some relevant information on the current state of the stock of these three species. This information would inform policies by helping to determine the appropriate effort required in the fisheries to maintain a sustainable exploitation rate, thereby ensuring the effective management of the fishery of the three species.

Research objectives

This study seeks to provide information on aspects of the growth, population dynamics and exploitation rates that would contribute to management strategies for sustainable exploitation of *S. sphyraena*, *A. fuscus* and *C. senegalensis* stocks in Ghana.

The specific objectives were to:

1. establish the length frequency distribution and length-weight relationship of *S. sphyraena, A. fuscus* and *C. senegalensis*,
2. determine the condition factor of the three species,
3. determine the sex ratio of *S. sphyraena* and *A. fuscus,*
4. estimate growth parameters (asymptotic length, growth coefficient and length at first capture)

5. estimate mortality parameters and exploitation levels.

Significance of the study

The findings of this study will contribute to close the knowledge gap on the aspects of the biology of the three species in Ghanaian waters. Again, the results of the study will provide the information needed to inform policies on management of the fishery of *S. sphyraena, A. fuscus* and *C. senegalensis* in Ghana.

Delimitations of the Study

a. This study was restricted to artisanal semi-industrial landings of *S. sphyraena*, *A. fuscus* and *C. senegalensis* from Tema fishing harbour (Greater Accra Region), Elmina fish landing site (Central Region) and Albert Bosomtwe-Sam Fishing Harbour (Western Region) in Ghana.
b. The sampling areas did not extend to the other coastal region (Volta) of Ghana.
c. Some periods of sampling were characterized by very low samples and in some cases no samples

Limitations of the Study

a. Analyses that required the use of length measurements were restricted to total length (TL) measurements.
b. This study sort to provide information on aspects of the growth, population dynamics and exploitation rates thereby not taking in account or details the entire biology of the fish species studied.

c. The challenge of not using the same instrument for taking fish weight in the laboratory and on the field was encountered because laboratory mounted electronic balance could not be used on the field.

Definition of Terms

Asymptotic length: It is the length a fish in a stock would attain if they were to grow for an infinitely long period.

Condition factor: Describes the well-being or fatness of a fish.

Mortality: It is used to account for the loss of fish in a fish stock either due to fishing or natural causes.

Total length: The length of a fish measured from the tip of the snout to the tip of the longest caudal fin rays.

Size: The length of a fish at any given period.

Organization of the Study

This work is systematized in six chapters. The first chapter introduces the study by providing the background relevant to the scope of study and provides the problem and justification thereof. In the same chapter, the purpose, research objectives, significance, delimitations and limitations of the study as well as definition of terms pertaining to the study are provided. Chapter two reviews various literature to carve the key concepts such as the dynamics and current trends in the Ghanaian fishery, fish growth, mortality and exploitation rates, computer-based fish stock assessment procedures (including ELEFAN and FiSAT) used in analyzing periodic collection of length or weight-based data. Chapter three speaks to the materials and describes the methods applied during the study. It touches on the sampling areas, laboratory approach, formulas, analytical tools, procedures used and provides a chapter summary. Chapter four unfolds the results presented in figures and tables with their corresponding comments or descriptions. Chapter five discusses the results in relation to the set objectives by comparing to other works within the scope of study and coming out with some buttressed inferences and asserted speculations. Chapter six summarizes the entire study, makes some logical conclusions and provides recommendations derived from the study based on the objectives.

Chapter Summary

This chapter introduced the study by providing the background relevant to the scope of study and the problem and justification thereof. In the same chapter, the purpose, research objectives, significance, delimitations, limitations of the study as well as definition of terms pertaining to the study are provided. An overview of how the study was organized in all six chapters was described in this chapter.

CHAPTER TWO

LITERATURE REVIEW

This chapter brings to light aspects of the biology and population dynamics of *S. sphyraena*, *A. fuscus* and *C. senegalensis*. Various literature relating to the three species were reviewed to come up with the key theories and practical concepts concerning the dynamics and current trends in the Ghanaian fishery, fish growth, mortality and exploitation rates and computer-based fish stock assessment procedures (including ELEFAN and FiSAT) used in analyzing periodic collection of length or weight-based data. An overview of the three as well as reports by other authors is provided.

Growth

According to Gayanilo et al., (2005), age and growth studies of bony fish are important basis for stock assessment. Gayanilo et al. define growth as the change over time of the body mass of a fish, being the net result of two processes with opposite tendencies, one the building-up of body substances (anabolism) and the other the breaking-down of these substances (catabolism). According to a training manual for assessing the status of fish stock prepared by Singh in 2009, the production from a fish stock is a function of the recruitment of new individuals and the growth of the existing individuals in the population. Methods such as hard tissue reading, tagging-recapture and length frequency analyses can be used to study growth of bony fish, however, in the tropics, age determination by the calcified structures is often difficult due to the lack of strong seasonality making the distinction of seasonal rings (Bagenal & Tesch, 1978). The development of the length-based stock assessment methods makes it is possible to investigate population dynamics of fish using the von Bertalanffy growth function in tropical waters (Pauly, 1986; Pauly & Morgan 1987)

Length is an alternative non-linear measure of time that can be used as a proxy for age, in addition, stock assessment methods work by transforming length to age (Mason, 1997). This is possible because fish grow throughout their lives, thus making it possible to determine growth rate from length. The process, he said, is somewhat complicated by the fact that fish growth is usually asymptotic, with growth continually slowing, therefore, using observations of fish length frequency and equations for growth and survival, it is possible to determine values for the stock parameters.

According to Mason (1997), length frequency analysis is a general term for a variety of methods that have been developed to determine the values for the stock parameters when only length information is available. Length based stock assessment is often seen as a last resort approach to stock assessment but it is often the only practical method available in tropical waters (Rosenberg & Beddington, 1988). Gulland and Rosenberg (1992) observed an upsurge in the use of length-based methods of assessing fish populations, the impetus results from at least three factors. These factors are: the increasing problems associated with age-based methods, the development of improved methods of analyzing length data and the increased availability of computers, especially desk-top microcomputers that put within the reach of all the computational power needed to take advantage of some of the new methods.

Length-weight relationship and condition factor are important for not only the mathematical relationship between fish length and body weight, but also to study the biology of fish. It is one of the important morphometric characters that can be used for taxonomy and ultimately in fish stock assessment. Length-weight relationship of a fish is essential, since various important biological aspects, such as general well-being of fish, appearance of first maturity, onset of spawning, etc., can be assessed with the help of condition factor, a derivative of this relationship (Le Cren, 1951). Moreover, the length-weight relationship of fish is an important fishery management tool because they allow the estimation of the average weight of the fish of a given length group (Beyer, 1991). This analysis reveals the extent to which the two variables, length and weight are related to each other and thereby help one to calculate with ease one variable when the other is known (Chandrika & Balasubramonium, 1986).

It must be noted, however, that length-weight relationships differ among fish species depending on the inherited body shape and the physiological factors such as maturity and spawning (Schneider, Laarman & Gowing, 2000). This relationship might change over seasons or even days (De Giosa, Czerniejewski & Rybczyk, 2014). It is argued that '*b*' may change during different time periods illustrating the fullness of stomach, general condition of appetite and gonads stages (Flura et al., 2015). In addition, the growth process can differ in the same species dwelling in diverse locations and influenced by numerous biotic and abiotic factors (Jisr, Younes, Sukhn & El-Dakdouki, 2018).

In fishery science, the condition factor or K is used in order to compare the 'condition', 'fatness' or 'well-being' of fish and it is based on the hypothesis that heavier fish of a given length are in better condition (Bagenal & Tesch, 1978). Condition factor also gives information when comparing two populations living in certain feeding, density, climate, and other conditions, when determining the period of gonadal maturation and when following up the degree of feeding activity of a species to verify whether it is making good use of its feeding source (Le Cren, 1951; Lizama & Ambrosio, 2002). Average indices gauge overall population condition, although for many species it is appropriate to evaluate condition only by discrete length classes (Neuman & Murphy 1991; Bister et al. 2000). Furthermore the empirical relationship between the length and weight of the fish enhances the knowledge of the natural history of commercially important fish species, thus making the conservation possible. The study of the condition factor is thus important for understanding the life cycle of fish species and contributes to adequate management of these species and, therefore, to the maintenance of equilibrium in the ecosystem.

Mortality and Exploitation

Recruitment, growth and mortality influence stock size of fish. The biomass of fish in the usable stock increases by reproduction and growth. Mortality assessment of exploited stocks is an important aspect of studies on dynamics of fish populations. As defined by Sparre (1998), a cohort is a batch of fish all of approximately the same age and belonging to the same stock. Singh (2009) points out that, the concept of mortality essentially is to describe the death process of a cohort (population) and is not individually focused, that is, the number of fish in each cohort and how it declines through time. All fish of a cohort are assumed to have the same age at a given time so that they all attain the recruitment age at the same time. The concept of mortality seeks to estimate the total mortality, natural mortality and fishing mortality (Gayanilo et al., 1988). There are a number of methods used in estimating total mortality (Sparre & Venema, 1992). The catch curve approach is the most commonly used method in the tropics in estimating total mortality which is based on the assumption of a constant parameter system (Gayanilo et al., 2005). This approach takes two different forms thus, the length-converted catch curve and age-converted catch curve depending on the type of data used. Of the two, the age-converted catch curve is less used in the tropics because of the difficulty in ageing teleost in the region.

According to King (1995), natural mortality (M) is the loss of fish due to all causes except fishing (example predation, old age, disease and starvation), and the direct estimation of natural mortality can therefore be obtained only from unexploited stocks. According to Singh, (2009) the natural mortality rate and pattern is one of the driving forces of evolution and consequently, the natural mortality rate has clear correlations with other life history parameters and the approaches are either based on situations such as using catch data from commercial fisheries, sampling programmes or mark and recapture methods. Natural mortality is normally calculated from Pauly's empirical equation (Pauly, 1980). Fishing mortality (F) is the mortality due to fishing and it is sometimes estimated by subtracting natural mortality from total mortality (King, 1995). The exploitation rate (E) is the ratio of fishing mortality to total mortality (Sparre & Venema 1992). This rate determines the level of exploitation of a fishery.

Stock assessment tool (FiSAT)

According to Gayanilo et al. (2005), a sub-set of one species having the same growth and mortality parameters, for which the geographical limits can be defined, may be considered as a stock. Cadrin and Dickey-Collas (2014) explained that, stock assessment is the synthesis of information on life history, fishery monitoring, and resource surveys for estimating stock size and harvest rate relative to sustainable reference points. The primary aim of fish stock assessment is to establish the status of the stock and to determine the levels at which it could be exploited sustainably. Stock assessment also involves forecasting the response of the resource to alternative management scenarios (Hilborn and Walters, 1992; Cadrin & Dickey-Collas, 2014).

Research on the population dynamics of fish stocks involves the estimation of stock abundance, determination of growth and mortality parameters, analysis of catch and effort data, determination of yield, reproductive activities and recruitment patterns (Osei, 2016). Most tropical teleost undergo continuous growth and reproduction thereby making the application of the conventional stock assessment procedures to tropical fisheries robust (Bagenal & Tesch, 1978; Pauly, 1979; Gayanilo et al., 2005). The development of modified methods of length-based procedures makes it easier and possible to assess tropical fish stocks (Gayanilo et al., 1988; Sparre, 1990; Cadrin & Dickey-Collas, 2014). Most fish stock assessment procedures are computer-based (ELEFAN and FiSAT) which are used in analyzing periodic collection of length or weight-based data (Pauly & Morgan, 1987; Sparre & Venema., 1992), as well as application of mathematical models that fit available information to provide simplified representations of population and fishery dynamics (Cadrin & Dickey-Collas). According to Gayanilo and Pauly (1997), more relevance should be given to length measurements than age data because time-series of length frequencies are the most common data type collected for tropical fish stock assessment. However, they provided two reasons that makes age data important. The first is the possibility of carrying out small number of age readings and comparing to length measurements, while the second allows for easy explanation of stock assessment concepts and theories on the basis of age and length data than on the basis of length data only.

Researchers in Ghana have used length-based data by the use of ELEFAN I (FiSAT) in estimating the exploitation rates and determining suitable levels of exploitation as well as growth and mortality parameters (Blay & Asabere-Ameyaw, 1993; Blay, 1998; Kwafo-Apegyah et al., 2008; Ofori-Danson Kwarfo-Apegyah, 2008).

Sphyraena sphyraena **(Linnaeus, 1758)**

Sphyraena sphyraena commonly called the European Barracuda is a tropical and subtropical fish species found in the Atlantic, Pacific and Indian Oceans. In West Africa, the distribution of the species is from Morocco to Angola. It is an epipelagic species which is found in coastal and offshore water ranging to a depth of approximately 100 metres (Schneider, 1990; Aggrey-

Fynn, Fynn-Korsah & Appiah, 2013). There appears to be some ontogenetic separation, with young individuals being found in shallow waters in small schools, while adults tend to be sedentary (Barreiros, Santos & de Borba, 2002; Pastore 2009). Additionally, it is inferred that at some stage in the life history, it is spatially distributed amongst schools of commercially-important small pelagics, as estimates of biomass of "small pelagics" gathered from trawl surveys in the Adriatic Sea include *S. sphyraena* (Palomera et al. 2007).

It is primarily a specialized piscivore with a diet consisting of >99% pelagic and supra-benthic fishes, less often on cephalopods and crustaceans (Kalogirou, Mittermayer, Pihl & Wennhage, 2012). *S. sphyraena* feeds almost exclusively on small pelagic fishes. The primary components of the diet include commercially-important Clupeids and the commercially important *Boops boops* (Kalogirou et al., 2012). In the Mediterranean this species is recorded to 50 m depth, and grows to about 150 cm length (de Morais et al., 2015). The maximum age for this species is about eight years (de Sylva, 1963; Allam, Faltas, & Ragheb, 2004a). At Elba Island, recruits were encountered in July and August (Biagi, Gambaccini, & Zazzetta, 1998).

***Apsilus fuscus* (Valentines, 1830)**

Apsilus fuscus commonly known as the African forktail snapper is one of the species belonging to the family Lutjanidae. The common characteristic feature of this species is that its caudal fin is deeply forked. This demersal species inhabits rocky bottoms (Schneider, 1990), deep coral and rock reefs. It is found mostly solitary or in small groups. It feeds on small fishes, squids and crustaceans, including cephalopods, and may be caught in the commercial octopus fishery (de Morais et al., 2015).

This species inhabits depths between 15 m and 300 m, but is more commonly observed at depths greater than 50 m. *A. fuscus* has been reported in estuaries in Badagry Creek, Nigeria (Agboola & Anatekhai 2008), and is common in assemblages observed along the coast of Ghana at depths of less than 40 m, although this may reflect seasonal abundance during upwelling (Koranteng, 2001b). In Senegal and Ghana, maximum sizes observed are about 30 cm to 38.5 cm. All West-African Lutjanidae species are found at maximum depths which are within the range (30 m to 70 m) commonly fished by industrial, artisanal and/or recreational fisheries. According to Aggrey-Fynn et al. (2013), this species is present in mixed-catch commercial trawling fisheries, and caught by artisanal fishers by beach seine, hand line and industrial trawling in Ghana (which operates between 30 m and 70 m depth). In Nigeria, this species is more commonly seen in scientific surveys (e.g. Nansen surveys) at depths of greater than 50 m (Agboola & Anetekhai, 2008).

According to de Morais et al. (2015) there are no species-specific catch statistics available for lutjanids and that there may be widespread inconsistencies in reporting aggregate catches of Lutjanidae species when lutjanids are misidentified as sparids. Lutjanids are fished by artisanal, recreational, and industrial fisheries in many West African nations, including Congo (estimated 5.5% artisanal, 10% industrial), Togo (estimated 1.03% artisanal, also taken in beach seine fisheries), Benin (estimated 2.9% artisanal), Guinea Bissau (3% recreational fishery, 0.32% foreign industrial catches), Nigeria (industrial fishery operating within 5 miles of the coast to the edge off continental shelf) and Ghana (estimated 3.5% artisanal (Aggrey-Fynn et al., 2013; Belhabib & Pauly, 2015; Belhabib, Ramdeen, & Pauly, 2015).

***Cynoglossus senegalensis* (Kaup, 1858)**

Cynoglossus senegalensis is one of the species belonging to the family Cynoglossidae. Its common name is the Senegalese tongue sole. It is the most common *Cynoglossus* species in the region and most abundant that enter coastal estuaries and lagoons (Adeofe et al., 2015). This flat fish is distinguished by the presence of a long hook on the snout overhanging the mouth, and the absence of pectoral fins. Their eyes are both on the left side of their body, which also lacks a pelvic fin. They feed on molluscs, shrimps, crabs and fish and sold as frozen filet under the name *filets de sole* (Longhurst, 1957). *C. senegalensis* are demersal, brackish, marine fish living in the depth range of 10-110 m (Adeofe et al.). They are found in tropical range (22ºN-18ºS, 18ºW-14ºE) and subtropical oceans, mainly in shallow waters and estuaries though a few species are also found in deep sea floors and rivers but distributed mainly in the Eastern Atlantic from Mauritania to Angola (Abowei, 2009). According to Abowei, some species have been observed congregating around ponds of sulphur that pool up from beneath the seafloor on sand and mud bottoms of coastal waters, however, scientists are not sure of the mechanism that allows the fish to survive and even thrive in such a hostile environment.

The fishery of the flat fish is highly commercial and marketed fresh, smoked or dried. Apart from being a cheap source of highly nutritive protein, it also contains other essential nutrients required by the body (Sikoki & Otobotekere, 1999). This species is also impacted by habitat degradation and pollution, in addition to targeted fishing. It is thought that the juveniles are not being targeted in the majority of its range, however in some areas there are seasonal sole fisheries where juveniles are taken and dried (Adeofe et al., 2015). Adeofe et al. presented that in December 2011, Fisheries Committee for East Central Atlantic (COPACE) estimated that the *Cynoglossus* fishery (represented by *C. monodi*, *C. senegalensis* and *C. canariensis*) was overexploited in Gabon. In Guinea, average annual captures of mixed species of *Cynoglossus* from 1995 to 2006 declined from 7,000 T to 4,000 T per year. In Mauritania, catch statistics for *C. monodi* show at least a 60% decline over the past five years (2007-2010). In Nigeria there does not appear to be any decline in catch over the past 10 years, but nothing is known of effort.

CHAPTER THREE

MATERIALS AND METHODS

This chapter describes procedures and techniques used to collect and analyse data during the study. It touches on the sampling areas, laboratory and field approaches, formulae, data processing and analytical tools applied.

Study area

Fish samples were collected from semi-industrial fishing operations at Tema fishing harbour (Greater Accra Region), Elmina fish landing quay (Central Region) and Albert Bosomtwe-Sam Fishing Harbour (Western Region) in Ghana. Samples were collected monthly for six (6) months from February, 2017 to July, 2017. Bernacsek (1986) stated that the coastline of Ghana is about 550 km in length with a narrow continental shelf varying in width from a minimum of 20 km off Cape St. Paul (Keta) to 100 km between Takoradi and Cape Coast. The sea bed, according to Buchanan (1957) is a mixture of soft and muddy to sandy mud, hard and rocky bottoms in the inshore areas at depths between 10 m and 50 m and is traversed by a belt of dead madreporarian corals beginning at 75 m (Bannerman & Cowx., 2002).

According to Bannerman et al. (2002) upwelling occurs as a result of the southern edge of the Guinean current, which flows along the coast in the eastward direction at the surface, encountering the westward flowing south equatorial current. Each year, two upwelling events occur on the continental shelf namely major and minor upwelling. The period of upwelling is characterized by low sea temperature below about 22^{o}C, high salinities greater than 35‰ and the cold, nutrient-rich waters that replace the warm surface layers (Ukwe, Ibe, Nwilo, & Huidobro, 2006; Krampah, Yanksson, & Blay, 2016).

The Albert Bosomtwe-Sam (Figure 1) fishing harbour is one of two fishing harbours in the country and is mainly used by industrial and semi-industrial fishing vessels in the Western region (MoFA, 2010). The harbour holds about 123 fishing vessels during the major fishing season while fish production is estimated at 2,800 MT (MoFA, 2012). Mensah (2012) observed that high profitability is associated with the use of Ali, Poli and Watsa (APW) and hook line during the major and minor upwelling seasons. Tema Fishing harbour is located in the land area of Port of Tema and comprises of inner and outer harbours and a canoe basin. Artisanal activities are carried out at the canoe basin with canoes numbering over 400. Operations peak from June to September which falls within the major upwelling season. According to Addo (2015), artisanal operations contribute about 70% of the catch recorded at the Tema fishing harbour.

Tema Fishing Harbour (Figure 1) is located in the land area of Port of Tema and comprises of inner and outer harbours and a canoe basin. Artisanal activities are carried out at the canoe basin with canoes numbering over 400. Operations peak from June to September which falls within the major upwelling season. According to Addo , artisanal operations contribute about 70% of the catch recorded at the Tema fishing harbour.

The Elmina fishing quay (Figure 1) is the third largest in Ghana where fishing operations are largely artisanal. The quay is built along the bank of the

Benya lagoon which provides a comfortable berthing site for all types of canoes and small semi-industrial boats engaged in traditional fisheries in the area. The fisheries at Elmina landing quay contributes about 15 % of the country's total fish output hence significantly contributes to the national fisheries GDP (Aheto et al., 2012). A canoe frame survey by Akyempon, Bannerman, Amador and Nkrumah (2013) found that there were 10,104 fishermen and 847 canoes operating in the town. Some semi-industrial vessels are also involved in the fishing operation. According to Ato-Arthur and Mensah (2006), 75 % of the inhabitants of Elmina are engaged in direct and indirect jobs related to fishing such as processing and trading of fish and canoe building.

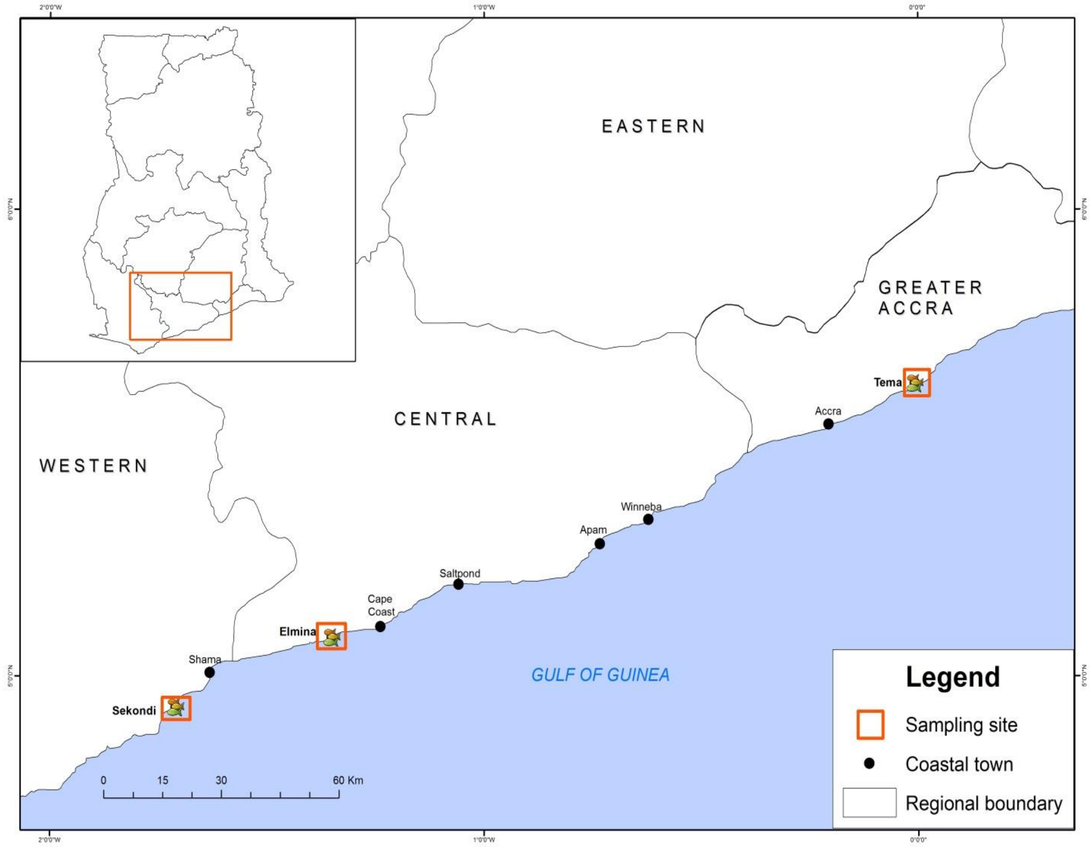

Figure 1: Map showing the sampling sites

Samples and Sampling Procedure

The sample size of each population of fish species was not predetermined. The stratified random sampling method was applied during sampling and this allowed for fish to be randomly selected from an already existing or naturally occurring sub-group. Therefore, it was useful to employ this sampling method as it offered the opportunity for specimens of *Sphyraena sphyraena* (Sphyraenidae), *Apsilus fuscus* (Lutjanidae) and *Cynoglossus* *senegalensis* (Cynoglossidae) to be sampled from the array of species in their respective families.

Data collection procedure

The sampling sites were visited once every month from February, 2017 to July, 2017, where samples of varied sizes were randomly purchased from fishers. Samples were then preserved on ice and transported to the laboratory. Fish identification was done using identification keys (Schneider, 1990; Edwards, Gill & Abohweyere, 2001). Total length (TL), standard length (SL) and fork length (FL) were measured to the nearest 0.1 cm using the fish measuring board, except for specimens of *Cynoglossus senegalensis* where fork length was not measured. The body weight of each specimen was weighed to the nearest 0.01 g using the Ohaus Ranger 7000 model electronic balance. Specimens were dissected and the sex of each fish was identified by visual examination of gonads.

Data processing and analysis

Total length data was used to plot histograms to show the length-frequency distributions for fish of each species. To determine the relationship between TL and BW, $\log_{10}$ transformation of TL and BW were plotted and a regression line was calculated by the method of least squares.The relationship between TL and BW was expressed by (Le Cren, 1951; Lagler, 1956):

$BW = {}_aTL^b$ where BW (g) is fish body weight, TL (cm) the total length, "*a*" intercept and "*b*" the slope.

The condition factor (K) of the specimens of each species was calculated using the equation of Le Cren (1951) as:

$K = \frac{BW}{TL^3} \times 100$ where TL (cm) is the total length and BW (g) is the body weight.

Condition factor was assessed for males, females and pooled data. Data was analysed for the various months and length groups to understand the well-being of the specimens sampled. A Chi-square ($\chi 2$) test was undertaken to compare the male-female ratios per month with the hypothesized sex-ratio of 1:1.

Monthly total length data were analyzed using the Electronic Length Frequency Analysis I (ELEFAN) routine in the Fisheries Stock Assessment Tool II (FiSAT) software according to Gayanilo et al. (2005). The ELEFAN I routine in FiSAT II software was used to estimate the asymptotic length ($L\infty$) and growth coefficient (K) of the species (Pauly, 1986). The derived growth curves for the various species were obtained from the ELEFAN I routine (FiSAT) using the von Bertallanfy Growth Function (VBGF) and Length Frequency Plot. The mean length at first capture (Lc) of the fish was estimated by procedures of Sparre and Venema (1992) as incorporated in FiSAT.

The total mortality (Z) of the fish species was estimated from the slope of the descending right arm of the linearized length-converted catch curve (Pauly & Munro 1984; King, 1995). The natural mortality (M) was estimated by Pauly's (1980) empirical formula:

$$\text{Log}(M) = -0.0066 - 0.279\log(L\infty) + 0.6543\log(K) + 0.463\log(T)$$

where, M is the natural mortality, K and L∞ are growth parameters of the von Bertallanfy growth function (VBGF) and T (°C) is the annual mean sea surface temperature of the study area (Pauly, 1980). The fishing mortality coefficient (F) was determined as the difference between the total and natural mortality (King, 1995) and the level of exploitation (E) of the stocks was calculated from equation:

$E = \frac{F}{Z}$. (Gulland, 1971) where E is the exploitation rate, F the fishing mortality and Z the total mortality.

CHAPTER FOUR

RESULTS

Data collected were subjected to computerized analyses in Microsoft Excel and ELEFAN I routine in FiSAT II. The length-frequency distributions, length-weight relationships, condition factor, sex ratio, growth parameters, mortality and exploitation rates were determined and estimated.

Length-frequency distribution

Sphyraena sphyraena

A total of 420 specimens of *S. sphyraena* were examined. The length measurements were grouped into 3 cm class intervals and size groups ranging from 10.0 – 12.9 cm to 64.0 – 66.9 cm TL (Figure 2a). The males, females and the pooled samples showed a unimodal frequency distribution with a modal length class of 37.0 – 39.9 cm TL. Male length sizes ranged from 33.9 to 64.0 cm TL (Figure 2b) and weighed 280.0 to 962.4 g while females measured 32.2 to 66.5 cm TL (Figure 2c) and weighed 180.0 to 1,319.8 g. The mean size for the pooled samples, males and females were 36.9 cm, 43.7 cm and 45.3 cm respectively.

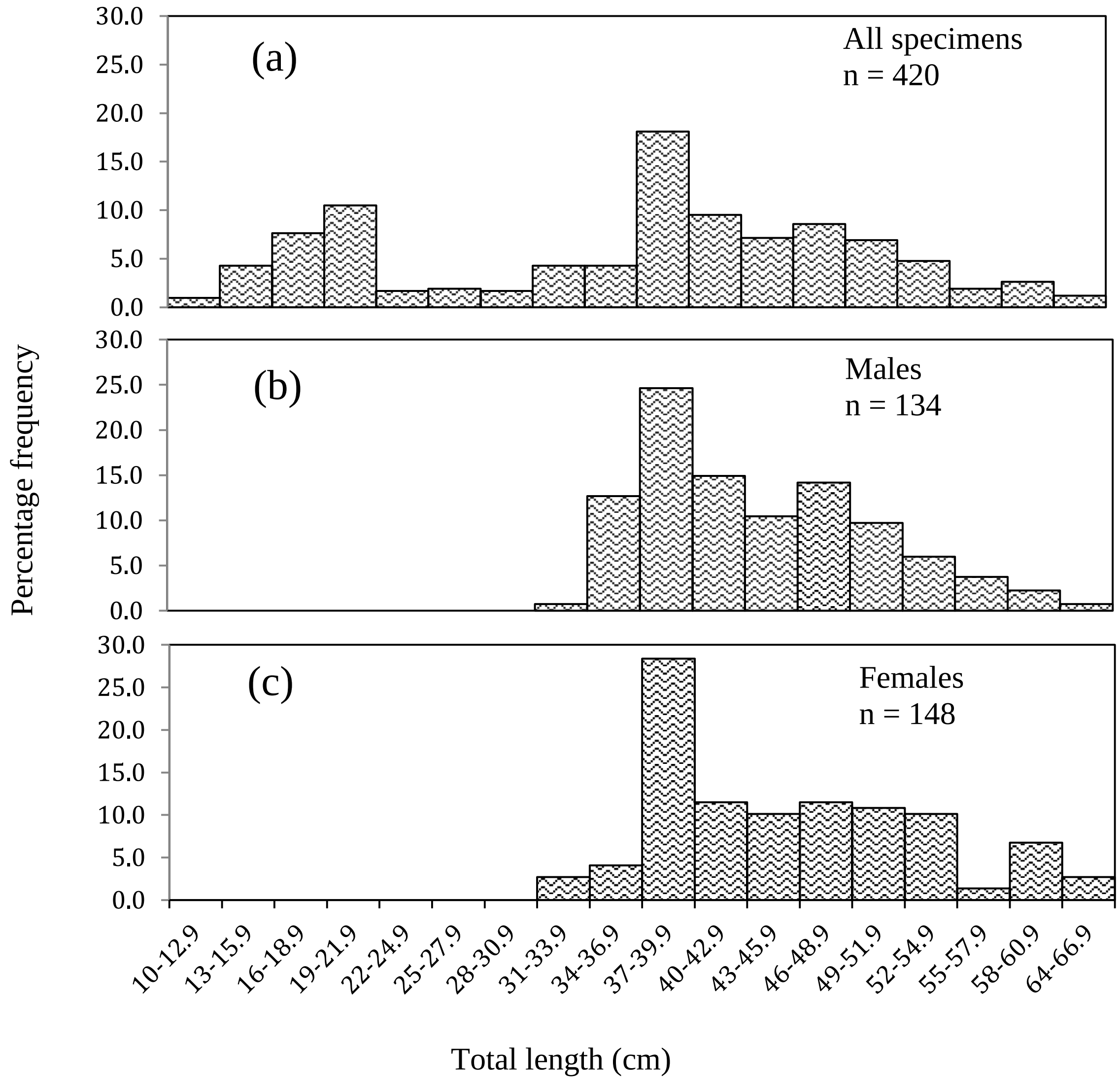

Figure 2: Length-frequency distribution for *Sphyraena sphyraena* samples obtained from coastal waters of Ghana from February 2017 to July 2017

Apsilus fuscus

A total of 423 specimens of *A. fuscus* were examined. The length measurements were grouped into 2 cm class intervals with size groups ranging from 20.0 – 21.9 cm to 50.0 – 51.9 cm TL (Figure 3a). The males, females and the pooled samples showed a unimodal frequency distribution with a modal length of 34.0 – 35.9 cm TL. Male sizes ranged from 25.2 to 46.8 cm TL (Figure

3b) and weighed 163.2 to 1,305.6 g while females measured 25.1 to 45.8 cm TL (Figure 3c) and weighed 165.0 to 980.0 g. The mean size for the pooled samples, males and females were 32.4 cm, 34.3 cm and 35.2 cm respectively.

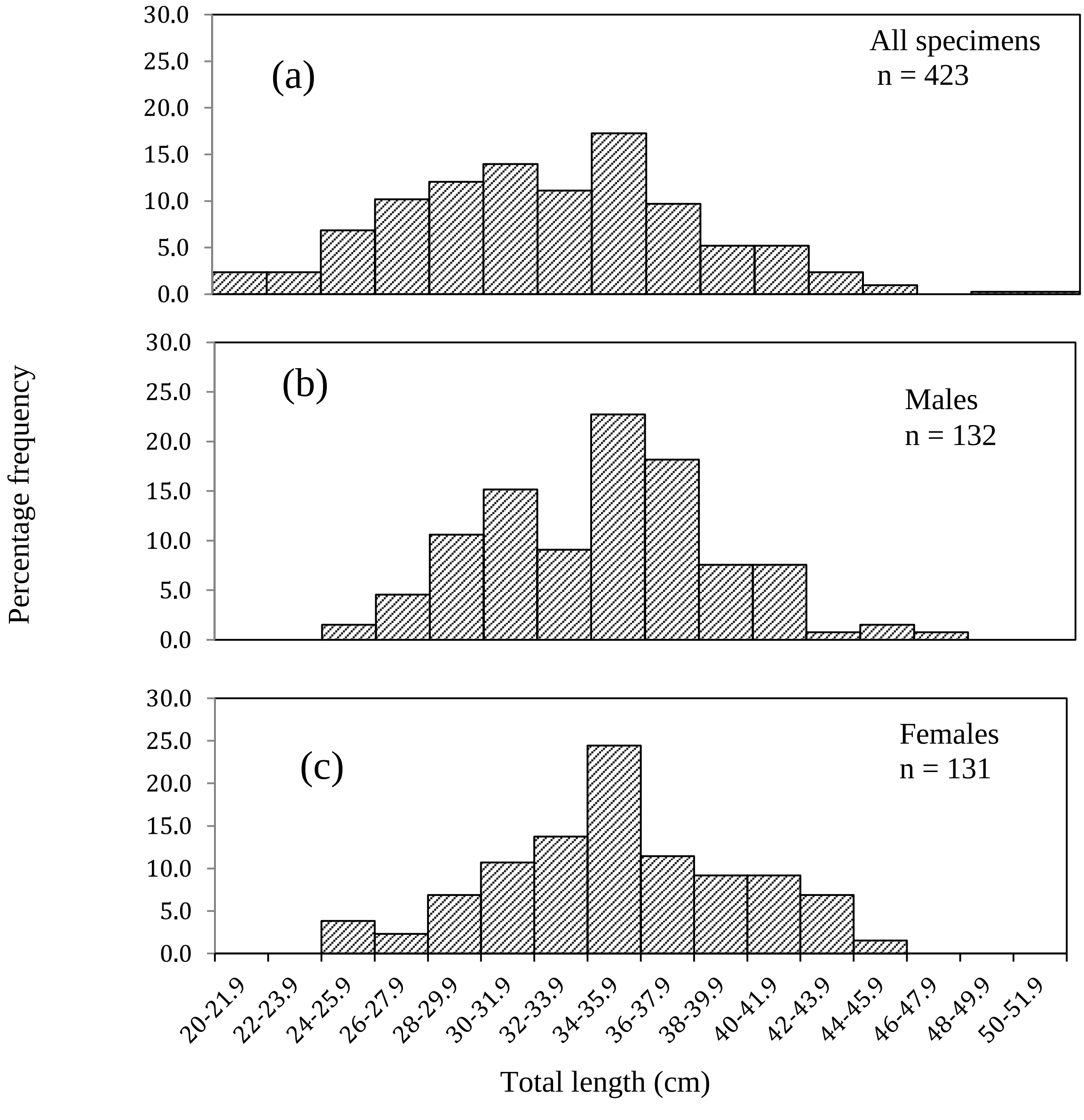

Figure 3: Length-frequency distribution for *Apsilus fuscus* samples obtained from coastal waters of Ghana from February 2017 to July 2017

Cynoglossus senegalensis

A total of 562 specimens of *C. senegalensis* were examined. The length measurements were grouped into 1 cm class interval and size groups ranging from 11.0 – 11.9 cm to 56.0 – 56.9 cm TL (Figure 4). The pooled data showed a polymodal frequency distribution with modal classes 19-19.9 cm and 38-38.9 cm and an estimated mean size of 32.5 cm TL.

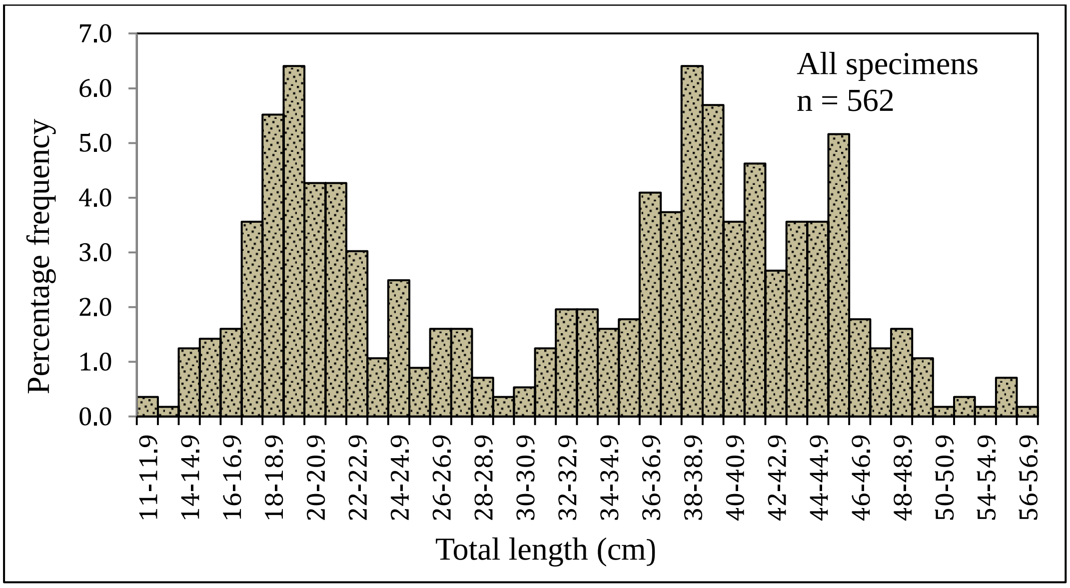

Figure 4: Length frequency distribution of *Cynoglossus senegalensis* samples obtained from coastal waters of Ghana from February 2017 to July 2017

Monthly length-frequency distributions

Sphyraena sphyraena

The monthly length-frequency distribution of *S. sphyraena* fitted with growth curve is shown in Figure 5. The March samples had the most class sizes from 10.0 – 12.9 cm to 64.0 – 66.9 cm TL. The February samples were polymodal with modal class sizes of 19.0 – 21.9 cm, 37.0 – 39.9 cm and 49.0 – 51.9 cm TL. The March samples were bimodal with modal class sizes 19.0 – 21.9 cm and 46.0 – 48.9 cm TL. The April, May and June samples were all unimodal with modal class sizes 37.0 – 39.9 cm, 49.0 – 51.9 cm and 40.0 – 42.9 cm TL respectively. The July samples showed bimodal distribution with modal class sizes 19.0 – 21.9 cm and 37.0 – 39.9 cm TL.

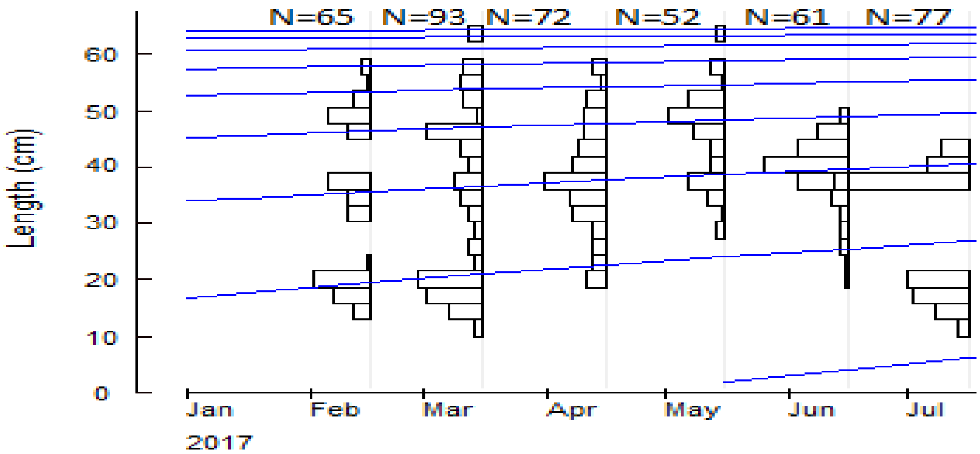

Figure 5: Monthly length-frequency distributions of *Sphyraena sphyraena* fitted with growth curve obtained by ELEFAN I routine (N = sample size)

Apsilus fuscus

The monthly length-frequency distribution of *A. fuscus* fitted with growth curve is shown in Figure 6. The March samples showed the most class sizes from 14.0 – 15.9 cm to 50.0 – 51.5 cm TL. The February samples appeared to be bimodal with modal class sizes of 30.0 – 31.9 cm and 34.0 – 35.9 cm TL. The March appeared to have polymodal distribution of modal class sizes 24.0 – 25.9 cm, 26.0 – 27.9 cm, 32.0 – 33.9 cm and 34.0 – 35.9 cm TL. The April and May samples showed unimodal class size 26.0 – 27.9 cm and 34.0 – 35.9 cm, TL respectively. The June samples also showed unimodal distribution of modal class size 36.0 – 37.9 cm TL. The July samples appeared to have trimodal distribution of class sizes 28.0 – 29.9 cm, 30.0 – 31.9 cm and 34.0 – 35.9cm TL.

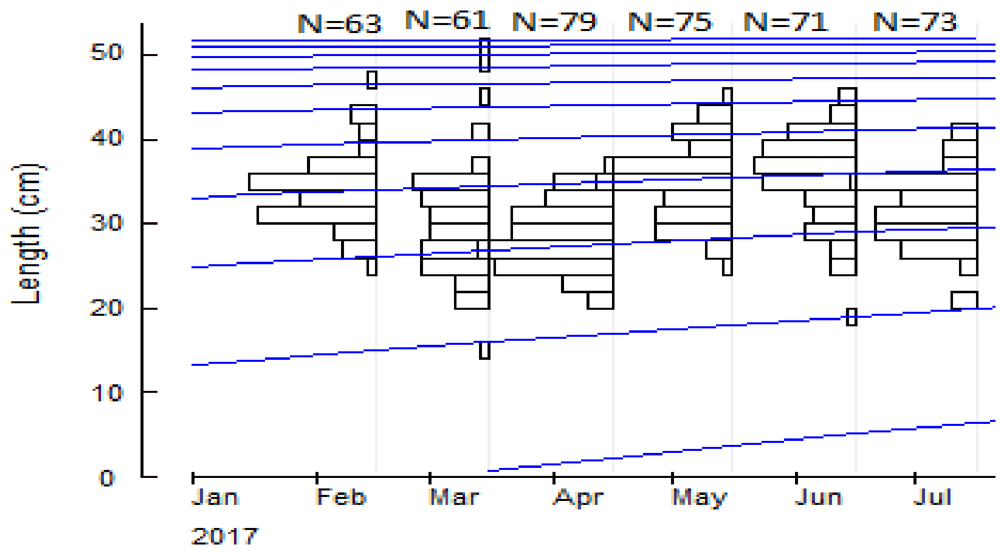

Figure 6: Monthly length-frequency distributions of *Apsilus fuscus* fitted with growth curve obtained by ELEFAN I routine (N = sample size)

Cynoglossus senegalensis

The monthly length-frequency distribution of *C. senegalensis* fitted with growth curve is shown in Figure 7. February samples appeared to be bimodal with modal class sizes of 38.0 – 38.9 cm and 45.0 – 45.9 cm TL. March samples showed unimodal distribution of modal class size 43.0 – 43.9 cm TL. The April samples showed polymodal distribution of modal class sizes 21.0 – 21.9 cm, 37.0 – 37.9 cm and 45.0 – 45.4 cm TL. The May samples appeared to show a bimodal distribution of modal class sizes 21.0 – 21.9 cm and 4.0 – 40.9 cm TL. The June samples showed polymodal distributions of modal class sizes 36.0 – 36.9 cm, 41.0 – 41.9 cm and 45.0 – 45.9 cm TL. The July samples also showed polymodal distributions of modal class sizes 38.0 – 38.9 cm, 41.0 – 41.9 cm and 45.0 – 45.9 cm TL.

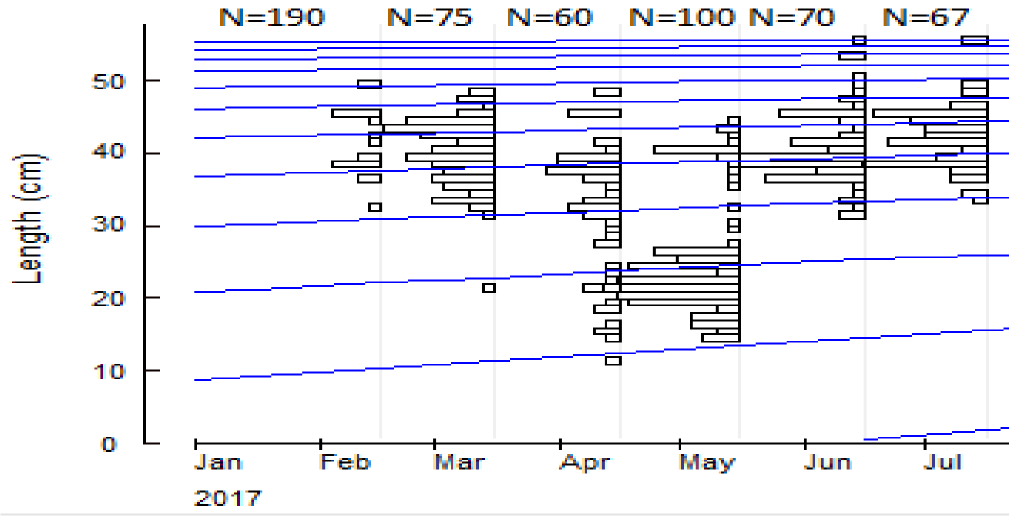

Figure 7: Monthly length-frequency distributions of *Cynoglossus senegalensis* fitted with growth curves obtained by ELEFAN I routine (N = sample size)

Length-weight relationship

Sphyraena sphyraena

The relationship between total length (TL) and body weight (BW) of *S. sphyraena* samples studied over the study period is shown in Figure 8. The smallest fish size was 10.5 cm TL and weighed 11.8 g while the largest fish size was 66.5 cm TL with a weight of 1,319.8 g. The expression $BW = 0.0118TL^{2.75}$ shows a significant exponential relationship between total length and body weight. The regression showed a strong correlation for *S. sphyraena* (r = 0.99) between the variables. The regression coefficient '*b*' differed statistically (b = 2.75 ±0.11; P<0.05, student t-test) from the hypothetical value of 3.0.

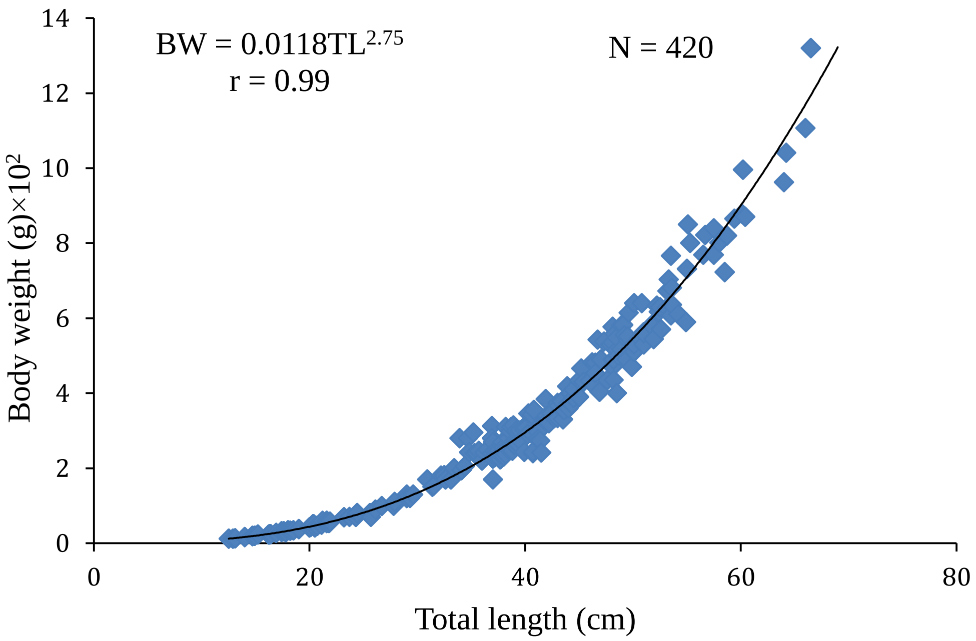

Figure 8: Length-weight relationship of *Sphyraena sphyraena* samples obtained from coastal waters from coastal waters of Ghana from February 2017 to July 2017

Apsilus fuscus

The relationship between total length (TL) and body weight (BW) of *A. fuscus* is shown in Figure 9. The smallest fish size was 20.3 cm TL with a corresponding body weight of 94.0 g while the largest fish size was 50.9 cm TL and weighed 1,399.6 g. The expression BW= $0.0172TL^{2.84}$ shows a significant exponential relationship between total length and body weight. The regression showed a strong correlation for *A. fuscus* (r = 0.97) between the variables. The regression coefficient '*b*' did not differ statistically (b = 2.84 ±0.12; P<0.05, student t-test) from the hypothetical value of 3.0.

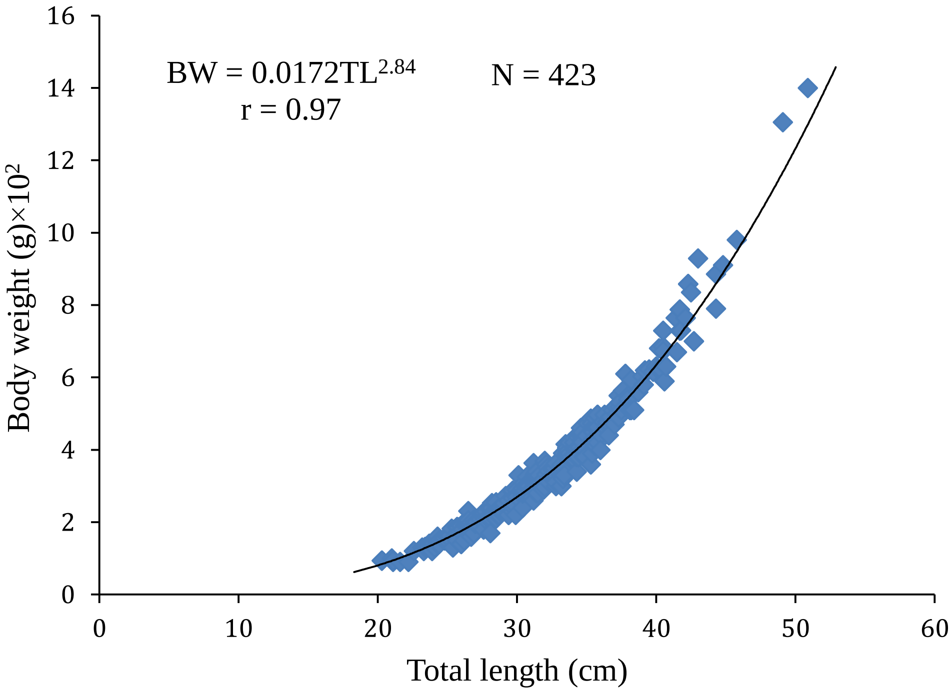

Figure 9: Length-weight relationship of *Apsilus fuscus* samples obtained from coastal waters of Ghana from February 2017 to July 2017

Cynoglossus senegalensis

The relationship between total length (TL) and body weight (BW) of *C. senegalensis* is shown in Figure 10. The smallest fish size was 11.0 cm TL and weighed 8.0 g and the largest fish size was 56.4 cm TL with a weight of 1,030.8 g. The expression $BW = 0.0036TL^{3.08}$ shows a significant exponential relationship between total length and body weight. The regression showed a strong correlation for *C. senegalensis* (r = 0.99) between the variables. The regression coefficient '*b*' did not differ statistically (b = 3.08 ±0.11; P<0.05, student t-test) from the hypothetical value of 3.0.

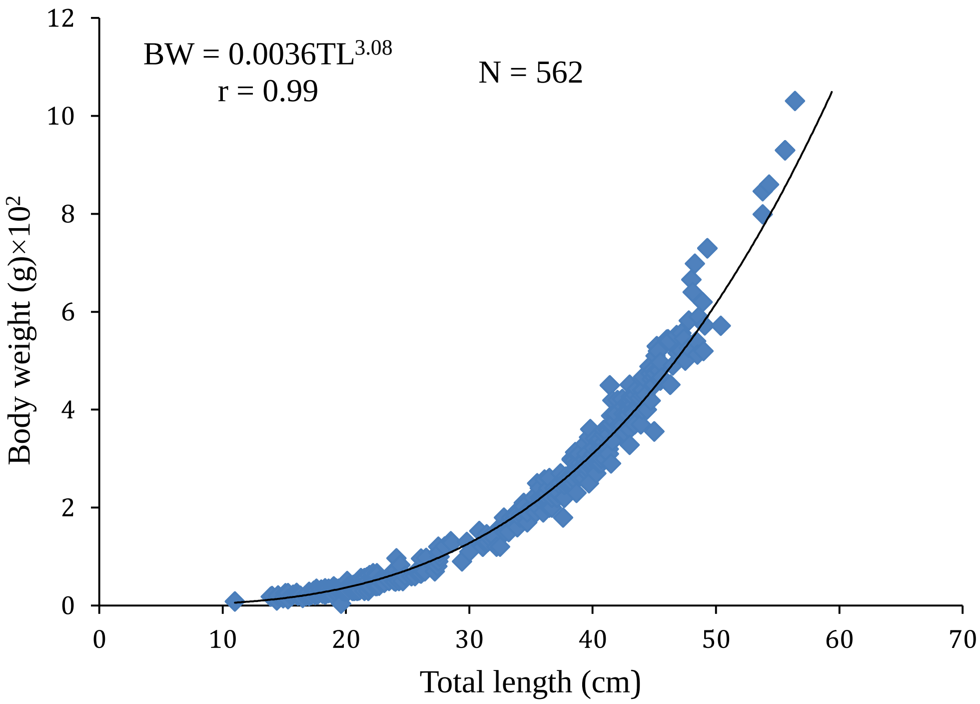

Figure 10: Length-weight relationship of *Cynoglossus senegalensis* samples obtained from coastal waters of Ghana from February, 2017 to July, 2017

Variations in condition factor (K)

Sphyraena sphyraena

Condition factor of *S. sphyraena* specimens is presented in Figure 11. Condition factor for all the specimens ranged from 0.41 (±0.03) to 0.60 (±0.02) for size classes 10.0 – 12.9 cm to 64.0 – 66.9 cm. The highest K value (0.60 ±0.02) was recorded in size class 10.0 – 12.9 cm while the lowest K value (0.41 ±0.03) was recorded in size class 64.0 – 66.9 cm. Generally condition factor was higher within the smaller size groups than the larger size groups in all cases for *S. sphyraena*. The lowest K value for males (0.37) was recorded in size class 64.0 – 66.9 cm while that of in females the lowest K value (0.38 ±0.04) was recorded in size class 58.0 – 60.9 cm. The highest K value for males (0.72) and females (0.54) were both recorded in size class 31.0 – 33.9 cm.

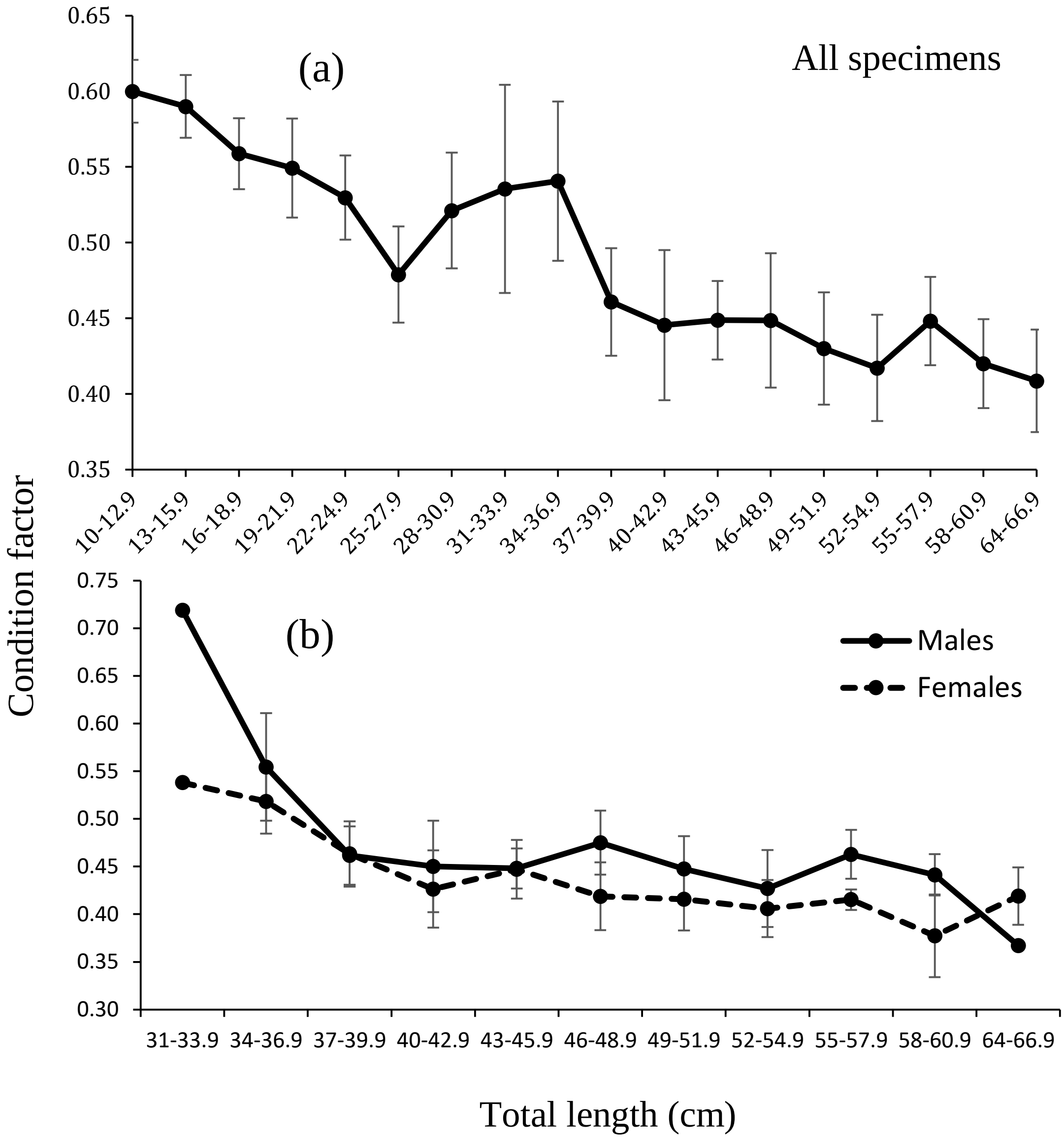

Figure 11: Condition factor of size classes *Sphyraena sphyraena* samples obtained from coastal waters of Ghana from February 2017 to July 2017

Apsilus fuscus

Condition factor of *A. fuscus* is presented in Figure 12. Condition factor for all the specimens ranged from 0.93 to 1.09 for size classes 20.0 – 21.9 cm to 50.0 – 51.9 cm. The highest K value (1.09 ±0.03) was recorded in size class 20.0 – 21.9 cm while the lowest K value (0.93) was recorded in size class 50.0 – 51.9 cm. Condition factor was relatively high in all the specimens and both sexes eventhough K values increased for smaller size groups and decreased within largersize groups. The lowest K value for males (0.94) was recorded within size class 44.0 – 45.9 cm. The lowest K value for females (0.95 ±0.03) was recorded within size class 42.0 – 43.9 cm. The highest K value for males (1.09) and females (1.08 ±0.03) were recorded in size class 24.0 – 25.9 cm.

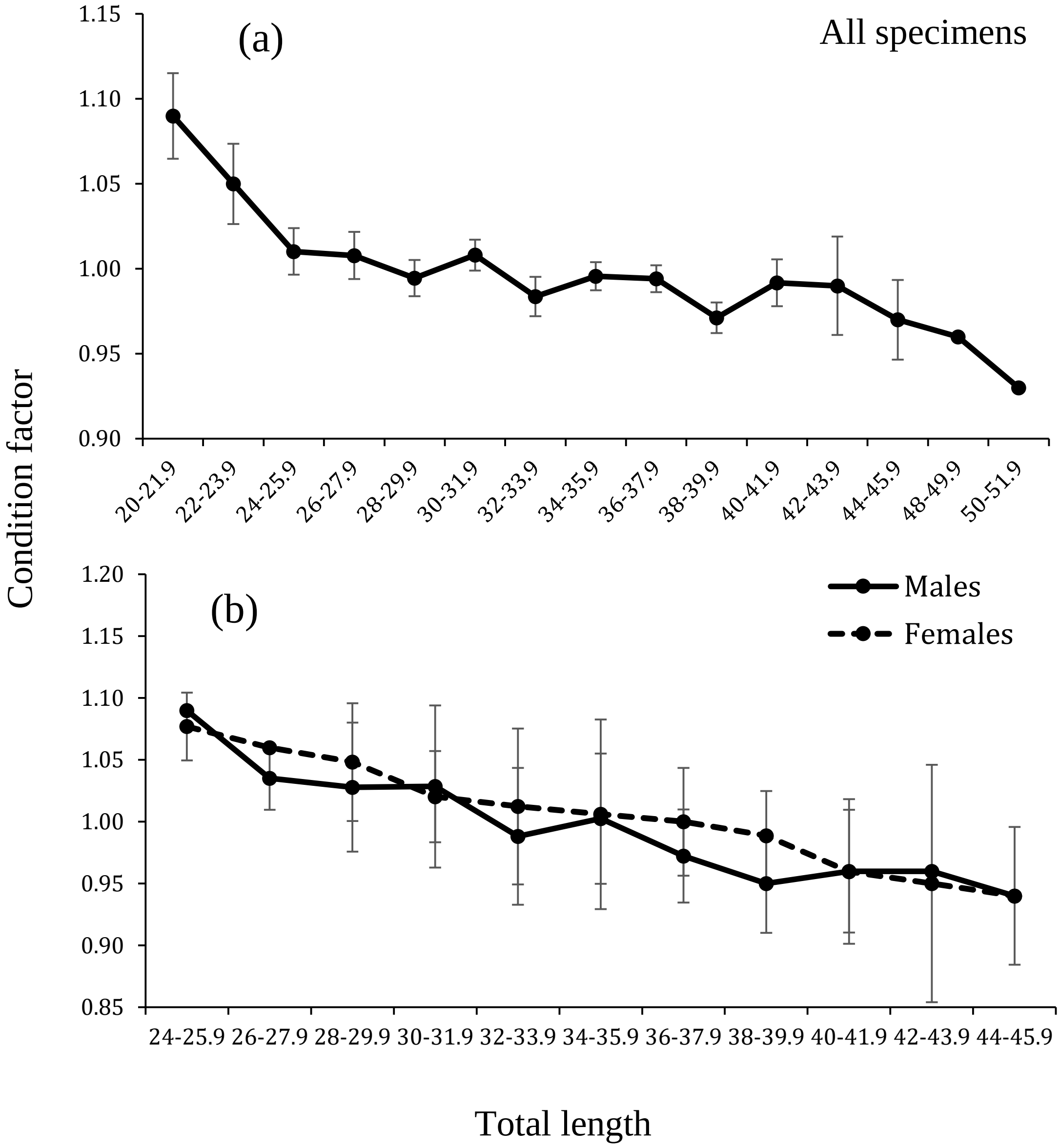

Figure 12: Condition factor of size classes of *Apsilus fuscus* samples obtained from coastal waters of Ghana from February 2017 to July 2017

Cynoglossus senegalensis

Condition factor of the various size classes of *C. senegalensis* is presented in Figure 13. Condition factor for all the specimens ranged from 0.39 to 0.68 for the size classes 11.0 – 11.9 cm to 56.0 – 56.9 cm TL. Smaller size groups recorded higher K values than the larger size groups. The highest K value (0.68) occurred in size class 11.0 – 11.9 cm while the lowest K value (0.39) was observed in size class 50.0 – 50.9 cm.

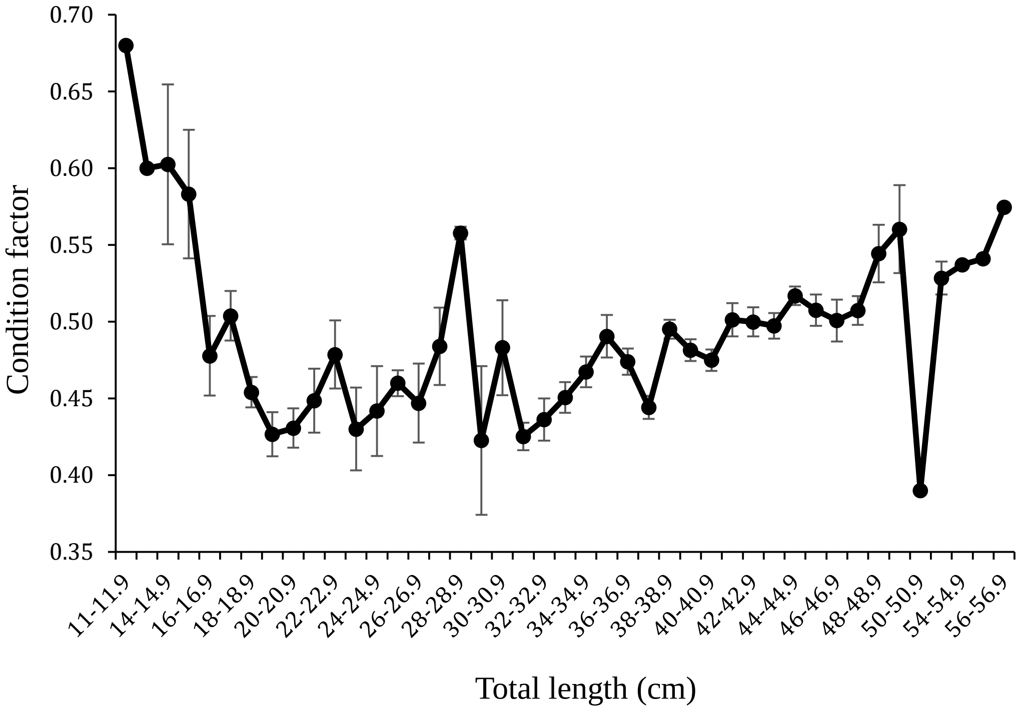

Figure 13: Condition factor of size classes of *Cynoglossus senegalensis* samples obtained from coastal waters of Ghana from February 2017 to July 2017

Sex ratio

The monthly sex ratios of *S. sphyraena* and *A. fuscus* are shown in Tables 1 and 2 respectively. A total of 282 *S. sphyraena specimens* were sexed, out of which 134 were males and 148 females. A total of 263 *A. fuscus* were sexed, out of which 132 were males and 131 females. Overall male to female ratio was 1:1.1 for *S. sphyraena* specimens and 1:1 for specimens of *A. fuscus* studied over the six months period.

Table 1: *Monthly sex ratios (February 2017 to July 2017) of Sphyraena sphyraena samples obtained from coastal waters of Ghana*

Month	Number of specimens		Sex ratio	χ^2	$P_{(0.05)}$
	Male	Female	M:F		
February	17	20	1:1.2	0.85	NS
March	21	27	1:1.3	0.60	NS
April	29	26	1.1:1	0.57	NS
May	22	27	1:1.2	0.71	NS
June	21	28	1:1.3	0.51	NS
July	24	20	1.2:1	0.35	NS
Total	134	148	1:1.1	0.79	NS

Table 2: *Monthly sex ratios (February 2017 to July 2017) of Apsilus fuscus samples obtained from coastal waters of Ghana*

Month	Number of specimens		Sex ratio	χ^2	$P_{(0.05)}$
	Male	Female	M:F		
February	23	27	1:1.2	0.57	NS
March	20	16	1.3:1	0.50	NS
April	20	19	1.1:1	0.87	NS
May	22	24	1:1.1	0.77	NS
June	19	23	1:1.2	0.60	NS
July	27	22	1.2:1	0.48	NS
Total	131	131	1:1	0.10	NS

Growth parameters

Estimates of the growth parameters of specimens of the three species were generated from their respective monthly length-frequency data collected from February 2017 to July 2017. Initial estimates were obtained using the Powell-Wetherall Plot to guide the final estimates by the ELEFAN I routine (Sparre & Venema, 1992).

Sphyraena sphyraena

Powell-Wetherall Plot for estimating the asymptotic length ($L\infty$) and Z/K of *S. sphyraena* is shown in Figure 14. The asymptotic length of *S. sphyraena* was estimated at 69.9cm TL and Z/K was 2.99, and K (1.64/yr) is growth coefficient of the species.

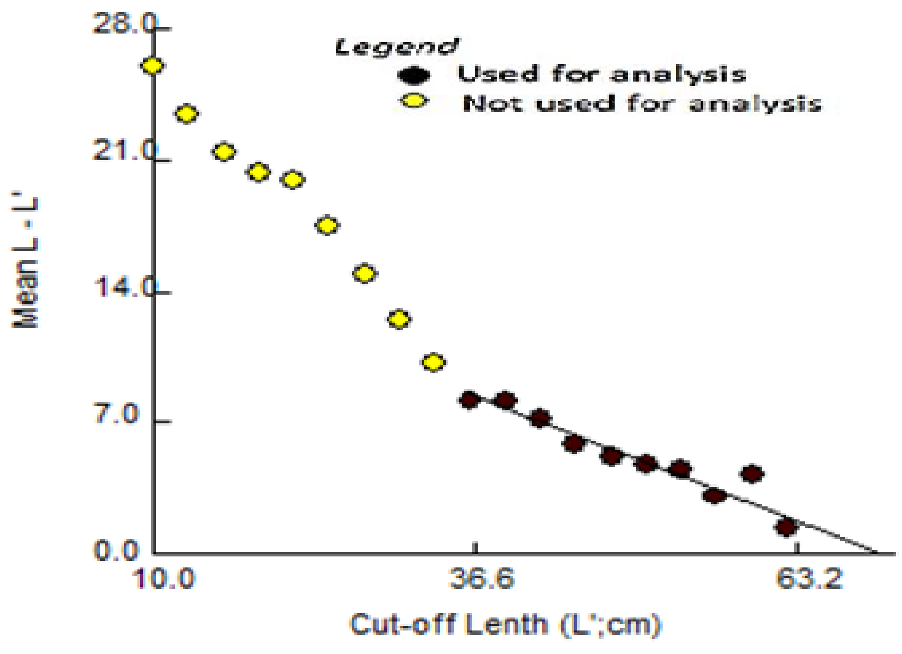

Figure 14: Powell-Wetherall plot for estimating the asymptotic length of *Sphyraena sphyraena* samples obtained from the coastal waters of Ghana

Apsilus fuscus

Powell-Wetherall Plot for estimating the asymptotic length (L∞) and Z/K of *A. fuscus* is shown in Figure 15. The asymptotic length of *A. fuscus* was estimated at 53.5cm TL and Z/K was 3.32 and K (0.50/yr) is growth coefficient of the species.

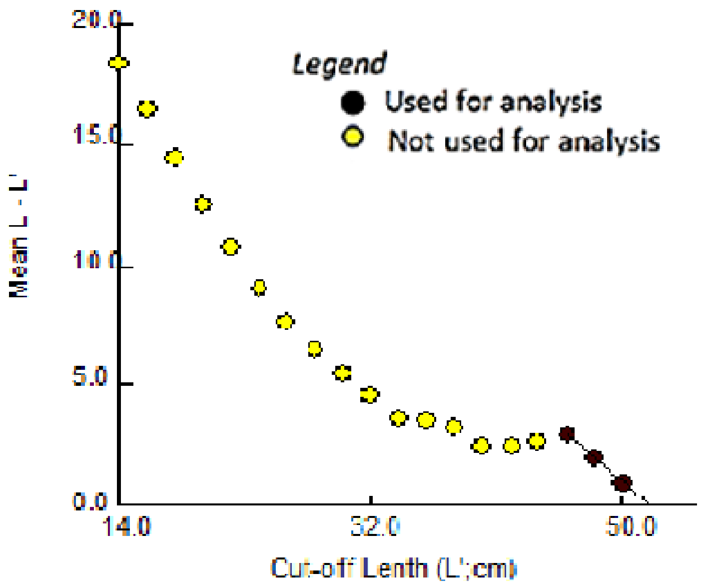

Figure 15: Powell-Wetherall plot for estimating the asymptotic length of *Apsilus fuscus* samples obtained from the coastal waters of Ghana

Cynoglossus senegalensis

Powell-Wetherall Plot for estimating the asymptotic length (L∞) and Z/K of *C. senegalensis* is shown in Figure 16. The asymptotic length of *C. senegalensis* was estimated at 58.2cm TL and Z/K was 3.83 and K (0.34/yr) is growth coefficient of the species.

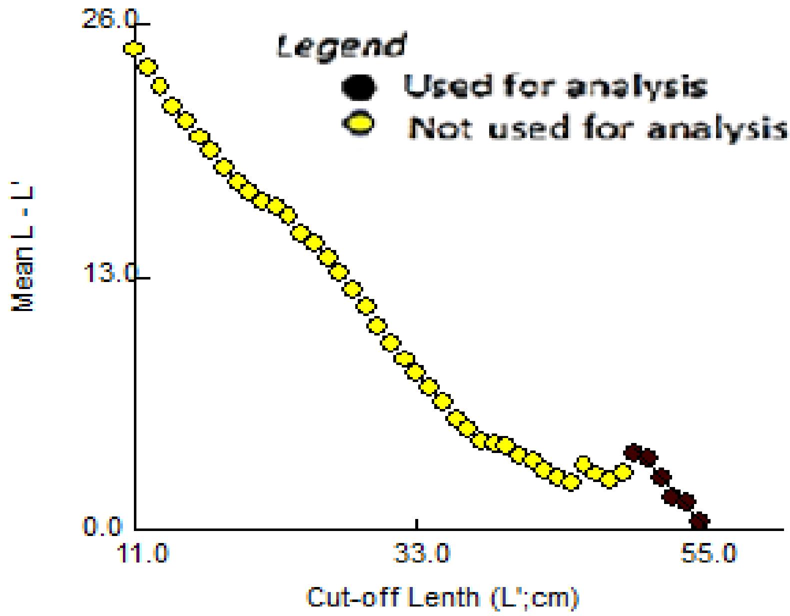

Figure 16: Powell-Wetherall Plot for estimating the asymptotic length of *Cynoglossus senegalensis* samples obtained from the coastal waters of Ghana

Length at first capture

The proportions of fish going through the net at every length due to gear selection were generated from the ascending arm of the length-converted catch curve.

Sphyraena sphyraena

Figure 17 illustrates the probability of capture for *S. sphyraena* samples. The length at first capture (L_{C50}) was estimated at 39.3 cm TL.

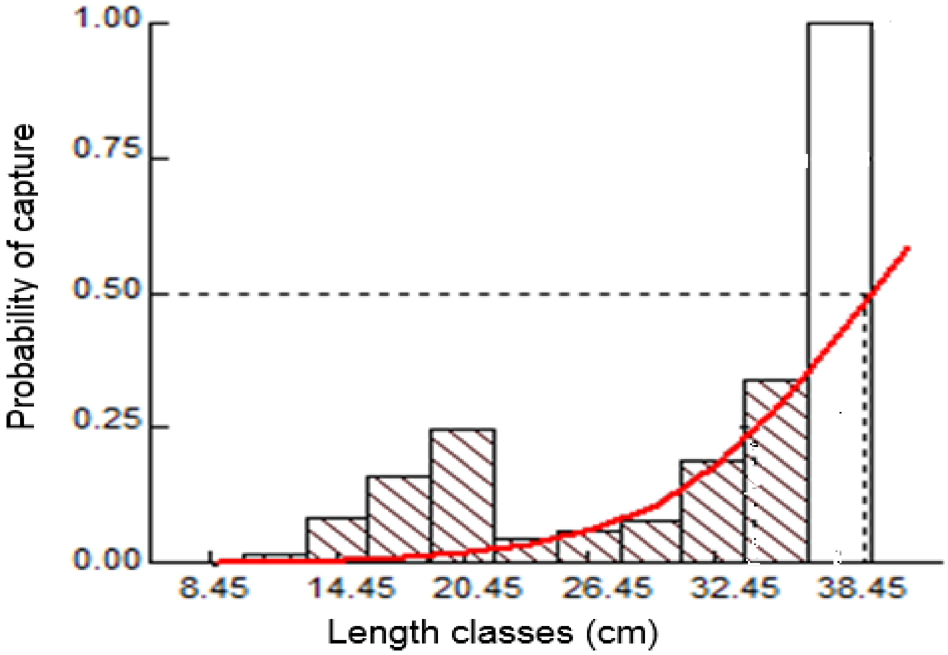

Figure 17: Probability of capture of *Sphyraena sphyraena* in the fishery

Apsilus fuscus

Figure 18 illustrates the probability of capture for *A. fuscus* samples. The length at first capture (L_{C50}) was estimated at 32.8 cm TL.

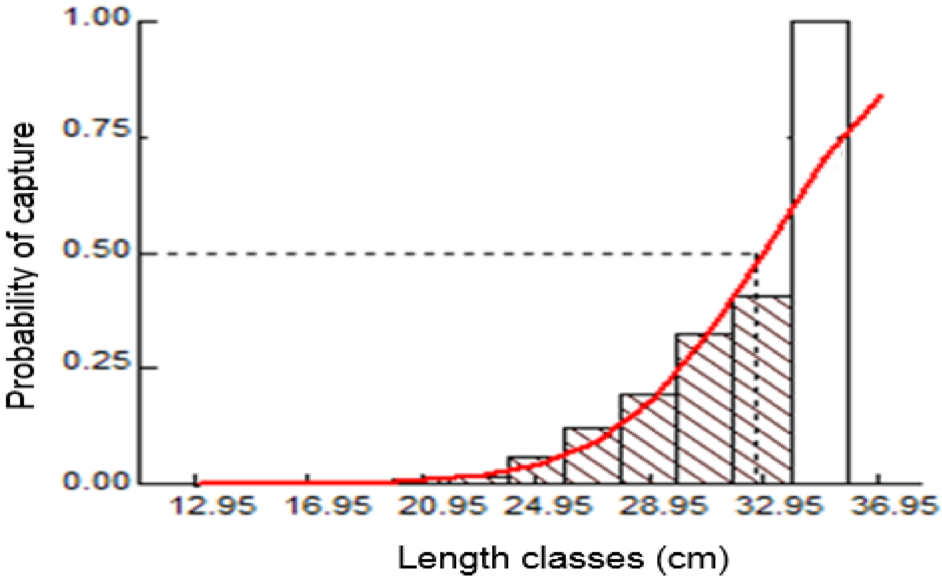

Figure 18: Probability of capture of *Apsilus fuscus* in the fishery

Cynoglossus senegalensis

Figure 19 illustrates the probability of capture for *C. senegalensis* samples. The length at first capture (L_{C50}) was estimated at 32.2 cm TL.

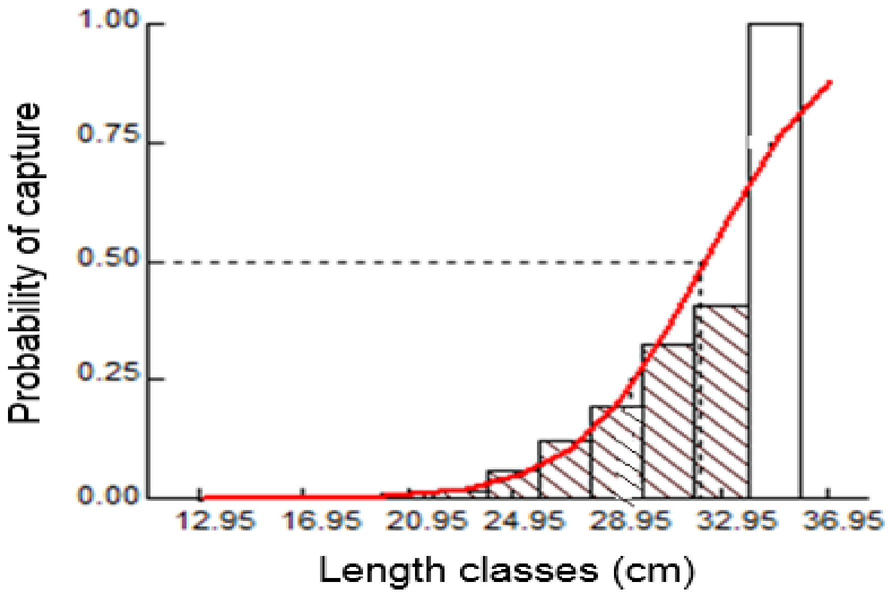

Figure 19: Probability of capture of *Cynoglossus senegalensis* in the fishery

Mortality and Exploitation

The length-converted catch curves was used to estimate the total mortality rate (Z) from the slope of the descending right arm of the linearized length-converted catch curve of the specimens based on fish that were fully exploited. The annual mean sea surface temperature during the sampling period was 26.9 °C (Fisheries Scientific Survey Division, FSSD, Tema).

Sphyraena sphyraena

The length-converted catch curve of *S. sphyraena* is shown in Figure 20. The total mortality (Z), natural mortality (M) and fishing mortality (F) of *S.*

sphyraena were estimated at 4.92/yr, 1.88/yr and 3.04/yr respectively. The estimated exploitation rate (E) for *S. sphyraena* is 0.62.

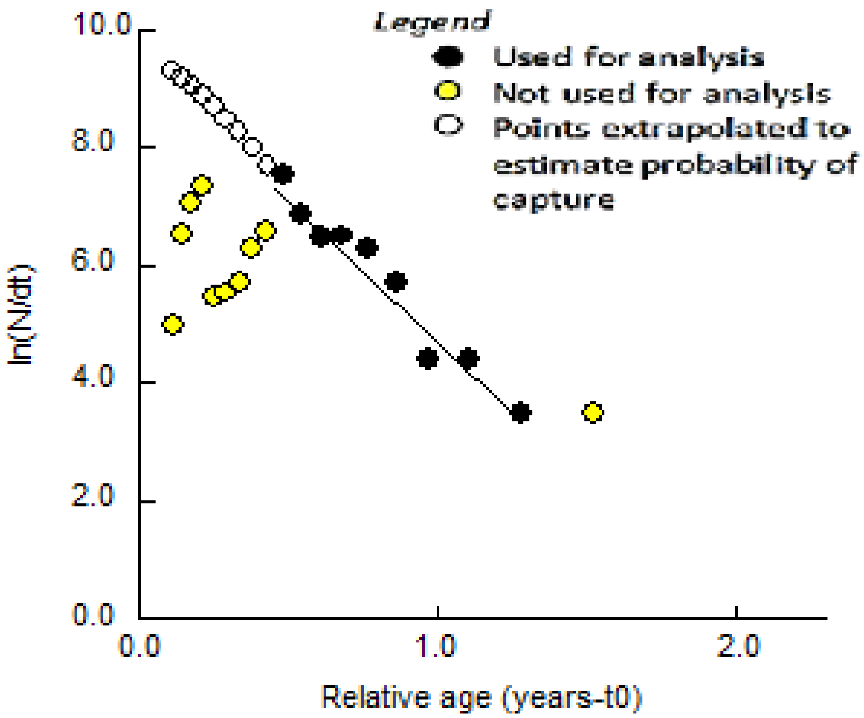

Figure 20: Length-converted catch curve of *Sphyraena sphyraena* samples obtained from the coastal waters of Ghana

Apsilus fuscus

Figure 21 shows the length-converted catch curve of *A. fuscus*. The estimates of total mortality (Z), natural mortality (M) and fishing mortality (F) of *A. fuscus* were 1.67/yr, 0.74/yr and 0.93/yr respectively. The estimated exploitation rate (E) for *A. fuscus* is 0.56.

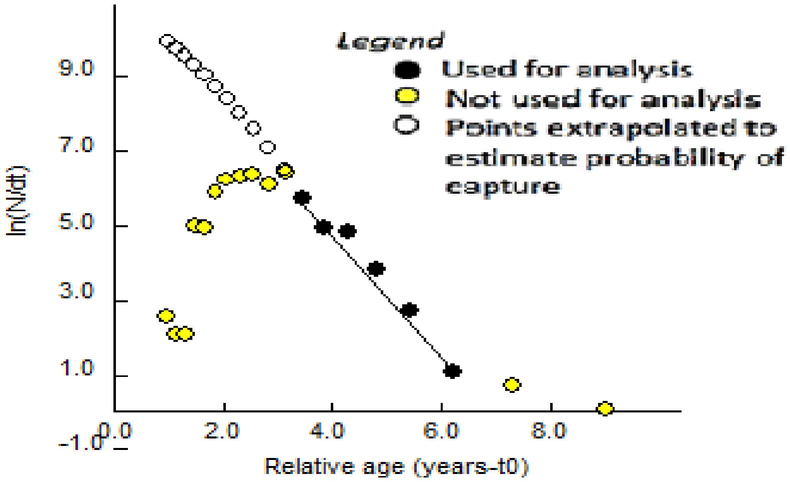

Figure 21: Length-converted catch curve of *Apsilus fuscus* samples obtained from the coastal waters of Ghana

Cynoglossus senegalensis

The length-converted catch curve of *A. fuscus* is shown in Figure 22. The total mortality (Z), natural mortality (M) and fishing mortality (F) of *C. senegalensis* were estimated at 1.32/yr, 0.63/yr and 0.69/yr respectively. The estimated exploitation rate (E) for *C. senegalensis* is 0.52.

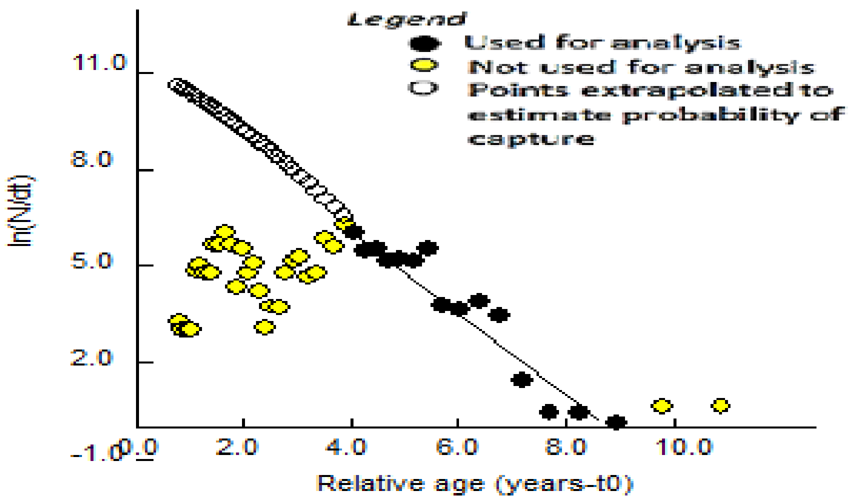

Figure 22: Length-converted catch curve of *Cynoglossus senegalensis* samples obtained from the coastal waters of Ghana

CHAPTER FIVE

DISCUSSION

This chapter discusses the results by making pertinent arguments in relation to the set objectives by comparing to other works within the scope of study and coming out with some buttressed explanations and speculations. The discussions centered on the length-frequency distributions, length-weight relationships, condition factor, sex ratio, growth parameters, mortality and exploitation of the species.

Length-frequency distribution

Length-frequency distributions are useful analytical tools for managing and monitoring fisheries as well as studying the growth and age of fish (Akanse & Eyo, 2018). The monthly length-frequency distributions of *Sphyraena sphyraena* (Fig. 5), *Apsilus fuscus* (Fig. 6) and *Cynoglossus senegalensis* (Fig. 7) did not show consistent shifts in the monthly modes. However, the overall length-frequency distributions suggest a single cohort for *Apsilus fuscus* (Fig. 3a) and two cohorts for *Sphyraena sphyraena* (Fig. 2a) and *Cynoglossus senegalensis* (Fig. 4a). Bagenal and Tesch (1978) explained that the lack of consistent shifts in modes could be attributed to lack of marked seasonal changes in temperature and availability of food throughout the year which guarantee continuous growth in tropical fish. Additionally, younger fish might have catch up with older generations due to the decline in growth rate with increase in age. Thus, younger fish cohort distributions superimpose on the older ones (King, 1995), which made it difficult to clearly identify the cohorts in the stock as well as the monthly modal alterations in sizes.

Allam, Faltas and Ragheb (2004b & 2005) reported larger maximum size than the size recorded in the present study (66.5 cm) for *Sphyraena sphyraena.* Larger maximum sizes were also recorded for other *Sphyraena* species (Ayo-Olalusi & Ayoade, 2018; Kasim, 2000). Petrakis and Stergiou (1995) reported a maximum size of 49.8 cm Greek waters which is smaller than the size recorded in the present study. López, Jakes, Gonzalez and Floresramírez (2016) and Zavala-Leal et al. (2018) reported maximum sizes for other *Sphyraena* species lower than the maximum size recorded in the present study.

The observed maximum length of *Apsilus fuscus* (50.9 cm) did not differ much from Oliveira et al. (2015) who recorded 52.7cm while working on the same species in Cape Verde. Varied values were recorded for other Lutjanidae species like *Lutjanus peru*, *Lutjanus malabaricus*, *Lutjanus fulgens* and *Lutjanus fulviflamma* (Gallardo-Cabello, Sarabia-Méndez, Espino-Barr & Anislado-Tolentino, 2010; Raeisi et al., 2011; Oliveira et al.; Razi & Noori, 2018)

The maximum length of *Cynoglossus senegalensis* (56.4 cm) is greater than the maximum size observed in The Gambia waters (Gibril-Gabis, Mateo, Burnett & Castro, 2011) but smaller than sizes reported by Akanse and Eyo (2018) and Udo, Ayua, Akpan, Umana, and Isangedighi (2014) at the Cross River State in Nigeria for the same species. According to Akanse and Eyo, length composition of a fish population exhibits modes among species with a fast and uniform growth. The overall length-frequency distribution in this study showed that, *S. sphyraena* and *A. fuscus* exhibited a unimodal size distribution (Fig. 2a & 3a) while *C. senegalensis* showed a bimodal size distribution (Fig. 4a).

Length-weight relationship

Evidence on the condition and growth patterns of fish is obtained from length-weight relationships (Bagenal et al., 1978). The length-weight relationships for the *Sphyraena sphyraena, Apsilus fuscus* and *Cynoglossus senegalensis* specimens were exponential and described by the relationship:

$$BW = aL^{b}$$

where BW is the body weight, L is the length, '*a*' is a constant and '*b*' the exponent or regression co-efficient. Fish are said to exhibit isometric growth when length increases in equal proportions with body weight. The regression co-efficient for isometric growth is '3' and values greater or lesser than '3' indicates allometric growth (Gayanilo & Pauly, 1997).

The total length and body weight of *Sphyraena sphyraena* specimens showed a significant relationship and a strong correlation. The exponent '*b*' differed significantly (b = 2.75 ±0.11; $P<0.05$) from 3. Such a fish is said to exhibit negative allometric growth. This kind of growth pattern has been reported to be characteristic of barracuda, where the individuals grow faster in length than in weight (De Sylva, 1963; Zavala-Leal et al., 2018), thus in contrast with other bumpy, heavy-bodied fishes. Allam et al. (2004a) reported negative allometry for *S. sphyraena* in the Egyptian Mediterranean waters. Similar observation has been reported for *S. barracuda* and *S. ensis* in Florida Bay and Gulf of California (Schmidt, 1989; Zavala-Leal et al.).

A significant relationship and strong correlation between total length and body weight was exhibited by the *Apsilus fuscus* specimens studied. The exponent '*b*' differed significantly (b = 2.84 ±0.12; P<0.05) from 3. This implies negative allometry suggesting that the fish become less slender as it increases in length (Rejitha & Pillai, 2015). Agboola and Anetekhai (2008) and Oliveira et al. (2015) reported positive allometry for *A. fuscus* in Nigeria and Cape Verde respectively. Negative allometry for other snapper species have been reported by some authors (Newman, Williams & Russ, 1996; Kumolu-Johnson & Ndimele, 2010; Rejitha & Pillai). Consequently Gomez, Guzman and Marcano (1996) reported near-isometric growth for *L. synagris* and *L. buccanella* and isometric growth for *L. vivanus* in the same study.

The *Cynoglossus senegalensis* specimens showed a significant relationship and strong correlation between total length and body weight. The exponent '*b*' did not differ significantly (b = 3.08 ±0.11; P>0.05) from 3 and this shows isometric growth. Reports by other authors are in agreement with the findings of the present study for the same species (Abowei, 2009; Sanyang, Kretsch & Castro, 2011). Seshappa (1981) reported isometric growth for *C. lida* in Indian coastal waters. Allometric growth has been reported for other Cynoglossidae species like *C. canariensis* in Nigeria (Ajayi, 1983), *C. robustus* (Katayama & Yamamoto, 2012) and *C. zanzibarensis* on the Agulhas Bank, South Africa (Booth & Walmsley-Hart, 2000).

Bagenal and Tesch (1978) point out that differences in the length-weight relationship can be found with regard to sex, sexual maturity, season and even time of the day as a result of stomach filling; therefore, changes in '*b*' value can be found in different developmental stages, first sexual maturity and when important environmental changes occur. These differences in growth patterns may be due to factors such as temperature, food availability, prey-predator relationships, changes in the environmental condition, maturity stage, differences in sample number and sampling period, experimental design, and gear differences (Bagenal & Tesch.; Sumer, Ozdemir & Ertekin, 2014). The 'b' value obtained in the present study could be ascribed to one or a combination of most of the above mentioned.

Condition Factor

Condition factor is an expression of relative fatness of fish and generally larger values of K, indicates better condition of the fish. The results of the condition (K) in *S. sphyraena* showed that higher K values were recorded in smaller size groups than in the larger size groups. Again the highest K value for all the specimens (0.60 ±0.02), males (0.72) and females (0.54) were recorded within the smallest size group (Fig. 11). In the reverse, the lowest K value for all the specimens (0.41 ±0.03), males (0.37) and females (0.38 ±0.04) were recorded within the larger size groups. Smaller sizes of *A. fuscus* recorded higher K values than the larger size groups. The highest K value for all the specimens and males (1.09) and females (1.08 ±0.03) were recorded within the smallest size group while the lowest K values for all the specimens (0.93) and both sexes (0.94) were recorded in the largest size group (Fig. 12). In *C. senegalensis* the smaller specimens also recorded higher K values than the larger specimens. The highest K value for all the specimens (0.68) was recorded within the smallest size group while the lowest K values (0.39) was recorded in a larger size group (Fig. 13).

The results of the present study affirms the general rule that, the highest values of the condition factor occur in the smallest size groups (Lizama & Ambrosio, 2002). Kachari, Abujam and Das (2017) revealed that K values are higher in small fishes and lower in fish having large size due to voracious feeding nature. The results of condition factor can be used to deduce the wellbeing of the fish species studied and it is based on the theory that heavier fish of a given length are in better condition (Bagenal & Tesch, 1978) and therefore used as an index of growth and feeding intensity (Fagade, 1979). From the present study, smaller sizes of *S. sphyraena*, *A. fuscus* and *C. senegalensis* had better condition indicating a better feeding regime. The lower K values recorded in the larger sizes of *S. sphyraena*, *A. fuscus* and *C. senegalensis* may have resulted from reduced feeding which translates into little lipids and fats deposition (Rao, 1985; Razi & Noori, 2018). This therefore indicates less weight gain relative to length and agrees with reports by Fagade that condition factor relatively decreases due to the gradual increase in length. Amongst the three species studied, the highest K values were recorded in *A. fuscus.*

The fluctuation of K values between the species as well as within the species could be due to feeding difference, climate and environmental conditions (Blackwell, Brown & Willis, 2000). Blackwell et al. (2002)

commented that high condition factor values indicate favourable environmental conditions and low values indicate less favourable environmental condition. Drawing from this, it possible that the specimes of *A. fuscus* thrived in a favorable hahitat with abundant food, good climate and environmental conditions and were feeding well.

Sex ratio

Sex ratio can change considerably among species, or differ between populations, or even among different years for the same population (Nikolsky, 1963). However, in most populations, the ratio is usually close to unity according to Nikolsky as observed in this study for *S. sphyraena* and *A. fuscus*. Allam et al. (2004b) and Hosseini et al. (2009) reported similar results for *S. sphyraena* and *S. jello* respectively. Similar results were reported for other Lutjanid species such as *Lutjanus synagris*, *Lutjanus guttatus* and *Lutjanus argentiventris* (Cruz-Romero, Chávez, Espino & García, 1996; Rivera-Arriaga, Lara-Dominguez, Ramos-Miranda, Sánchez-Gil & Yanez-Arancibia, 1996)

Growth

In this study the asymptotic length of *S. sphyraena* differed from reports for other related species like *S. obtusata* (Kasim & Balasubramanian, 1990) and for *S. barracuda* (Abowei & Davies, 2009) and *S. afra* (Ayo-Olalusi & Abeke-Ayoade, 2018). The asymptotic length of *A. fuscus* in the current study was greater than reports by Stobberup, Ramos and Coelho (2004) for the same species in Cape Verde. The asymptotic length of *C. senegalensis* estimated by Meissa and Gascuel (2014) in the mixed Mauritanian *Cynoglossus* stock was longer than estimated in the current study, while lower were recorded by Gibril-Gabis et al. (2011) for the same species in The Gambia. Variations in estimates may be attributed to factors like differences in maximum observed length, sampling methods, nature of data, computation methods used and the obtained length frequency (Amponsah, Ofori-Danson, Nunoo & Ameyaw, 2016).

The von Bertallanfy growth coefficient in other studies were relatively slower than in the present study (Kasim, 2000; Abowei & Davies, 2009; Ayo-Olalusi & Abeke-Ayoade, 2018). The relatively high growth rate might depict the response by *S. sphyraena* stock to the intense fishing pressure (Amponsah et al., 2016). Allam et al. (2004a) reported a slower growth rate for *S. sphyraena* in the Egyptian Mediterranean waters and suggested variation in growth rate by other workers may result from disparity in food abundance or size composition of the stock. Najmudeen, Seetha and Zacharia (2015) reported that regional differences in growth rate are common among the same exploited species and attributes this to sample strength and size. Sparre and Venema (1992) submitted that growth parameters differ from species to species and also stock to stock even within the same species as a result of different environmental conditions. The growth rate recorded in this study varied from other reports possibly due to the above reasons.

The von Bertallanfy growth coefficient of *A. fuscus* in the current study agrees with other authors for the family Lutjanidae (Cruz-Romero et al., 1996; Mees, 1996; Martinez-Andrade, 2003; Mann, Lee & Cowley, 2016). The estimated growth rate can be explained by the report that, snappers especially the tropical populations are generally slow growing and long lived (Haight, Kobayashi & Kawamoto, 1993; Martinez-Andrade; Piddocke et al., 2015).

Even though the von Bertallanfy growth coefficient estimated for *C. senegalensis* in the current study was slow, it seemed faster than reported in The Gambian and mixed Mauritanian stocks (Gibril-Gabis et al., 2011; Meissa & Gascuel, 2014). The slow growth rate suggests that *C. senegalensis* is a long lived fish. The von Bertallanfy growth coefficient results of other related species like *C. zanzibarensis* in the Agulhas Bank and *C. canariensis* in Nigeria (Ajayi, 1983; Booth & Walmsley-Hart, 2000) support the assertion that *Cynoglossus* species are relatively long lived demersals, with lower growth rates.

Mortality and Exploitation

The alteration in mortalities in relation to other studies could be due to the intensity of predators and competitors whose population dwell heavily on the abundance of the fish species studied (Al-beak, 2016). Greater proportion of the mortalities in the *S. sphyraena* stocks studied resulted from fishing than natural. Results by Allam et al. (2004a), Najmudeen et al. (2015) and Ayo-Olalusi and Abeke-Ayoade (2018) are in agreement to this observation. Similar observation was made for the *A. fuscus* population from the Hawaiian archipelago and eastern Australia confirms the report that snappers have low rates of natural mortality (Haight et al., 1993; Martinez-Andrade, 2003, Piddocke et al., 2015). Other authors have reported high fishing mortality than natural mortality for other *Cynoglossus* species (Booth & Walmsley-Hart, 2000; Manojkumar, Vivekanandan, Zacharia, Nair & Pavithran, 2014). This therefore suggests that *S. sphyraen*a, *A. fuscus* and *C. senegalensis* stocks are fishing mortality dominated, hence exposed to a marginally higher fishing pressure than natural deaths which could be caused by age, predation, lack of food, spawning stress, diseases and pollution (Abowei, Davies & George, 2010; Amponsah *et al.*, 2016).

From the present study, estimated exploitation rate of *S. sphyraena* (0.62) and *A. fuscus* (0.56) are greater than the optimum exploitation level ($E_{0.5}$) for sustainable fishery. In other words, these stocks are currently exploited beyond the optimum value for sustainable yield for the fishery. *S. sphyraena* and *A. fuscus* stocks. This result is supported by the Z/K of *S. sphyraena* and *A. fuscus* that these populations are fishing mortality dominated.

The present exploitation rate (0.52) of the *C. senegalensis* stock is comparable to the optimum exploitation ($E_{0.5}$) level criterion for a sustainable fishery even though a greater proportion of the mortalities resulted from fishing (Osei, 2016).

The current exploitation level of *S. sphyraena, A. fuscus* And *C. senegalensis* suggests that any further expansion in the current exploitation rate will fasten the rate of the stock depletion as the stocks are already experiencing excessive fishing pressure. This is based on the assumption that in an optimally exploited stock, natural and fishing mortalities should be equal (Abowei et al., 2010). The mesh size to a large extent determines the varying estimates of length at first capture, therefore the varying estimates of length at first capture in different areas reflect the different mesh sizes employed in fishing.

CHAPTER SIX

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

The chapter provides a summary, conclusions and recommendations of the study. The summary and conclusions have been organized on the premise of the specific objectives of the study. The chapter also presents some recommendations based on the conclusions derived from the study and suggested areas for further research.

Summary

Ghana's marine fisheries is in crisis; landings (fish caught and retained) of all stocks have declined dramatically over the last decade. While official national statistics indicate a 30% decline from a high of 492,776 metric tons in 1999 to 333,524 metric tons in 2011, the reality in coastal fishing communities is much worse than these figures indicate. The shrinking harvest is particularly dramatic for the pelagic, small, sardine-like *Sardinella* species, by far the most critical for coastal livelihoods and food security. This has occurred at a time of dramatic increase in fishing effort by all fleets. Worse still, the *Sardinella* catch for the all-important canoe fleet, is now around 20,000 metric tons, down from a peak of approximately 140,000 metric tons in 1992.

Sustaining fishery resources is crucial to the survival and wealth of fishers and the economy, as the sector continues to contribute significantly to Ghana's GDP. There is a worldwide perception that modern fisheries management strategies are failing to address the overexploitation of fishery resources, however, stocks that are managed by both modern and traditional fisheries are improving globally. Fisheries experts now recognize that a fishery cannot be managed effectively without the cooperation of fishers to make laws and regulations work. There is inadequate understanding of traditional fisheries management practices in Ghana by both the formal managers, scientists, researchers, and the general populace. This has resulted in formulation of unsustainable and ineffective policies and management plans which sometimes lead to conflicts and mistrust between fisheries officers, fishers and fishing communities.

Sphyraena sphyraena, *Apsilus fuscus* and *Cynoglossus senegalensis* forms part of Ghana's high price fishes, yet specific management measures are not been taken to sustainably exploit these species due to the paucity of biological and population dynamics information on these stocks. It was therefore reasonable to investigate the aspects of the biology and conduct stock assessment of these three commercially important species of fish as the knowledge would help close the knowledge gap on these three species. Again, the study would provide information on the current state of the stock of the three species. This vital information would however inform policies by helping to determine the appropriate effort required in the fisheries to maintain a sustainable exploitation rate, thereby ensuring the effective management of the fishery of the three species.The objectives of the study were to; establish the length frequency distribution and length-weight relationship, determine the condition factor, determine the sex ratio, estimate growth parameters (asymptotic length, growth coefficient and length at first capture), estimate mortality parameters and exploitation levels.

Fish samples were randomly collected by purchase from semi-industrial fishing operations at Tema fishing harbour (Greater Accra Region), Elmina fish landing site (Central Region) and Albert Bosomtwe-Sam Fishing Harbour (Western Region) in Ghana over six (6) months from February, 2017 to July, 2017. Standard laboratory procedures were employed to take various weights and morphometric parameters of fish. Data organized were subjected to relevant computerized analyses in Microsoft Excel and the ELEFAN I routine in FiSAT II to produce the needed outputs related to the set objectives.

A total of 420, 423 and 562 individuals of *Sphyraena sphyraena*, *Apsilus fuscus* and *Cynoglossus senegalensis* respectively were examined. Total length (TL) measurements ranged from 12.5 cm to 66.5 cm for *S. sphyraena*, 20.3 cm to 50.9 cm for *A. fuscus* and 11.0 cm to 56.4 cm for *C. senegalensis.* The total length and body weight of the specimens of the three species showed a significant relationship and a strong correlation. The growth of *S. sphyraena* and *A. fuscus* were allometric (b = 2.75 ±0.11; $P<0.05$ for *S. sphyraena* and b = 2.84 ±0.12; $P<0.05$ for *A. fuscus*). *C. senegalensis* showed an isometric growth pattern (b = 3.08 ±0.11; $P>0.05$). The overall length-frequency distributions suggested a single cohort for *A. fuscus* and two cohorts for *S. sphyraena* and *C. senegalensis*.

The highest K value for all specimens of *S. sphyraena* was 0.60 (±0.02) while that of males and females were 0.72 and 0.54 respectively. Consequently, the lowest K value recorded in all specimens was 0.41 (±0.03) while that of males and females were 0.37 and 0.38 (±0.04) respectively. For *A. fuscus*, the highest K value for all specimens was 1.09 (±0.03) whiles males and females recorded 1.09 and 1.08 (±0.03) respectively. The lowest K value recorded in all specimens was 0.93 while both males and females recorded 0.94. The highest K value recorded in all specimens of *C. senegalensis* was 0.68 and the lowest was 0.39. In all three species condition factor was higher in smaller fishes and lower in larger fishes. The overall male to female ratio was 1:1.1 for *S. sphyraena* specimens and 1:1 for specimens of *A. fuscus* studied over the six months period. The overall and monthly sex ratio of *S. sphyraena* and *A. fuscus* did not differ significantly from 1:1.

The asymptotic length, von Bertalanffy growth coefficient and Z/K estimated were 69.9 cm TL, 1.64/yr and 2.99 for *S. sphyraena*; 53.5 cm TL, 0.50/yr and 3.32 for *A. fuscus*; and 58.2 cm TL, 0.34/yr and 3.83 for *C. senegalensis* respectively. The length at which 50% of the species became exposed to the gear was estimated at 39.3 cm, 32.8 cm and 32.2 cm TL for *S. Sphyraena*, *A. fuscus* and *C. senegalensis* respectively. The total mortality (Z), natural mortality (M), fishing mortality (F) and exploitation rate (E) were estimated at 4.92/yr, 1.88/yr, 3.04/yr and 0.62 for *S. sphyraena*; 1.67/yr, 0.74/yr, 0.93/yr and 0.56 for *A. fuscus*; and 1.32/yr, 0.63/yr, 0.69/yr and 0.52 for *C. senegalensis* respectively.

Conclusions

The monthly length-frequency distributions of *Sphyraena sphyraena*, *Apsilus fuscus* and *Cynoglossus senegalensis* did not show consistent shifts in the monthly modes. However, the overall length-frequency distributions suggest a single cohort for *A. fuscus* and two cohorts for *S. sphyraena* and *C. senegalensis*. The total length and body weight of the specimens of the three species studied showed a significant relationship and a strong correlation, therefore grow exponentially like all teleost do. *S. sphyraena* and *A. fuscus* exhibited allometric growth while *C. senegalensis* showed an isometric growth.

The results of the condition factor for all three species showed that higher K values were recorded in smaller size groups than in the larger size groups. Smaller sizes of *S. sphyraena, A. fuscus* and *C. senegalensis* had better condition which suggests a better feeding regime while the lower K values recorded in the larger sizes may have resulted from reduced feeding. Amongst the three species studied, the highest K values were recorded in *A. fuscus.*The overall and monthly sex ratio of *S. sphyraena* and *A. fuscus* were in unity. Neither of the sexes showed preponderance over the other. It could be inferred that both species exhibited characteristics of gonochorism.

The asymptotic length and von Bertalanffy growth coefficient estimates suggest that *A. fuscus* and *C. senegalensis* are slow growing and long lived fishes. The *S. sphyraena*, *A. fuscus* and *C. senegalensis* stocks are mortality dominated and are exploited above $E_{0.5}$ revealing that all three stocks are possibly exposed to a marginally higher fishing pressure than natural deaths.

Recommendations

1. A precautionary approach to managing *S. Sphyraena*, *A. fuscus* and *C. senegalensis* fisheries in Ghana is recommended in the present circumstances, therefore, the present level of fishing mortality should be of urgent concern for fisheries managers in Ghana.
2. A detailed study on the microstructural features of the otoliths, reproductive biology and catch per unit effort (CPUE) of *S. Sphyraena, A. fuscus* and *C. Senegalensis* stocks in Ghana is recommended.

3. The upcoming Fisheries Co-management Policy should be adopted as it would strengthen the capacity of local fishermen required to ensure the regulation, monitoring and enforcement which promotes all-inclusiveness in the management of the fishery.

4. Livelihood diversification programs should be encouraged among fisher folks to help reduce the fishing pressure on fish stocks.

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APPENDICES

Appendix A: *Sphyraena sphyraena* specimens

Appendix B: *Apsilus fuscus* specimens

Appendix C: Cynoglossus senegalensis specimens