UNIVERSITY OF CAPE COAST

POPULATION DYNAMICS OF *Chloroscombrus chrysurus* AND *Decapterus punctatus* IN COASTAL WATERS OF GHANA

CECILIA AKUA ANIMAH

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By

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

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DECLARATION

Candidate's Declaration

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

Candidate's Signature ………………………………… Date……..…………….

Name: CECILIA AKUA ANIMAH

Supervisor's Declaration

We hereby declare that the preparation and presentation of the thesis were supervised under 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: DR. ISAAC OKYERE

ABSTRACT

Carangids are considered as commercially important fish species in Ghana. In recent times, there has been a decline in Ghana's pelagic stock which includes carangids. The purpose of the study was to assess the population dynamics of some common commercially important carangid stocks in the coast of Ghana to inform management decisions. The study was conducted specifically in the Tema fishing Harbour, the Elmina landing site and the Albert Bosomtwe Sam fishing Harbour in Ghana from November, 2020 to June, 2021. Length- frequency data of fish samples were used to calculate the growth and mortality parameters as well as the exploitation ratio. The growth parameters assessed for *Chloroscombrus chrysurus* and *Decapterus punctatus* were; asymptotic length (L_{∞}) = 28.9 and 21.4 cm standard length, growth rate (K) = 0.38 and 0.55 per year, growth performance index (ϕ) =2.50 and 2.40, theoretical age at birth (t_o) = - 0.23 and -0.08 respectively. The Z/K ratio were 7.26 and 4.51 respectively, indicating that the stock is mortality dominated. Total mortality (Z) was estimated at 2.76 and 2.48 per year, while natural mortality (M) was 0.67 and 1.03 per year and fishing mortality (F) at 2.09 and 1.45 per year respectively. The estimated fishing mortality (F) was found to be greater than the natural mortality. Further, the current exploitation rate (E) was calculated as 0.75 and 0.58, portraying over exploited stock. The length at first maturity (L_{m50}), was estimated at 13.9 cm and 14.1 cm for male and female *Chloroscombrus chrysurus* and 14.7 cm and 12.6 cm for male and female *Decapterus punctatus*. The length at first capture (L_{c50}) was obtained at 10.6 cm and 10.5 cm respectively. The estimated length at first capture was lower than the length at maturity inferring that these species do not get the chance to spawn at least once before they are harvested. From the study, it was confirmed that the Carangid stock within Ghana's coastal waters is currently overexploited and there is a need for a decrease in fishing pressure on carangids to aid in sustainable management of the stocks.

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DEDICATION

To my family: Mr. Kusi Boateng, Serwaa Ama Kusi-Boateng, Lucy Agyabeng, Melody Anokyewaa, and Albert Agyapong

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CHAPTER ONE

INTRODUCTION

Background to the Study

Ghana shares border with the Gulf of Guinea which is described as a zone or sea with the highest fish production area in Africa producing about 305,000 tonnes in 2010 (FAO, 2011). Ghana's fishing industry encompasses the inland and marine sectors. The marine sector contributes about 85% of the overall fish catch. The inland sector contributes to the remaining 15% of Ghana's fish resources. The marine industry is grouped into four main units, which are, the artisanal sector, semi-industrial, industrial and tuna sectors (Nunoo & Asiedu, 2013). Artisanal fleet employs numerous gears which catch fish species and contributes to between 245,000 mt of Ghana's total marine fish catch (MOFAD, 2014). Ghana's fisheries account for about 4.2% of the agricultural GDP ((Nunoo, Asiedu, Amador, Belhabib and Pauly, 2014). Fish forms the main basis of proteins in Ghana and the per capita ingesting is known to be near 26 kg which represents 60% of all protein (Asare-Donkor, Adaagoam, Voegborlo, & Adimado, 2018). The fisheries sector in Ghana again represents a major part in the state economy and security of food with marine capture fisheries accounting for 343,800 mt of fish yearly (FAO, 2011).

According to World Bank (2011), Ghana's fisheries sector employs about 372,049 fish processors, fishermen, canoe builders and traders and about 2.2 million individuals rely on it for survival. The known species landed in Ghana's fish landing sites are the pelagic fishes such as species of the families Engraulidae, Clupeidae and Carangidae.

The carangids are pelagic fishes widely distributed in Ghana’s coastal waters with about twenty-five species and their importance in Ghana’s fishery is highly significant (Mehl, Oslem & Bannerman., 2005). The family Carangidae includes the trevallies (crevalles), amberjack, jacks, moonfish, rainbow runner and many other species, representing about one hundred and forty (140) species under twenty- five genera and they occur richly up to 60 m depth in waters that are shallow (Honebrink, 2000). Carangids possesses minor to huge body size (about 150 cm) and they may range from either fusiform or elongate to deeply compressed (Vinothkumar, Remya, Rajkumar and Thirmalaiselvam*an*, 2020). They possess head which is elongated and rounded to very compressed. Carangids are mostly move in schools and an example is the *Alectis* spp. Most young species are widely distributed and are found mainly in brackish water environments (especially when they are young). Other species such as the *Elagatis* and *Naucrates*, are pelagics that usually occur near the surface of oceanic waters (Vinothkumar et al., 2020). Some juvenile of carangid species often hides underneath jellyfishes. Carangids are harvested on commercial bases using gears like the purse seines, trawl, hook-and-line and traps. Species highly used for sport fishing includes huger species of *Caranx*, *Seriola* and *Trachinotus* (Vinothkumar et al., 2020). In Ghana, purse seiners mostly target Carangidae species. Species such as the Atlantic bumper, Atlantic horse mackerels, and Cunene horse mackerel are caught in large numbers and are either sold fresh or smoked whiles the large ones such as Jack mackerel are generally salted (Kwei & Ofori-Adu, 2005). Relatively, carangidae is an inexpensive resource which constitutes a means of support along the coastal areas of Ghana to many traders, fish processors and fishers (Nunoo, Asiedu, Kombat & Samey, 2015).

Population dynamics define how the fish population or fish stocks change in weight (biomass) and number in response to characteristics such as growth and mortality (Rashed-Un-Nabi, Hoque, Rahman, Mustafa & Kader, 2007). In analysing the dynamics of a fish population, the greatest mission is the evaluation of parameters such as growth, and mortality of a particular fish species. Nevertheless, the fish population is subjected to change and values of parameters gained may change with regards to stock difference and environment of the same fish species (Rashed-Un-Nabi et al., 2007).

These parameters being estimated often leads to the acquisition of information and knowledge on stock assessment of fish from which a clear picture on the current status the fishery can be established for management and sustainability purposes (Rashed-Un-Nabi et al., 2007). Concerning the economic importance and heavy exploitation of carangids such as *Decapterus* spp in Ghana's coastal waters with a consequent decline in yields according to (MOFAD, 2015), there is the need for adequate biological information about population dynamics for effective management of the species belonging to Carangidae in coast of Ghana.

Problem Statement

In Ghana, Carangidae species are considered as one of most the commercial and important fish species in coastal communities and it is available throughout the year (Forson & Amponsah, 2020). This fish is normally consumed fresh, smoked, or dried. However, scientific research proves that, there is a decline in Ghana's marine catches over the past decade and it has led to the import of 40% of fish requirements (MOFAD, 2015). According to Environmental Justice Foundation & Hen mpoano, (2017), annual landings of Ghana’s pelagic stocks has declined from 250,000 tonnes in the 1990s to less than 50,000 tonnes. This is due to factors such as the increase in the number of fishermen and vessels with an amplified geographical spread, weak governance, and open- access fishery resources (Ofori-Danson, Addo, Animah, Abdulhakim, & Nyarko, 2018). Moreover, overexploitation exists within Ghana’s fishery as a result of a growth in the population of humans and urbanization over the years. Coastal resources in Ghana have become polluted and depleted leading to the extinction of some species (Ofori-Danson et al., 2018).

According to (FSSD, 2019) catch data on carangids from 2015 to 2019 have declined from 38,312.58 tonnes to 28,976.53 tonnes.

Also, information on population dynamics for species of the Carangidae family in Ghana appears to be limited, making stock assessments and policies on sustainable management unproductive. Consequently, declining landed catch for Carangidae species in Ghana will increase the severity of poverty and food insecurity within vulnerable fishing communities whose livelihood depends on fish (Nunoo & Asiedu, 2013).

Again, undertaking a new survey in stock assessment was part of the goals of the fisheries management plan (2015-2019) which could not be fully achieved.

Justification

There is a need to undertake this research to assess the key commercial fish stocks such as the Carangidae species to support the fisheries management plan. Again, due to the high demand of carangids and the destructive nature of activities of fishing in Ghana, it is essential to assess the parameters of the carangid population periodically for proper management and sustainability of the fishery. This will further promote United Nations' Sustainable Development Goals 1,2 and 14 which suggests No poverty, zero hunger and Life under water respectively. Furthermore, knowledge about the true size structure of the population will help assess whether there has been an overexploitation of the stocks over a while and the possible presence of collapse of the carangid fishery. The information gained from this study will predict the stock assessment which will review the present status of Carangidae species and will contribute to implementing management strategies or policies for the Ministry of Fisheries and Aquaculture Development.

Aim and Objectives

The study was to assess population dynamics of two commercial and important carangid stocks in the coast of Ghana to inform sustainable management decisions.

Specific Objective

1. Determine growth and mortality parameters of carangids;
2. Estimate the exploitation levels of the Carangidae species;
3. Assess the reproductive biology of the Carangid species to determine their spawning period and reproductive cycles;

4. Assess the gears used in the exploitation of Carangidae species and their sustainability for the carangid stock.

CHAPTER TWO

LITERATURE REVIEW

This chapter highlights important information surrounding the subject area of the study.

Overview of the Fishing Industry in Ghana

Ghana with its natural water bodies has important capture fisheries and aquaculture potential. The capture fisheries comprise of inland and marine sectors. The marine sector contributes more than 70% of the total fish production (MOFAD, 2015). The inland fisheries sector adds about 17% of the total fish production whereas the aquaculture sector produces 13% of the total fish production in Ghana. The most favourable geographic position of Ghana comes with a wide range of aquatic species and provides many resources to support fisheries potentials. Ghana has a maritime domain and coastline which is about 550 km with a territorial sea and an Exclusive Economic Zone (EEZ) of 228,000 km^2 (MOFAD, 2015). The narrow continental shelf opens wide from a lowest of 20km at Cape St. Paul to a highest of 100km in the middle of Takoradi and Cape Coast (Bannerman and Cowx, 2002). The EEZ of Ghana comprises a 218,100 km^2 region (GCLME, 2006). Fisheries in Ghana plays a major role in supporting the livelihood of about 30 million individuals and also supports the national economy by adding about 5% gross domestic product (GDP) to agriculture. Moreover, 10% of the nation's population are employed (Frimpong et al., 2022). The per capita consumption of fish annually in Ghana is about 26kg (FAO, 2016). Ghana's fisheries industry has been growing by an average of 3 % per annum for the past 20 years. Foreign exchange earnings from fish and other seafood products rose from US$ 165.7 million in the year 2010 to US$ 309.7 million in the year 2015, having a corresponding increment within total production of fish by volume of 9% from the year 2010 to 2015 (Aseidu et al., 2017).

Marine Fisheries in Ghana

The marine fishing sector has three sub-sectors; artisanal, semi-industrial and industrial fishery. The artisanal fishing industry is one of the significant sectors with regards to output, accounting for about 70% of fish supply totally. It operates at 304 landings in 189 coastal waters and serves as a livelihood for an estimated 1.5 million people (Lenselink, 2002). The semi-industrial fishery division harvests both demersal and pelagic species which operates from only seven landing sites. It contributes 2% of the total marine catch. The industrial also contributes to about 18500 mt annually (MOFAD, 2015) and the sector constitutes trawlers, shrimpers and tuna vessels.

Ghana experiences two upwelling seasons; which is a mass of water rich in nutrients derived from the surface and stimulates primary production. A major season of upwelling occurs from July to September, and minor season in the later parts of December to earlier parts of February. The marine fishery sector supplies fish at the local level mostly, offering around 70% of the production of fish. Ghana’s marine fishery sector is made up of about 300 completely distinct important species, 25 crustacean species, 3 sea turtle species and 17 species of cephalopods (Amador, Bannerman, Quartey & Ashong, 2006). Almost all domestic supply of marine fish is done by the artisanal sector and the major harvest of the marine resources are the small pelagics particularly the anchovy, chub mackerel, flat sardinella and round sardinella (Asiedu et el., 2021).

The Artisanal Fisheries in Ghana

The artisanal fisheries sector is composed of many fishing gears. These embody seine net, drifting gillnet and hook and line. The sector also uses 9,951 motorized and non-motorized canoes with engine power of 40 hp (MOFAD, 2015). There are over 11, 200 canoes and over 124,000 fishers recently working from over 300 landings situated along the entire 550 km coastline (Fisheries Commission, 2016). The dimensions of the canoes range between 3 meters to nearly about 20 meters and created from *Triplochiton* species locally known as wawa. Harvests from this sector is estimated to be 254,000 mt. Artisanal gears are accustomed to make use of molluscs and crustaceans (Amador et al., 2006). Artisanal fishery sector supplies about 70% of all fish landings annually. Distinct artisanal fishing gears aim at catching diverse fishes and the purse seines is normally used by artisanal fishers to exploits principally small pelagics (FAO, 2007). Presently, trawlers contribute about 80% of the landings annually. Research have made it known that canoe catches have decline considerably recently affecting the profit of fishers and fish traders (MOFAD, 2015).

Inshore or semi-industrial Fisheries in Ghana

The inshore fisheries sector utilizes indigenously wooden vessels built-in with inboard engines which are about 400 hp with the lengths of the wooden vessels ranging from 8 to 37 m (Cobbina, 2018). Wooden vessels that have lengths lesser than 12 m are also classified as small-sized wooden fleets whereas vessels ranging from 12 to 22 m are classified as medium sized wooden fleets. Wooden fleets in the inshore sector are mostly used on dual purposes; they use trawls and purse seines (Cobbina, 2018). Wooden vessels are usually used for purse seining during the up-welling seasons and trawling is done in shallow waters during non-upwelling season (Amador et al., 2006). The catches by fishers in the sector have steadily reduced and are recently estimated at below 10,000 mt. of the total fish production in Ghana. Profit gained from the semi-industrial sector fishing operations has been very low for decades (Anon, 2003). The purse seiners in the inshore fisheries industry pick out the sardines and Carangidae species. The inshore fleets exploit fish in coastal waters similar to the artisanal vessels throughout the seasons of upwelling (Afoakwah et al., 2018). The smaller trawlers harvests *Balistes capriscus*, whereas big size trawlers target *Pagellus bellottii*, *Dentex canariensis, Lutjanus fulgens, Lutjanus goreensis, Pseudupeneus prayensis,* and many others. Fishers in this sector use ice cubes for the preservation of fish at sea to prevent post-harvest losses; this enables the fishers to transfer their catch to retailers safely before it lands on the consumer’s table.

Industrial Fisheries

Industrial fleet is comprised of huge, steel hulled foreign-built vessels which are more notable than the other fleet for their capacity of freezing fish stumped, and also their propensity of remaining stumped for hours without melting. The main players of this sector are the bottom trawlers with about 30m depth. These vessels operate where there are deep water ports and so they operate between Tema and Takoradi. As a marine registered fleets, they are legally authorized to function in deeper waters of at least 30 m depth (Fisheries Act 625, 2002). According to Quaatey, (1997), the industrial vessels have undertaken significant changes with regards to numbers when the Ghana Economic Recovery Programme was introduced in 1984. The Ghana Economic Recovery Programmed aim to encourage nontraditional export to earn the country foreign exchange (Quaatey, 1997). The vessels exploit fish species such as snappers, cuttlefish, soles, sea breams, cassava fish and groupers for exportation (Mawuku, 2015).

Biology and Ecology of Carangids

Carangidae comprises a varied collection of species with common names such as amberjacks, scads, pilotfish, rainbow runners, jacks and many others (Honebrink, 2000). Carangids live in the tropic and subtropic marine ecosystems worldwide, however, some species are also found in temperate regions (Honebrink, 2000). Carangid fishes form one of the most significant fish resources worldwide with regards to their distribution, high rate and demand from markets and sea resource industry (Azim, Amin, Romano, Arshad, & Yusoff, 2017). Carangids are mostly predators inhabiting the pelagic areas and feeds on plankton, small fish and invertebrates (Kingston, Venkataramani, & Venkataramanujam, 1999). These species have very smaller cycloid scales and most of them are improved into rows of extended scutes on the lateral line posteriorly (Gunn, 1990). Their body form usually ranges from forms slender like that of *Decapterus* and *Elagatis* and deep-bodied like the *Selene* (Honebrink, 2000).

The attention of most researchers has been drawn to fish in the world due to their demand, market value, recreation and its recognition when it comes to sport fishing (Qamar, Panhwar & Siddiqui, 2016). There are studies which cover numerous parts of the life as well as the ecology of species of the family. These studies include, studies on food habits of fishes in the family (Sivakami, 1996), population dynamics of yellowtail scad in Malaysia (Azim et al., 2017) and many others. In Ghana, studies on the population dynamics of carangids include studies on the biology of false scad found in Elmina, Ghana (Forson & Amponsah, 2020) and studies on African Moonfish (growth, mortality and exploitation rates) along the coast of Ghana (Amponsah, Asiedu, Avornyo, Setufe, Afranewaa & Failler, 2021).

Population Dynamics Indicators

Population dynamics explains how the population increases and decreases over time, as it is influenced by reproduction, demise, and movement from one location to another. Population dynamics helps in acquiring knowledge on the changes in fishing forms and challenges like ecological destruction, predation and levels of harvesting. Population dynamics is important in fishery management as it is used by researchers of fisheries to estimate sustainability of yields (Wilderbuer & Zhang, 1999)

The three main indicators of a fishery population dynamics are as follows: i) Birth rate which suggests reaching a level of reproduction; thus, the age at which a fish that is being caught can be numbered in the gear or nets, ii) Growth rate, which deals with the increase in size of organisms or species length. iii) Mortality which comprises fishing death and natural death of fish.

Food Security in Relation to Fish

The state of food security and nutrition in the World as at 2018 revealed that about 1 billion individuals were food and nutrient insecure. This is a major global challenge that is emphasized by the United Nations Sustainable Development Goal (SDG) 2, aimed at eradicating hunger, achieving food security, improving nutrition and eliminating malnutrition (Hasselberg, Aakre, Scholtens, Overå, Kolding, Bank & Kjellevold, 2020).

Securing food is a tedious concept in determining and measuring since it works in a wide range of ways industry production, distribution and consumption of food and has undergone redefinitions over the years (Napoli, Muro & Mazziotta, 2011). The 1996 World Food Summit, looks at securing food in which everybody always has access to adequate, harmless as well as healthy food to satisfy their primary nutritional needs and food preference to achieve a healthy life. It therefore encompasses the dimensions, availability of diet, and diet access, steadiness of provisions and biological use which must be simultaneously fulfilled (Gibson, 2012; Hasselberg et al., 2020). Fish makes massive contributions (direct and indirect) to achieving food security and these contributions should not be ignored but rather boosted.

Described as nature's super food, fish (including finfish and shellfish) contributes directly to food security by contributing protein and calories (FAO, 2017). Fish contains 17% proteins gained from animal as well as 7% of all essential proteins meant for nearly three million individuals found in developed and developing states (Obiero, 2019). In Ghana, it is makes up to 50 to 80% of the protein (animal) consumed (Sumberg, Jatoe, Kleih & Flynn, 2016) and per capita consumption in a year is assessed at about 28 kg (FAO, 2016). Fish also adds many different micronutrients which are very important in dealing with various health problems around the world. It provides calcium, iodine, high-quality important minerals, amino acids and vitamins, often in highly bioavailable forms (Bennett, Patil, Kleisner, Rader, Virdin, & Basurto, 2018). Also, it provides essential fatty acids, needed for heart health (Bennet et al., 2018). Indirectly, fish contributes to food security by providing for poor individuals especially those in the coastal communities. Small-scale fisheries and related activities (trade and processing) provides income for rural societies where other job opportunities are scarce or even not available (Béné & Heck, 2005). In Ghana, the fishery sector is very important to the economy and contributes an essential part in curbing poverty as it employs about 10% work force and contributes 4.5% of its (GDP) (FAO, 2016). Fish contributes largely to food security; therefore, its role in countries efforts to achieve food security should not be underestimated.

Overfishing

Overfishing is a major concept in fisheries with models such as Thompson & Bell (1934) model, stock production model, and yield per recruit being developed to assist in measuring the notion of overfishing (Sissenwine, Mace, Lassen, 2014). Cunningham & Whitmarsh, (1981), argue that many definitions of overfishing are possible, depending on what purpose is sought by the fishing industry. According to Beamish, McFarlane, & Benson, (2006), overfishing explains a decrease in weight and number less than a certain perilous level as the residual stock are incapable to restock the population.

Safina & Duckworth (2013) identified seven kinds of overfishing. Harvesting small fish for humans to gain a minimum proportion of their probable development is known as growth overfishing (Beamish et al., 2006). Recruitment reduces the value of the catch to such an extent that young fish numbers cannot fill the population and can only be described as breeding failure due to declining breeders (Beamish et al., 2006; Safina & Duckworth, 2013). Demographic overfishing occurs when as a result of fishing it changes a population possessing several age assemblies into one with only one or two significant classes while genetic overfishing takes place when intense fishing changes a populations gene pool (Safina & Duckworth, 2013). Ecosystem overfishing brings about a significant change in species formation and loss of vital species and Malthusian overfishing is directly related to population growth (Safina & Duckworth, 2013).

The causes of overfishing include by-catch, subsidies and economies, increase in human population and technological advancement that has enhanced harvest of fish. Again, Safina & Duckworth (2013) suggested that, overfishing leads to a significant decline in species diversity, loss of fish, very few productions and increased risk of infertility in times of environmental degradation and declining fish and other marine resources.

Illegal, unreported and unregulated (IUU) ways of fishing are regarded as a significant contributor to the current era of the world’s overexploitation, leading to food insecurity, destroying maritime livelihoods and importantly undermining the sustainable use of the world’s oceans (Petrossian, 2014; Mackay, Hardesty & Wilcox, 2020). According to FAO (2001), IUU broken into its component parts encompasses, illegal fishing, which means fishing events done by a state or international fleet without seeking consent in state-owned waters, or in defiling a state’s rules or global requirements. Unreported fishing is fishing events not informed, or misreported to appropriate state authorities, in contravention of state rules as well as protocols fishing activities not regulated, i.e., catching fish in a zone where there are ineffective sustainable practices and where such activity is done unsustainably and contrary to international law. This practice creates a major problem that directly and indirectly affects the environment and the environment in which the fish rely for survival (Petrossian, 2014). According to the United States National Intelligence Council, IUU fishing appears to be most prevalent when management is weak, local fisheries management systems are lacking (or lacking resources) and countries have refused to sign important international agreements and / or regional management arrangements (NICs., 2016). The persistence of this practice is due to the ever-increasing demand for marine fish stocks, the overcrowding of many fishing vessels, the pool of cheap and accessible workers, poor funding and weak governance) and the lack of international political decision to address its causes.

The practice of IUU fishing has severe impacts. According to Evans (2000), large-scale and unregulated fisheries disrupt the sustainability and productivity of the environment, illegal fishing may damage the environment and any unreported or poorly reported information in order to obtain better research reduces the capacity to construct this research to obtain information needed to effectively manage the industries involved. IUU fishing reduces fish stocks and threatens the economic interests and livelihoods of all participants by disrupting small and large-scale fishing operations that rely heavily on people relying on threatened fishing areas as it robs the economy of full and steady income from their fishing resources (Nunoo & Ofori- Danson, 2015). IUU fishing also eliminates the rule of law by providing illegal people and organized crime groups with a source of income and infrastructure that benefits from trafficking and other unlawful actions like human trafficking (Telesetsky, 2014). Overfishing and IUU fishing seriously threaten the conservation of fishery resources and the health of communities that rely on fishermen.

Bycatch and Discards

Bycatch and discards that are not retained or sold as a result of economic or regulatory reasons, is a global issue facing fishery. Bycatch can increase population declines, block reconstruction and recruitment efforts, and alter or change the marine environment (Kelleher, 2005). The terms "bycatch" and "discard" may vary in explanation from diverse nations and administrative authorities. Both are similar and are associated with undesirable parts of fishing commercially. Discard is the disposal of unnecessary parts of the catch, which is deducted in reference to the part of the catch caught by accident in the target species (Saila, 1983). Disposal is currently a major topic in fishery management, both of which are based on theory; (Catchpole & Gray, 2010). However, disposal cannot be considered as a separate seizure of the catch. In fact, the related levels of catch or dump may depend on the catch. In Ghana, for example, fish from our waters is not rejected, instead, they are traded to skilled fishers for human consumption or other purposes such as feeds production for agricultural purposes (Nunoo, Boateng, Ahulu, Agyekum & Sumaila, 2009).

Therefore, in several mixed fisheries, not all are considered to be discarded as some of these catches may represent a major source of income (Ambrose, Solarin, Isebor, & Williams, 2005). Establishing this classification is necessary in determining issues related to fishing and identifying ways to reduce the economy. To some extent, these effects are not diverse from that of fishing, meanwhile all types of fishing cause the death of marine animals and may even affect the structure and function of the marine environment. The main difference that can be identified is that dumping (and any sub-catches that are not economically important) does not give economic value to fishers and therefore represents another 'unnecessary' death (Nunoo et al., 2009)

It has been indicated by Crean & Symes (1994) that a strong effect on discard rates is imposed by the management framework used to monitor the fisheries. Management structures that depend solely on output management (e.g., catch quotas and small size) are regularly linked to overfishing rates because fishers are often made to dump to stay within control constraints (Clean & Syms, 1994). In the case of mixed fish stocks where the acquisition of a scale is controlled by landmine management rather than catching it, dumping the rate by voting is a challenge. In cases where fishing opportunities (quota) remain of one species but limited to others, fishing activities may continue to conserve the remaining species and discard others (Graham, Ferro, Karp & MacMullen, 2007). In overfishing fisheries, discarded prices are often higher, with older fish being limited to usable stock (Bellido, Santos, Pennino, Valeiras, & Pierce, 2011). Fishers in particular rely heavily on younger classes that are closer to the market or to legal boundaries. Also, many fish of less than the maximum lawful size can be trapped and eventually cast-off due to poor gear selection (Bellido et al., 2011).

Another major motivation for dumping is related to market needs. Fish have a small market or price due to size preference or lack target market is discarded (Kelleher, 2005). In high-density fisheries, especially in tropical and subtropical fishing areas, this can be a worrying problem. The biggest contribution to the biomass of discarded fish is the disposal of commercial or non-commercial species in many trawl fishing areas although dumping instigated by catch quota limits and high grading can be challenging and mostly disposed of properly as a good fishery disposal (Kelleher, 2005). Therefore, in a particular fishery, a combination of fishery regulations is taken into account the economic importance and diversity of the fishery that determines the patterns and level or levels of disposal. Proper consideration of these determinants will help to define the best strategies and strategies for adapting and reducing the level of unwanted fishing and dumping (Kelleher, 2005).

‘’Saiko’’ and its Impacts on Carangids

“Saiko” in Ghana is termed as transfer or “transshipment” and it is a severe damaging way of fishing illegally where foreign trawlers target the catch of canoe fisher in Ghana and sell at a profit to their local communities (EJF & Hen mpoano, 2017).

In 2017, about 100,000 tonnes of pelagics were harvested in the process of ‘’Saiko’’ equating to about 40% of landings of the artisanal fishing sector of which is 80,000 tonnes was recorded in the port of Elmina (Central Region) (EJF &Hen Mpoano, 2017). This represents about US$ 26-41 million worth of fish purchased at sea, with a projected landing pre-process worth in between US$ 34-65 million (EJF & Hen Mpoano, 2017). According to the Fisheries Act 625. (2002) Saiko includes the transshipment of by-catch which is frozen to artisanal canoes which lacks supervision and it is banned under the fisheries laws of Ghana.

According to Aheto, Okyere, Asare, Eshilley & Odoi, (2020), a total of 68 fish species which comprises shellfish and finfish were recognized in the Saiko business. Carangids such as the *Decapterus punctatus*, *Caranx rhonchus* and other species such as sardines and *Pagellus bellottii* were the main species recognized and it is a vibrant danger to the marine environment as well as the sustainability of Ghana’s fish production.

Nunoo *et al*. (2009) proposed that by-catch considered as waste fish (saiko) is treasured by most fishers. Lazar *et al*. (2018) contended that saiko is a main source of the collapse of Ghana’s fishery. Saiko poses several implications on fish stocks particularly small palagics. It contributes to the eroding of reproductive potential of juveniles and further intensifying the crisis of the ecology. Again, Saiko results in the increase of poor quality and cheap fish in the market which pushes the prices of fish down affecting the income of artisanal fishers.

Saiko worsen the problem of overfishing and impedes on proper sustainable management of the fisheries. Transshipment at-sea has robust connections with illegal, unreported and unregulated (IUU) fishing activities and other crimes such as money laundering, transport of drugs, and human trafficking (Aheto et al., 2020).

Growth, Mortality and Exploitation Levels on Carangids

Numerous research conducted on the growth, mortality and exploitation levels of carangids in Ghana specifies a fast developing and short-lived fishes with less natural death. According to Barr et al. (2008), growth parameters of carangids are very sensitive to a sample which implies that, larger individuals tend to poses a higher asymptotic length as the growth rate decreases. Species with slow growth rate have longevity of approximately twenty-three years. According to Amponsah et al. (2021) overexploitation exist among carangids and it could be attributed to the fact that, some carangids are known to inhabit a 30 m zone which increase their vulnerability to the fishing gears of about 100,000 artisanal fishers in Ghana.

Reproductive Studies on Carangids

Reproductive studies such as the length-weight relationship, sex ratio, gonadosomatic index as well as length at first maturity gives important information on the success of fisheries management (Arra, Sylla, Kouame, Zan & Ouattara, 2018). Most marine species are nocturnal spawners, and their diel season of major reproduction is normally uniform with respect to families (Ferraro, 1980). Diurnal spawning has been anticipated in some carangidae such as *Caranx ignobilis* (Clarke & Privitera, 1995). Diurnal courtship has been detected for species like *Caranx sexfasciatus* and *Alectis indicus* (Westernhagen, 1974). Nocturnal spawning has been described for species like *Decapterus russelli*, and *Trachurus symmetricus* (Delsman, 1926; Farris, 1961). According to the conclusions made by Arra et al., (2018) on reproductive studies of some carangids particularly *Selene dorsalis*, length and weight grows proportionally and the ratio of sex does not change meaningfully from the projected 1:1 proportion. Also, females have a higher condition factor as compared to males and both exhibited a higher peak in the month of August. In January and February, male and females exhibited a higher gonadosomatic index. Ohshimo (2006), also reported that the round scad has its spawning period in June and most observation on the spawning periods of carangids occurs in the day time. Werstenhagan (1974) reported that *Alectis* and *Caranx spp* spawn during the day and suggested interactions require visual contact.

CHAPTER THREE

MATERIALS AND METHODS

This chapter explains the techniques, methods as well as approaches of the research. This study was conducted using quantitative data.

Study Area

This study was undertaken in Ghana which is found in the Western part of Africa which shares borders at the west end with Côte d'Ivoire, Burkina Faso at the northern, Togo towards the east as well as the Gulf of Guinea at the southern end with an entire land size of 238 527 km^2. Ghana possesses a shoreline of about 550 km with a continental shelf of about 24300 km^2 and an exclusive economic zone size of about 218 100 km^2 (FAO, 2007).

This study was focused on the coast of Ghana encompassing three coastal regions namely; Greater Accra, Central and Western Region. One coastal community was selected from each region which included the East coast of the Tema fishing Harbour in Greater Accra region; the Central coast was represented by Elmina in the Central Region and the West coast was represented by the Albert Bosomtwe Sam fishing Harbour in the Western Region.

Tema Fishing Harbour

Tema canoe beach is a section of the Tema fishing harbour located on the geographical coordinates 5.6333° N, 0.0167° W. It has over 500 artisanal fishing vessels with 318 canoes operating with purse seine fishing gears and 182 canoes operating with drift gill net (Ofori-Danson *et al*., 2018).

Albert Bosomtwi Sam Fishing Harbour (ABS)

The ABS fishing harbour is located in Sekondi with a large market center for trading in processed and fresh fish. The males in this area often engage in the fishing while the females are in charge of the processing of the exploited stocks. The processing methods being practiced in this landing site includes smoking, salting and frying. During periods of abundant supply of fish, freezing is considered to be the best preservation method used. Months of abundant supply is known to be between June to August.

Elmina Landing Site

Elmina, also known as Edina is located on the geographical coordinates (5.5′0″N 1.21′0″W). It is a fishing society located in the Central region of Ghana (Aheto, Quinoo, Tenkorang, Asare & Okyere, 2011). Catches are landed and marketed at the landing site of Elmina by local fishers and fish traders. Some fish species are also processed using preservation methods such as smoking, drying and salting before marketing. The major fish preservation site is situated close to the landing site.

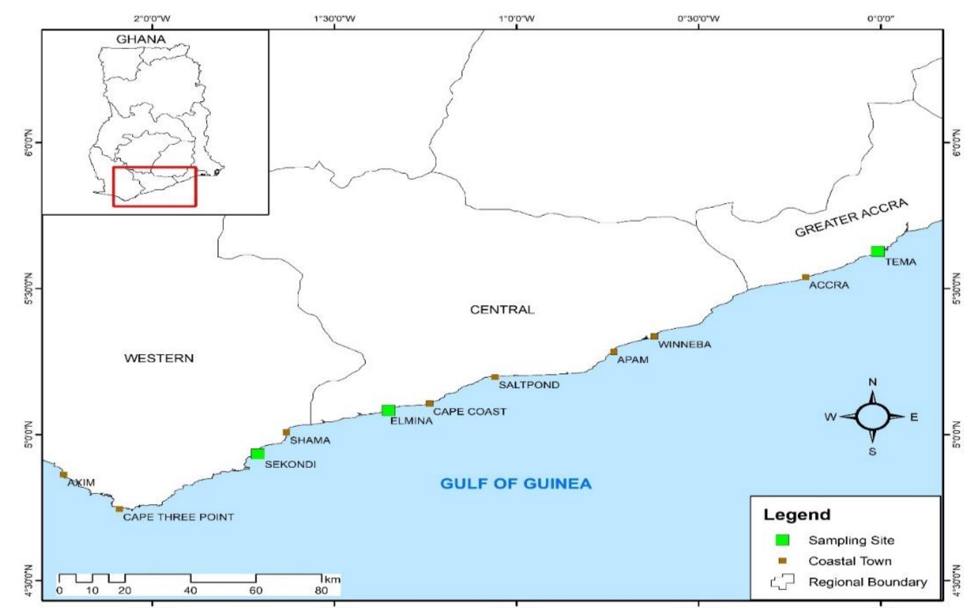

Figure 1: Fish sampling sites along the coast

Species Availability and Abundance

Data derived from the Fisheries Scientific Survey Division (FSSD) of the Fisheries Commission of Ghana suggested that, the most common and abundant Carangid species landed along the coast of Ghana between 2015-2019 included *Chloroscombrus chrysurus, Trachurus tracae, Selene dorsalis* and *Caranx rhonchus.*

Relative Composition

Data collection for the first three months indicated that the most common, abundant and commercially important species were *Chloroscombrus chrysurus* and *Decapterus punctatus*.

Figure 2: *Chloroscombrus Chrysurus* species sampled

Figure 3: *Decapterus punctatus* species sampled

Fish Sampling

Collection of fish was done randomly from fishers and fish traders who used fishing gears including the purse seine gears at the various landing areas. Sampling was done monthly from November, 2020 to June, 2021. During this period, the mesh sizes of the fishing gears used in exploiting Carangids species were measured with the use of a mesh gauge. Preservation was done on ice blocks in an ice chest and sent to the Department of Fisheries and Aquatic Sciences laboratory of the University of Cape Coast. The samples were sorted into groups and identification was done to the species level using the manual by FAO (2016). The total weight of the identified specimen was measured with an electronic balance (Model: Ranger 7000) to the nearest 0.01 g. To the nearest 0.1 cm the standard lengths as well as the total length were measured using a fish measuring board. The length and weight data were taken to assess the various growth parameters of the species. The specimens were dissected and the gonads were taken, measured and graded macroscopically using the model by (Nikolsky, 1963). The measurements of the gonads were used to estimate the gonadosomatic index of the species.

Length Weight Relationship

Length weight relationship was estimated using the expression:

$W= aL^b$ and in the linear form: $\text{Log}_{10} W = b \text{ Log}_{10} TL + \text{Log}_{10} a$, where W is the weight of fish (g), TL is the total length of fish (cm), a and b are coefficients of functional regression between weight and length. (Ricker, 1975).

Condition Factor

Condition factor is a method of accessing the physiological well-being of a fish. Monthly mean condition factor (K) was established with the expression by Froese (2006);

$$K=BW/L^3\times100.$$

where BW is the weight of the fish (g) and L is the length of the fish (cm).

Growth Parameters

Monthly length distribution data from November, 2020 to June, 2021 of all two species selected in the study were entered into the Tropfish R software to estimate the growth and mortality parameters. This was estimated with the von Bertanlaffy Growth Function (VBGF) inputted in Tropfish R. The Wetherall Plot placed in Tropfish R was used to estimate Z/K relations of the evaluated species (Pauly, 1986)

The von Bertalanffy equation expressed in terms of length is:

$L_t = L_\infty (1- \exp[-K(t - t_0)])$ where L_t is the mean length predicted at age t_o, L_∞ is the maximum theoretical length that the fish would attain when left to grow to infinity, K represents the growth coefficient which estimates the frequency where the highest size of the fish is attained.

Mortality Parameters

The total mortality rates (Z) were acquired using the length-converted catch curve analysis by (Sparre et al., 1989) in Tropfish R software. Natural mortality rate (M) was calculated using Pauly's empirical formula (1980) below.

$\text{Log}_{10}M = -0.0066 — 0.279 \text{Log}_{10} L_\infty + 0.6543 \log_{10} K + 0.4634 \log_{10} T$ (Pauly, 1980)

Where M represents the natural mortality, L_∞ represents the asymptotic length, T represents the mean surface temperature of the sea and K is the growth rate coefficient of the Von Bertalanffy Growth Function. Fishing mortality (F) was determined using the equation;

$F = Z - M$ (Pauly, 1986)

Z represents the total mortality rate; F represents the fishing mortality rate and M is the natural mortality rate.

Exploitation Ratio

The ratio of exploitation (E) was estimated with the equation; $E = F/Z$ Gulland (1971).

Length at First Maturity (L_m)

L_m assessed was determined using the technique of (King, 1995) as: In (1-p/p)/Midlength. Where p represents the proportion of length.

Probability of Capture

The Tropfish R software was used to estimate the probability of capture using the method by Enin (1995).

Sex Ratio

Sex of all species was assessed by examining the gonads. Sex ratio was determined by establishing the proportion of the two sexes as (Male: Female)

Gonadosomatic Index

The gonadosomatic index (GSI) was estimated with the equation below by

Chapman (1982) as:

$GSI=Gonad\ weight/Body\ weight \times 100$

Gonadal Staging

The stages in gonadal development (Table 1) were determined macroscopically and graded on a scale by Nikolsky (1963).

Table 1: Descriptions of stages in gonadal development Nilkolski (1963)

Maturity stage	Terminology	Male	Female
Stage I	Immature	Testes appear to be grayish to white in color	Ovaries are slightly pink which are smaller in size and poorly develop
Stage II	Maturing	Testes show an increase in size from Stage I with a grayish to white color. No milt seen when cut.	Increased size from Stage I. Ovaries is light yellow to light orange in color.
Stage III	Ripening	Creamy in color with milt expressed when slashed but does not flow freely. Testes are developed	Well-developed orange-colored ovaries with of blood capillaries visible internally.
Stage IV	Ripe	Testes are large with freely flowing milt when cut.	Ovaries fill most of the body cavity and free running when pressed.
Stage V	Spent	Testes are smaller in size from Stage IV and have small amount of residual milt or empty	Ovaries had few residual eggs or empty

Selection Factor

Fishers exploit Carangids using the purse seine fishing gear of different mesh sizes. The selection factor of all species was determined using the formula by (Pauly, 1984).

L_{c50}= S.F×Mesh size.

Where Lc_{50} is the length at which 50% of the species were captured and S.F is the selection factor.

Data Analysis

Data analyses were based on the objectives of the study using TrofishR software, Minitab and Microsoft excel.

Student t-test established at 95% confidence interval (p=0.05) was used to assess the significant difference between the length distribution, gonadosomatic index and condition factor of all the male and female species. The b values which represent the slope of the length-weight relation were as well subjected to the student's t-test to assess whether b differs meaningfully from the projected isometry of 3.0.

Chi square analysis was used to express the significant difference amongst the two sexes.

CHAPTER FOUR

RESULTS

This chapter outlines outcomes from the study site and laboratory. The results are presented on population dynamics on three perspectives including changes in catch, reproductive biology and the selection factor.

Length-frequency Distribution

Chloroscombrus chrysurus

During the sampling period, 659 males and 634 females *of Chloroscombrus chrysurus* were sampled at all the landing sites and assessed. The specimen assessed ranged from 3.8 to 21.5 cm TL.

Figure 4 illustrates a unimodal distribution of male and female *Chloroscombrus chrysurus.* The mean length and modal classes for males were estimated at 11.5 cm and 12.0 cm respectively. Female *Chloroscombrus chrysurus* had a mean length and modal length of 11.7 cm and 9.0 cm respectively. A sample t test was assessed to determine the significant difference between the length distribution of males and female.

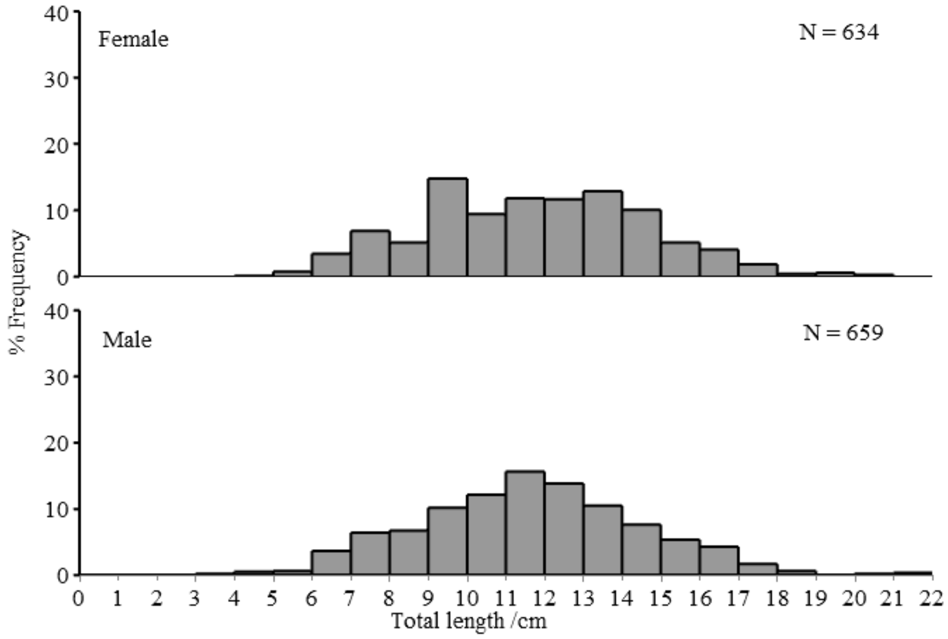

Figure 4: Length frequency distribution for female and male *Chloroscombrus chrysurus*

Decapterus punctatus

Decapterus punctatus was sampled along the various landing sites, 580 males and 586 females were identified. The length of the female species ranged from 5.1 cm to 18.8 cm while the males ranged from 6.1 cm to 19.6 cm.

Figure 5 shows a unimodal length frequency distribution. Males presented a maximum length, modal, and mean length of 19.6 cm, 9.5 cm and 11.6 cm respectively whiles Females exhibited a maximum length, modal and mean length of 18.8 cm, 11.5 cm and 11.5 cm respectively.

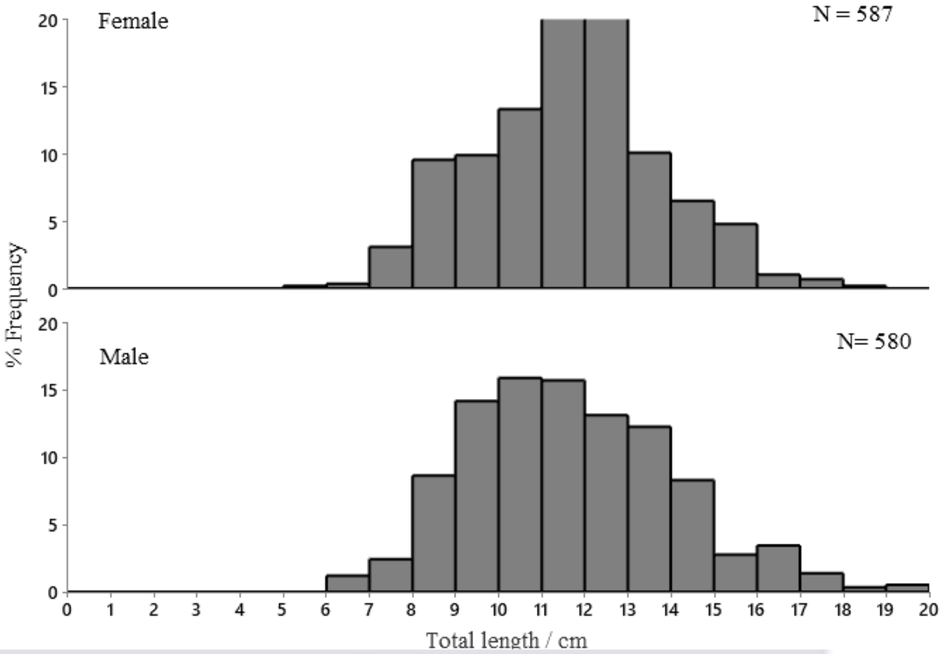

Figure 5: Length frequency distribution of female and male *Decapterus punctatus*

Length-weight Relationship

Length-weight relation was assessed with the equation: W = aL^b (Carlander, 1969). *W* represents the body weight of the species in grams, *L* represents the total length (TL) in centimeters, *a* is constant assessed through empirical observation, *b* is an exponential value ranging from 2 and 4.

Male *Chloroscombrus chrysurus* as shown in Figure 6 exhibited a calculated slope (b) of 2.9 was not significantly different (t-test=0.82; p>0.05) from the hypothetical value of 3.0 implying an isometric growth.

Female *Chloroscombrus chrysurus* on the other hand in Figure 7 exhibited a slope (b) of 3.1. The calculated (b) value was not significantly different (t-test=0.84; p>0.05) from the hypothetical value of 3.0 also indicating an isometric growth. However, both sexes had a strong positive correlation regression coefficient(r) of 0.96 between the length and weight of *Chloroscombrus chrysurus*.

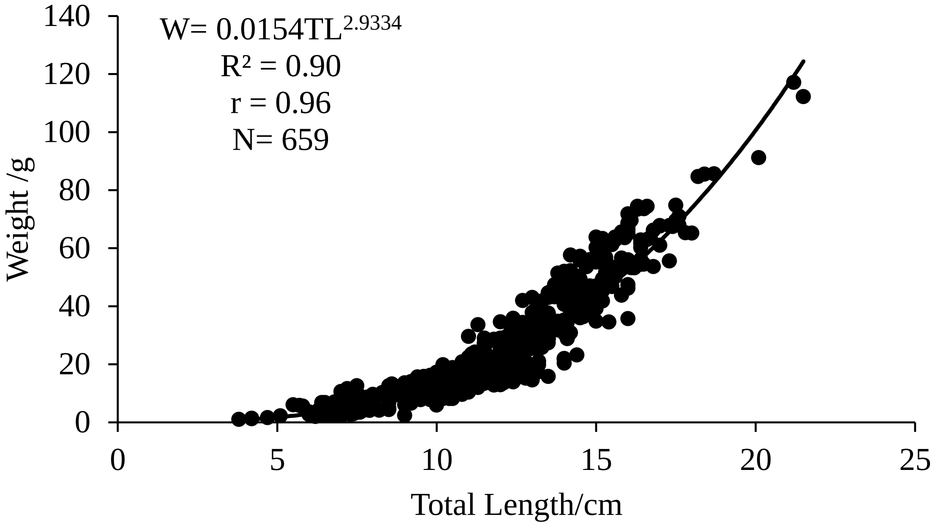

Figure 6: Length-weight relationship of male *Chloroscombrus chrysurus* along the coast of Ghana.

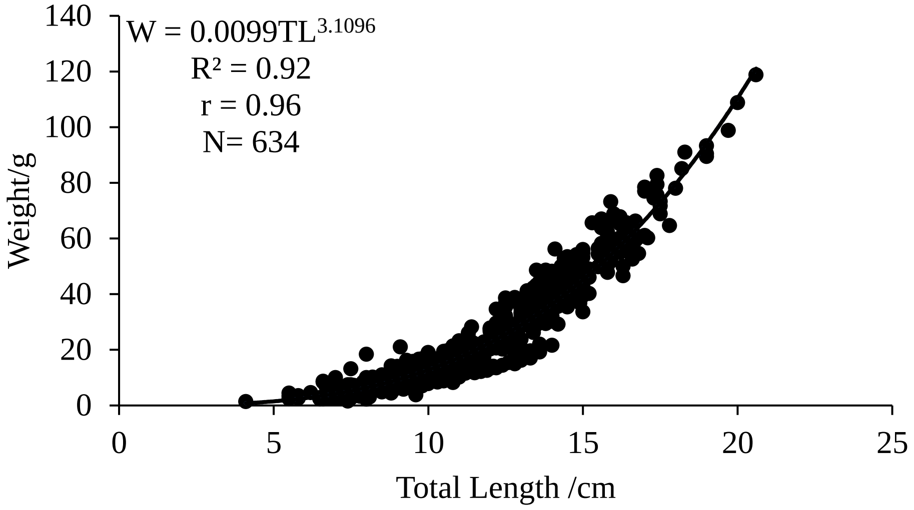

Figure 7: Length-weight relationship of female *Chloroscombrus chrysurus* along the coast of Ghana.

Male *Decapterus punctatus as* shown in Figure 8 exhibited a calculated slope (b) of 3.1 which was not significantly different (t-test=1.07; $p>0.05$) from the hypothetical value of 3.0 implying an isometric growth with a strong positive correlation of regression coefficient (r) of 0.96 between the length and weight of male *Decapterus punctatus*.

Female *Decapterus punctatus* as shown in Figure 9 also exhibited a slope (b) of 3.1 which was not significantly different (t-test=0.75; p>0.05) from the hypothetical value of 3.0 indicating an isometric growth between the length and weight with a strong positive correlation of r=0.95 amongst the length and weight of female *Decapterus punctatus*.

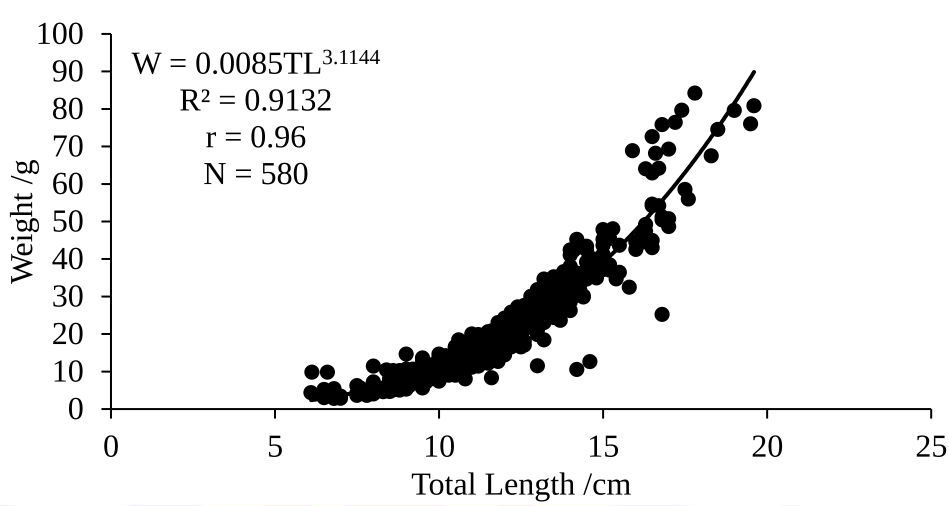

Figure 8: Length-weight relationship of male *Decapterus punctatus*

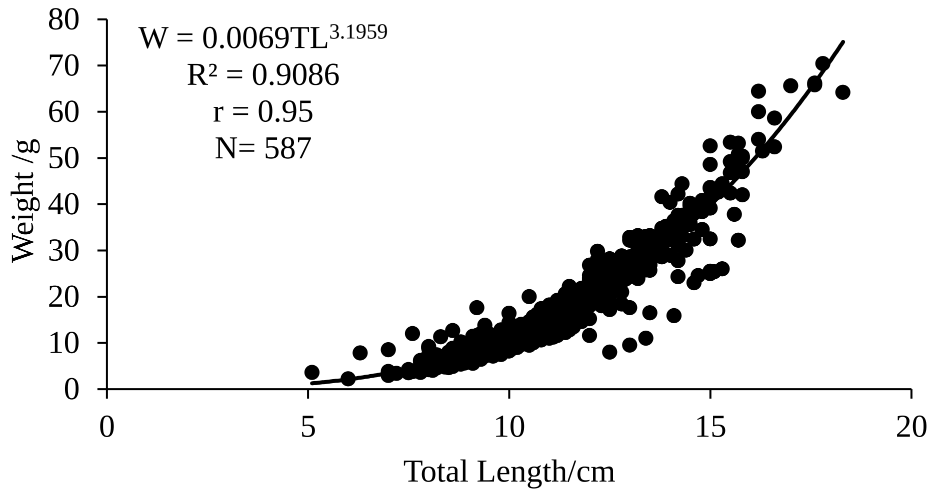

Figure 9: Length-weight relationship of female *Decapterus punctatus*

Condition Factor (K)

Condition Factor of species is an estimate of the ratio of the weight and length indicates and can be termed as an index of the wellbeing of a fish (Tesch, 1968).

The K for both male and female *Chloroscombrus chrysurus* are illustrated in Figure 10. K for both sexes of *C. chrysurus* were lower than 1 in April 2021 (0.86±0.02) and (0.96±0.07) respectively; and in June 2021 (0.86±0.04) and (0.96±0.1) respectively. It was higher for male and female in December 2020 (1.7±0.01) and (1.6 ± 0.01); January 2021(1.5±0.02) and (1.6±0.02) and May 2021(1.6±0.07) and (1.4 ± 0.05) respectively**.** The mean monthly condition factors for both sexes were equal to or higher than 1.00 for all the sampled months showing that the assessed species were in better physiological condition.

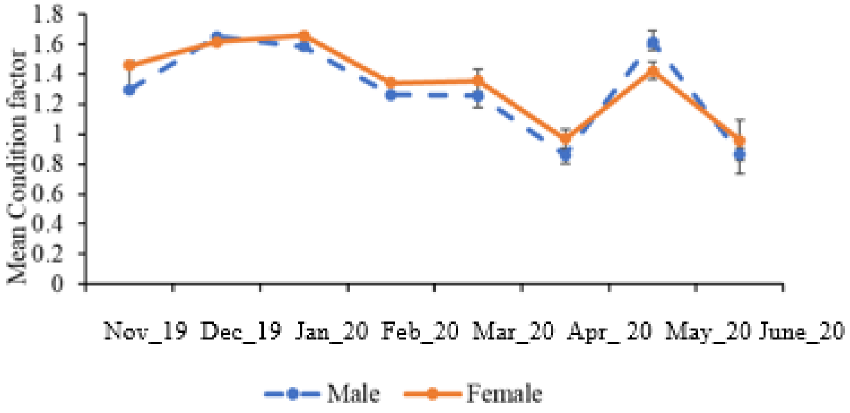

Figure 10: Mean monthly condition factor of *Chloroscombrus chrysurus*

Figure 11 shows the K for both male and female *Decapterus punctatus*. Mean monthly condition factor for male *D. punctatus* was lower throughout the sampling period; however, it recorded a higher condition factor of (1.3±0.02) in May, 2021. The females on the other hand exhibited a lower K from November, 2020 to February, 2021 and recorded a higher value of (1.5±0.4) in March, 2021 and (1.2±0.03) in May, 2021. Although some species recorded a lower condition factor, most of the species recorded a higher K greater than 1.00. This indicated that most of the species were in good physiological condition.

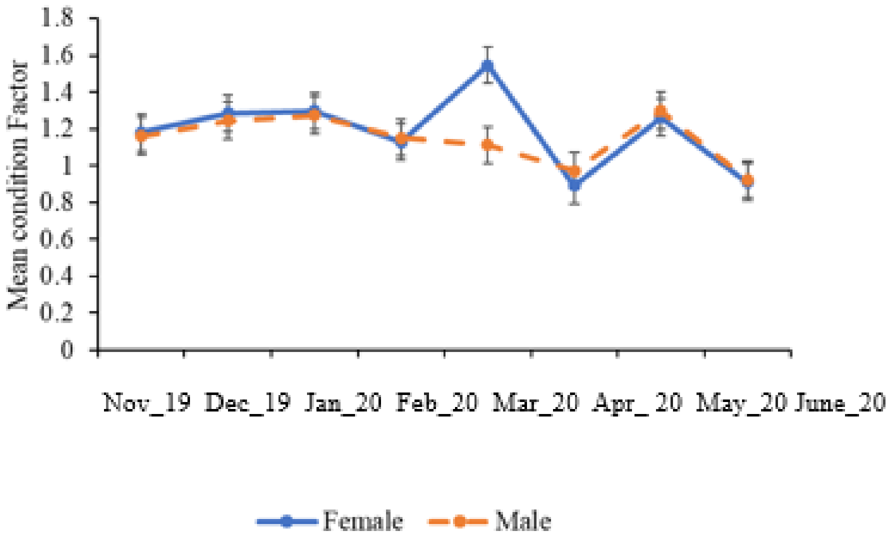

Figure 11: Mean monthly condition factor of *Decapterus punctatus*

Sex Ratio

A total of 660 male and 635 females *Chloroscombrus chrysurus* were identified and examined. Overall ratio of the sexes of male: female was balanced at 1.03: 1 (Chi- Square $\chi^2 = 0.48$, d.f. = 1, n = 1295, $p > 0.05$) and did not change from the projected 1:1 ratio.

A total of 562 male and 587 female *D. punctatus* were identified and examined. Overall sex ratio of male: female was balanced at 1: 1.04 (Chi-

Square $\chi^2 = 0.54$, d.f. = 1, n = 1149, p >0.05) and did not differ meaningfully from the projected 1:1 ratio.

Chloroscombrus chrysurus

Growth Parameters

Figure 12 shows the reconstructed length frequency superimposed with growth curves. The L_∞, K and ϕ, were 28.9 cm, 0.38 year^{-1} and 2.50 respectively with a response surface Rn value of 0.50. The Von Bertalanffy growth function for *Chloroscombrus chrysurus* was: $L_t = 28.9 \times (1 - e^{-0.38(t+0.48)})$

The calculated t_o and the t_{max} of the species is indicated in Table 2.

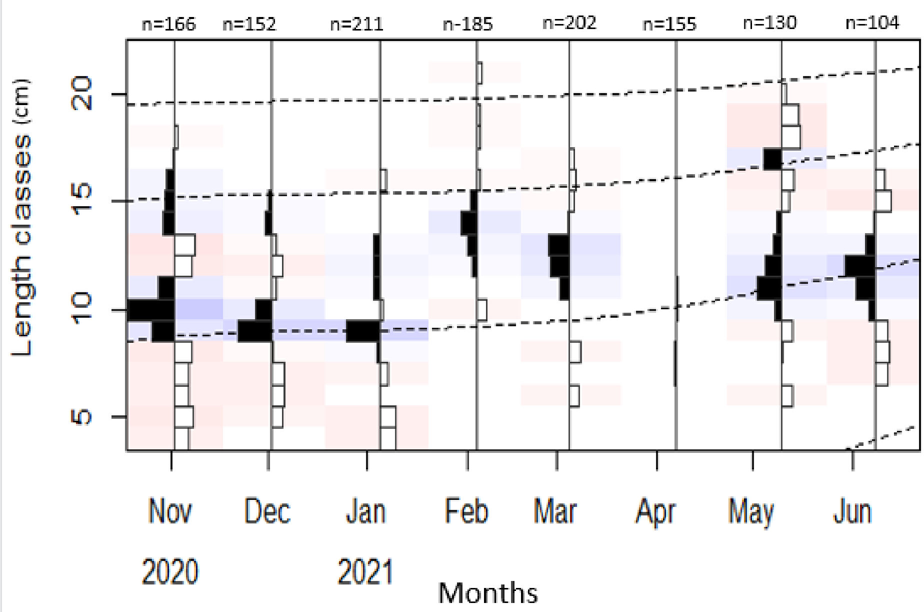

Figure 12: Reconstructed length frequency distribution with growth curves for *Chloroscombrus chrysurus*

Table 2: Estimated population parameters of *Chloroscombrus chrysurus* along the coast of Ghana.

Parameters	Unit	*Chloroscombrus chrysurus*
Age at birth (t_o)	Years	**-0.23**
Longevity (t_{max})	Years	**7.66**

Mortality Parameters

From the length converted catch curve in Figure 13, the estimated (Z) rate for *Chloroscombrus chrysurus* was 2.76 year^{-1} and (M) was 0.67 year^{-1}. The (F) was 2.09 year^{-1} and (E) was 0.75.

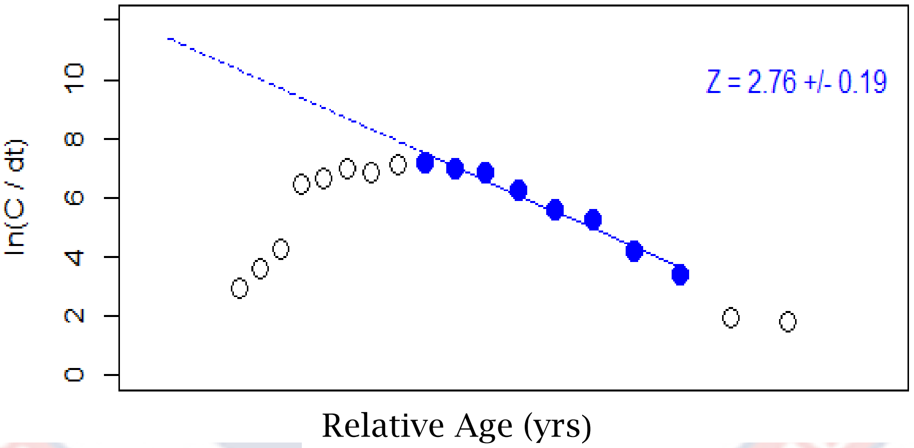

Figure 13: Linearized length-converted catch curve for the assessment of total mortality of *Chloroscombrus chrysurus*

Probability of first Capture (L_{c50})

The L_{c50} of *Chloroscombrus chrysurus* is represented in Figure 14. L_{c50} was 10.6 cm. The assessed L_{c75} and L_{C95} were 11.5 cm and 12.8 cm respectively.

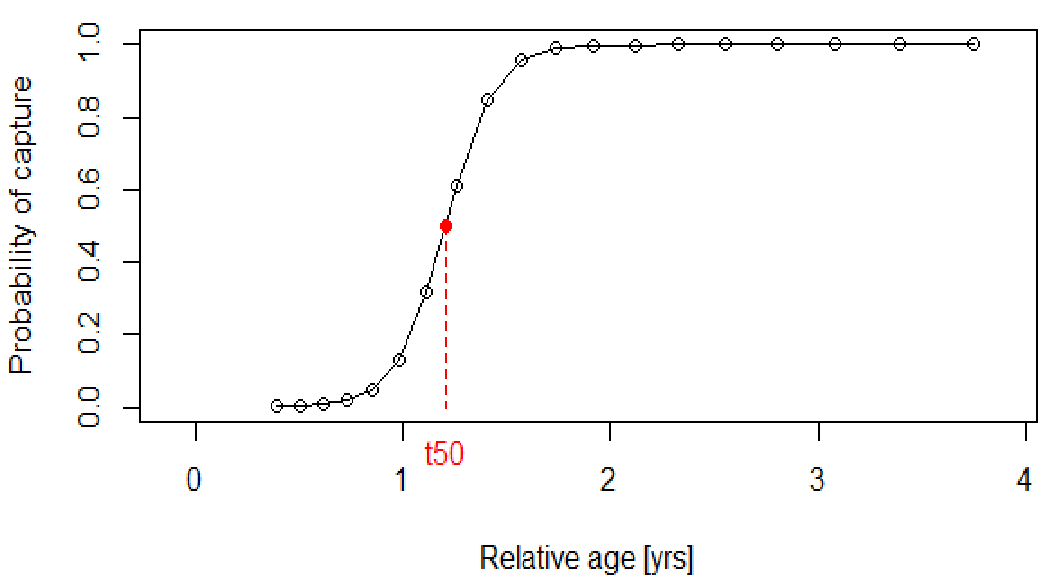

Figure 14: Selectivity function of catch curve for the estimation of length at first capture (L_{c50}) of *Chloroscombrus chrysurus*

Selection Factor

The estimated selection factor was 1.80 for *Chloroscombrus chrysurus*. The average stretched mesh size which was the main input for calculating Selection Factor (SF) was 6.0 cm.

Decapterus punctatus

Growth Parameters

The reconstructed length frequency superimposed with growth curves is indicated in Figure 15. The L_∞, K and ϕ, were 21.4 cm, 0.55 year^{-1} and 2.40 respectively with a response surface Rn of 0.36. The von Bertalanffy growth function for *Decapterus punctatus* was: $L_t=21.4\ (1-e^{-0.55(t+0.08)})$

The estimated t_o and the t_{max} of the species is indicated in the Table 3.

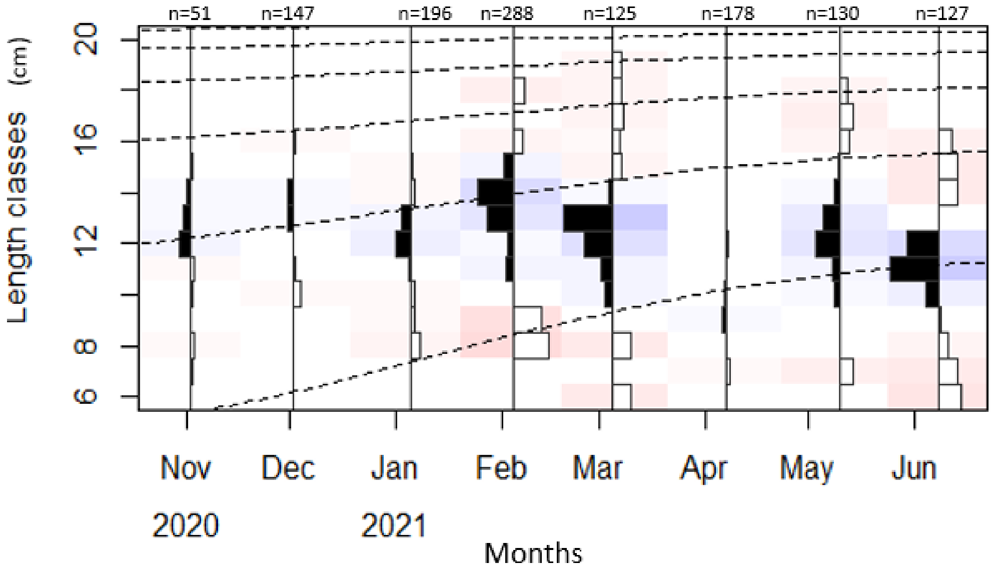

Figure 15: Reconstructed length frequency distribution with growth curves for *Decapterus punctatus*

Table 3: Estimated population parameters of *Decapterus punctatus* along the coast of Ghana.

Parameters	**Unit**	***Chloroscombrus chrysurus***
Age at birth (t_o)	year^{-1}	**-0.08**
Longevity (t_{max})	year^{-1}	**5.53**

Mortality Parameters

The estimated (Z) rate for *Decapterus punctatus* from the length converted catch curve as indicated in Figure 16 was 2.48 year^{-1}. The (M) was 1.03 year^{-1}. The (F) was 1.45 year^{-1} while the (E) was 0.58.

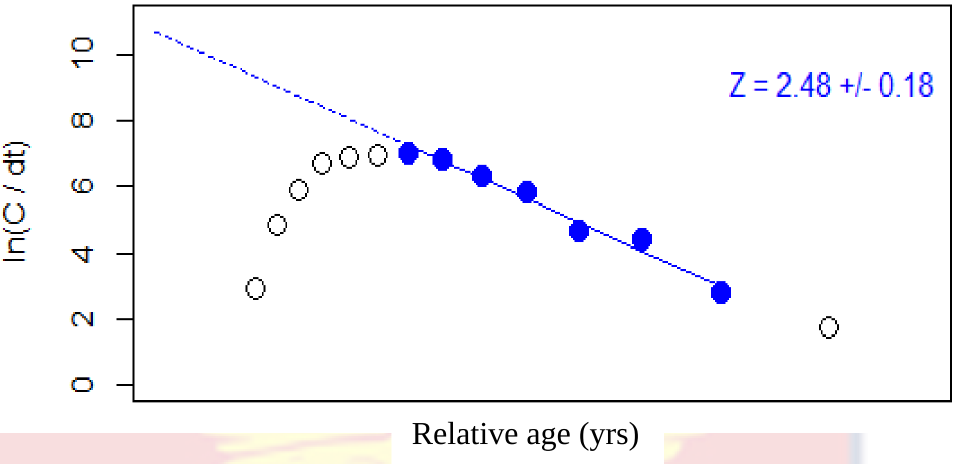

Figure 16: Linearized length-converted catch curve for the assessment of total mortality of *Decapterus punctatus*

Probability of Capture (L_{c50})

The (L_{c50}) was 10.5 cm. The assessed L_{c75} and L_{C95} were 11.3 cm and 12.4 cm respectively for *Decapterus punctatus.*

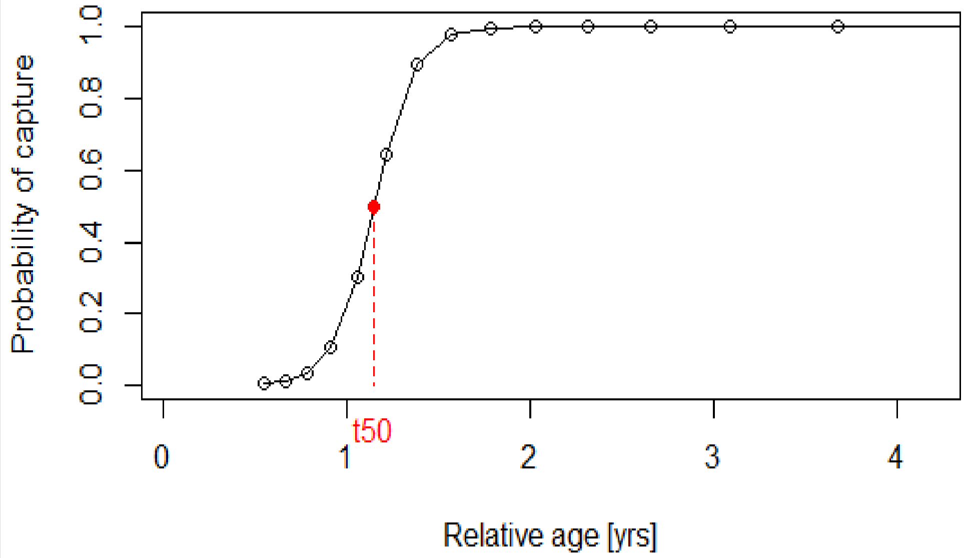

Figure 17: Selectivity function of catch curve for the estimation of length at first capture of *Decapterus punctatus*

Selection Factor (SF)

The Selection Factor (SF) was estimated using the relation: L_{c50}= S.F x Mesh size. The estimated selection factor was 1.67 for *Decapterus punctatus* with an average stretched mesh size used in calculating Selection Factor (SF) of 6.3 cm.

Gonadosomatic Index (GSI)

The gonadosomatic index was determined to describe the changes in gonadal development of the assessed species.

Chloroscombrus chrysurus

The monthly mean gonadosomatic index as shown in Figure 18 for female *C. chrysurus* was higher in January, 2021 (2.9±0.2) and February (3.0±0.1), 2021. However, it recorded a lower gonadosomatic index in April, 2021 (1.10±0.1) and rose up again in June, 2021 (2.2±0.1). Male *C. chrysurus* had a higher gonadosomatic index in January, 2021 (2.0±0.2) and June, 2021 (2.2±0.1), however, it also recorded a lower gonadosomatic index in November, 2020 and from February, 2021 to May, 2021. Comparing both female and male *C. chrysurus*, the females recorded higher values of gonadosomatic index as compared to the males. A sample t test showed a significant difference between the gonadosomatic index of both sexes.

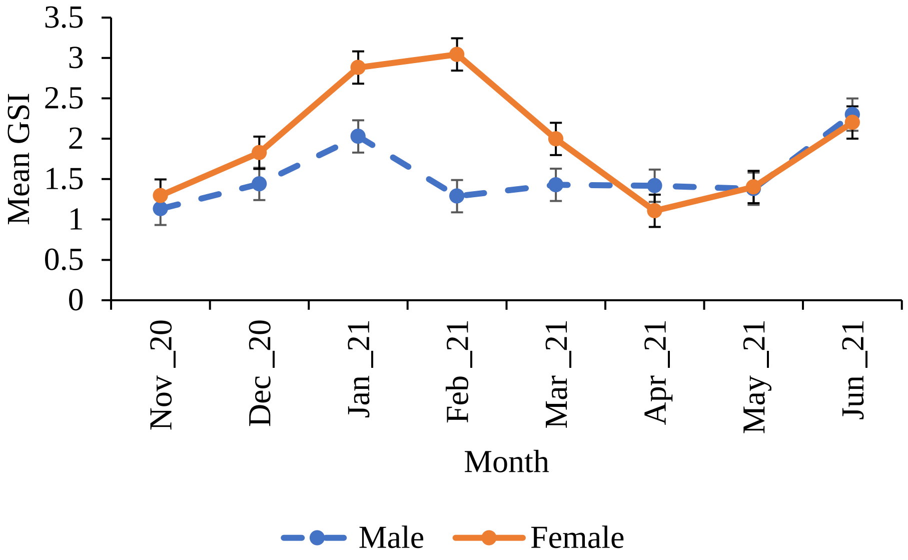

Figure 18: Mean gonadosomatic index of Male and Female *Chloroscombrus chrysurus*

Decapterus punctatus

Figure 19 illustrates the mean monthly GSI for both male and female *Decapterus punctatus*. The male *Decapterus punctatus* recorded a lower GSI in November, 2020. It however rose from December, 2020 (0.6±0.1) till it reached a peak in April, 2021 (2.5±0.1) and then declined in May, 2021 (1.1±0.07) and rose up to highest peak in June, 2021(2.8±0.1).

Female *Decapterus punctatus* also illustrated a lower GSI in November, 2020 (0.5±0.1) and rose to its peak in February (3.4±0.1) and March, 2021(3.4±0.1). It however declined from March to May, 2021 (1.2±0.06) and rose again in June, 2021(2.7±0.1). Females therefore recorded a higher GSI as compared to the males. A sample t test showed a significant difference of gonadosomatic index between both sexes of *Decapterus punctatus*.

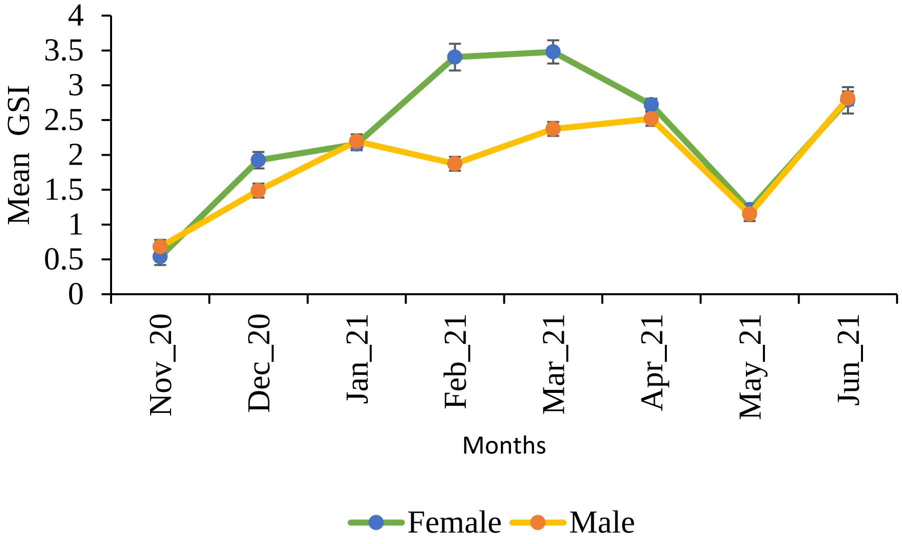

Figure 19*:* Mean gonadosomatic index of Male and Female *Decapterus punctatus*

Gonadal Stages

This study recorded five stages of gonadal development. In (Fig 20-23) the stages ranged from immature, maturing, ripening, ripe and spent (Nikolsky, 1963). Fish in all reproductive stages were found occurring throughout the study period. Immature and maturing fish were the most dominant. Individual fish with ripe and spent ovaries and testes were not encountered as often as the others during the study period.

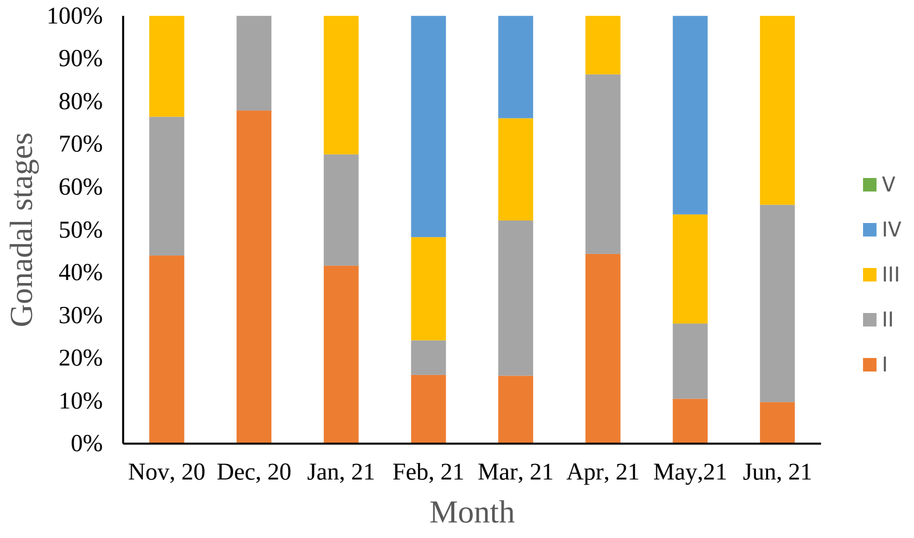

Figure 20: Gonadal stages of Male *Chloroscombrus chrysurus*

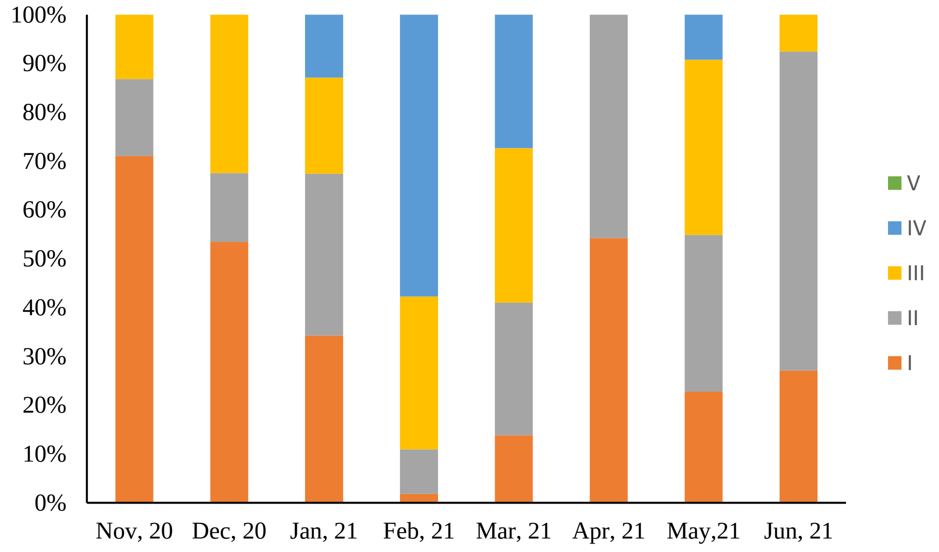

Figure 21: Gonadal stages of Female *Chloroscombrus chrysurus*

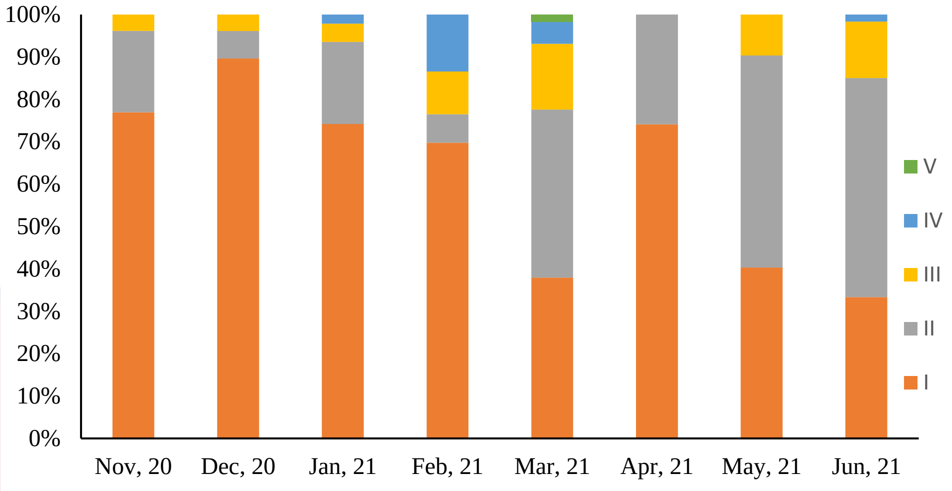

Figure 22: Gonadal stages of male *Decapterus punctatus*

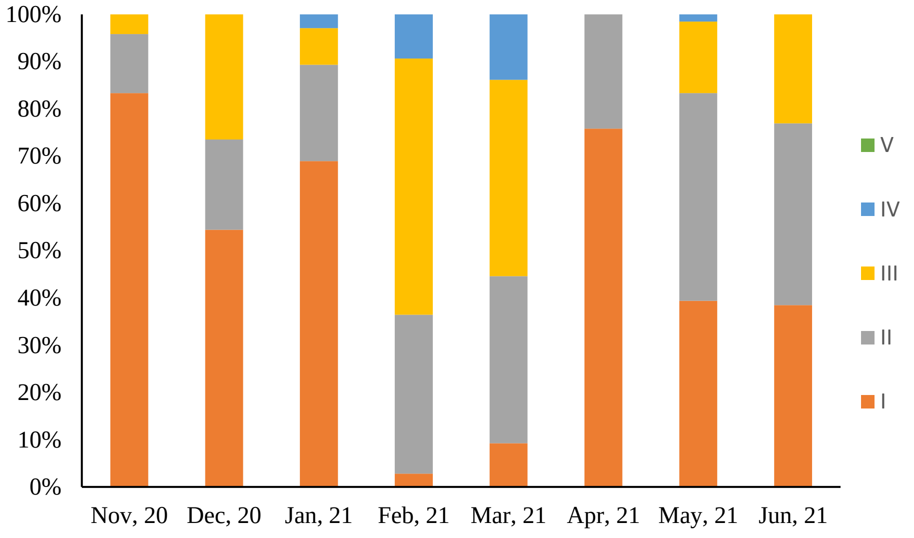

Figure 23: Gonadal stages of Female *Decapterus punctatus*

Length at First Maturity

Based on a 5-stage macroscopic scale, only first at gonadal stages I and II were excluded from the estimations of the length at first maturity and as a result only few individuals were considered for analysis. In analyzing the length at maturity, 137 females and 62 males of *Chloroscombrus chrysurus* and 157 females, and 66 males of *Decapterus punctatus* were considered as sexually mature.

Chloroscombrus chrysurus

During the study period, the assessed length at maturity for male and female *Chloroscombrus chrysurus* were 15.8 cm and 14.2 cm respectively based on the intercept and the slopes of Figures 24 and 25.

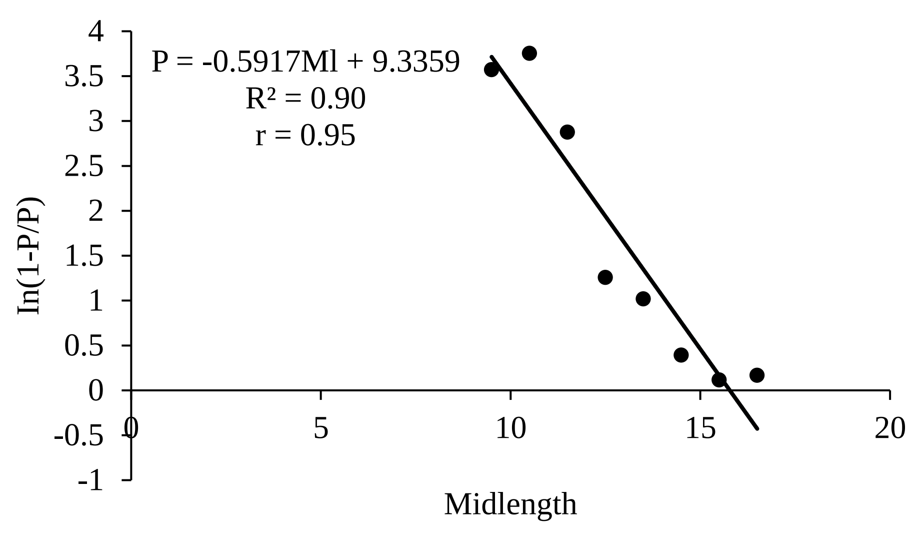

Figure 24: Length at first maturity of male *Chloroscombrus chrysurus*

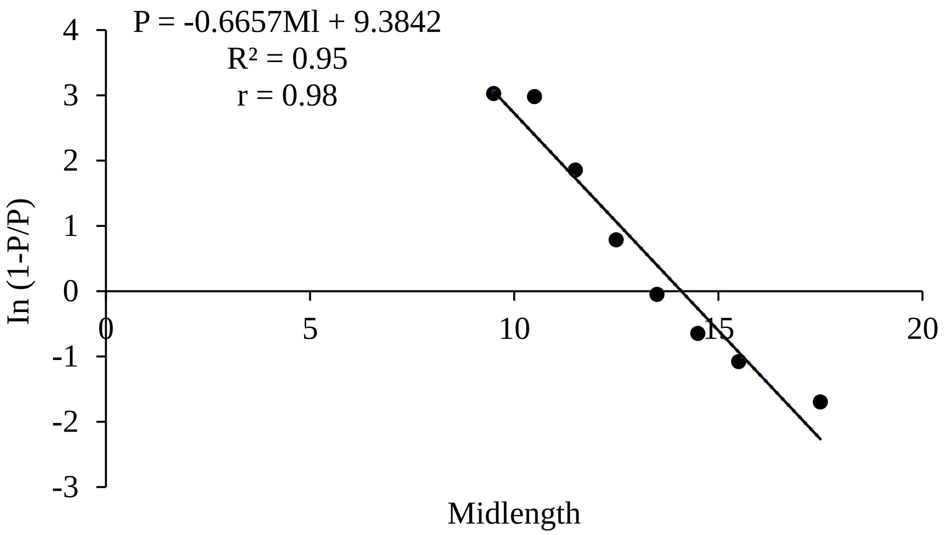

Figure 25: Length at first maturity of female *Chloroscombrus chrysurus*

Decapterus punctatus

The length at first maturity for both male and female *Decapterus punctatus* were found to be 14.8 cm and 12.8 cm respectively from Figure 26 and 27.

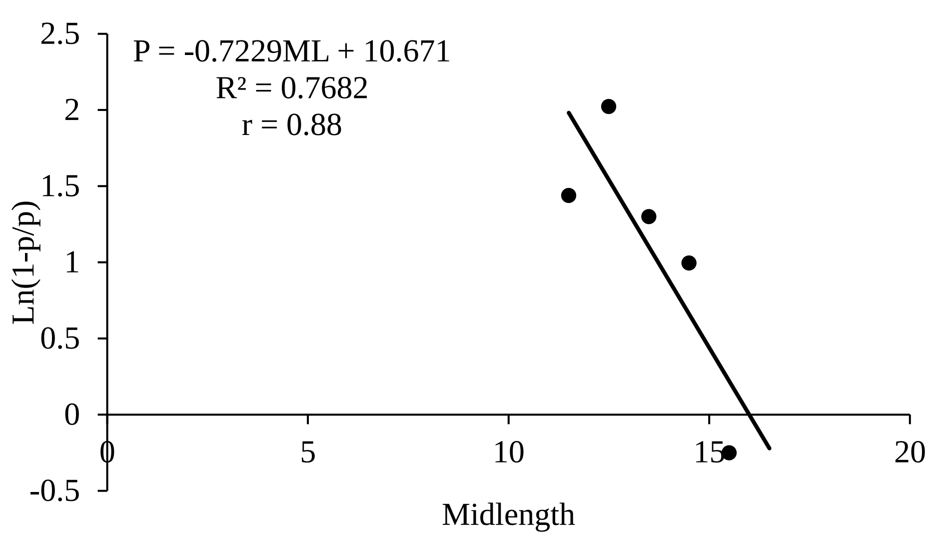

Figure 26: Length at first maturity of male *Decapterus punctatus*

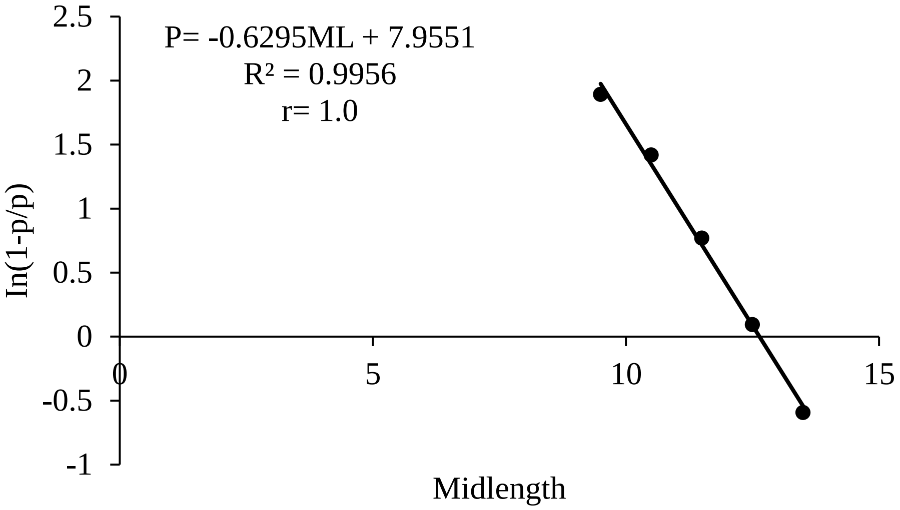

Figure 27: Length at first maturity of female *Decapterus punctatus*

CHAPTER FIVE

DISCUSIONS

This chapter elaborates discussion of the main findings from the research.

Length Frequency Distribution

The results showed that, the length frequency distribution of *Chloroscombrus chrysurus* and *Decapterus punctatus* were normally distributed and ranged from 3.8 cm to 21.5 cm and 5.1 cm to 19.8 cm respectively in length. There was a dominance of males in *Chloroscombrus chrysurus* and females in *Decapterus punctus*. Generally, there was a dominance of *Chloroscombrus chrysurus and Decapterus punctatus* species throughout the study period. This could be attributed to consumer preference, time of fishing, sampling and ecological factors such as salinity and temperature (Ofori-Danson et al., 2018).

Length-weight Relationship

Estimation of length-weight relationships are essential for stock assessment and are also beneficial for fishery conservation and management (Ecoutin & Albaret, 2003). Length weight relationship is mainly exaggerated by factors like sex, health, diet and size at maturity (Jennings, Kaiser & Reynolds, 2009).

Chloroscombrus chrysurus exhibited a growth value of 2.9 and 3.1 for male and female respectively indicating an isometric development for male and a positive allometry for females. The isometric growth in male *Chloroscombrus chrysurus* indicates that the fish grows proportionally to the cube of length. Again, it signifies that, fishes become larger with increase in length indicating a good ecological factor like oxygen, temperature and food abundance

(Quarcoopome, 2016). On the contrary, female *Chloroscombrus chrysurus* had the growth value to be 3.1, suggesting a positive allometric growth where the fish grows at a rate higher than the cube of length. An R value of 0.96 for both males and females indicate a strong positive correlation between the length and weight signifying an increase in both parameters at the same period. The differences in growth type for both sexes could be related to reproduction, size at maturity and size at capture. A positive allometric result obtained for male and female species according to Ndiaye, (2021) could be due to ecological conditions like salinity.

Decapterus punctatus exhibited a length weight relationship growth value to be 3.1 for males and 3.1 for females. This shows a positive allometric growth for both sexes indicates that the species grow at a rate more than the cube of length. A strong positive correlation was exhibited between the length and weight of male and female *Decapterus punctatus* of 0.96 and 0.95 respectively, which could be attributed to the fact that the length increases as the weight increase.

The *b* value parameters are reliant on the physiological conditions of fishes such as gonadal stages development and food availability in the environment of the species (Jeninigs et al., 2009). Again, the changes in the value of *b* could be due to factors such as swimming habit and sampling procedure which could cause an increase or decrease in the growth pattern in the sense that passive swimmers may show a higher *b* value as compared to active swimmers which may probably be linked to the energy assigned to growth and mobility (Muchlisin, Musman, & Siti-Aziza, 2010). A higher positive correlation indicates a higher probability with the length and weight.

Nevertheless, the *b* value may also indicate the well-being of the stocks and may vary over time and space (Pauly & Froese, 2006).

Condition Factor

The condition factor estimated from monthly sampling may suggest seasonal changes in the physiological well-being of the species. This can differ due to abundance of food and reproductive stages of the samples (King, 1995). The condition factor index gives indication of the morphological characteristic, growth rate and lipids composition of the fish stock and is affected by factors such as the quality of water and density of predator and prey (Stevenson & Woods, 2006).

The observed (K) for both sexes of *Chloroscombrus chrysurus* for the various months were equal to or greater than one (K=1or > 1) suggesting the species were in good physiological condition. Therefore, a high condition factor could be associated with factors such as availability of food. However, the decrease in condition factor for both sexes in the month of April and June could be related to ecological conditions like temperature and rainfall (Ndiaye, 2021).

Condition factor for both male and female *Decapterus punctatus* were as well high indicating a good physiological condition except for the month of April and June which recorded a low condition factor. This may be attributed to factors such as higher temperature which could result in a decrease in food availability (Stevenson & Woods, 2006).

Sex Ratio

Sex ratio as well as the structure of sizes constitutes the main evidence for evaluating reproductive potentials and establishing stock in fish population (Vazzoler, 1996).

A total of 660 male and 635 female *Chloroscombrus chrysurus* were recorded with ratio 1.03:1. There was no significant difference from the anticipated 1:1 ratio. However, the slightly more males obtained could be due to time of sampling and faster growth rate of males.

Decapterus punctatus recorded slightly more females than males i.e., 587 and 562 respectively with a ratio of 1:1.04 and did not differ significantly. More females may be due to differences in growth rate of both sexes associated with abundance and availability of the ideal food which favours females (Quarcoopome, 2017).

Implication of Estimated Growth Parameters

The (L_∞) of *Chloroscombrus chrysurus* in this study was 28.9 cm TL which varied from other studies. Amponsah et al., (2021) recorded a lower (L_∞) of 24.9 cm TL of *Chloroscombrus chrysurus*. Again, Garcia & Duate (2006) reported a higher (L_∞) of 30.5 cm TL. The (K) and (ϕ) was estimated at 0.38 year^{-1} and 2.50 respectively. The estimated (K) was lower than that estimated by Da-Costa, Albieri & Araújo (2005). The (ϕ) of *C. chrysurus* was lower than that of (Amponsah et al., 2021) and Sossoukpe, Aissan, Adite & Fiogbe (2017) recorded at 2.72 and 2.59 respectively. The differences in growth parameters may be due to reasons like the range of size of the samples which constitutes major role in the assessments of growth parameters.

Decapterus punctatus exhibited a (L_∞) of 21.4 cm, a (ϕ) of 2.40 and a (K) of 0.55 year^{-1}. The (L_∞) exhibited in this research was lower than that recorded for other related species like *Decapterus rhonchus* (40.6 cm) estimated by (Forson & Amponsah, 2020). However, the (K) and (ϕ) was higher than that of *Decapterus rhonchus* recorded by (Forson & Amponsah, 2020). The changes in (L_∞) in relation to other species may be due to the fact that, bigger species increase their (L_∞) with decreasing(K), therefore, species size ranges constitute a major part in the estimation of asymptotic length (Barr et al., 2008). The (ϕ) estimated was out of the range stated by Baijot et al., (1997) for fishes in Africa with fast growth performance, hence portraying that *Decapterus punctatus* as a slow growing fish. The changes in growth parameters could also be due to the maximum length observed, methods of sampling, methods of computation and the length frequency attained (Amponsah et al., 2016). The differences in the parameters of growth may again be association with the type of climate, latitudinal difference and environmental factors like the habitat and species life pattern adaptation (Qamar et al., 2016).

Implications of Estimated Mortality Parameters

The results obtained for the (M) of *Chloroscombrus chrysurus* was estimated at 0.67 year^{-1} which was lower than that estimated by Amponsah et al., (2021) and De Queiroz, Salvador, Sousa, Silva, Fabré, Vandick & Batista (2018) who recorded 1.31 year^{-1} and 0.92 year^{-1} respectively. Species with lower growth rate do not usually have a higher natural mortality which usually results in species undergoing extinction if possible (Pauly, 1984). On the other hand, species with high (K) obtains a higher (M) which implies reproduction at an early size to compensate for the higher (M) which may also result into smaller length and weight of spawners with smaller eggs (Solemdal, 1997). The ratio of M/K according to Macer, (1977) ranges between 1.12-2.5 for a number of fishes. The ratio attained in this study was estimated at 1.76 which fell within the defined range.

The (Z) and (F) were estimated at 2.76 year^{-1} and 2.09 year^{-1} respectively. The recorded (F) was higher than the (M). Similar result was estimated by Amponsah et al., 2021) at 1.31 year^{-1} (M) and 1.96 year^{-1} (F). However, Sossoupke et al. (2017) recorded a higher (M) than (F) at 1.16 and 0.26 respectively in Benin in near shore waters.

This study suggests that the fish species assessed are presently not sustainably exploited. The ratio of sizes, rate of growth, composition of sizes and size-at-first maturity is described to cause variations in parameters of a population due to higher fishing mortality (Chimatiro, 2004). This additionally proves that, high exploitation presently exists among *C. chrysurus* stocks (Pajuelo & Lorenzo, 1998).

The (E) of *Chloroscombrus chrysurus* was estimated at 0.75, which indicate that they are overexploited because, the level of exploitation exceeds the optimum ratio of 0.5 (Gulland, 1971).

Decapterus punctatus exhibited a (M) of 1.03 years^{-1} which was higher than its related species *Decapterus rhonchus* recorded by Forson & Amponsah, (2020). This could be related to a major decline in the abundance of food, amplified intensity of predators and a rise in temperature. The recorded (F) was higher than the (M) suggesting an imbalanced stock position (Azim, 2017). Again, it may be due to forceful fishing pressure, the type of gear and sizes of mesh used, sampling methods and efforts within the months.

The exploitation rate of *Decapterus punctatus* was estimated at 0.58. This suggests a moderate exploitation of this species. By way of a management, pressure in fishing should be reduced through actions like decreasing active canoe quantities, elimination of subsidies on outboard motor and establishing closed fishing season and increase fishing holidays.

Implications on the Probability of Capture

The ratio of L_{c50}/ L_{∞} of *Chloroscombrus chrysurus* which is the critical length at capture was estimated at 0.36. This estimation is lower than 0.5 on Ghana's continental shelf and according to Pauly & Soriano, (1986) it indicates the harvesting of smaller and juvenile species. This is an indication that there is a presence of growth overfishing within the *C. chrysurus* stock.

Decapterus punctatus exhibited a critical length at capture L_{c50}/ L_{∞} of 0.49 indicating the presence of growth overfishing.

Selection Factor

Selectivity of a gear shows the size selection as well as fishing approaches used by a particular fleet. The relatively lower selection factor in *Decapterus punctatus* (1.67) as compared to *Chloroscombrus chrysurus* (1.80) may have been due to the lower L_{c50}. The higher selection factor (SF) for *Chloroscombrus chrysurus* may be as a result of the higher L_{c50} obtained in the study. The lower selection factor and a huge number of smaller fishes in the samples may be as a result of smaller mesh gears and non-selectivity of fishing gears used on juvenile fishes. However, an increase in mesh size would increase the length at which both *C. chrysurus* and *D. punctatus* species become vulnerable to fishing gear. This management strategy would result in the curbing of future overfishing as more of these fish species will have the chance to mature to marketable size and reproduce before being harvested by fishing gears.

Length-at- maturity

The estimated **(**L_m) of *Chloroscombrus chrysurus* was 15.8cm for males and 14.2 cm for females. However, the calculated length- at-first-capture for these species was estimated to be 10.6 cm which was lower than the length at which the species mature. *Decapterus punctatus* also recorded the length-at-fist-capture of 14.8 cm for males and 12.8 cm, meanwhile the estimated length-at-first-capture was 10.5 cm. This infers that these species do not get the chance to reproduce before harvesting. This may have some implications on the potentials of recruitment of these species in the future (Gheshlaghi, Vahabnezhad & Taghavi, 2012). Again, this result suggests that growth overfishing is occurring in the assessed fish species because of the gears used to harvests a huge quantity of juvenile stocks (Agyakwa, 2010). It is essential to implement length at 95% capture which is achievable when sizes of mesh are enlarged to ensure matured fishes are captured.

Implications on the Gonadosomatic Index (GSI)

The standard (GSI) is calculated to describe the changes in development of gonads of male and female species.

Higher gonadosomatic indices were estimated for both species of *Chloroscombrus chrysurus* in this research in the month of January, February and June which suggested maturity period within these months. However, Petermann & Schwingel (2016) recorded a higher gonadosomatic index in the month of September and May.

Decapterus punctatus recorded a higher gonadosomatic index in the month of February, March, April and June and a decline in November and May.

However, Mcbride et al., (2002) recorded GSIs for both sexes which increased across all maturity categories within the study period.

The variation in the months could be due to the sizes of the species in relation to their gonad weight, type of food available to the species, type of environment and availability of environmental conditions which favors the species.

Implications on Gonadal Staging

The gonadal staging observed in both sexes of *Chloroscombrus chrysurus* in this study were according to Nikolsky (1963). In this study, *Chloroscombrus chrysurus* recorded four stages (Immature, Maturing, Ripening and Ripe) with immature species dominating. This was unlike the stages of gonadal development observed according to Petermann & Schwingel (2016).

Decapterus punctatus observed also recorded five stages for both male and female species (immature, maturing, ripening, ripe and spent) with immature stage dominating. Mcbride et al, (2002) however recorded immature, maturing and mature stages for male *Decapterus punctatus* and immature, maturing, regressed and mature for female of the same species.

Changes in the gonadal stages for all species could be due to the possibility that individuals breed at different seasons of the year with the result of different gonadal macroscopic stages and diverse gonad weights which might result in a major difference in the gonadosomatic index (Bonilla-Gómez, Chiappa-Carrara, Galindo, Cuzón & Gaxiola, 2013)

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

Based on the information derived from preceding chapters, some conclusions and recommendations were outlined.

Conclusions

- *Chloroscombrus chrysurus* exhibited an isometric development for males and a positive development of allometry for females. *Decapterus punctatus* exhibited a positive allometric growth for both sexes. An isometric growth indicates that the fish grows proportionally to the cube of length while a positive allometric signifies a growth in length higher than the cube of length.
- All assessed fish species exhibited a condition factor equal to or greater than one for most of the study months indicating that all the assessed species were in good physiological condition.
- *Chloroscombrus chrysurus* and *Decapterus punctatus* recorded a lower L_∞ and a higher K as compared to other researches showing that these species are short-lived and slow growing species.
- The (ϕ) estimated was out of the range stated by (Baijot et al., 1997) for fishes in African waters with fast growth performance, hence portraying that these species have a slow growth performance.
- The lower natural mortality obtained indicates that *C. chrysurus* and *D. punctatus* do not have a higher growth rate which usually result in species undergoing extinction if possible (Pauly, 1984).
- The recorded (F) higher than the (M) suggests that the assessed fish species are presently not sustainably exploited.

- The recorded exploitation ratio for both species of *C. chrysurus* and *D. punctatus* suggest overexploitation and moderately exploited stocks respectively.
- The probability of capture was lower than 0.5 on Ghana's continental shelf and this indicates the harvesting of smaller and juvenile species (Pauly & Soriano, 1986). This is an indication that there is a presence of growth overfishing in the fisheries of the *C. chrysurus* and *D. punctatus.*
- The assessed lower selection factor could be as a result of the usage of smaller mesh gears which are not selective enough and targets juvenile fishes.
- The estimated L_m was lesser than the L_{c50}, suggesting that *C. chrysurus* and *D. punctatus* are not fortunate to at least reproduce ones before they are harvested.
- Higher gonadosomatic index suggest their maturity stages, however, change in the maturity months compared with other studies could be due to the sizes of the species in relation to their gonad weight, type of food available to the species, type of environment and availability of environmental conditions which favours the species.
- Changes in the gonadal stages for all species could be due to the possibility that individuals breed at different periods in a year resulting in different gonadal macroscopic stages and diverse gonad weights which might result in a major difference in the gonadosomatic index.

Recommendations

The recommendations obtained from the studies include the following.

- Some commercially important carangid species in Ghana should be assessed monthly in terms of length frequency data at the various landing sites in order to provide the knowledge on length-based stock assessment and management of marine fish resources.
- Higher exploitation rates assessed for this species requires management measures like a decrease in efforts of fishing, increase fishing holidays, closed fishing season, creating marine protected areas (MPAs) to aid sustaining the fish stocks.

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APPENDICES

APPENDIX A

Table 4: Estimated of mean gonadosomatic indexes of *Chloroscombrus chrysurus*

month	Sex	Mean	SE	N	Minimum	Maximum	t-test
Nov	F	1.308098	0.112588	74	0.29316	7.678571	
	M	1.141122	0.101481	89	0.1	7.692308	0.271761
Dec	F	1.808276	0.124522	71	0.568182	6.477733	
	M	1.437156	0.076538	79	0.277778	3.254438	0.010401
Jan	F	2.888816	0.207537	99	0.714286	19.82434	
	M	2.016317	0.108259	110	0.087873	3.846154	0.000167
Feb	F	3.050428	0.152526	87	0.582363	7.359656	
	M	1.301199	0.130769	94	0.08547	5.524862	1.59E-15
Mar	F	1.997467	0.10638	98	0.344828	6.870229	
	M	1.429262	0.058544	99	0.416667	3.333333	5.08E-06
Apr	F	1.116608	0.116826	85	0.115473	5.780347	
	M	1.427446	0.253781	66	0.208333	14.82558	0.233486
May	F	1.402825	0.070614	61	0.578035	3.076923	
	M	1.379277	0.068501	65	0.628931	3.225806	0.811236
Jun	F	2.213009	0.130927	51	0.392157	5.660377	
	M	2.295407	0.140507	49	0.769231	5	0.668521

APPENDIX B

Table 5: Estimated of mean gonadosomatic indexes of *Decapterus punctatus*

Month	**Sex**	**Mean**	**SE**	**N**	**Minimum**	**Maximum**	t-test
Nov	F	0.529905	0.118314	23	0.006494	2.631579	
	M	0.677854	0.137358	25	0	3.333333	0.422356
Dec	F	1.931686	0.118083	67	0.45045	4.651163	
	M	1.493334	0.070689	76	0.257732	3.063063	0.001345
Jan	F	2.154367	0.088341	100	0.3125	5.511811	
	M	2.193988	0.077566	92	0.793651	4.123711	0.738269
Feb	F	3.405244	0.191816	106	0.547945	19.14894	
	M	1.879222	0.086416	118	0.292135	7.222222	1.48E-12
Mar	F	3.513376	0.166714	64	1.030928	7.407407	
	M	2.386966	0.122594	57	0.917431	4.761905	4.66E-07
Apr	F	2.733089	0.087078	90	0.705882	4.950495	
	M	2.539613	0.108416	84	0.192678	5.012531	0.163259
May	F	1.220283	0.060549	65	0.543478	3.125	
	M	1.150923	0.072617	61	0.423729	4.761905	0.462452
June	F	2.799349	0.189185	64	0.833333	10.43478	
	M	2.828954	0.154839	59	0.862069	6.956522	0.904737