**DEPARTMENT OF MARINE AND FISHERIES SCIENCES**

# FOOD AND FEEDING HABITS OF THREE TUNA SPECIES LANDED IN GHANA

**THIS THESIS IS SUBMITTED TO THE UNIVERSITY OF GHANA, LEGON IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF PHILOSOPHY DEGREE IN FISHERIES SCIENCE**

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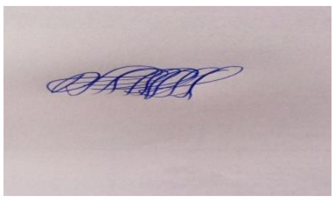
## DECLARATION

This thesis is the result of research work undertaken by Alidu Tuga in the Department of Marine and Fisheries Sciences, University of Ghana, under the supervision of Dr. Angela Manekuor Lamptey.



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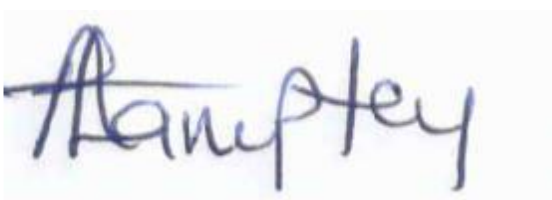

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Dr. Angela M. Lamptey

(Principal Supervisor)

# DEDICATION

This work is solely dedicated to Almighty Allah whom I trust and worship, my lovely wife, Bintu Seidu Tuga, and my mum, Ajarah Ohui Tuga for their sincere love, commitment, and support given to me. It is my prayer that this work will improve the quality of our lives in subsequent years to come.

**ACKNOWLEDGEMENTS**

I wish to express my sincere thanks and gratitude to God Almighty for the many blessing, strength, favour, and love granted me throughout my stay in University of Ghana. Without Him, this study would have been impossible. May His name forever be glorified, Amen! This work has been executed successfully not only through the prowess and the instrumentality of the Researcher, but also with the active involvement of a good number of people, and institutions who in diverse ways contributed immensely to this work.

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I wish to extend my profound gratitude to my parents, Mr. Adamu Tuga and Mrs. Ajarah Ohui Tuga and my wife, Mrs. Bintu Seidu Tuga, for their financial support, guidance, and motivation. To my siblings; Abass, Abiba, Isha, Ramatu, Hawa, and all members of the Tuga family I say thank you all for the prayers, love, and the time you shared with me.

To my friends, thank you for the friendship, I am grateful for the time we have come to know each other and the time we have shared during my study.

## ABSTRACT

Food and feeding habits of the three tuna species landed in Ghana were investigated for a period of six (6) months from October 2019 to March 2020. The species are *Thunnus albacares, Katsuwonus pelamis,* and *Thunnus obesus.* The study sampled a total of 210 individuals of the three tuna species, out of which 90 individuals were *Katsuwonus pelamis*, 60 individuals of *Thunnus albacares*, and 60 individuals of *Thunnus obesus*. The study sampled 90 specimens for *Katsuwonus pelamis* because they are of high abundance and very common in Ghanaian waters than *Thunnus albacares* and *Thunnus obesus*. These tuna species were sampled for stomach content analysis, to determine which type of prey item is most important and preferred as food for these three tuna species. The samples were transported to the Fisheries Scientific Survey Division (FSSD) laboratory in Tema, under the Ministry of Fisheries and Aquaculture Development for analysis.

At the laboratory, some morphometric measurements of the samples were taken. The fish samples were dissected and their guts were removed for examination. Gut content analysis was conducted on each of the fish sampled. The gut fullness was determined on a scale of 0/4 to 4/4 by visual inspection. The commonest prey items discovered in the stomachs during the studies were *Engraulis encrasicolus*, *Exocoetus* spp, *Penaeus kerathurus*, *Sepia hierredda*, *Loligo* spp, and *Metapenaeus monoceros.*

*Engraulis encrasicolus* was found to be the most preferred food item accounting for 58% occurrence by number, with *Diplodus spp* being the least preferred food item accounting for 2% for *Thunnus albacares*. For *Katsuwonus pelamis, Penaeus kerathurus* was found to be the most preferred food item accounting for 57% occurrence by number, with *Sepia hierredda* being the least preferred food item accounting for 10% of total prey items found. *Exocoetus* spp was also found to be the most preferred food item accounting for 86% occurrence by number, with *Metapenaeus monoceros* being the least preferred food item accounting for 12% for *Thunnus obesus*. Similarly, the most important food items identified using Index of relative importance were *Engraulis encrasicolus*, *Penaeus kerathurus* and *Exocoetus* spp with *Diplodus* spp, *Sepia hierredda* and *Metapenaeus monoceros* recording the least important for *Thunnus albacares*, *Katsuwonus pelamis* and *Thunnus obesus* respectively. There was a significant difference among these three tuna species *w*ith respect to *Engraulis encrasicolus*, *Penaeus kerathurus Exocoetus spp,* *Sardinella aurita*, *Caranx crysos*, *Sepia hierredda*, *Loligo spp*, and *Brachyuran spp*. Continuous research on food and feeding habits of these Tuna species to cover all the yearly seasons was recommended owing to their commercial importance to Ghana and the international community.

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## LIST OF ABBREVIATION/ ACRONYMS

FAO - Food and Agriculture Organization

LIFDC - Low-Income Food Deficit Countries

FASDP - Fisheries and Aquaculture Sector Development Plan

GDP - Gross Domestic Production

FAD - Fish Aggregating Devices

UNCLOS – United Nation Convention on the Law of the Sea

ISSF – International Seafood Sustainability Foundation

NOAA – National Oceanic and Atmospheric Administration

RFMO – Regional Fisheries Management Organization

# CHAPTER ONE

# INTRODUCTION

## 1.1 Background of Study

In recent times, demand for fish continues to rise in some parts of the world as a result of increasing population growth and promoting the consumption of animal protein (FAO, 2020; Addi, 2014). In a well-established economy, demand for high-value fish species like tunas, shrimp, and salmon has increased over the years, due to the rise in population, income, and urbanization and a shift in preference from red meat to fisheries products (Merino *et al*., 2012).

Fish is a very essential source of protein and micronutrients, which contains omega 3 fatty acids and used for managing high blood pressure. According to the Food and Agriculture Organization, fish contribute roughly 20 percent of animal protein consumption in Low-Income Food Deficit Countries (LIFDCs). In some islands and coastal communities such as Sri Lanka, Indonesia, Senegal, and Bangladesh, it provides more than 50 percent of animal protein to people in these countries (Buckland *et al*., 2017). Moreover, it contributes to about 62 percent in Gambia and up to 63 percent in Ghana and Sierra Leone (FAO, 2020). It's one of the most important components in the food of poor communities because it is often the cheapest means of getting animal protein in the world (Devries and Phillips, 2015).

Within Sub-Saharan Africa, the fishery industry directly provides work for about three (3) million populace and other extra 7.5 million populace found in fish processing and trading sectors (Costello *et al*., 2016, FAO, 2020). Furthermore, it's expected that the recent yearly income from capture fishery would increase to about US$2 billion which will generate a multiplier effect of 2.5 times (US$5 billion) throughout Africa (Costello *et al*., 2016).

Ghana has valuable fisheries that produced about US$ 1 billion revenue in the year 2011 to 2016 and accounted for about 5% of Agriculture Gross Domestic Production (AGDP), according to Fisheries and Aquaculture Sector Development Plan (FASDP, 2015).

The tuna fishery is a highly commercial fishing sector that uses industrial fishing vessels with either purse seine or baited hooks to catch tuna and tuna-like species (*Thunnus albacares, Thunnus obesus,* and *Katsuwonus pelamis*). These species are very essential and most significant food sources for humans (Bayliff, 2016). In 2017, Tuna landings were projected at 100,000 metric tonnes yearly by the Fisheries Commission of Ghana. However, the current tuna landings have been much lower than the expected threshold (Kwadjosse *et al*., 2018).

The overall demand for tuna products has been increasing gradually since the 1980s (Hassan, 1997). Tuna fishery is a very essential seafood in terms of volume and value of catch landings with respect to the three most important tuna species (*Thunnus albacares, Thunnus obesus*, and *Katsuwonus pelamis*) which accounted for 20.93 % of the overall marine fisheries production in 2008 (Addi, 2014). A reduction in tuna stock will, therefore, have a great effect on the protein supply of consumers (Evans *et al.*, 2011). In general, Ghana's tuna production has been erratic due to a decline in catches year after year (FAO, 2014).

Fish continues to be the anchor of the country's source of protein intake. In Ghana it's estimated to be about 60% of all diet consumption and also holds sufficient potential for job creation (Kwadjosse, 2009). The study of food composition in the fish diet plays an important role in fisheries management. The examination of food and feeding habits of fish has usually been a significant area of study in Fish Biology. However, it is very difficult to compare the outcome with research from other areas (FAO, 1974). Food and feeding habits of fish cannot be measured in segregation nevertheless; it has to be deliberated in relation to the entire aquatic ecosystem, in which fish is a single component of the ecosystem (Mahesh *et al.*, 2018; Setyadji, *et al.*, 2017; Sivadas and Anasukoya, 1999).

These species serve as a key source of protein, especially to most coastal communities found in Ghana. However, converting them to fish meal is also a common practice among fish feed manufacturers in Ghana (Addi, 2014; Abdul Hakim *et al.*, 2018). In Ghana, these species are often caught and classified as high- target export fishery due to its market value in the international communities. The research focused on these three (3) common tuna species namely, *Thunnus obesus*, *Katsuwonus pelamis*, and *Thunnus albacares*.

*Thunnus obesus* (Bigeye tuna) is a species of true tuna in the genus *Thunnus*, belonging to the family Scombridae. *Thunnus obesus* are found in open waters of temperate and tropical Oceans but are not found in the Mediterranean Sea (Addi, 2014). They are large pelagic species with deep bodies. They are streamlined fish with a large head and big eyes. The pectoral fins are very elongated to the back beyond the start of the second dorsal fin in juveniles and space between the first and second dorsal fins in adults (Carpenter *et al*., 2014). They also have between 13 to 14 dorsal spines. *Thunnus obesus* has a distinctive physiological characteristic that permits them to feed in deep colder water and tolerate water with poor oxygen content (Dizon and Brill, 1979).

*Thunnus obesus* are observed to stand oxygen level at 1.0 ml/L and usually attain depths of despair ambient oxygen content below 1.5 ml/L (Holland *et al.*, 1992; Magnuson, 1973). This is mainly due to the existence of blood with high oxygen content (Magnuson, 1973; Dizon and Brill, 1979). The vascular counter of the existing heat exchanger maintains the body temperature above the optimum water temperature (Aoki *et al*., 2020; Carey and Lawson, 1973; Dizon and Brill, 1979). This heat exchanger is affianced to preserve heat in deep colder waters that are disconnected to permit fast warming as the species rise from cold water into warmer surface waters (Holland *et al.*, 1992). This provides short latency and physiological thermoregulation of the species (Carey and Lawson, 1973; Aoki *et al*., 2020; Dizon and Brill, 1979). The eyes of *Thunnus obesus* is well modified with a huge sphere-shaped lens that permits them to see very clearly in a low light environment (Holland *et al.*, 1992; Dizon and Brill, 1979). *Thunnus obesus* carry out different diel movement in upright manners, normally downward movement to deep, cool water and recurring to shallow, warmer water at sunset (Aoki *et al*., 2020;

Dizon and Brill, 1979). In the day time, *Thunnus obesus* embark on an upright shift into waters of about 300m – 500 m downward and can be 20 °C cooler than surface waters (Holland *et al.*, 1992). The individuals embark on thermoregulatory behaviour even as depth, occasionally recurring from deep, cool water to shallow, warmer waters to rewarm (Dizon and Brill, 1979; Carey and Lawson, 1973). The typical vertical behaviour of *Thunnus obesus* movement occurs when they are connected with buoys, seamounts, and FAD, with those left behind the surface of waters (Holland *et al.*, 1992).

*Thunnus obesus* normally grow up to a maximum length of 250 centimeters (100 inches) or 8 feet. The greatest weight of individuals *Thunnus obesus* is about 180 kg (Carpenter *et al*., 2014).

*Thunnus albacares* (Yellowfin tuna) belongs to a family Scombridae. These species are mostly found in the surface of waters of subtropical and tropical Oceans globally (Aoki *et al*., 2020). For *Thunnus albacares*, the anal fin and the second dorsal fin in addition to the finlets, between the fins and the tail are bright yellow, which accounts for the common name (Yellowfin tuna). The anal fin and second dorsal are very elongated in a full-grown species, which are prolonged to almost the tail of the fish giving it the appearance of scimitars or sickles shape (Carpenter *et al*., 2014; Aoki *et al*., 2020; Perera *et al.,* 2015). They have long and wilder pectoral fins.

*Thunnus albacares* is one of the large tuna species found in the world and has a maximum weight of over 180 kg. They are extensively smaller than Atlantic and Pacific bluefin tuna, which weight more than 450 kg (Aoki *et al*., 2020; Dizon and Brill, 1979;).

*Thunnus albacares* are also somewhat smaller than *Thunnus obesus* (Addi, 2014). The body of *Thunnus albacares* is a very dark metallic blue, varying to silver on the belly. They have about 20 vertical lines on the skin (Aoki *et al*., 2020).

*Thunnus albacares* normally travel in schools within the same size cohort. They occasionally move with other tuna species and mixed together with other schools of pelagic species such as barracuda, trigger fish and blue runner in a particular area. They are frequently linked themself with various species of porpoises or dolphins, and with bigger marine mammals like sharks and whales. They are also known for chasing floating objects such as FAD, pallets, and logs. Sonic tagging shows that, some *Thunnus albacares* like chasing moving vessels (Perera *et al.*, 2015).

*Katsuwonus pelamis* (Skipjack tuna) is an average size perciform species belonging to the family, Scombridae. They are also called mush mouth, victor fish, oceanic bonito, aku, balaya, arctic bonito, and striped tuna. It can grow up to a length of about 3 ft (1 m) long (Carpenter *et al*., 2014). They are multinational tuna species living in warm temperate and tropical waters. They are significant pelagic species in the world.

*Katsuwonus pelamis* are fast-swimming pelagic species with a streamlined body, common in tropical Oceans all over the globe (Collette *et al*., 2011). They inhabit the surface of waters in large shoals. They are very essential food source for large surface-dwelling pelagic species and sharks and are frequently used as baitfish especially for Marlins (Collette *et al*., 2011). They are non-scales fish species, apart from the lateral line and on the corselet. The corselets are broad scales forming a ring around the body at the back of the head.

The fork length of *Katsuwonus pelamis* is about 80 cm and can weigh between eight (8kg) to ten (10 kg). The maximum total length for *Katsuwonus pelamis* is about 108 cm and the maximum weight is up to 34.5 kg. The lifespan of *Katsuwonus pelamis* ranges between 8 to 12 years (Collette *et al*., 2011).They are species that spawn in batches. The reproduction occurs throughout the year in equatorial waters. Normally, the fork length of the first batch reproduced is around 45cm. *Katsuwonus pelamis* is also known for its potent smell (Carpenter *et al*., 2014; Collette *et al*., 2011).

## 1.2 Problem Statement and Justification

Fish is the most important source of protein for human beings and offer opportunities for people to be employed in the fisheries sector. The fisheries sector also contributes significantly to the development of the economy. On the other hand, with a better understanding of fisheries resource management, it has been realized that aquatic resources are decreasing rapidly. Although they are renewable resources but need to be sustainably managed. Due to the role it plays in the nutrition, economic, and social well-being of the increasing populace, fisheries resources need to be sustained for future generations (Kwadjosse, 2009).

According to the Fisheries Commission of Ghana tuna stocks have gradually declined over the years. However, studying the food and feeding habit of these three most important Tuna species in Ghana could help Fisheries Managers to plan and manage the resource better. The excessive utilization of these fisheries resources without scientific research on their feeding habit would endanger the long term sustainability of the tuna species.

Studying food and feeding habits of fish species and other organisms is based on the investigation of the stomach content and this has become the accepted protocol to assess fish feeding habits (Hyslop 1980). The analysis of the stomach content of fish gives an imperative understanding of fish feeding patterns in an ecosystem. The quantitative assessment of food composition as well as feeding habits of fishes is vital in fisheries management and ecological studies of fish. Generally, feeding habits of fish present the basis to understand the trophic relations in the marine environment. Feeding habits of fish signify a combination of many essential ecosystem mechanisms which encompasses weather conditions, behaviour, habitat use, intra/inter specific interactions, and energy intake (Mahesh, 2019).

Tunas (*Katsuwonus pelamis, Thunnus albacares*, and *Thunnus obesus*) are considered as important commercial pelagic species found in Ghanaian coastal waters. Despite its high abundance and the economic value of these species in Ghanaian coastal waters, little or no information is known about the food and feeding habit of these important fish species. This research was conducted to increase the understanding of the food and feeding habit of these three Tuna species. Research has indicated that studying the trophic ecology of fishes is very essential to appreciate the functional role of fishes within an aquatic ecosystem (Bahou *et al*., 2007; Blaber, 1997; Cruz-Escalona *et al*., 2000; Hajisamae *et al*., 2003).

## 1.3 Objectives

### 1.3.1 Main Objectives:

The main objective of the study is to investigate food and feeding habits of the three most common tuna species (*Katsuwonus pelamis*, *Thunnus obesus*, and *Thunnus albacares*) in Ghana.

### 1.3.2 Specific Objectives:

The specific objective of the study is to determine;

- The frequency of occurrence of prey items in the stomach of the three most common tuna species (*Katsuwonus pelamis*, *Thunnus obesus*, and *Thunnus albacares*).

- The percent composition by Number and Weight of prey items in the stomach of the three most common tuna species (*Katsuwonus pelamis*,*Thunnus obesus*, and *Thunnus albacares*)

- Which food type is most important and preferred by the three most common tuna species (*Katsuwonus pelamis*, *Thunnus obesus*, and *Thunnus albacares*).

# CHAPTER TWO

# LITERATURE REVIEW

## 2.1 State of the World Fisheries

Over the years Fisheries Managers have been facing a series of challenges in the fisheries sector until The Code of Conduct for Responsible Fisheries (CCRF) was adopted to ensure sustainable utilization of fisheries resources. The Code was introduced to assist in the improvement of intercontinental mechanisms, guidelines, and programs toward conscientious administration of fisheries nationally, regionally and globally. The pains in adopting the Code of Conduct have been more solid and important since its introduction, to mainly deal with challenges in a rational and harmonized manner (FAO, 2020). This is to safeguard the use of marine resources, Seas, and Oceans for sustainable growth (FAO, 2018).

A 10-year study putting together over 50 organizations and 400 researchers concluded that the total marine fisheries landing are 50 percent higher than the reported landing and fisheries resources are declining due to improper administration of the resources (FAO, 2014). The overall catches of the marine fishery are higher than in the past reports, contributing more to the local and worldwide food security.

The overall fish landing is expected to have reached about 179 million tonnes in 2018 of the overall total catch. 156 million tonnes of fish were consumed by humans as food which is equal to the expected yearly contribution of 20.5 kg per capita (FAO, 2020). In 2018, the overall worldwide capture fishery production reaches the maximum point ever documented at 96.4 million tonnes increment, of about 5.4% from the average in the past three (3) years (FAO, 2020; ICCAT, 2003). The first 7 countries with high landings of capture fisheries include India, Russian Federation, Vietnam, United States of America, China, Indonesia, and Peru contributing about 50% of global landings (ICCAT, 2003).

Landings of *Engraulis ringens* by Chile and Peru contributes the majority of the increment of landings in 2018, following comparatively small landings for this fish species in current years, making it the highest fish species of over 7.0 million tonnes.

*Theragrach alcogramma* was also the second, of about 3.4 million tonnes, whereas *Katsuwonus pelamis* was graded the third, for nine successive years at 3.2 million tonnes (FAO, 2020).

Finfishes represent 85% of the entire ocean capture fisheries production. The smaller surface-dwelling species were the major groups, followed by tuna and tuna-like species as well as Gadiformes. The catch of tuna and tuna-like species persist to increase year after year, reaching the peak levels in 2018 with more than 7.9 million tonnes (FAO, 2020). On the quantity of catch, 78.7% of the recent catch was obtained from biologically sustainable resources. In 2017, the under-fished resources contributed about 6.2% and the highest sustainably fished resources also contributed about 59.6% of the entire number of assessed resources (FAO, 2020).

In 2018, about 88% of the entire 179 million tonnes of overall fish landing was directly consumed by humans, whereas the leftover of 12% was utilized for non-consumption purposes (ICCAT, 2003).

In 2017, fisheries contributed about 17 percent of the overall population ingestion of animal protein. People are eating more fish than ever before due to increasing production, rising incomes, and increased awareness of the health benefits associated with fish consumption (Bene *et al*., 2010). However, FAO has predicted that due to Africa's projected population growth, per capita fish utilization is estimated to increase, raising concerns of food security (Bene *et al*., 2010; FAO, 2020).

FAO has estimated that 2.9 billion people depend on fish for a substantial component of their animal protein. In some countries in Africa and Asia, fish provide more than half of their animal protein supply (Kosamu, 2015; FAO, 2014). FAO again has estimated that the contribution of marine fisheries to food security may even be higher than before in a lot of developing countries (Evans *et al*., 2011; Kosamu, 2015).

In Ghana, the fisheries industry supports livelihoods of about 10% of the population and significantly contributes about 60% of the country's protein intake. Also, about $87 million of fisheries resources were exported in 2009 (Samey, 2015). Fish and other seafood contribute about 16% of the overall household expenditure on food for an average Ghanaian (Ghana Statistical Service, 2014).

## 2.2 Global tuna production and management

Tunas have been very significant to human beings over the years. There is an archaeological proof that early people harvested this species over six thousand (6,000) years ago, tuna products were the first manufactured fisheries commodities traded among the early people (Nootmorn *et al.,* 2008). Catches between 1975 and 1992 increased significantly for tuna species throughout the world especially for *Thunnus obesus, Katsuwonus pelamis, and Thunnus albacares.* On the other hand, there were times of rapid decrease in tuna production. From 1991 to 1996 tuna landings continued to be reasonably stable, between 3.1 and 3.2 million metric tonnes. Within 1997 tuna production (landing) hit 3.4 million tonnes and has sustained the rise year after year, to reach 3.9 million tonnes in 1999 (Hasarangi *et al.*, 2012).

The increased tuna production that occurred from 1970 to 1978 was as a result of the extension of fishing effort in eastern Atlantic Ocean and the improvement in the latest offshore fishing grounds in eastern Pacific (FAO, 2015). The few years of modest rise in global tuna productions were attributed to the discovery of novel fishing areas. From the year, 1996 to 1999 the tuna landings were augmented by 19%, owing to enhancement and improvement in the use of FAD (FAO, 2015).

Tunas are highly migratory species and form part of significant fish species listed in United Nations' Convention on the Law of the Sea (UNCLOS) Annex I. Article 64 of the Convention states that, the administration of extremely migratory fish species needs collaborative approach among coastal countries in the world (FAO, 2015). Due to the high commercial value of tuna species throughout the world, several global organizations, as well as scientific research organizations, NGOs and resource protection groups such as US National Oceanic and Atmospheric Administration (NOAA), International Seafood Sustainability Foundation (ISSF), and Pew Environmental Group, are helping to manage these resources sustainably. These organizations play essential roles in the administration of tuna fishery in the world (Pons *et al*., 2017).

The Regional Fisheries Management Organization (RFMO) has the management powers to put in place technical measures, catch and fishing effort limits, and control responsibilities over fish productions. Tunas are essential economic commodities and a primarily important source of food to human beings. The yearly landings of these tuna species have increased from 1.6 million tonnes in 1950 to over 6 million tonnes in 2003 (ICCAT, 2003; FAO, 2014).

Furthermore, because the fisheries sector gives a direct job to over 200 million populace in the world (Dunn *et al*., 2016), and contributes about 19 percent of the overall animal protein consumption by human beings, it needs to be properly managed (Chalamaiah *et al*., 2012). The collapse and decline of these fish species would possibly have an extremely social and economic impact on some fishery reliant regions of the world (Howarth *et al.*, 2014).

According to the International Seafood Sustainability Foundation, the fishing pressure on tuna species has increased greatly on the global scale indicating an overexploitation of these resources. Hence, it is necessary that mechanisms be put in place to preserve these fish species (ISSF, 2012). The degree of exploitation should be measured to ensure that tuna populations are maintained at preferred levels of abundance (ISSF, 2012).

According to Regional Fisheries Management Organization, tuna stocks are approaching or exceeding their full exploitation level (RFMO, 2014). Yield per recruit (Y/R) is reducing due to increasing juvenile catches. Competition among gear types has been accentuated and the global fishing capacity has risen (Miyake *et al*., 2010).

Water temperature also has a high physiological consequence on tuna species, as it affects their cardiac function, swimming abilities, spawning activity, egg hatching, and larval growth (Dizon *et al*., 1977). On the other hand, tolerances in water temperature vary widely among tuna species. With respect to Ocean warming, the marine populations are inclined to travel in the direction of the poles in the deeper Oceans (Anker-Nilssen *et al*., 2008). Hence, the reflection is as a result of increases in warmer water fish species in several higher latitude regions. The change in the biogeography and ecology of marine fishery may be valuable signs of climate change (Sharp, 1978).

Tropical species like *Thunnus albacares* and *Katsuwonus pelamis* are found in water with temperature ranges between 30-32°C and an ambient temperature greater than16°C (Boyce *et al.*, 2008). On the other hand, *Thunnus thynnus* (Atlantic bluefin tuna) feed extensively in water with a temperature that is less than 10°C. They may be physiologically stressed in temperature greater than 28-29°C (Block *et al*., 2005). Sea surface temperature (SST) is a target area of several studies in order to explain the oceanic environment and tuna species distribution (Block *et al*., 2005).

The thermal limits for *Thunnus albacares* range from 18°C to 31°C with an optimum temperature between 21°C and 24°C. For *Katsuwonus pelamis* the thermal limits ranges from 17°C to 28°C with an optimum temperature between 20°C and 22°C and also for *Thunnus obesus* the thermal limits interval is from 11°C to 28°C with optimum temperature between 18°C and 22°C (Musyl *et al*., 2003). Lehodey *et al*. (1998) pointed out that, the greatest profusion for *Thunnus albacares* is between 20°C and 30°C, for *Katsuwonus pelamis* is between 20°C and 29°C and for *Thunnus obesus*, the greatest profusion depends on fishing gear used.

The estimation of climate change impacts on highly migratory fish species is difficult to access due to differences in life stages of the fishery. The ability of tuna to tolerate warm water frequently reduces with respect to the size and age of the fish, whereas the ability of tuna to tolerate cold water may rise, depending on their physiological distinctiveness (Barkley *et al.*, 1978). Due to the extensive distribution of tuna fishery and their reliance on the most favorable water temperature, their populations may be an excellent indicator of the causes of climate change on worldwide fisheries.

External reasons such as salinity, oxygen content, ocean fronts, prey accessibility, islands, zooplankton, seamount as well as the existence of other organisms including sea birds and porpoises are very important indicators. These external factors are assumed to correlate with the abundance and distribution of these species (Worm *et al*., 2006). Sea surface temperature has continually been used as the best way to predict species density and richness (Worm *et al*., 2006). This indicates that ambient water temperature may be key to oceanographic variable motivating distribution and abundance of tunas and billfishes on a global scale. Although information about the comprehensive distribution pattern for individual species of tuna, has highly been developed in recent years such as tuna tagging studies (Block *et al*., 2001). The community of fish migration patterns on abundance and richness remains poorly known (Worm *et al*., 2006). The information on patterns and oceanographic factors (temperature) that drives species is important to effectively conserve and manage fish populations comprehensively (Worm *et al*., 2006).

## 2.3 Tuna production in Ghana

The tuna fisheries are very essential marine fisheries with respect to the volume and value of the catch. In Ghana, commercial tuna fishery started in 1962 (Kwadjosse, 2009). International Commission for the Conservation of Atlantic Tuna (ICCAT) identified three commercial species of tuna fisheries in Ghana namely: *T. albacares*, *T. obesus*, and *K. pelamis*. Even though, the Ghanaian tuna fisheries using different types of gears, including drift gill net, pole and line, longline, poli/watsa, trolling, purse seines and bait boats but the most significant fleet used in the tuna fishery sector are purse seines and bait boats (Addi, 2014). Tuna fleets working in Ghana water are limited to catch fish in a depth of about 50-75m deep water. However, they go astray often into shallow waters to fish. The tuna industry has 24 active vessels landing in Tema and Takoradi (Fisheries Commission unpublished data, 2021). The Atlantic Ocean within the 200 nautical miles of the Exclusive Economic Zones (EEZs) in Ghana has a very important renewable resource and presents the best opportunity for economic development (Secretariat of the

Pacific Community, 2010). On a historical basis, the highest tuna landing in Ghana was in 2001 recording 88,806.49 tonnes of tuna production (Table 2.1).

Table 2.1: Tuna landing (in metric tonnes) records in Ghana

| **Year** | **Yellowfin tuna** | **Bigeye tuna** | **Skipjack tuna** | **Total catch** |
|---|---|---|---|---|
| 1989 | 28883.3 | 16.4 | 23154.2 | 25053.9 |
| 1990 | 7710.1 | 98 | 29498.6 | 37306.7 |
| 1991 | 6628.4 | 138.3 | 28249.6 | 35016.3 |
| 1992 | 6253.8 | 95.8 | 21336.3 | 27685.9 |
| 1993 | 10646.8 | - | 22639.3 | 33286.1 |
| 1994 | 7394.1 | 291.4 | 23863.3 | 31548.4 |
| 1995 | 7119 | 4 | 22923 | 30046 |
| 1996 | 12242.4 | 615.1 | 24284.7 | 37142.2 |
| 1997 | 2324.6 | 27.5 | 24177.1 | 47454.2 |
| 1998 | 19290.48 | 3920.54 | 41997.42 | 65208.44 |
| 1999 | 28282.18 | 3680.11 | 51283.84 | 83246.13 |
| 2000 | 15910 | 1651 | 34986 | 52547 |

| Year | Yellowfin tuna | Bigeye tuna | Skipjack tuna | Total catch |
|---|---|---|---|---|
| 2001 | 29303.3 | 2357.23 | 56417.15 | 88077.68 |
| 2002 | 20310.6 | 2033.9 | 38934.4 | 61278.9 |
| 2003 | 19030.39 | 4815.81 | 32766.14 | 56612.34 |
| 2004 | 15137.72 | 6943.56 | 33600.2 | 55681.48 |
| 2005 | 19833.1 | 2333.2 | 54322.05 | 76488.35 |
| 2006 | 14548.06 | 1590.29 | 42788.85 | 58927.2 |
| 2007 | 15107.14 | 5748.15 | 46415.35 | 67270.64 |
| 2008 | 14250 | 9269.2 | 37387.2 | 60906.4 |
| 2009 | 18355 | 10554.4 | 36063.5 | 64972.9 |
| 2010 | 12511 | 6768 | 53812 | 73091 |
| 2011 | 14389.8 | 2110.2 | 34412 | 50912 |
| 2012 | | | | |
| 2013 | 13920.70 | 2963 | 48130.50 | 65014.2 |
| 2014 | 18939 | 4175 | 50146 | 73260 |
| 2015 | 19659 | 5917 | 62114 | 87690 |
| 2016 | 20217.60 | 5193.60 | 54883.30 | 80294.5 |

| Year | Yellowfin tuna | Bigeye tuna | Skipjack tuna | Total catch |
|---|---|---|---|---|
| **2017** | **20398.40** | **3837.70** | **57907.10** | **82143.2** |

Source: Fisheries Commission unpublished data, 2021

## 2.4 Food and feeding habits

In fisheries resource management and fish ecology, information about food and feeding habit is very important in the decision-making process (Kido, 1996; Mahesh, 2019). Gut contents (Stomach contents) can be collected from both freshly died or live fish (Hyslop, 1980). A research conducted by Lagler (1949) shows that gut content only indicates what fishes prefer to feed on in their habitat.

Theoretically, studying the trophic relation of fisheries resource commences with food and feeding habits (Mahesh, 2019). Stomach content investigation can be used to assess prey selection, habitat preferences, and to develop conservation strategies for sustainable management of fisheries resource (Chipps and Garvey, 2007). According to Mahesh (2019) feeding habit is used as a scientific approach to determine the frequently consumed prey species by an organism. Feeding habit is also used to determine the relative importance of different food types to fish nutrition, and to quantify ingestion rate of individual food types (Mahesh, 2019). The method of evacuation or dissection and assessment of stomach contents is still the most preferred and easiest technique for biological/ecological studies in fisheries (Manko, 2016).

The taxonomic investigation of fish gut contents (Stomach contents) provides very important information about both pelagic and benthic community composition as well as trophic relationships between fish, benthos, and plankton (Mahesh, 2019).

Fish gut content analysis is a method used for analyzing fish feeding habits through assessment of materials found in dissected fish gut. Fish gut contents are normally assessed in terms of mass and volume of prey items identified by taxonomists for their state of digestion (Chipps and Garvey, 2007).

Fish feeding habits and ecology are highly variable among different fish species and can vary among developmental phases for a particular fish as well. Fish gut contents can consequently be used to identify differences in fish feeding approach, food accessibility, fish health, habitat relationship as well as to gather information concerning the trophic relationships in an aquatic environment.

The investigation of fish gut contents is particularly significant to understand fish ecology and health, due to the difficulties associated with observing fish feeding habits in their natural habitats (Chipps and Garvey, 2007). Fish gut size can vary with the body size of the fish which required experience scientist to understand the dynamics fisheries resources (Hyslop, 1980; Lagler, 1949; Mahesh, 2019).

Stomach content analyses are mostly using to study different aspects of feeding ecology of fishes. (Liao *et al*., 2001; Chipps and Garvey, 2007; Ahlbeck *et al*., 2012 ;Manko, 2016; Pillay, 1952; Hyslop, 1980; Cortes, 1997; Baker *et al*., 2014; Hansson, 1998;  Hynes, 1950). The grading and comparing of prey items in feeding habit, scientist assume that some prey is more important than others to the survival, growth, recruitment, size structure, condition, reproductive success, or other aspects of the ecology of the fishes, hence it is important to describe the true importance of food item in the stomach (Bowen, 1996; Mahesh, 2019).

Stomach content analysis can provide data which aids to doggedness more complex questions of fish ecology (Mahesh, 2019; Baker *et al*., 2014). Information obtain from stomach content analysis provides in-depth insight to fish feeding ecology, potential competition, resources availability and other aspects of fish biology and ecology, as well as predation (Liao *et al*., 2001; Mahesh, 2019). The individual food item from gut content can also provide exclusive information about relative importance of particular food item (Hynes, 1950; Pillay, 1952).

## 2.5 Method used in stomach content analysis

Fish feeding habitat are measured using different methods. Stomach contents analysis are generally categorized into quantitative and qualitative techniques (Mahesh, 2019). The qualitative analysis consists of a complete identification of the organisms in the stomach contents (Hyslop, 1980; Ahlbeck *et al*., 2012; Mahesh, 2019). However, the quantitative techniques of analysis are also categorized in to three types which includes, volumetric, gravimetric and numerical (Manko, 2016; Mahesh, 2019; Pillay, 1952). The numerical techniques are centred on the counts of essential food items in the stomach contents (Hansson, 1998; Liao *et al*., 2001). These techniques have been modified in different means to evaluate the relative importance of food items and these are classified under four different heads such as Dominance, Frequency of occurrence, Number, and Point methods (Manko, 2016; Hansson, 1998; Liao *et al*., 2001; Mahesh, 2019; Pillay, 1952).

Volumetric techniques are considered as a more satisfactory method by many researchers for quantitative analysis of stomach contents analysis (Mahesh, 2019; Chipps and Garvey, 2007). The volume of each food item or of the total food of each fish is given in this method (Mahesh, 2019; Chipps and Garvey, 2007).

Gravimetric technique comprises of the estimation of the mass of each food item, or of the total food content of each fish, which is frequently expressed as a percentage of the total weight of the fish as in other quantitative techniques (Hansson, 1998; Hyslop, 1980). Stomach content can be expressed as wet, dry or ash-free dry weight (Hyslop, 1980).

Food and feeding habits of fishes begin with the stomach content analysis and can be used to evaluate the habitat preferences, prey selection, effects of ontogeny and developing conservation policies for the fisheries sector (Mahesh, 2019; Chipps and Garvey, 2007). Stomach content analysis is used in many aspects of fish ecology on individual fish population and the ecosystem levels (Hynes, 1950; Mahesh, 2019; Pillay, 1952). It also helps us to explain specific problems of interactions, nature protection, speciation, evolution, invasions and fishery management (Hyslop, 1980; Ahlbeck *et al*., 2012; Mahesh, 2019). Gut content analysis can be integrated into a variety of different research objectives (Mahesh, 2019; Chipps and Garvey, 2007). Therefore, the stomach content is not only use to identify the diet but also provide source of information on many aspects of fish ecology and biology (Hynes, 1950; Hyslop, 1980; Pillay, 1952).

Food and feeding habits of fish is based on direct investigation of gut content has become a standard practice for several years (Mahesh, 2019; Hyslop, 1980). In recent times, many other methodologies for instance stable isotope analysis, fatty acid analysis, radioisotopes and direct species observations are currently being used for stomach content analysis

(Braga *et al.*, 2012; Mahesh, 2019). These methodologies are more accurate and can tell even the food items which cannot be identified by microscopic but can expensive and complicated procedures (Braga *et al.*, 2012; Cortes, 1997). On the other hand, the stomach content analysis involves dissection or evacuation and investigation of gut contents is still the most used and easiest method for most ecological/biological studies (Manko, 2016; Braga *et al.*, 2012). Other aspects such as prey availability, time of day, sampling location and the type of gear used to collect the fishes also needed to be considered before beginning a diet studies (Zacharia, 2017; Mahesh, 2019). The analysis of stomach content gives accurate interpretation of fish feeding habits (Zacharia, 2017).

In stomach content analysis live or dead fishes are normally used (Cortes, 1997). When fish samples are not analysed forthwith, fish should be preserved immediately freeze or fixing in formalin to avoid continued digestion of food contents (Chipps and Garvey, 2007). Sampled fish should be measured to its total length to the nearest 1 mm and weight to the nearest 0.1 g, then a make a longitudinal cut on the ventral side of the fish from just behind the isthmus of the gills posterior to the anal fin (Nootmorn *et al*., 2008; Rohit *et al*., 2010; Buckland *et al*., 2017; Kido, 1996; Mahesh, 2019). Two transverse cuts at each end of the first cut to open the coelom to expose the viscera and record the maturity stage and sex of the fish sampled (Buckland *et al*., 2017). The digestive tract are separated from other visceral organs, then examine the degree of the stomach fullness and classify as ‘gorged, such as ‘full’, ‘3/4 full’, ‘1/2 full’ ¼ full, these are than by eye estimation and note down the weight to the nearest 0.1 g. (Rohit *et al*., 2010; Buckland *et al*., 2017).

The fishes which do not have a distinct gut, the first half of the intestine can be dissected and the contents are transferred into a petri dish for further analysis (Nootmorn *et al*., 2008; Mahesh, 2019). However analysing formalin preserved fish samples, keep stomach contents out or in water on petri dishes for five (5) minutes to eliminate excess formalin in the samples (Hynes, 1950; Hyslop, 1980; Pillay, 1952). Analyse the stomach content to the genus and up to species level where it's possible by identify the large prey item using the eye observation and examination of small prey items under binocular microscope (Perera *et al*., 2015; Setyadji. *et al*. 2012; Buckland *et al*., 2017; Kido, 1996).

# CHAPTER THREE

# MATERIALS AND METHODS

## 3.1 Study Area

Ghana coast is divided into three zones using the length of the coastline namely: Eastern, Central, and Western coasts. The Volta and Greater Accra regions constitute the eastern coast being the shortest coastline of both regions; the Central region for the central coast and Western region constitute the western coast and also has the longest coastline in Ghana (Akyempon *et al.*, 2014).

The industrial tuna sector has only two landing sites, one in Tema in the Greater Accra Region and the other one in Takoradi in the Western Region. The country has 24 active vessels fishing within the Atlantic Ocean. Twelve (12) of these vessels are operating with pole and line and the other 12 are using purse seine. All the 12 pole and line vessels berth at Tema port. Out of the 12 purse seiners, 8 berths at Tema port and 4 berths at Takoradi port (Fisheries Commission data, 2021). Also, there are seven (7) non – Ghanaian registered vessels that discharge tuna in Tema port. Five (5) of these vessels are from Berlin and the other two (2) are from Liberia. The various sampling stations (fishing position) were presented in the map below (Fig 3.1).

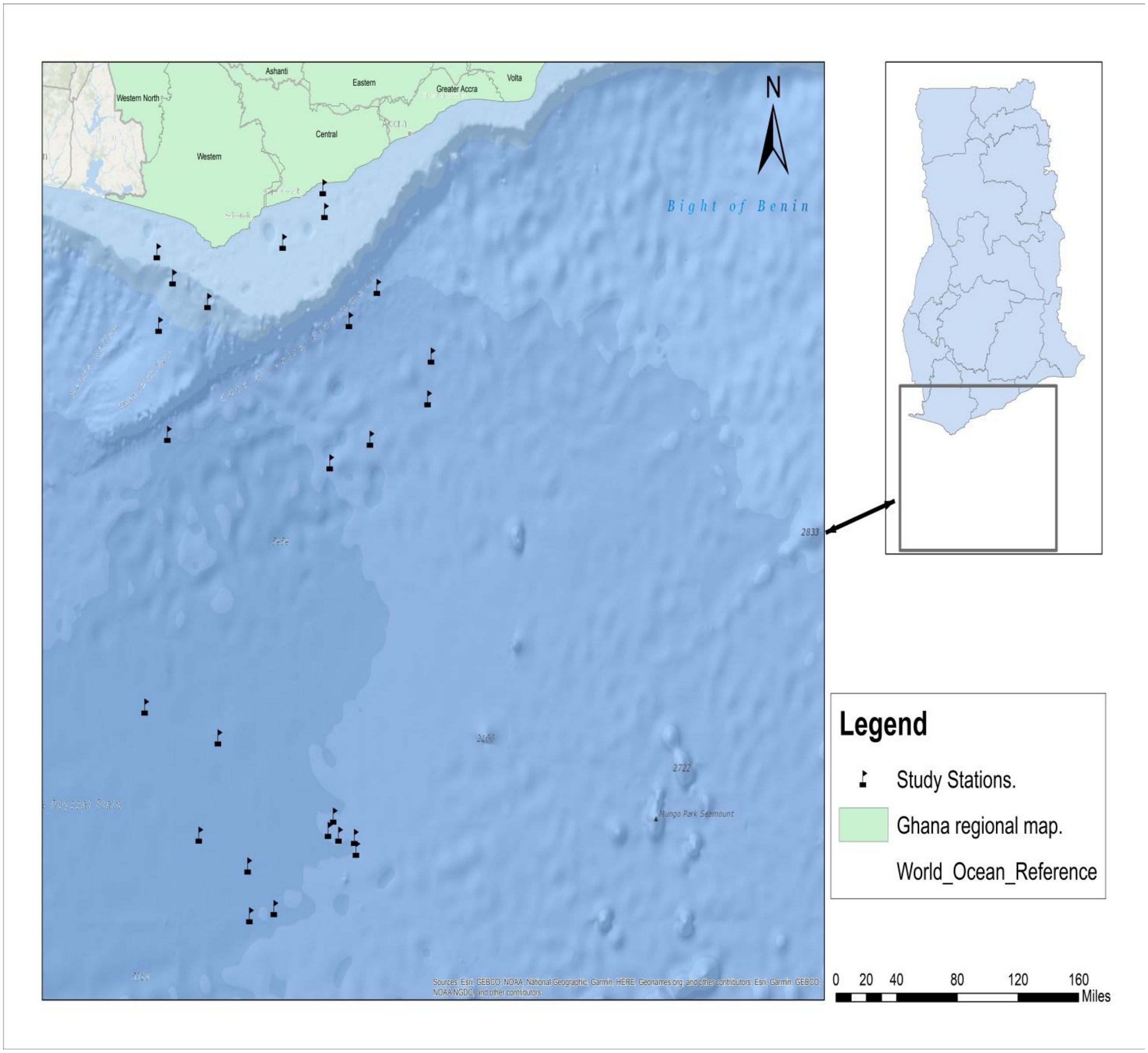


Figure 3.1: Map of Ghana showing the study area.

## 3.2 Field procedure

From October 2019 to March 2020, data were collected onboard from three tuna fleets (Atlantic Queen, Panofi Frontier, and Marine 707). The data were collected from different fishing grounds, off the Ghanaian coast, on stomach content analysis of the three most common species of tuna (*Katsuwonus pelamis, Thunnus obesus,* and *Thunnus albacares*). The samples were taken during the fishing activities of the vessel. After the samples were taken from the fisher folks onboard, a total of 10 samples of each species of tuna (*Thunnus albacares*, *Katsuwonus pelamis*, and *Thunnus obesus*) were randomly selected from the population.

These samples were taken each month during fishing activities for six months, which started from October 2019 to March 2020. A total of 210 individual tuna species were sampled, out of which 90 were *Katsuwonus pelamis*, 60 *Thunnus albacares,* and 60 *Thunnus obesus* respectively. The study sampled 90 specimens for *Katsuwonus pelamis* because they are of high abundance and very common in Ghanaian waters than *Thunnus albacares* and *Thunnus obesus*. Samples were preserved in iced chests with ice block placed on top of the samples in the chest to prevent it from going bad or spoiling. The samples were transported to the Fisheries Scientific Survey Division (FSSD) laboratory in Tema for analysis.

### 3.3 Laboratory procedure

At the laboratory, total lengths, as well as fork length of the samples, were taken. The samples were measured to the nearest 0.1 cm using a 100 cm plastic fish measuring board. The weights of samples were also taken using an electronic digital balance with 0.01g accuracy (Abdul Hakim *et al.*, 2018).

The fish samples were dissected and their guts were removed for examination. Gut content analysis was conducted on each of the fish sampled after some morphometric data were collected on the field. The gut fullness was determined on a scale of 0/4 to 4/4. The 4/4 means full stomach, 3/4 implies a three-quarter full stomach, 2/4 indicates half-full stomach, 1/4 also implies quarter full stomach, and 0/4 means empty stomach. This information was determined using eye estimation (Abdul Hakim *et al.*, 2018).

The contents of the stomach were emptied into petri dish and spread it out with a forceps for ease of identification. The individual food items were sorted and identified using FAO fish identification guides 2012, FishBase (Electric Media, 2020) research.calacademy.org (Electric Media, 2020), FAO Fishfinder, 2014 and World Register of Marine Species (Electric Media, 2020).

The contents were observed under a binocular microscope which was magnified to about 100X for further identification. The individual food items were counted and the volume was determined using the displacement method. The prey occurrence was determined as a ratio of the number of the stomach in which each food item occurs over the total number of stomachs containing food items (Abdul Hakim *et al.*, 2018). The research identified individual food items to the species level where was possible.

### 3.4 Data analysis

The feeding habit of the three most common species of tuna (*Katsuwonus pelamis, Thunnus obesus,* and *Thunnus albacares*) were assessed using percent composition by number (N), percent composition by weight (W) model, and frequency of prey occurrence (O). The Index of Relative Importance (IRI) was also applied in the study. The following mathematical formulas were used to calculate the data taken from the samples.

Percentage by Number, $N = \frac{Ni}{\sum_{i1}^{Q} Nt} \times 100$…………………... (1)

Where Ni is the total number of prey items i and Nt is the total number of all prey items found in the stomach of the fish (Hureau, 1970).

Percentage by Weight, $W = \frac{Wi}{\sum_{i1}^{Q} Wt} \times 100$……………….…... (2)

Where Wi is the total weight of prey item i and Wt is the total weight of all prey items found in the stomach of the fish (Hyslop, 1980).

Frequency of occurrence, $FO = \frac{Ji}{P} \times 100$…………………...... (3)

Where Ji is the number of fishes containing prey items i and P is the number of fishes with food in their stomach (Hyslop, 1980).

The Index of relative importance was also used to summarize and rate food items found in the stomach of these tuna species (*Thunnus albacares*, *Katsuwonus pelamis*, and *Thunnus obesus*) in the order of importance to the species. This is mathematically expressed as:

Index of relative importance, IRI= (%N+%W) % FO………………..…. (4)

Jaccard's index was used to compare the prey item similarities between *Thunnus albacares*, *Katsuwonus pelamis*, and *Thunnus obesus*. The Mathematical formula for Jaccard's Similarity index ($C_j$) was;

Jaccard's Similarity index, $C_j$=J/ (A+B-J)…....................................... (5)

Where, $C_j$= Jaccard's Similarity index, A= number of prey items found in the stomach of species one (1), B= number of prey items found in the stomach of species two (2), J= number of prey items found in the stomach of both species. The interpretation of values from result obtain using Jaccard's Similarity index is important in ecological studies (Aikins *et al*., 2017). The following are used to explain Jaccard's Similarity index results;

If the value is < 0.25, then the similarity is very low (indicating a very high ß-diversity).

If the value is between 0.25 - 0.50, then the similarity is moderate (indicating moderate diversity).

If the value is between 0.50 - 0.75, then the similarity is high (indicating low ß-diversity).

If the value is > 0.75, then the similarity is very high (very low ß-diversity).

Microsoft Excel was used to compile all the data collected on the species before the analysis was done. All the data were analyzed using Analysis of variances (ANOVA) and Tukey test for multiple comparisons of the prey items found in the stomachs of all the three tuna species (*Thunnus albacares*, *Katsuwonus pelamis*, and *Thunnus obesus*). GenStat (12th Edition) and SPSS (23rd Edition) were the statistical packages used in the data analysis. The degree of freedom used in the analysis for both ANOVA and the Tukey multiple comparisons test was 95%.

# CHAPTER FOUR

# RESULTS

## 4.1 Stomach content

Table 4.1 shows the number of *Thunnus albacares, Katsuwonus pelamis, and Thunnus obesus* stomachs sampled.

It was observed that the stomach contents consisted of cephalopods, fishes, molluscs, and crustaceans. In addition to these, some squid beaks particles were also found in the stomachs of these tuna species which were used in determining the prey item in the stomach. The percentage composition by the number of stomach contents shows that crustaceans formed 36%, fishes 53%, molluscs 11%, and unidentified 4% with respect to *Thunnus albacares*.

Table 4.1: Total number of stomachs sampled for the three tuna species

| | | | **Empty stomach** | | **Non-empty stomach** | |
|---|---|---|---|---|---|---|
| **Species** | **Number of sample** | **Length (FLT)** | **N** | **%** | **n** | **%** |
| Skipjack tuna | 90 | 46 – 67 | 9 | 10 | 81 | 90 |
| Yellowfin tuna | 60 | 52 – 120 | 3 | 5 | 57 | 95 |
| Bigeye tuna | 60 | 56 – 112 | 1 | 1.7 | 59 | 95 |

**4.2 Yellowfin tuna (*Thunnus albacares*)**

The size range of *Thunnus albacares* sampled for the study ranges from 52cm to 120 cm with an average fork length of 82 cm. In all the 60 *Thunnus albacares* stomachs examined, 3 samples were unfilled. The investigation was based on 57sampled stomachs that contained prey items. The Visual examination of the dissection of tuna stomach showed that the proportion of 4/4, 3/4, 2/4and 1/4 was 24.3%, 9.2%, 32.5%, and 29.1% respectively (Fig 4.1). The food items in the stomach formed 0.1 to 1.7% of the wet body weight of *Thunnus albacares*. The food items were grouped into four (4) categories namely; fishes, crustaceans, molluscs, and unidentified (Fig 4.2), fishes formed the majority (53%) of the diet of *Thunnus albacares*.

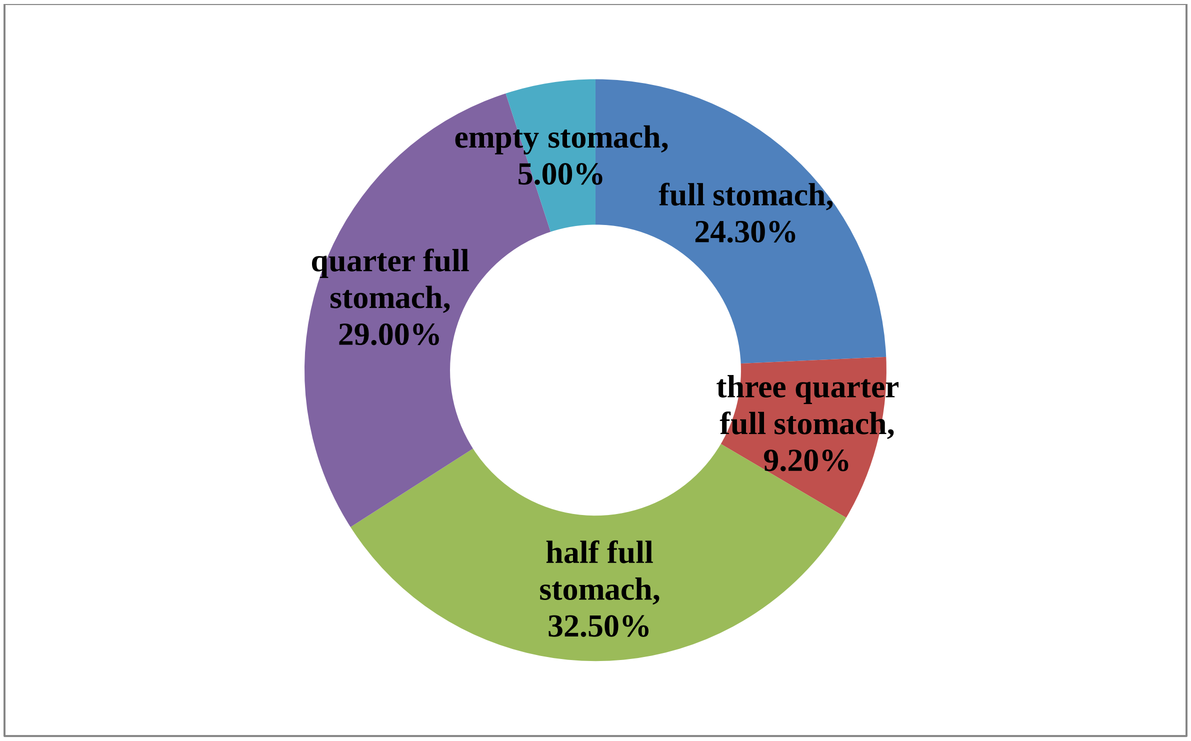


Figure 4.1: Proportion of stomach fullness for *Thunnus albacares*

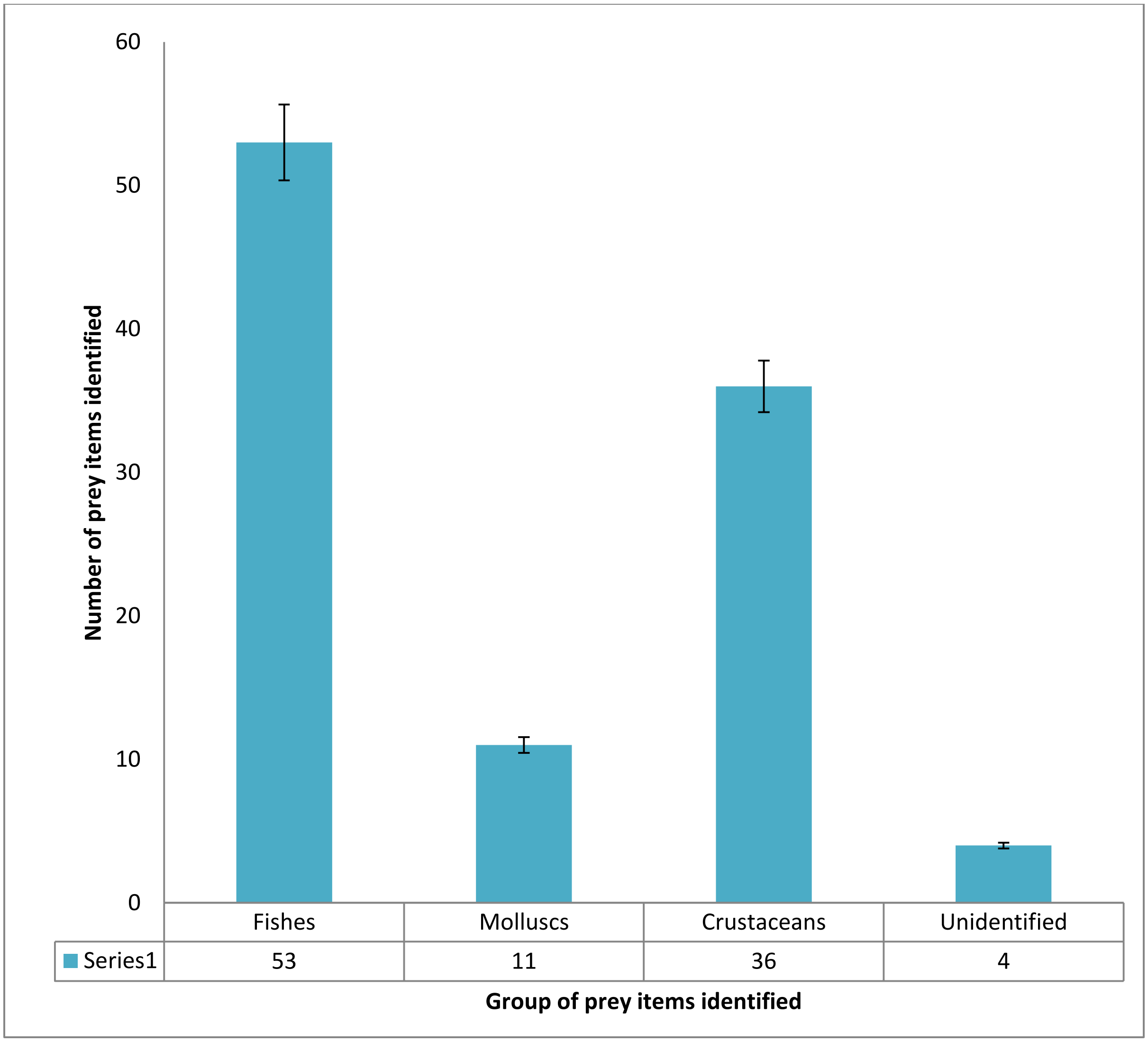


Figure 4.2: Prey species composition in the stomach of *Thunnus albacares*

The diversity in the prey composition was 15 families of fishes, crustaceans, molluscs, and other unidentified species which were observed during the research (Table 4.2). Fishes were the most dominant food item in the gut content (53%) followed by crustaceans (36%) and molluscs (11%). The partially digested unidentified food content comprises 4%. Fish dominated the food by occurrence (58 %), and crustaceans by number (40%). Table 4.2 shows that *Engraulis encrasicolus*, *Exocoetus spp,* and *Penaeus kerathurus* were the important prey species found in the gut of *Thunnus albacares*. *Engraulis encrasicolus,* the most important and most preferred prey item to the *Thunnus albacares*. The *Sepia hierredda is* a medium important food item found in the feeding habit of *Thunnus albacares*. *Boops boops* and *Diplodus* spp was less important prey item consumed by *Thunnus albacares*.

Index of Relative Importance (IRI), the main prey item for *Thunnus albacares* was fishes (69.47%) where *Engraulis encrasicolus* was the most preferred and important food item representing 57.9 % of the entire occurrence of the prey items with IRI of 37.6% (Table 4. 2). The additional important food items by occurrence were juveniles and adults of *Exocoetus* spp, *Caranx crysos*, *Sardinella* spp, *Pagellus* spp, and *Belone belone*. The occurrence of juvenile species of *Atherina* spp, *Scomber* spp, *Diplodus* spp, and *Boops boops* as food content was marginal. Crustaceans were also abundant prey in the gut of *Thunnus albacares*.

The Index of Relative Importance of the total crustaceans analyzed was 16.2%. Although *Penaeus kerathurus* was more numerically abundant (40.4%) but *Metapenaeus monoceros* was less important in the diet forming 10.5% of entire prey wet weight with an IRI of 14.5. The *Sepia hierredda* and *Loligo* spp represented the molluscs prey item in the stomach with an IRI of 12.2%. These food items are presented in Table 4.2.

Table 4.2 shows the results obtained from the analysis of *Thunnus albacares* gut contents. A total of 1361 prey items belonging to 15 families were identified and 67 prey items were unidentified (partially digested and unknown organisms), which consist of 8 families of fish, 2 families of molluscs, and 5 families of crustaceans.

Table 4.2: Results of stomach content analysis for *Thunnus albacares*

| **Group** | **Family** | **Name of prey species** | **Prey number** | **Prey number (%)** | **Prey weight (g)** | **Prey weight (%)** | **Frequency of occurrence (%)** | **Index of Relative Importance (IRI) (%)** |
|---|---|---|---|---|---|---|---|---|
| Fish | Engraulidae | *Engraulis encrasicolus* | 312 | 22.9 | 4351.7 | 28.2 | 57.9 | 37.59 |
| | Sparidae | *Boops boops* | 3 | 0.2 | 76.1 | 0.5 | 3.5 | 0.03 |
| | | *Diplodus* spp | 2 | 0.1 | 64.2 | 0.5 | 1.8 | 0.01 |
| | | *Pagellus* spp | 18 | 1.3 | 234.6 | 1.5 | 14.0 | 0.49 |
| | Scombridae | *Scomber* spp | 5 | 0.4 | 19.8 | 0.1 | 5.3 | 0.03 |

| Group | Family | Name of prey species | Prey number | Prey number (%) | Prey weight (g) | Prey weight (%) | Frequency of occurrence (%) | Index of Relative Importance (IRI) (%) |
|---|---|---|---|---|---|---|---|---|
| | Clupeidea | *Sardinella aurita* | 28 | 2.1 | 412.3 | 2.7 | 24.6 | 1.50 |
| | Atherinidae | *Atherina* spp | 3 | 0.2 | 69.2 | 0.4 | 3.5 | 2.67 |
| | Belonidae | *Belone belone* | 6 | 0.4 | 382.6 | 2.5 | 7.0 | 0.26 |
| | Exocoetidae | *Exocoetus* spp | 270 | 19.8 | 3457 | 22.4 | 49.1 | 26.36 |
| | Carangidae | *Caranx crysos* | 82 | 6.0 | 36.4 | 0.2 | 29.8 | 2.35 |
| Molluscs | Sepiidae | *Sepia hierredda* | 120 | 8.8 | 2876.4 | 18.6 | 35.1 | 12.22 |
| | Loliginidae | *Loligo* spp | 137 | 10.1 | 90.3 | 0.6 | 8.8 | 1.19 |
| Crustaceans | Penaeidae | *Penaeus kerathurus* | 147 | 10.8 | 2704.7 | 17.5 | 40.4 | 14.53 |
| | | *Metapenaeus monoceros* | 28 | 2.1 | 212.6 | 1.4 | 10.5 | 0.47 |

| Group | Family | Name of prey species | Prey number | Prey number (%) | Prey weight (g) | Prey weight (%) | Frequency of occurrence (%) | Index of Relative Importance (IRI) (%) |
|---|---|---|---|---|---|---|---|---|
| | Squillidae | *Squilla mantis* | 134 | 9.8 | 134.2 | 0.9 | 8.8 | 1.19 |
| | Isopoda | | 38 | 2.8 | 67.8 | 0.4 | 7.0 | 0.28 |
| | Decapoda | | 6 | 0.4 | 17.6 | 0.1 | 10.5 | 0.07 |
| | | *Brachyuran* spp | 18 | 1.3 | 5.2 | 0.0 | 7.0 | 0.12 |
| Unidentified | | | 67 | 4.9 | 211.8 | 1.4 | 15.8 | 1.26 |

### 4.3 Skipjack tuna (*Katsuwonus pelamis*)

The fork length of *Katsuwonus pelamis* measured during the studies ranged from 46 to 67 cm. Out of 90 stomachs sampled, only 9 samples were empty, whereas the remaining 81 samples contain at least one prey item in the stomach. The investigation was based on 81 guts containing food items. The stomach content analysis conducted on *Katsuwonus pelamis* identified four (4) groups of prey species, namely molluscs, fishes, crustaceans, and unidentified. The partially digested prey items are made up of fish, crustacean, and molluscs. A total of 925 food items were encounter, belonging to 7 families and 26 prey items were partially digested (unidentified), which comprise 4 families of fish, 2 families of molluscs, and 1 family of crustaceans.

The observations made on the dissected *Katsuwonus pelamis* stomach indicates that proportion of stomach fullness were full (4/4), three-fourth full (3/4), half full (2/4) and one-fourth full (1/4) was 33%, 28%, 21%, and 8% respectively (Fig 4.3). The prey contents were found to be 0.1 to 1.5% of the wet body weight. The food items were grouped into four (4) categories namely; fishes, crustaceans, molluscs, and unidentified (Fig 4.4).

Crustaceans were the most dominant food item in the gut content (54.7%) followed by fishes (31.5%) and molluscs (11%). The partially digested (unidentified) prey items are made up of 2.8% of total prey items found in the stomach (Fig 4.4).

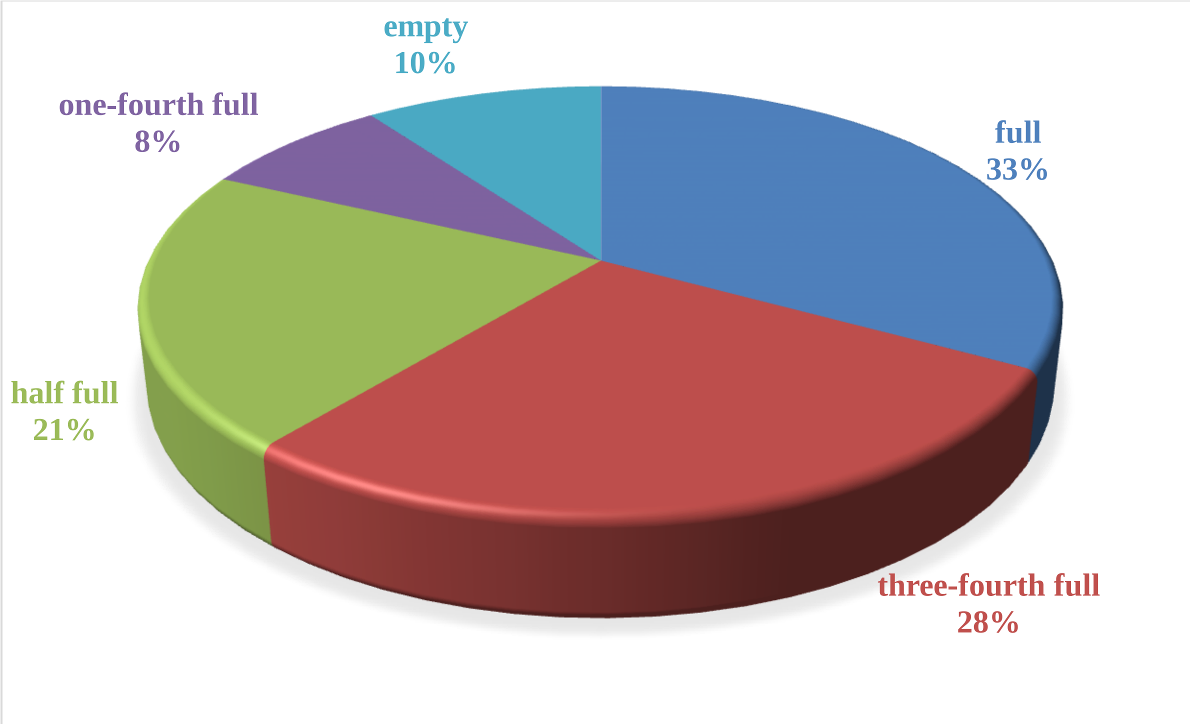


Figure 4.3: Proportion of stomach fullness for *K. pelamis*

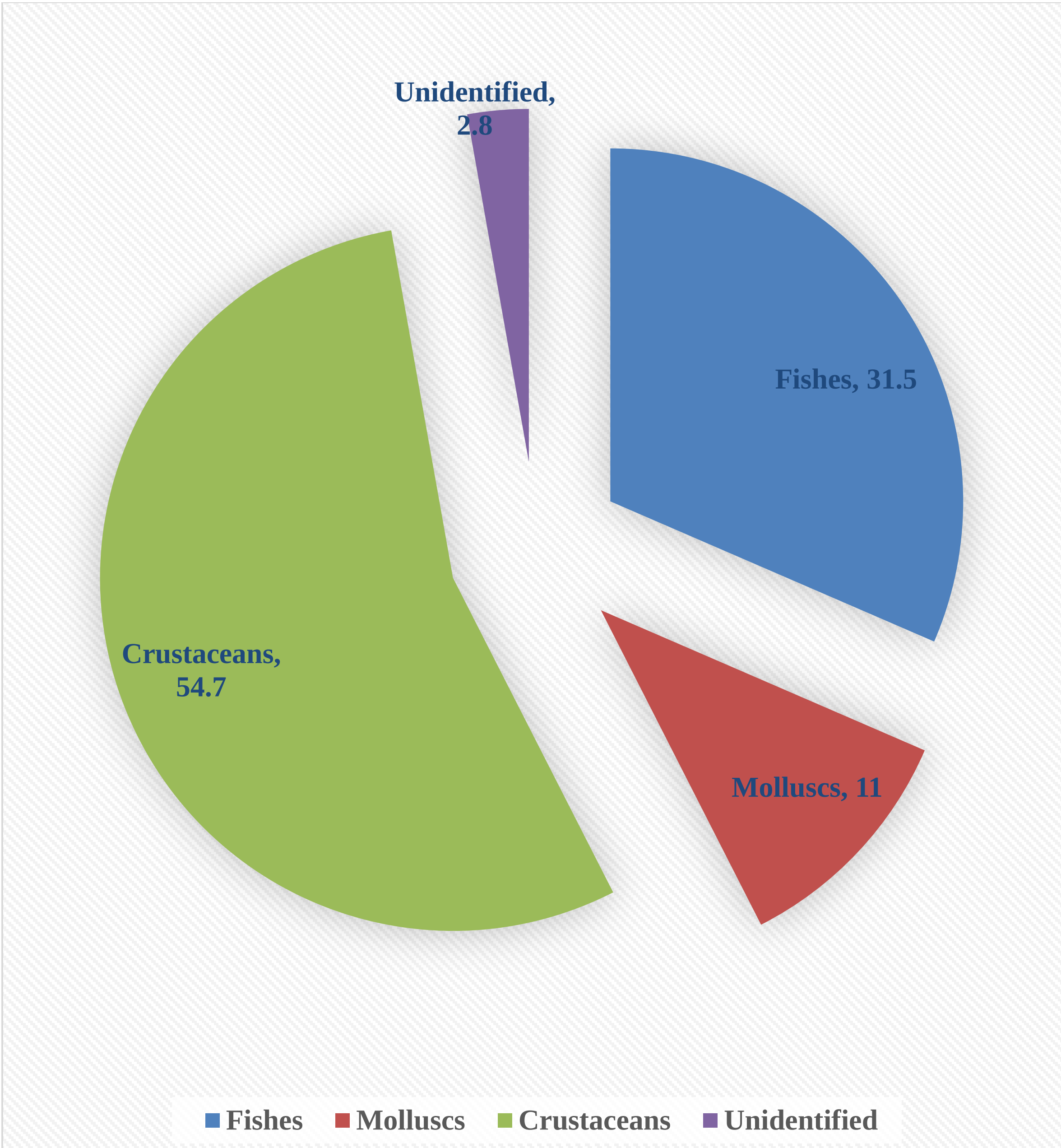


Figure 4.4: Major prey groups in the stomach *Katsuwonus pelamis*

Table 4.3 shows that Crustaceans dominate the diet by occurrence (57%), followed by fish by representing (42%) in terms of prey items groupings.  From the results presented in (Table 4.3) shows that both juvenile and adult of *Penaeus kerathurus*, *Engraulis encrasicolus*, *Brachyuran* spp, and Mackerel spp were the preferred and important prey species found in diets of *Katsuwonus pelamis*. The *Sardinella* spp, *Loligo* spp as well as Lancet fish were also moderate preferred prey items found in diets of *Katsuwonus pelamis*. Lobster and *Sepia hierredda* are less preferred food items for this species.

For Index of Relative Importance (IRI), the key prey item identified in the stomach of *Katsuwonus pelamis* was crustaceans (42%), of which the majority of this food item is made up of *Penaeus kerathurus*. *Penaeus kerathurus* were the most important and preferred prey item representing 57 % of a total occurrence of the prey items with IRI of 39% (Table 4.3). The other essential food items by occurrence were *Brachyuran* spp *a*nd Lobster. The occurrence of these two prey species as food items in the stomach of *Katsuwonus pelamis* was marginal. Fishes were also abundant food items found in the stomachs of *Katsuwonus pelamis*.

The Index of Relative Importance of the total fishes analyzed was 36.4%. Even though *Engraulis encrasicolus* were more numerically abundant (42%), Mackerel spp were important in the diets forming 37% of total food wet weight with an IRI of 22.5%. The *Loligo spp* and *Sepia hierredda* represented the molluscs prey item in the stomach with an IRI of 6.3%.

Table 4.3: Results of the stomach content analysis for *Katsuwonus pelamis*

| Group | Family | Name of prey species | Prey number (n) | Prey number (%) | Prey weight (g) | Prey weight (%) | Frequency of occurrence (%) | Index of Relative Importance (IRI) (%) |
|---|---|---|---|---|---|---|---|---|
| Crustacean | Penaeidae | *Brachyuran* spp | 180 | 12.5 | 582 | 17.4 | 37.0 | 14.6 |
| | | *Penaeus kerathurus* | 210 | 22.7 | 956 | 28.6 | 56.8 | 38.5 |
| | | Lobster | 116 | 6.1 | 185 | 5.5 | 14.8 | 2.3 |
| Fish | Engraulidae | *Engraulis encrasicolus* | 56 | 19.5 | 706 | 21.1 | 42.0 | 22.5 |
| | Scombridae | *Mackerel* spp | 111 | 12.0 | 132 | 4.0 | 37.0 | 7.8 |
| | Clupeidae | *Sardinella aurita* | 46 | 5.0 | 79 | 2.4 | 34.6 | 3.4 |
| | Alepisauridae | Lancetfish | 78 | 8.4 | 112 | 3.4 | 17.3 | 2.7 |
| Molluscs | Loliginidae | *Loligo* spp | 72 | 7.8 | 415 | 12.4 | 23.5 | 6.3 |

| Group | Family | Name of prey species | Prey number (n) | Prey number (%) | Prey weight (g) | Prey weight (%) | Frequency of occurrence (%) | Index of Relative Importance (IRI) (%) |
|---|---|---|---|---|---|---|---|---|
| | Sepiidae | *Sepia hierredda* | 30 | 3.2 | 98 | 2.9 | 9.9 | 0.8 |
| Unidentified | | | 26 | 2.8 | 75 | 2.2 | 16.0 | 1.1 |

### 4.4 Bigeye tuna (*Thunnus obesus*)

The size range of *Thunnus obesus* sampled during the studies ranged from 56 to 112 cm. The observed samples of all the 60 *Thunnus obesus* stomachs analyzed, one was empty while 59 stomachs were with food. The examination of the dissected *Thunnus obesus* showed the quantity of full stomach, three - fourth full stomach, half-full stomach, one - fourth full stomach and empty were 44%, 10%, 16%, 28%, 2% respectively (Fig 4. 5).

The stomach content analysis conducted on *Thunnus obesus* identified four categories (groups) of food items, namely fishes, molluscs, crustaceans, and unidentified. The fully digested prey items were made up of fish, crustacean, and molluscs. Fishes were the most dominant prey items found in the stomach content (75%), followed by Crustaceans (22%) and molluscs (3%). The unidentified prey item was 1%.

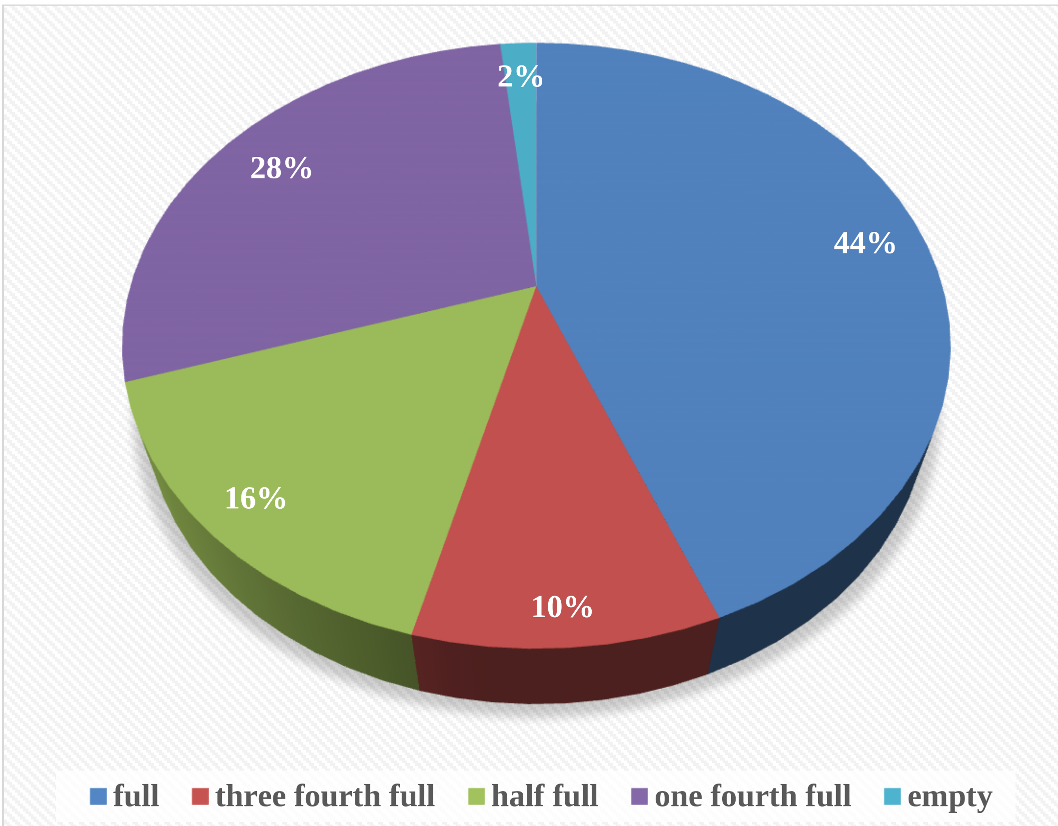


Figure 4.5: Stomach fullness of *Thunnus obesus*

Table 4.4, shows that the undigested prey items found in the stomach of *Thunnus obesus* were both adults and juveniles of *Exocoetus* spp, *Engraulis encrasicolus*, *Sardinella* *aurita*, *Caranx hippos*, *Decapterus* spp, *Brachyuran* spp, *Penaeus kerathurus, Metapenaeus monoceros*, *Loligo* spp and other unidentified species. The most copious prey item observed in the gut of *Thunnus obesus* was *Exocoetus* spp followed by *Engraulis encrasicolus*. *Metapenaeus monoceros* was very low in abundance. Based on the grouping of prey items observed in the stomach of *Thunnus obesus*, fishes were the most preferred food in their diet (75%), while Crustacean as the complementary food item (22%), Molluscs as the additional diet (3%) and unidentified fishes (1%).

For Index of Relative Importance, the main food item identified in the gut of *Thunnus obesus* were fish species (83%), of which the majority of this food item is made up of *Exocoetus spp*. *Exocoetus spp* was more important and preferred prey items representing 86% of the overall occurrence of the food items with IRI of 27% (Table 4.4). The other important prey items by occurrence were *Decapterus spp*, *sardinalla spp*, *Engraulis encrasicolus* and *Caranx hippos*. The occurrence of this species as prey items in stomach content was marginal. Crustaceans were also abundant prey items observed in the stomach of *Thunnus obesus*.

The Index of Relative Importance of the total crustaceans analyzed was 15%. Although *Penaeus kerathurus* was more numerically abundant (54%), *Brachyuran spp,* was less important in the diets making up to 42% of overall prey wet weight with an IRI of 13%. The *Loligo spp* also represents the molluscs prey item in the stomach sampled with an IRI of 2%. Table 4.4 shows the various prey items and their frequency of prey occurrence, IRI and other parameters.

Table 4.4: Results of stomach content analysis for *Thunnus obesus*

| Group | Family | Name of prey species | Prey number (n) | Prey number (%) | Prey weight (g) | Prey weight (%) | Frequency of occurrence (%) | Index of Relative Importance (IRI) (%) |
|---|---|---|---|---|---|---|---|---|
| Fish | Exocoetidae | *Exocoetus* spp | 386 | 26.6 | 1236 | 17.0 | 86.4 | 26.9 |
| | Engraulidae | *Engraulis encrasicolus* | 342 | 23.5 | 1012 | 13.9 | 67.8 | 18.1 |
| | Clupeidae | *Sardinella aurita* | 52 | 3.6 | 1190 | 16.4 | 78.0 | 11.1 |
| | Carangidae | *Caranx hippos* | 30 | 2.1 | 921 | 12.7 | 67.8 | 7.2 |
| | | *Decapterus* spp. | 272 | 18.7 | 1146 | 15.8 | 81.4 | 20.0 |
| Crustacean | Penaeidae | *Brachyuran* spp | 28 | 1.9 | 382 | 5.3 | 42.4 | 2.2 |

| Group | Family | Name of prey species | Prey number (n) | Prey number (%) | Prey weight (g) | Prey weight (%) | Frequency of occurrence (%) | Index of Relative Importance (IRI) (%) |
|---|---|---|---|---|---|---|---|---|
| | | *Penaeus kerathurus* | 282 | 19.4 | 986 | 13.6 | 54.2 | 12.8 |
| | | *Metapenaeus monoceros* | 13 | 0.9 | 132 | 1.8 | 11.9 | 0.2 |
| Molluscs | Loliginidae | *Loligo spp* | 38 | 2.6 | 122 | 1.7 | 47.5 | 1.5 |
| | Unidentified | | 10 | 0.7 | 148 | 2.0 | 8.5 | 0.2 |

## 4.5 Prey Species Similarities

Out of the twenty-three (23) prey species encountered during the research, nine (9) of them were shared prey species between the three tuna species at the study area. The shared species between the *Thunnus obesus* and *Katsuwonus pelamis* (8 species) was higher compared to the shared species between *Thunnus albacares* and *Katsuwonus pelamis* (5 species) as well as the *Thunnus obesus* and *Thunnus albacares* (Table 4.5).

However, from the qualitative Jaccard's Similarity Index ($C_J$), the species similarity was moderate for *Thunnus albacares* and *Katsuwonus pelamis* ($C_J$ =0.29). There was also a moderate species similarity ($C_J$=0.33) between *Thunnus obesus* and *Thunnus albacares*, this means that prey species detected in both tuna species were not different from each other. There was high similarity ($C_J$=0.52) between *Thunnus obesus* and *Katsuwonus pelamis* species, this indicates that the species detected in both *Thunnus obesus* and *Katsuwonus pelamis* are the same. Table 4.5 illustrate the calculated Jaccard's Similarity Index ($C_J$) for the three tuna species.

Table 4.5 shows that, although these three tuna species belong to the same Family Scombridae but do not have the same preference, with respect to the type of food they feed on in their respective habitat. This implies that they feed on different prey items and have specific prey items that are most important and most preferred to a particular tuna species.

Table 4.5: Qualitative Jaccard's species similarity indices for the three tuna species in the study area

| Tuna species | Qualitative Jaccard's Similarity index (shared species) |
|---|---|
| *Thunnus albacares* and *Katsuwonus pelamis* | 0.29 (5) |
| *Thunnus obesus and Thunnus albacares* | 0.33 (6) |
| *Thunnus obesus and Katsuwonus pelamis* | 0.52 (8) |

**$C_J$=J/ (A+B-J)**

Table 4.6 shows that there is no significant difference among the three (3) tuna species with respect to *Metapenaeus monoceros* (0.509) species of prey item found in their stomachs. Since significance value is greater than (0.05) for the objective.

On the other hand, there is a significant difference among these three tuna species with regard to *Engraulis encrasicolus* (0.000), *Sardinella aurita* (0.000), *Exocoetus spp*. (0.017), *Caranx crisos* (0.016), *Sepia hierredda* (0.002), *Loligo* spp. (0.004), *Squilla mantis* (0.009), Isopoda (0.006), and *Brachyuran spp*. (0.000) (Table 4.6).

Table 4.6: Analysis of variances (ANOVA) on prey items found in the stomach of the three tuna species

| | | ***Sum of Squares*** | ***df*** | ***Mean Square*** | ***F*** | ***Sig.*** |
|---|---|---|---|---|---|---|
| *Engraulis encrasicolus* | Between Groups | 538.177 | 2 | 269.089 | 11.401 | .000 |
| | Within Groups | 3091.882 | 131 | 23.602 | | |
| | Total | 3630.060 | 133 | | | |
| *Sardinella aurita* | Between Groups | 16.109 | 2 | 8.055 | 12.593 | .000 |
| | Within Groups | 49.891 | 78 | .640 | | |
| | Total | 66.000 | 80 | | | |
| *Exocoetus spp.* | Between Groups | 179.751 | 1 | 179.751 | 5.901 | .017 |
| | Within Groups | 2802.207 | 92 | 30.459 | | |
| | Total | 2981.957 | 93 | | | |
| *Caranx crysos* | Between Groups | 119.490 | 1 | 119.490 | 6.093 | .016 |
| | Within Groups | 1431.630 | 73 | 19.611 | | |
| | Total | 1551.120 | 74 | | | |
| *Sepia hierredda* | Between Groups | 41.287 | 1 | 41.287 | 10.882 | .002 |
| | Within Groups | 223.860 | 59 | 3.794 | | |
| | Total | 265.148 | 60 | | | |
| *Loligo spp.* | Between Groups | 49.173 | 2 | 24.586 | 5.792 | .004 |
| | Within Groups | 390.512 | 92 | 4.245 | | |
| | Total | 439.684 | 94 | | | |
| *Metapenaeus monoceros* | Between Groups | .056 | 1 | .056 | .444 | .509 |
| | Within Groups | 4.250 | 34 | .125 | | |
| | Total | 4.306 | 35 | | | |
| *Squilla mantis* | Between Groups | 77.652 | 2 | 38.826 | 4.920 | .009 |
| | Within Groups | 946.998 | 120 | 7.892 | | |
| | Total | 1024.650 | 122 | | | |
| Isopoda | Between Groups | 33.469 | 1 | 33.469 | 7.921 | .006 |
| | Within Groups | 321.146 | 76 | 4.226 | | |
| | Total | 354.615 | 77 | | | |

| | | ***Sum of Squares*** | ***df*** | ***Mean Square*** | ***F*** | ***Sig.*** |
|---|---|---|---|---|---|---|
| *Brachyuran spp.* | Between Groups | 368.207 | 2 | 184.104 | 11.464 | .000 |
| | Within Groups | 1927.159 | 120 | 16.060 | | |
| | **Total** | **2295.366** | **122** | | | |

The mean difference is significant at the 0.05 level

The result from table 4.7 show that, about 12 prey items were pelagic and 11 prey items were demersal species found in the stomach of the three tuna species. These prey items consumed by the tuna species are both adult and juvenile species of fish, crustacean and molluscs in the study area.

Table 4.7: Prey items found in the stomach of the three tuna species and their habitat

| **Tuna species** | **Name of prey item** | **Habitat of prey item** |
|---|---|---|
| *T. albacares*, *K. pelamis* and *T. obesus* | *Engraulis encrasicolus* | Pelagic species |
| *T. albacares* | *Boops boops* | Demersal species |
| *T. albacares* | *Diplodus* spp | Demersal species |
| *T. albacares* | *Pagellus* spp | Demersal species |
| *T. albacares* | *Scomber* spp | Pelagic species |
| *T. albacares*, *K. pelamis* and T. *obesus* | *Sardinella aurita* | Pelagic species |
| *T. albacares*, | *Atherina* spp | Pelagic species |
| *T. albacares* | *Belone belone* | Pelagic species |
| *T. albacares* and *T. obesus* | *Exocoetus* spp | Pelagic species |

| | | |
|---|---|---|
| *T. albacares* | *Caranx crysos* | Pelagic species |
| *T. albacares, K. pelamis* and *T. obesus* | *Sepia hierredda* | Demersal species |
| *T. albacares, K. pelamis* and *T. obesus* | *Loligo* spp | Demersal species |
| *T. albacares, K. pelamis* and *T. obesus* | *Penaeus kerathurus* | Demersal species |
| *T. obesus* | *Metapenaeus monoceros* | Demersal species |
| *T. albacares* | *Squilla mantis* | Demersal species |
| *T. albacares* | *Isopoda* | Demersal species |
| *T. albacares* | *Decapoda* | Demersal species |
| *T. albacares, K. pelamis* and *T. obesus* | *Brachyuran* spp | Pelagic species |
| *K. pelamis* | Lobster | Demersal species |
| *K. pelamis* | Mackerel spp | Pelagic species |
| *K. pelamis* | Lancetfish | Pelagic species |
| *T. obesus* | *Caranx hippos* | Pelagic species |
| *T. obesus* | *Decapterus* spp. | Pelagic species |

Appendix 3, shows, the significant difference among *Thunnus albacares*, *Thunnus obesus*, and *Katsuwonus pelamis* using Tukey test for multiple comparisons of prey items found in the stomach of these species.

For *Thunnus albacares* and *Katsuwonus pelamis*, the significant level is (0.000). Since this significant level is less than the (0.05) value needed for mean significance, these two tuna species are significantly different with respect to *Engraulis encrasicolus*.

For *Thunnus albacares* and *Thunnus obesus*, the results indicate no significant difference (sig= 0. 814 which is greater than (0.05). After each of the three tuna species were compared with each other with regard to *Engraulis encrasicolus*, the final results show that the feeding habits of *Thunnus albacares* and *Katsuwonus pelamis* are significantly different from *Thunnus obesus*, but *Thunnus albacares* and *Thunnus obesus* are not significantly different from each other in terms of prey items consumed.

# CHAPTER FIVE

# DISCUSSION

## 5.1 Species Composition in the stomach of *Thunnus albacares, Thunnus obesus and Katsuwonus pelamis*

The study sampled 210 individual tuna species, out of which 90 individuals were *Katsuwonus pelamis*, 60 individuals for *Thunnus albacares* as well as 60 individuals of *Katsuwonus Thunnus obesus* were collected for analysis. The study sampled 90 specimens for *Katsuwonus pelamis* because they are of high abundance and very common in Ghanaian waters than *Thunnus albacares* and *Thunnus obesus*. This is in line with a research conducted in Eastern India Ocean by Setyadji *et al*. (2012) and Nootmorn, *et al*. (2007). Therefore, the study sampled high number of *Katsuwonus pelamis* as against the other two tuna species which are of low abundance.

The diversity in the prey composition was about fifteen (15) families of fishes, crustaceans, molluscs and other unidentified species which indicate that, they are not selective feeders and that the feeding habit depends on prey availability rather than selectivity (Menard *et al*., 2006; Junior *et al*., 2003; Perera *et al.*, 2015). The analysis of food composition and feeding habit of tuna species in the Atlantic Ocean (Ghana) as discovered from the stomach contents analysis indicated table 4.2, 4.3, and 4.4, showed that fishes, crustaceans and molluscs were the most important component of food items found (Dissanayake *et al*., 2008; Prathibha Rohit *et al*., 2010; Perera *et al*., 2015; Nootmorn *et al*., 2008).

The study identified diverse prey items in the gut of these three tuna species during the analysis. The diversity of prey items identified is in concordance with a research conducted by Aikins *et al.,* (2017); Mahesh, (2019) and Mahesh *et al*. (2019), which indicates that the researcher's familiarity with the identification of stomach content can affects the prey numbers during analysis.

The observations made from this study indicate that most of the tuna species were an opportunistic predator (Setyadji *et al*., 2012; Menard *et al.*, 2006). The feeding on a multiplicity of suitable sized prey species, such as crustaceans and squids and this could be attributed to the size of the predator (tuna species) (Setyadji *et al*., 2012; Nakamura, 1965).

The food composition of three tuna species was dominated by a group of fishes as their main food items, crustaceans as complementary food item as well as molluscs as an additional food items (Perera *et al*., 2015; Setyadji. *et al*. 2012; Dissanayake *et al*., 2008). Similar result reported by Allain (2005a) in Western and Central Pacific for *Thunnus obesus, Thunnus albacares* and *Katsuwonus pelamis* where the important prey item found in the stomachs were fish, molluscs and crustaceans. According to research carried out by Setyadji *et al*. (2012) in Eastern Indian Ocean on *Katsuwonus pelamis, Thunnus albacares* and *Thunnus obesus* show that, the most important food items found in their stomachs were crustaceans, fish and molluscs. The finding from this report is in line with the outcome of the studies carry out in Ghanaian waters.

Setyadji *et al.* (2012) and Manko (2010), research studies indicates that fishes were the most important food items by weight for *Thunnus albacares* in equatorial zones of Indian Ocean. This is in support of the findings obtain form the study of food and feeding habits of the three tuna species investigated.

## 5.2 Comparison of Species Composition found in *Thunnus albacares, Thunnus obesus*, and *Katsuwonus pelamis*

There is no significant difference among the three tuna species with respect to *Metapenaeus monoceros* (0.509) species of prey item (Table 4.6) since the significant value is greater than the given significance level (0.05) for the research problem. The quantity of *Metapenaeus monoceros* consume is almost the same for all the three tuna species that's *Thunnus albacares, Thunnus obesus,* and *Katsuwonus pelamis.* This can be attributed to the work of Nootmorn, *et al*. (2007) and Perera *et al*. (2015), which indicates that the quantity of this prey item consumed by the three tuna species could be attributed to the fact that they were consumed together with other most important and preferred food items. It could also be attributed to the fact that they were the only readily available food for all the three tuna species (Setyadji. *et al*. 2012).

Moreover, there is a significant difference among the three tuna species with regards to prey items such as *Engraulis encrasicolus*, *Sardinella aurita*, *Excoetus* spp, *Caranx* *crysos*, *Sepia hierredda*, *Loligo* spp, *Squilla mantis*, *Isopoda* and *Brachyuran* spp (Table 4.6). The quantities consumed among the three tuna species were significantly different. This could be attribute to the fact that each of the three tuna species has different prey preferences that are important to them (Nootmorn, *et al*., 2007; Perera *et al*., 2015).

For *Thunnus albacares* and *Katsuwonus pelamis* comparison, there is a significant difference between these two tuna species with respect to *Engraulis encrasicolus.* Since the significant value (0.000) is less than 0.05 (Appendix 3). This implies that the quantities of *Engraulis encrasicolus* consumed by the two tuna species are statistically different from each other (Dissanayake *et al.*, 2008; Prathibha Rohit *et al*., 2010; Sivadas and Anasukoy, 1998).

For *Thunnus albacares* and *Thunnus obesus* comparison, there is no significant difference between the two (2) species with respect to *Engraulis encrasicolus*. Since the significant level (0.814) is greater than 0.05. This means that the quantity of *Engraulis encrasicolus* consumed by these two tuna species is almost the same. This finding can also be attributed to a study by Setyadji. *et al*. (2012) in Indian Ocean which indicates that, *Thunnus albacares* and *Thunnus obesus* preferred to feed on *Engraulis encrasicolus*.

For *Katsuwonus pelamis* and *Thunnus obesus* comparison, there is a significant difference between the two species with respect to *Engraulis encrasicolus*. Since the significant value (0.000) is also less than 0.05 (Appendix 3). Sivadas and Anasukoy,

(1998) and Manko (2010), investigation shows that *Katsuwonus pelamis* and *Thunnus obesus* feed on different prey items.

For *Thunnus albacares* and *Katsuwonus pelamis* comparison, there is no significant difference between the two tuna species with respect to *Sardinella aurita*. Since the significant level (0.894) is greater than (0.05). This finding is in line with research report by Perera *et al*. (2015) and Sivadas and Anasukoy, (1998) which shows that *Katsuwonus pelamis* and *Thunnus albacares* don't feed on the same prey items in Sri Lanka and Minicoy, Lakshadweep.

For *Thunnus albacares* and *Thunnus obesus* comparison, the significance value is 0.000 for that matter, there is a significant difference between the two tuna species with respect to *Sardinella aurita*. Since the significant value is less than 0.05 (Appendix 3). This finding can also be attributed to a study by Setyadji. *et al*. (2012) in Indian Ocean which indicates that, *Thunnus albacares* and *Thunnus obesus* preferred to feed on *Sardinella aurita*.

For *Thunnus obesus* and *Katsuwonus pelamis*, there is a significant difference between the two tuna species with respect to *Sardinella aurita*. Since the significant value of 0.000 is less than (0.05). This could attribute to the fact that each of the three tuna species has different prey preferences that are important to them (Nootmorn, *et al*., 2007; Perera *et al*., 2015).

For *Thunnus albacares* and *Thunnus obesus*, the significant value is (0.205). Since this value is greater than (0.05) level required for statistically significant, these imply that there is no significant difference between the two tuna species with respect to *Loligo* spp. This could attribute to the fact that each of the three tuna species has different prey preferences that are important to them (Nootmorn, *et al*., 2007; Perera *et al*., 2015).

For *Thunnus albacares* and *Thunnus obesus* comparison, there is a significant difference between the two tuna species. Since the significant level (0.003) is less than (0.05) with respect to *Caranx crysos*. This result can be attributed to the fact that *Thunnus albacares* and *Thunnus obesus* has different prey preferences that are relatively important to them (Dissanayake *et al.*, 2008; Prathibha Rohit *et al*., 2010; Nootmorn, *et al*., 2007; Perera *et al*., 2015).

**5.3 Prey Species Similarities**

There is a moderate species similarity of prey items identified in stomach content analysis among the three tuna species. This could be as a result of the fact that most prey tends to be captured by chance and may require a longer time in other to identify more prey items. However, Crustaceans are the most exclusive food source of surface swimming species including *Thunnus obesus, Thunnus albacares,* and *Katsuwonus* *pelamis* which has contributed to the moderate species similarity during the study (Batlagla *et al*., 2013). These tuna species feed primarily on pelagic and demersal fish species in Ghanaian waters which is similar to the finding of this study in Minicoy, Lakshadweep (Sivadas and Anasukoy, 1999). Similar result appeared in this study, with *Caranx crysos*, *Engraulis encrasicolus*, and *Penaeus kerathurus* also found in the stomach of tuna species.

The occurrence of *Caranx crysos* in all three tuna species stomachs was interesting because it by-catch in almost every tuna fisheries vessel in Ghana and Indonesia (Nugraha and Nurdin, 2006; Prisantoso *et al.*, 2010; Nugraha and Wagiyo, 2006; Barata and Prisantoso, 2009; Nugraha and Triharyuni, 2009). This happened because *Caranx crysos* plays an important role on pelagic food chain. These predators appeared to be the most active chaser of prey in the Ocean (Potier, 2004; Setyadji *et al*., 2012).

All the tuna species sampled for stomach content analysis were captured on Fish Aggregation Device (FAD) due to the behaviour of tunas following floating objects (Perrin *et al*., 1973) The gut content examines food composition associated with aggregation conducted by Grubbs *et al*., (2001) found that *Thunnus obesus* feed on vertically migrating species rather than crustaceans on FAD associated environment in waters. The result from this study also indicates that, the three tuna species feed on crustaceans that are constantly following FADs in Ghanaian waters. This finding is in line with a research conducted by Setyadji *et al*. (2012) and Grubbs *et al*. (2001).

# CHAPTER SIX

# CONCLUSIONS AND RECOMMENDATIONS

## 6.1 Conclusions

In conclusion, it was observed that these tuna species are not opportunistic feeders. Their prey item comprises mainly juvenile teleosts, crustaceans, and molluscs as their major food items. The most important and preferred prey items to these three tuna species (*Thunnus albacares*, *Katsuwonus pelamis*, and *Thunnus obesus*) were *Engraulis encrasicolus*, *Penaeus kerathurus* and *Exocoetus spp*, although *Sardinella aurita*, *Brachyuran spp*. *Decapterus spp.* and *Loligo spp*. were equally important prey items to these tuna species.

*Engraulis encrasicolus* was observed to be the most preferred food item accounting for 58% occurrence by number, with *Diplodus spp* being the least preferred food item accounting for 2% for *Thunnus albacares*.

The Index of Relative Importance of the total crustaceans analyzed was 16.2%. Although *Penaeus kerathurus* was more numerically abundant (40.4%) but *Metapenaeus monoceros* was less important in the food item forming 10.5% of entire prey wet weight with an IRI of 14.5%. The *Sepia hierredda* and *Loligo spp* represented the molluscs prey item in the stomach with an IRI of 12.2%.

*Penaeus kerathurus* was found to be the most preferred food item accounting for 57% occurrence by number, with *Sepia hierredda* being the least preferred food item accounting for 10% for *Katsuwonus pelamis*.

The Index of Relative Importance of the total fishes analyzed was 36.4%. Even though *Engraulis encrasicolus* were more numerically abundant (42%), Mackerel spp were important in the food item forming 37% of total food wet weight with an IRI of 22.5%. The *Loligo spp* and *Sepia hierredda* represented the molluscs prey item in the stomach with an IRI of 6.3%.

*Exocoetus spp* was found to be the most preferred food item accounting for 86% occurrence by number, with *Metapenaeus monoceros* being the least preferred food item accounting for 12% for *Thunnus obesus*.

The Index of Relative Importance of the total crustaceans analyzed was 15%. Although *Penaeus kerathurus* was more numerically abundant (54%), *Brachyuran spp,* was less important in the diets making up to 42% of overall prey wet weight with an IRI of 13%.

## 6.2 Recommendation

Based on the study conducted, the following was recommended.

- In order to determine the seasonal preferences for various prey species, further research should be conducted on these tuna species throughout the year.

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**APPENDICES**

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**Appendix 1: Biological Data Sheet (Field)**

Date ………………………….

Number of samples………………………

| No | Species | Fork Length(cm) | Set number | GPS Position | Remarks |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| | | | | | |
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**Appendix 2: Biological Data Sheet (Laboratory)**

Date ………………………….

Number of samples………………………

Total weight (kg)………………………………

| No | Species | ForkLength(cm) | Stomach weight(g) | Stomach fullness | Stomach contents | Contents weight(g) | Remarks |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
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**Appendix 3: Tukey test for multiple comparisons on prey items found in stomachs of these three tuna species**

| *Dependent Variable* | *(I) SPECIES* | *(J) SPECIES* | *Mean Difference (I-J)* | *Std. Error* | *Sig.* | *95% Confidence Interval* | |
|---|---|---|---|---|---|---|---|
| | | | | | | **Lower Bound** | **Upper Bound** |
| *Engraulis encrasicolus* | 1.0 | 2.0 | 4.3676* | 1.0956 | .000 | 1.770 | 6.965 |
| | | 3.0 | -.5882 | .9621 | .814 | -2.869 | 1.692 |
| | 2.0 | 1.0 | -4.3676* | 1.0956 | .000 | -6.965 | -1.770 |
| | | 3.0 | -4.9559* | 1.0956 | .000 | -7.553 | -2.359 |
| | 3.0 | 1.0 | .5882 | .9621 | .814 | -1.692 | 2.869 |
| | | 2.0 | 4.9559* | 1.0956 | .000 | 2.359 | 7.553 |
| *Sardinella aurita* | 1.0 | 2.0 | -.0969 | .2147 | .894 | -.610 | .416 |
| | | 3.0 | -1.0435* | .2358 | .000 | -1.607 | -.480 |
| | 2.0 | 1.0 | .0969 | .2147 | .894 | -.416 | .610 |
| | | 3.0 | -.9466* | .2147 | .000 | -1.459 | -.434 |
| | 3.0 | 1.0 | 1.0435* | .2358 | .000 | .480 | 1.607 |
| | | 2.0 | .9466* | .2147 | .000 | .434 | 1.459 |
| *Loligo spp.* | 1.0 | 2.0 | .8784 | .5118 | .205 | -.341 | 2.098 |
| | | 3.0 | 1.7245* | .5118 | .003 | .505 | 2.944 |
| | 2.0 | 1.0 | -.8784 | .5118 | .205 | -2.098 | .341 |
| | | 3.0 | .8462 | .5714 | .305 | -.515 | 2.207 |
| | 3.0 | 1.0 | -1.7245* | .5118 | .003 | -2.944 | -.505 |
| | | 2.0 | -.8462 | .5714 | .305 | -2.207 | .515 |
| *Squilla mantis* | 1.0 | 2.0 | -.2171 | .5674 | .923 | -1.564 | 1.130 |
| | | 3.0 | 1.8989* | .7257 | .027 | .177 | 3.621 |
| | 2.0 | 1.0 | .2171 | .5674 | .923 | -1.130 | 1.564 |
| | | 3.0 | 2.1159* | .6939 | .008 | .469 | 3.763 |
| | 3.0 | 1.0 | -1.8989* | .7257 | .027 | -3.621 | -.177 |

| *Dependent Variable* | *(I)* | *(J)* | *Mean* | *Std.* | *Sig.* | *95% Confidence Interval* | |
|---|---|---|---|---|---|---|---|
| | | 2.0 | -2.1159* | .6939 | .008 | -3.763 | -.469 |
| *Brachyuran spp*. | 1.0 | 2.0 | -2.4412 | 1.1011 | .072 | -5.054 | .172 |
| | | 3.0 | -5.0716* | 1.1375 | .000 | -7.771 | -2.372 |
| | 2.0 | 1.0 | 2.4412 | 1.1011 | .072 | -.172 | 5.054 |
| | | 3.0 | -2.6304* | .7854 | .003 | -4.494 | -.767 |
| | 3.0 | 1.0 | 5.0716* | 1.1375 | .000 | 2.372 | 7.771 |
| | | 2.0 | 2.6304* | .7854 | .003 | .767 | 4.494 |

The mean difference is significant at the 0.05 level. *1. Thunnus albacore 2.Katsuwonus pelamis 3. Thunnus obesus*