College of Basic and Applied Sciences

School of Biological Sciences

Assessment of the Security of Coastal Fishing Operations in Ghana from the Perspectives of Safety, Poverty and Catches

This thesis is submitted to the Department of Marine and Fisheries Sciences of the University of Ghana, Legon

By

Samuel Kweku Konney Amponsah

(10220975)

In partial fulfilment of the requirement for the award of MPhil Fisheries Science degree

Department of Marine and Fisheries Sciences

JUNE, 2015

DECLARATION

I, Samuel Kweku Konney Amponsah, do hereby declare that this dissertation consists entirely of my own work and that no part of it has been previously published or submitted for a degree or diploma elsewhere.

Samuel Kweku Konney Amponsah ………………………….……… Date: ……………….…………

MPhil Candidate

Professor Patrick K. Ofori- Danson ………………….………… Date: ………………………….

(Principal Supervisor)

Professor Francis. K. E. Nunoo ...…………….………………… Date: ...…………………….

(Co-Supervisor)

ABSTRACT

The study was conducted in four fish landing sampling stations along the southern coastline of Ghana, namely: Vodzah and Denu (both in the Volta Region) as well as Jamestown and Tema (both in the Greater Accra Region) from June, 2014 to January, 2015. The purpose of the study was to assess the security of coastal fishing operations in Ghana from three main perspectives, namely safety, poverty and fish catches. Data was obtained from both primary sources (field data) and grey literature by courtesy of FSSD and MCSD. A number of factors were found to impact the security of coastal fishing from the perspective of safety. These included total fines and the number of IUU infractions recorded in Ghana's coastal waters; awareness of fisheries regulation measures, compliance with fisheries regulations and the absence of government officials as the prominent enforcement agent of fisheries regulation measures. From the perspective of poverty, the security of coastal fishing was found to be under high risk with respect to high poverty head count, vulnerabilities and marginalization indicators. Similarly, the security of coastal fishing operations from the perspective of catches was also under high risk. This was because the calculated fishing mortality rates (F) (ranging from F=1.48 yr^{-1} to F= 2.92 yr^{-1}, compared to Fopt = 0.4M) were beyond the limit for sustainable fishing. Consequently, the estimated exploitation rates (E) for majority of the assessed fish species ranging from 0.53 to 0.76 were greater than the optimum level of 0.5, implying heavy exploitation. Further, the calculated lengths at first capture (Lc) (3.71 cm – 13.19 cm) were less than the calculated lengths at first maturity (Lm) (7.4 cm – 17.9 cm) indicating the presence of growth overfishing. It was concluded that the overall security of coastal fishing operations was under very high risk requiring urgent management attention. Some recommendations for effective management have

been provided including initiating community sensitization programmes and partition of marine patrols between Ghana Navy and Ghana Marine Police.

DEDICATION

This dissertation is dedicated to my parents, Mr. J. B. K. Amponsah and Miss Victoria Kwei, for their care and support. Their contribution to my education is beyond measure - may God richly bless them.

ACKNOWLEDGMENTS

This thesis would not have been successfully completed without the assistance from a number of people. First and foremost, I wish to express my heartfelt gratitude to my Principal Supervisor, Professor P.K Ofori-Danson for his professional guidance as well as his insights and knowledge of coastal fishing operations in Ghana. I would also like to thank Professors E. Nyarko and F.K.E Nunoo (both of the Department of Marine and Fisheries Sciences, University of Ghana) for their support and encouragement.

I acknowledge the financial support by courtesy of the ‘Fishing for Security’ project under the ‘Commonwealth of Australia through the Australia Agency for International Development’ (AusAID) to undertake this research.

A special appreciation goes to the technicians (Messrs. James Akomeah-(retired), Emmanuel Klubi, Kofi Ayan and Mario Boateng); teaching assistants (Agbemabiese Nunana, Nii Amaquaye Commey and Jeremiah Azu) and the 2014/2015 4th year students (Benita, Genève and Selase) at the Department of Marine and Fisheries Science, University of Ghana for their assistance in diverse ways.

Further, I salute the role of Messrs. Kofi Amador (Deputy Director of Fisheries Scientific Survey Division, Ghana) and Joseph Yeboah (Deputy Director of Monitoring, Controlling and Surveillance Division) for kindly facilitating access to data on annual catch for the selected fish species required for this research and data on IUU fishing recorded in Ghana’s coastal waters, respectively.

Finally, I am extremely grateful to my family and loved ones particularly Victoria, Joseph, Rachel, Barbara and Anita for their unending support, love, encouragement, and gift of time.

TABLE OF CONTENTS

Page

TABLE OF CONTENTS – (continued)

Page

TABLE OF CONTENTS – (continued)

Page

TABLE OF CONTENTS – (continued)

Page

TABLE OF CONTENTS – (continued)

Page

LIST OF APPENDICES

Page

LIST OF FIGURES

LIST OF FIGURES-(continued)

Page

LIST OF FIGURES-(continued)

Page

LIST OF TABLES

PLATE

LIST OF ABBREVIATIONS

CRC	: Coastal Resource Centre
CRFM	: Caribbean Regional Fisheries Mechanism
EFTEC	: Economics for the Environment Consultancy
EJF	: Environmental Justice Foundation
FAO	: Food and Agriculture organization
GoG	: Government of Ghana
GSS	: Ghana Statistical Service
MoFAD	: Ministry of Fisheries and Aquaculture Development
OCED	: Organization for Economic Co-operation and Development
UNCTAD	: United Nations Conference on Trade and Development
UNODC	: United Nations Office on Drugs and Crime
USAID	: United States Agency for International Development
IFAD	: International Fund for Agricultural Development
WFP	: World Food Programme
IICA	: Inter-American Institute for Cooperation on Agriculture
LI	: Legal Instrument
NDPC	: National Development Planning Commission
UNDP	: United Nations Development Programme
IUU	: Illegal, Unreported and Unregulated
WHO	: World Health Organization
WWC	: World Water Council
FEU	: Fisheries Enforcement Unit

LIST OF ABBREVIATIONS - (continued)

SPSS	: Social Package for Statistical Software
ANOVA	: Analysis of variance
VBGF	: Von Bertanlaffy Growth Function
FISAT	: FAO-ICLARM Stock Assessment Tools
VMS	: Vessel Monitoring System
AIS	: Automatic Identification System
IEZ	: Internal Economic Zone
MFMR	: Ministry of Fisheries and Marine Resources
US	: United States
RRAs	: Remote Rural Areas
MCS	: Monitoring, Control and Surveillance
DEEDI	: Department of Employment Economic Development and Innovation
IFPRI	: International Food Policy Research Institute
GDP	: Gross Domestic Product
MEY	: Maximum Economic Yield
UNEP	: United Nation Environmental Program
WTO	: World Trade Organization
TURFs	: Territorial User Rights in Fisheries
CCRF	: Code of Conduct for Responsible Fisheries
GLSS	: Ghana Living Standards Survey
EU	: European Union
UNICEF	: United Nations Children's Fund

LIST OF ABBREVIATIONS - (continued)

MRAG : Marine Resources and Fisheries Consultants

NPOA : National Plans of Action

CHAPTER ONE

1.0 INTRODUCTION

This chapter gives a brief overview of the background of the study; general and specific objectives; research questions; justification and organization of the study.

1.1 Background of the study

Humans have, for thousands of years, exploited fish populations for food, employment and profit. Thus, the last fifteen decades have seen massive increases in geographic reach and depth range, an unprecedented fishing intensity and a global commoditization of fishery products (Pitcher & Cheung, 2013). This huge irreversible depletion of marine biodiversity by location and depth partly due to intense fishing activities has led to a grand scale decline of marine capture fisheries (Christensen *et al.*, 2003; Swartz *et al.*, 2010). The declining trend in global marine catches has led some fisheries scientists to forecast the collapse of ocean fisheries (Worm *et al.*, 2006). More so, the trends in catches forecast that more stocks will become overexploited and collapse (Pitcher & Cheung, 2013). Massive degrees in the exploitation of fish populations has been linked to technological advances, weak governance, rising prices of fish food, fish demand and supply imbalances, narrow scientific focus and increase in human population (World Bank, 2004).

Consequently, FAO (2012a) has indicated that 70% of all world fish populations are unsustainably overexploited, while almost half of these have biomass collapsed to less than 10% of unfished levels. Also, the state of world fisheries for the past decade has reported that the net annual increase in global fish catches is close to zero with almost no improvement in sight, partly because the total global reported marine fish catch landings have stagnated at 80.0-82.7 million tonnes since the 2005 (FAO, 2012a; FAO, 2014). Nonetheless, the reduction in global marine capture fisheries comes along with other negative impacts, such as rapid decline in net income for fishers, endangers the livelihoods of fishers especially in the absence of alternative livelihoods; increase in price of food fish resulting in malnutrition among the vulnerable groups as well as a reduction in the contribution of the fisheries sector to the economic growth of coastal states at the macroeconomic level and food security (World Bank, 2004).

Focusing on the contribution of fish to food security, fish is known to be highly nutritious, rich in essential micronutrients, minerals, essential fatty acids and proteins, and represents an excellent supplement to nutritionally deficient cereal-based diets providing food for more than 1.5 billion people, particularly in low-income food-deficit countries (FAO, 2010). In view of the benefits accrued from fisheries, its importance was emphasized in the resolution adopted by Rio+20, the United Nations Conference on Sustainable Development during which the crucial role of healthy marine ecosystems, sustainable fisheries and sustainable aquaculture for food security and nutrition as well as in providing for the livelihoods of millions of people were stressed (Veitch *et al.*, 2012). However, the observed depletion of fish stocks, among other threats victimizing the fisheries sector globally, will not only diminish these benefits but will further worsen challenges currently encountered in ensuring the materialization of food security interventions for the increasing world population.

Notable among these threats are Illegal, Unreported and Unregulated (IUU) fishing activities, biodiversity losses, climate change, increasing fishing effort, fisheries subsidies and piracy.

Illegal, Unreported and Unregulated fishing appears as the single biggest threat to the diversity and local fishing community livelihoods. It includes all fishing that breaks fisheries laws or occurs outside the reach of fisheries laws and regulations. IUU fishing takes roughly 11-26 million tonnes of fish annually with an estimated fish value of US$ 10-26 billion (Agnew *et al.*, 2009). According to FAO (2014), IUU fishing motivated by economic gains happens due to corrupt administration and exploits weak management regimes especially in developing countries that lack capacity and resources for effective Monitoring, Control and Surveillance (MCS). In addition, open registry of fleet coupled with ease of reflagging has diluted flag state responsibility and enforcement contributing to the increasing tide of IUU fishing practices. In the wake of increasing tides of IUU fishing practices, FAO members have adopted the International Plan of Action to prevent, deter and eliminate IUU (IPOA-IUU) as a toolbox for use by all states in general, flag states, coastal states and port states (FAO, 2014). IPOA-IUU, a crucial plan to facilitate the prevention of IUU and enhance the sustainability of the fisheries sector required States to develop the National Plans of Action (NPOAs) by 2004 (FAO, 2004). However, after ten years, NPOAs have either not been developed or not been enforced by most African coastal states.

Further, maritime piracy poses a threat to the fisheries sector where pirates have been extending their attacks on fishing vessels, especially tuna fishing vessels, contributing to a decline in its economic contribution to national development. East African countries like Somalia, Comoros, Tanzania and Kenya have seen a marked decline in their fishing yields with exports of fish products from piracy - affected countries having dropped by 23.8 percent. For Seychelles, the cost of piracy stood at approximately 4 percent of the island's GDP in 2009 (UNCTAD, 2014).

In Nigeria where fishing is the second highest non-oil export industry, maritime pirate attacks on fishing trawlers have reached the point that many fishing boat captains refuse to sail. The attacks range from minor harassment to theft of fish cargo, engines and other materials on board; financial shakedowns; and the killing of fishermen (Nincic, 2009). In spite of recording at least 293 documented sea robberies and pirate attacks between 2003 and 2008 on its fishing vessels alone, Nigeria stands to lose up to US$600 million in export earnings due to piracy threats to its fisheries (Akinsanmi, 2008; Gabriel *et al.*, 2008). Though estimates concerning the cost of maritime piracy in Ghana is limited, maritime piracy issues are gradually becoming pervasive in Ghana's territorial borders. The resulting effects of these threats to food security will be most felt in Sub-Saharan Africa where the proportion of the malnourished population since 1970 keeps oscillating within the 33 to 35 percent range and achieving food security still remains a great challenge (FAO, IFAD & WFP, 2013).

Apart from being victimized by many threats, fisheries itself is observed by many (e.g. Hanich, 2014) as a catalyst for many marine related illegal activities such as trafficking of illicit drugs, humans, weapons and smuggling of immigrants. In maritime drug trafficking, the fisheries sector is seen as an integral component as a result of the multiple roles performed by fishing vessels and the fish itself. Fishing vessels in maritime drug trafficking are often used as transport vessels for point-to-point delivery of cocaine consignments, as transport from offloading mother ships to remote landing sites and commercial ports, and as the providers of offshore refueling and provisioning for "go-fast" boats in transit". According to United Nations Office on Drugs and Crime (UNODC), drug traffickers prefer using fish carcasses as hiding places for concealing illicit drugs as it makes the drugs so difficult to detect due to the strong smell that challenges drug detector dogs to find drugs hidden in fish (UNODC, 2011).

The fishing industry is also associated with human trafficking within which migrant labourers and fishers (both male and female or old and young) fall prey to human traffickers as victims of trafficking for the purpose of forced labour on board fishing vessels, rafts or fishing platforms, in port, or in fish processing plants. Victims of trafficking on board fishing vessels are frequently subjected to severe physical and psychological abuse which mostly ends in physical injuries and deaths induced by senior crew. Most victims of human trafficking at sea get tossed overboard when sick, injured or dead, while fishers who fall overboard in periods of struggle with traffickers are sometimes not rescued. Further, victims get locked up whilst at sea, introduced to threats of financial penalties such as non-payment or even threatened to be reported to the immigration authorities to facilitate deportation. Considering smuggling of humans, fishing vessels are known to be used as part of the 'modus operandi' of smuggling operations at sea and that fishers may be involved as transporters particularly in transporting migrants. Fishing vessels are reported to be available for use in facilitating migrant smuggling because depleted fish stocks have also led to an oversupply of fishing vessels (UNODC, 2011).

From unlawful maritime activities to unsustainable fishing practice, it is predicted that 75 per cent of coastal fisheries are expected to fall short of food needs by 2030 (Hanich, 2014). This foretold unpleasant future crisis in fisheries coupled with record food prices and drought (which are known to be pushing more people into poverty and hunger) will consequently increase the already 240 million people in sub-Saharan Africa, lacking adequate food for a healthy and active life (FAO, 2010).

In response to increased fisheries contribution to food security while identifying drivers for unlawful maritime activities especially in sub-Sahara Africa where marine conservation has implications for food security, many organizations aimed at sustainable fisheries resource use, have developed numerous scientific frameworks. Prominent among these developed scientific frameworks is that of Australian National Centre for Ocean Resources and Security (ANCORS), from University of Wollongong, Australia. ANCORS is an organization focused on sustainable fisheries in the West African coastal nations. In partnership with University of Cape Coast, Cape Coast and University of Ghana, Legon (both in Ghana), ANCORS seeks to identify the drivers of piracy, other unlawful maritime activities in the Gulf of Guinea, while evaluating the role of subsistence, artisanal, domestic industrial and foreign industrial fisheries in promoting or jeopardizing national and regional security. In harmony with ANCORS objectives, the security of fisheries is reviewed from three perspectives, namely an opportunity, a victim and a threat. These perspectives are elaborated below.

1.1.1 Fisheries as an opportunity

As an opportunity, fisheries provide increased resource rents to coastal countries. Resource rent is a key concept in the management of fisheries as it refers to a source of considerable wealth, potentially or actually available to society. Achieving resource rents which is an economic objective of fisheries management relies on using Maximum Economic Yield (MEY) as a key management target (DEEDI, 2009). Empirical studies in a wide range of multispecies fisheries have suggested that fishing at MEY (F_{MEY}) will require fleet reductions in excess of 50% to maximize economic profits (Clark, 1990). Though this reduction in capacity necessary to achieve MEY is accompanied by a reduction in employed fishers, it redirects these affected fishers towards embracing alternative livelihoods, while allowing fish stocks buildup especially in areas that are experiencing collapsed fisheries. Fishing at MEY will maximize economic profit to the remaining vessel owners, and is also likely to increase wages of the remaining crew depending on the share system used in the fishery and the state of the stocks. Indeed, it has been demonstrated empirically and results show that moving to MEY is likely to have an overall positive economic benefit to the economy both at the macro and micro economic levels, at least in the longer term (Norman-Lopez & Pascoe, 2011). However, if the potential of this management target (MEY) is not well understood and there are no limits on fishing effort, this wealth will not be realized. Again, the potential resource rents can easily be squandered on excess capacity, leading to depletion of fisheries resources. Inspite of the potential benefits accrued from fisheries, the fisheries sector is victimized by a number of threats.

1.1.2 Fisheries as a victim

Considering victimization to the fisheries sector, coastal fishing operations in Ghana is no exception. In that regard, the fisheries sector in Ghana has been victimized by a number of threats such as overfishing due to the increase in fishing efforts and the use of illegal fishing methods by sophisticated, industrial fishing vessels with pirate attacks gradually gaining grounds in its territorial borders. In the wake of depleting fish stocks in Ghana's coastal waters, poverty incidence among fishing households and their dependents' livelihoods have increased so much that very high school dropouts, child prostitution and teenage pregnancy have become a common sight in fishing communities along the coastline of the country (Asiedu *et al.*, 2013).

In an attempt to escape the harsh conditions of poverty, local fishermen resort to the use of bad fishing methods which include application of dangerous chemicals like the banned DDT, dynamite and also light fishing. Many also engage in the use of small-mesh sizes which harvest juvenile fish, whilst others also extract mangroves which serve as spawning grounds for many fish species for use as firewood. These unsustainable practices have further contributed to the collapse of many stocks of fish, possibly leading to extinction of fish species. Enforcement of fisheries regulations has become daunting as a result of inadequate human and material resources on the part the navy, the police and the judiciary in Ghana.

1.1.3 Fisheries as a threat

Aside the numerous threats confronting the fisheries sector, fishing, itself serves as a medium for perpetuating these threats mostly because of the deep involvement of fishing operators and fishers in transnational crime- a form of fisheries crime. In line with UNODC (2013), fisheries crime occurs when industrial fishing is used as a front page in money laundering and tax evasion as well as when fishing vessels are used as trafficking medium to transport illegal substances like weapons, drugs and people.

In agreement with the objectives of ANCORS, firsthand information concerning the security of coastal fishing operations in Ghana is required to ensure the development of strategies for effective management of Ghana's coastal fisheries resources.

1.2 Primary Objective

The primary objective of this study was to assess the security of coastal fishing in Ghana as proxy for ensuring secured sustainable fisheries for both future and present generations.

1.2.1 Specific objectives

The specific objectives for the study viewed the security of coastal fishing operations from three perspectives which were as follows:

i. To assess security from the perspective of safety based on indicators from coastal fishing operations arising from IUU fishing and level of compliance to fisheries regulations.

ii. To assess security from the perspective of poverty indices based on indicators from secondary livelihoods, poverty indices, marginalization from social amenities and vulnerabilities.

iii. To assess security from the perspective of fish catches based on indicators from fish catches; fish growth and mortality parameters, mean length at first maturity, mean length at first capture, recruitment and exploitation levels.

1.3 Research questions

To help achieve the overall aim, the specific objectives were used to answer the following research questions: How secured is the coastal fishing operation in Ghana from the perspectives of: i) safety, ii) poverty and iii) fish catches.

1.4 Justification

Good nutritional health and other socio-economic benefits accrued to Ghanaians, especially those living in the coastal communities, have long rested on fish consumption. Thus any significant decline in fish catches will not only deprive direct and indirect dependent livelihoods of such benefits but will also reduce their contribution to the economic growth of Ghana.

Illegal Unregulated Unreported (IUU) fishing denies a fishing nation of better contribution of the fishing industry to the stability of its gross development product (GDP) as well as increases the severity of poverty and migration among livelihoods that depend on fishery resources. This is as a result of the contribution of IUU fishing to dwindling fish catches as observed in Ghana.

Despite the overall poverty decline from 32 percent to 24 percent over the 2006-2013 period which reinforces the fact that Ghana has clearly achieved the Target 1A of the Millennium Development Goal 1, poverty appears to be prevalent among coastal fishing communities in Ghana which has the tendency to limit the achievement of Sustainable Development Goals (SDGs), particularly goals 1 and 14 in Ghana (FAO, 2015; UNDP-Ghana & NDPC/GOG, 2015).

1.5 Organization of the study

The study is structured in six chapters. Chapter one is this one which provides background to this study. Chapter two is a literature review which gives the theoretical background into issues related to overview of Ghana's fishing industry, fish population parameters, IUU issues, categorization of stock status, commercial fish species for the study and general perceptions about Ghana's coastal fisheries. Chapter three provides the methodology used for the study.

Chapter four qualitatively and quantitatively describes the results from the study. Chapter five provides discussions on key findings, while Chapter six completes the study with conclusions and key recommendations.

CHAPTER TWO

2.0 LITERATURE REVIEW

This chapter gives an overview of the theoretical issues related to the history of Ghana's fishing industry, monitoring the status of food security in developing countries, food security, security of coastal fishing from the perspectives of safety, poverty and fish catches.

2.1 Overview of the Ghanaian Fishing Industry

The total coastline of Ghana measuring about 550 km long comprises of long stretches of sandy beach characterized by rocky shores, estuaries and lagoons with ninety-two lagoons, of which some are described as open and others closed (Quartey, 1997; Koranteng, 1998). These lagoons, estuaries and the many wetlands dotting the coastline serve as nursery grounds for many marine fish and crustacean species. The fishing industry in the Ghanaian coastal waters is driven by the oceanography of the western Gulf of Guinea, which is divided into four regimes- short cold season in December-January of approximately three weeks (minor upwelling), long warm season between February and June, a long cold season between July and September and a short warm season in October – November (major upwelling season) (Mensah & Koranteng, 1988). The fishery sector of Ghana has two major components: the marine (sea and lagoons) and inland (lakes, rivers and reservoirs). The marine sector consists of a small-scale sector and industrial sector. The inland fishery is considered as small-scale. Nunoo *et al.* (2014) reports that the marine fisheries resource is exploited by a small-scale fleet of over 12,728 dugout canoes which operates from 334 landing sites and lands about 70% of the total marine fish production. At the industrial level, the fisheries resource is exploited by an inshore (semi- industrial) fleet of over 251 locally constructed wooden vessels operating from seven landing sites and land 2% of the total marine fish production. The steel vessels of the industrial fleet are made up of 142 bottom trawlers, 2 carrier vessels and 32 tuna vessels operating from two landing sites. This fleet lands the remaining 28% of the total fish production (Kwadjosse, 2009; WARFP, 2014; Amador, FSSD, personal communication, 2015).

It is estimated that Ghana's fish consumption is approximately one million metric tons annually, of which 400,000 metric tons is supplied by the marine capture fisheries. The deficit of 600,000 metric tons is supplied through import at a cost of 200 million US dollar annually (Tsibu, 2014). Depletion of fish stock through unorthodox means of fishing and growing population are some factors attributed to the inability of marine fishers to meet the fish demand of Ghanaians (Bannerman, 2014). Regarding depletion of stocks, both small pelagic and demersal stocks are heavily, if not overexploited. On the whole, the marine fishery resources are showing increasing signs of fully or overexploitation (Atta-Mills *et al.,* 2004). However, there is considerable uncertainty as to the exact contribution of inland fisheries to total production as statistical records are thought to considerably underestimate actual production (Kwadjosse, 2009). Despite the awakening signs of fully or overexploitation of the marine fisheries resources, the marine fisheries maintains its status as an important contributor to the Ghana's economy. This is because the fisheries sector accounts for 1.4 percent of Ghana's GDP (GSS, 2014). It is estimated that a total of 200,000 fishers are employed in the fisheries sector (with about 2 million dependents) (Amador *et al.*, 2006). The sector also plays a major role in sustainable livelihoods and poverty reduction in several fishing households and communities. Fishery and fishery products have gradually become the country's most important non-traditional export, accounting for over 50 percent of earnings from non-traditional export (Bank of Ghana, 2008). To ensure significant continual supply of coastal fisheries' contribution to the nation's GDP, there is the need to monitor fisheries resources resident in Ghana's coastal waters and fishing activities used in exploiting these fisheries resources (Kwadjosse, 2009).

2.2 Monitoring the status of food security in developing countries

Despite the significant role fish plays in food security, developing countries are facing enormous pressure on their fisheries resources from IUU fishing basically due to lack of 'monitoring, control and surveillance' communication and coordination between countries (Davis, 2000; FAO, 2014). Therefore, in monitoring marine fishing activities towards good fishery management, much emphasis is placed on ensuring that appropriate controls are set, monitored and complied with (FAO, 2002). In coastal states achieving good fishery management, with legal backings, is mostly the responsibility of the 'Monitoring, control and surveillance' (MCS) component of fisheries management. According to CRFM (2013), the definition of MCS most accepted by fisheries personnel is outlined as follows:

i. Monitoring – the continuous requirement for the measurement of fishing effort characteristics and resource yields which includes collecting, measuring and analyzing fishing activity. Data containing such information are primarily used by fisheries managers to make management decisions. The absence, inaccuracy or incompleteness of this information cripples managers in developing and implementing management measures (CRFM, 2013).

ii. Control – the regulatory conditions under which the exploitation of the resource may be conducted which are normally contained in national fisheries legislation and other arrangements whether national, sub-regional, or regional. The legislation makes available the platform for which fisheries management arrangements through MCS, are implemented. In order to attain maximum effect, framework legislation should clearly outline the management measures being implemented while defining the requirements and prohibitions that must be enforced (CRFM, 2013).

iii. Surveillance – the degree and types of observations required to maintain compliance with the regulatory controls imposed on fishing activities. These activities are important in ensuring that fisheries resources are not over exploited, poaching is reduced and fisheries management agreements are implemented (CRFM, 2013).

However, the widespread failure of fisheries management on a global scale has, in large part, been as a result of the inability of concerned authorities to enforce successfully or otherwise ensure compliance with their management regulations and to monitor accurately the behaviour and performance of the fishers. Proper monitoring, control and surveillance, is therefore dependent on the collection, gathering and analysis of accurate and relevant data and information (FAO, 1997)

In Ghana, the establishment of an Enforcement Unit in accordance with the L.I 1968 is responsible for; 'Monitoring, Control and Surveillance of fishing activities within the Ghana's fishery waters by whatever appropriate procedures, such as the use of a satellite base station for using satellite communications for data transmission relating to the activities of foreign fishing vessels licensed to operate within the Exclusive Economic Zone (EEZ) and the enforcement of the Fisheries Act 625, regulations made under the Act and any other enactment relating to the regulation of fishing activities'. The motive behind setting up the Enforcement Unit is to assist in the achievement of the main goal of policy area one of the Ghana National Fisheries and Aquaculture's four policies to ensure long term contribution of fisheries to the national economy and to allow the present generation to meet its needs without compromising that of future generations (Kwadjosse, 2009). Currently the launching and operationalization of Fisheries Enforcement Unit of the Fisheries Commission (Ghana) in 2013 has demonstrated some success in monitoring Ghana's marine fisheries resources. Some of these successes include training of stakeholders in surveillance activities (e.g. Ghana Naval Personnel, Police Prosecutors and Fisheries commission staff), undertakings of sea patrol, land patrol, electronic surveillance, arrests and prosecution of fisheries infractions (Nunoo, 2015). It is worthy to note that, well carried-out 'monitoring, control and surveillance' of fisheries resources in Ghana will not only help achieve the aforementioned policy but also, sustain the contribution of fisheries to food security at both national and international levels as well.

2.3 Food security

In relating security to food supply, the World Food Conference in 1974 defined the term "food security" as the "availability at all times of adequate world food supplies of basic foodstuffs to sustain a steady expansion of food consumption and to offset fluctuations in production and prices". On the other hand, The Declaration of the World Summit on Food Security (2009) indicated that "Food security exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food, which meets their dietary needs and food preferences for an active and healthy life (FAO, 2009). With agriculture seen as a key to eradicate hunger through the multiple dimensions of food security, recent food crisis has placed agriculture at the top of international agenda (FAO, 2012b). Food security borders on four dimensions namely: availability of food, accessibility to food; utilization of food and stability of food (vulnerability and shocks) over time (IICA, 2009).

Food accessibility which refers to a situation whereby food is allocated through markets and non-market distribution mechanisms mostly bothers on both economic access (affordability) and physical access to food (UNEP, 2009). Improvements in economic access to food can be reflected by reduction in poverty rates and prevalence of undernourishment. Regarding reduction in poverty rates, United Nations (2014) report on MDG has reported that the percentage proportion of global extreme poverty rate has been halved from 36 percent to 18 percent in 2012 even though sub-Saharan Africa is lagging behind the MDG 1 target with Nigeria ranked as the third region (globally) with high prevalence of extreme poverty (9 percent). Further, United Nations (2014) report on MDG states that between 1990 and 2013 undernourishment rates globally have declined from 24 percent to 14 percent in developing regions although Sub-Saharan Africa remains the only region with the highest prevalence of undernourishment. Physical access is determined by infrastructure availability and quality, such as ports, roads, railways, communication and food storage facilities and other installations that speed up markets functionality (FAO *et al.*, 2013). Infrastructure such as ports, roads, and railways are essential for moving food from areas of production to market centers as well as carrying farm inputs such as seeds, fertilizer, and chemicals to rural areas at the right times and in the amounts required to support agricultural production (FAO & WWC, 2015). However, absence of these infrastructure lowers accessibility of food to consumers hence compounding the intensity of food insecurity. FAO *et al.* (2014) in a nutshell, suggests that the greatest challenge regarding access to food remains in sub-Saharan Africa, where there has been slow progress in improving access to food, with sluggish income growth, high poverty rates and poor infrastructure, which hampers physical and distributional access.

The vulnerability dimension (stability of food supply) of food security is reliant on price volatility, weather conditions and conflicts. High agricultural volatile prices (fluctuation in food prices) often lead to low investment strategies of producers which destabilizes steady and reliable food supplies particularly in developing countries where consumers use large share of their income on food (UNEP, 2009). It is documented that weather conditions such as higher temperatures, droughts and humidity associated with climate change which are expected to become more variable with increasing frequency and severity of extreme events also impacts negatively on food stability resulting in increased food insecurity (Ludi, 2009; Edame *et al.*, 2011). For instance, it is projected that climate change is likely to increase the number of undernourished people by between 35 and 170 million people in 2080 (Shah *et al.*, 2008). In the presence of severe climate variability and drought, Ludi (2009) estimates that the net balance of changes in the cereal production potential of Sub-Saharan Africa resulting from climate change will be negative, with net losses of up to 12%. Indeed, food stability intrinsically linked to increased climate variability and subsequent decline in water resources, may have significant impact on food insecurity. FAO *et al.* (2014) concludes by stating that stability of food security remains a challenge in regions that are heavily reliant on international food markets for domestic supplies, have not ensured domestic food access, or are particularly vulnerable because of their limited and fragile natural resource base.

Food utilization connotes the importance of good health, as both an input to achieving food security and as an indicator of successful outcomes (FAO & WWC, 2011). Food utilization indicators mostly dwell on access to improved waters sources, access to improved sanitation facilities and percentage of children under 5 years of age who are undernourished. The last 22 years from 1990 to 2012 have seen significant progress in the area of access to improved source of water because the global population without access to clean water has reduced from 24 percent in 1990 to 11 percent in 2012. However, 325 million people (from sub-Saharan Africa) out of the global 745 million people still do not have access to clean water (UNICEF & WHO, 2014). United Nations (2014) report on MDG indicates that sub-Saharan Africa is the only region where the number of undernourished children has increased from an estimated 27 million to 32 million between 1990 and 2012. In spite of the large increase in sanitation coverage, from 49 percent in 1990 to 64 percent in 2012, one billion people still defaecate openly with sub-Saharan Africa as one of the most populous regions where open defaecation is most prevalent (United Nations, 2014). The act of open defaecation presents huge health risks (diseases) to vulnerable communities which subsequently undermine the importance of good health because of ineffective food utilization by the human body. For example, children suffering from inadequate nutrition or diarrhoea may not digest all the nutrients in their food leading to poor food utilization. In general, FAO *et al.* (2014) reports that the status of food utilization in sub-Saharan Africa remains a major concern due to the high prevalence of stunted and undernourished children under five years as well as limited progress in improving access to clean water and improved sanitation facilities.

Food availability plays a prominent role in food security. Some indicators mostly used in determining food availability include average value of food production, average protein supply, average supply of protein of animal origin and average dietary energy supply adequacy (FAO *et al.*, 2013). Globally, food availability has increased substantially in recent decades, as the growth in agricultural output has exceeded the rate of population growth with increased production per person all regions except sub-Saharan Africa (Ray *et al.*, 2012, 2013). Food production has increased faster than the rate of population growth in all regions except sub-Saharan Africa (Jayne *et al.*, 2010). Again, diet quality has improved in all regions except Africa and South Asia. In view of this, out of the 842 million people unable to meet their dietary energy requirements in 2011–13, 827 million are said to be in developing regions, where the incidence of undernourishment is now estimated at 14.3 percent in 2011–13 due to unimproved diet quality. It has been reported that, 223 million out of the 226 million undernourished people in Africa originated from Sub-Saharan Africa (FAO *et al.*, 2013). FAO *et al.* (2014) has documented that the global food availability remains major element of food insecurity in the poorer regions of the world, notably in sub-Saharan Africa and parts of Southern Asia, where progress has been relatively limited.

Overall, two sub-regions namely: sub-Saharan Africa and southern Asia have made least headway regarding food security, with almost all indicators still pointing to high levels of food insecurity whereas eastern (including South Eastern) Asia and Latin America have made the most progress in improving food security, with Eastern Asia experiencing rapid progress on all four dimensions over the past two decades (FAO *et al.*, 2014). Food availability is enhanced by improvements in agriculture; capture fisheries, aquaculture and the harvesting of forest products (FAO *et al.*, 2013).

Dwelling on the contribution of fish to food security, fish is noted to be the most preferred and cheapest source of animal protein in Ghana with about 75% of total annual catch of fish consumed locally (a reliable source of food security) (Nunoo and Asiedu, 2013). Fish provides 60% of the animal protein needs of Ghanaians and national per capita consumption was estimated at 24.5kg in 2011 (MoFAD, 2014). Moreover, the sector is significant for its gender distribution- where men are involved in pre-harvesting activities and the women mostly in post-harvesting activities (Nunoo and Asiedu, 2013). Inspite of the rapid progress in the declining rate of food insecurity, of which about 5 million people have been lifted out of poverty in last 15 years, Ghana has achieved minimal progress in lowering the rate of under-nutrition (FAO *et al.*, 2013). This inability of Ghana in erasing under-nutrition is because Ghana has moved away from the significant targets slated in the 'Maputo Declaration on Agriculture and Food Security in Africa' endorsed by African Heads of States and Governments in July, 2003 in Maputo of which Ghana is inclusive (FAO, 2012b).

Therefore, in ensuring food security from the fisheries arm of natural resources in Ghana and eventually in the sub-Saharan Africa, it is mandatory that coastal fishing operations are well-secured from the perspectives of safety, poverty and fish catches.

2.4 Assessment of the security of coastal fishing from the perspective of safety

The safety of coastal fishing activities dwells mostly on the degree of fishing efforts, subsidies, compliance with national and international fishing regulations as well as illegal, unregulated and unreported (IUU) fishing activities (FAO, 2004; Sundström, 2012). Concerning IUU fishing, the three different terms; illegal, unregulated and unreported are described by FAO (2001) as follows:

Illegal fishing refers to fishing activities:

i. conducted by national or foreign vessels in waters under the jurisdiction of a State, without the permission of that State, or in contravention of its laws and regulations

   or

ii. conducted by vessels flying the flag of States that are parties to a relevant regional fisheries management organization but operate in contravention of the conservation and management measures adopted by that organization and by which the States are bound, or relevant provisions of the applicable international law

   or

iii. in violation of national laws or international obligations, including those undertaken by cooperating States to a relevant regional fisheries management organization

Unreported fishing refers to fishing activities:

i. which have not been reported, or have been misreported, to the relevant national authority, in contravention of national laws and regulations

   or

ii. undertaken in the area of competence of a relevant regional fisheries management organization which have not been reported or have been misreported, in contravention of the reporting procedures of that organization

Unregulated fishing refers to fishing activities:

i. in the area of application of a relevant regional fisheries management organization that are conducted by vessels without nationality, or by those flying the flag of a State not party to that organization, or by a fishing entity, in a manner that is not consistent with or contravenes the conservation and management measures of that organization; or

ii. in areas or for fish stocks in relation to which there are no applicable conservation or management measures and where such fishing activities are conducted in a manner inconsistent with State responsibilities for the conservation of living marine resources under international law.

IUU fishing is not confined to certain types or categories of capture fisheries—to a greater or lesser extent it is found in both marine and inland fisheries. Evidence of IUU fishing includes rendition of false fisheries data; piracy; pilferage at sea; menace by trawlers; use of undersized nets and over-exploitation of the fisheries resources (Falaye, 2008).

Over-exploitation of the fisheries resources due to rising fishing effort introduces recruitment failure in the marine fisheries resulting in the disappearing of certain fish species from trawler landings (Falaye, 2008; Nunoo *et al.*, 2014). Menace by trawlers is evident in the persistent conflicts between artisanal (small scale) fishermen operating in the near shore waters and trawler operators which arise when trawlers operate within the first five nautical miles of the coastline, a place statutorily reserved for artisanal fishermen; destroying the fishing nets of the latter whiles disturbing the economic activities of the artisanal fishermen (Dubois & Zografos, 2012; Boachie-Yiadom, 2013).

Pilferage at sea mostly occurs when some of the crewmembers are encouraged by the trawler owners to use the proceeds of the illegal fish sales to illegally bunker oil at sea (Falaye, 2008). Rendition of false fisheries data implies operators of fishing vessels rendering false fish landing data as observed in the overestimation of catches reported by China (Garibaldi, 2012). This results in a false picture of the status of the fish stocks causing the publication of controversial and unacceptable fisheries data (Falaye, 2008). Pirates, operating with speedboats armed with automatic weapons particularly in the Gulf of Guinea threaten the social and economic development of fisheries through frequent attacks on trawlers at sea and at times demanding ransom (money) from fishing companies to release trawlers held as hostages (UNCTAD, 2014).

The use of undersized net meshes mostly below recommended sizes (e.g. in Nigeria, mesh size of 3 inches is recommended when trawling for fish in the inshore waters and 1¾ inches when trawling for shrimps) by some industrial fishermen ends in harvesting juvenile fishes and consequently resulting in the depletion of the resource (Akpalu, 2002; Falaye, 2008). Nonetheless, in Ghana, the major evidence of IUU fishing involves unlicensed trawlers from the EU, and China, illegal fishing gears and practices, including widespread fishing inside the IEZ (Nunoo *et al.*, 2014).

Concerning impacts on coastal countries' economy, IUU fishing also directly impacts the economies of developing countries that together comprise approximately 79% of all the countries in the world. Trade in IUU fishing deprives developing countries of US$9 billion a year, of which US$1 billion is lost by African countries (Black, 2007). In Ghana the estimated fish loss due to IUU fishing, particularly illegally fished tuna, could be much less when compared to Sierra Leone and Nigeria. Based on a report of assets IUU fish loss is estimated at US$100,000 per day, in addition to damage of artisanal fishing equipment in the marine waters of West Africa (Falaye, 2008).

IUU fishing has many facets and motivations, although the most obvious underlying motivations are driven by economic considerations. Other considerations likely to contribute to IUU fishing include the existence of excess fleet capacity, the payment of government subsidies (where they maintain or increase capacity), strong market demand for particular products, weak national fishery administration (including weak reporting systems), poor regional fisheries management, and ineffective monitoring, control, ineffective deterrent sanction framework and surveillance including the lack of vessel monitoring systems (VMS) (Falaye, 2008; Tsamenyi, 2014). Marine Resources and Fisheries Consultants (MRAG) (2008) estimated that the global scale of Illegal, Unreported and Unregulated fishing is at 11– 26 million tons with a corresponding cash value of $10–23.5 billion loss annually. The marine fisheries sector of developing countries stands the most risk from overfishing caused by IUU fishing by distant-water fleets with origin from developed countries which are a major contributor to this problem (OECD, 2013). As part of efforts to wipeout IUU fishing, the UN Conference on Sustainable Development, Rio+20, held in June 2012, reiterated the commitment of the parties to eliminate IUU fishing due to its role in destabilizing the economy in developing coastal nations and encouraging corruption (UNODC, 2011).

Fisheries subsidies provided by governments have been identified as a driving factor for the build-up of excessive fishing capacity, thereby undermining the sustainability of marine resources and the livelihoods that depend on them (FAO, 2001; Sumaila, 2003). The introduction of fisheries subsidies rests on two motivational factors. The first is to allow subsidy recipients to perform certain actions, which they would not otherwise do. The second is which is seen as part of poverty reduction program, to bring the incomes of fishers up to an acceptable minimum (Munro & Sumaila, 2012). World Bank, (2009) defines fisheries subsidy as a financial contribution by the public sector that provides private benefits to the fisheries sector which can be direct or indirect. Subsidies are given directly to fishers in various forms, including grants, loans and loan guarantees, equity infusions, tax preferences or exemptions, and price or income support programmes. Fisheries subsidies can be good, bad or ugly. ‘Good’ subsidies help to enhance the growth of fish stocks through conservation and monitoring of catch rates via control and surveillance measures. ‘Bad’ subsidies result in the growth of fishing effort, which can lead to outright destruction of the natural resource. ‘Ugly’ subsidies are ambiguous, and can lead to either decline or growth in fishing effort depending on the context and management effectiveness (Bjorndal & Munro, 1998). Asia among the six FAO regions of the world provides the highest capacity enhancing fisheries subsidies while Africa provides the least capacity enhancing fisheries subsidies (Sumaila *et al.*, 2010). The negative effect of fisheries subsidies as a contributor to fisheries overcapacity has been recognized in many international meetings, including the World Summit on Sustainable Development of the United Nations (2002) in

Johannesburg, the Ministerial Conference of the WTO (2001) in Doha, and the Millennium Ecosystem Report of the UNEP (2005), at Rio+20 in 2012 (Sumaila *et al.*, 2013).

In regulating the use of common pool resources, rules and regulations instituted are regarded as important mechanisms for avoiding individual overuse and resource degradation. Personal morals, economic returns, social norms, and legitimacy of rules are non-instrumental determinants of compliance behavior among resource users to these rules and regulations (Jenny *et al.*, 2006). The buildup of corruption among public authorities portrays non-compliance to rules and regulations as a gateway to escape the necessary sanctions (Sundstrom, 2013). Estimates covering compliance with the FAO Code of Conduct for Responsible Fishing (CCRF) for 53 countries landing 95% of the world fish catch has indicated that over 60% of countries recorded fail grades (e.g. Ghana, Nigeria, Argentina, Brazil, and Russia) without any countries awarded an overall ‘good’ grade. Even the top scoring countries (e.g. Canada, Norway, and Namibia) rarely reached a 60% compliance rating (Pitcher *et al.*, 2008). Other recent analyses of the quality of fishery management have observed similar conclusions (e.g., Mora *et al.*, 2009). Complying with well-established agreements on national and international fisheries rules and regulations will undoubtedly enhance conservation of ecological integrity, maintenance of food security on a long term basis, and prevention of stock collapses considering the fact that fishing activities can have long lasting effects on ecosystem structuring and functioning (Coll *et al.*, 2013). To that effect, the implementation of existing commitment to well-established arrangements is essential if the sustainability of the ocean is to be improved, as acclaimed under the context of the UN Conference on Sustainable Development (‘‘Rio + 20’’) (Veitch *et al.*, 2012).

Further, with global fishing effort estimated to exceed the optimum by a factor of three to four, the world's marine fisheries resources are under intense pressure (Pauly *et al.*, 2002). Anticamara *et al.* (2011) noted that fishing effort is evident in many ways such as number of vessels, size (or tonnage) of vessels and temporal intensity of fishing such as 'days at sea', 'hauls, tows, or trips per unit of space or time', dimension and characteristics of fishing gears such as number of hooks, number of pots, or total length of nets, engine power (horsepower or kilowatt) and the use of advanced technological aids such as fish finders. Increasing skills of skippers and fishing crews also influences the effectiveness of fishing effort and capacity. This excess fishing effort contributes to economic losses estimated at US $50billion annually – the "sunken billions" (World Bank, 2009). Increasing globalization and demands for fish products from a growing human population with higher incomes, and an insistent desire for seafood in developed countries all accounts for the increasing global fishing effort (Pitcher & Cheung, 2013). Also, while major conflicts, such as the two world wars (WW) contributed to temporary effort reduction, they also contributed to the development of new technologies which have improved the effectiveness of fishing effort globally (Anticamara *et al.*, 2011).

These aforementioned factors promoting effectiveness of fishing efforts have resulted in continual expansion in fishing fleet on the global scale where fishing vessels have increased from 68 percent (3.2 million vessels) to 74 percent (3.23 million vessels). At national level, a similar observation exists; for instance, the motorized fishing fleet in Cambodia increased by 19 percent from 38 960 vessels in 2007 to 46 427 in 2009. Indonesia's motorized marine fleet increased by 11 percent from 348 425 fishing vessels in 2007 to 390 770 fishing vessels in 2009 (FAO, 2012a). Also, the fleet's total combined power has increased continuously away from the set target, and its mean engine power increased from 64 to 68 kilowatts between 2010 and 2012 (FAO, 2014).

Though, natural disasters may contribute to declining number of fishing vessels as witnessed in Sri Lanka where tsunami reduced their fishing fleet from 15307 fishing vessels to 6700 fishing vessels, high fuel prices appears to be a more powerful medium. For instance –rising prices of fuel oil have prevented fishing operations in countries like Guatemala, Japan, Namibia, Philippines, and some parts of USA (FAO, 2010; FAO, 2012a). In response to the International Plan of Action for the Management of Fishing Capacity, several countries have established targets to tackle national overcapacity of fishing fleets. Further, implementation of restrictions in inshore waters on larger vessels or those using certain gear types have been put in place by several countries. However, while the numbers of fishing vessels have been decreasing in some parts of the world, they have been increasing elsewhere like Ghana (FAO, 2014; Amador, FSSD, personal communication, 2015).

2.5 Security of coastal fishing from poverty point of view

Coastal poverty is closely related to the nature of coastal ecosystems which are often characterized by their high degree of 'complexity associated with a number of distinctive open access to territorial user rights in fisheries (TURFS) features, including their diversity and dynamism, the fugitive nature of some of the resources available, their open access nature, the concentration of externalities and people on the coast, misunderstanding of TURFS by government, determining the extent of rights that should be exercised within TURFS and the often hostile nature associated with these features' (Christy, 1992; Charles, 2000; Campbell *et* *al.*, 2006). The concept of poverty encompasses different dimensions of deprivation that relate to human capabilities including consumption and food security, health, education, rights, voice, security, dignity and decent work (OECD, 2001). Poverty in fisheries has long rested on two schools of thoughts (Béné, 2003).

The first school of thought relates to endemic poverty in fisheries. A perception which holds the view that fishermen whatever they try to do, will remain poor. This perception, which is still widely held among decision-makers and experts from international agencies is based on two different logical arguments which eventually points to one conclusion, namely ‘‘fishery rhymes with poverty.’’ According to the first of these two logical arguments, poverty in fisheries is related to the (low) level of the natural resources which Copes (1989) described as Conventional Wisdom in poverty. The logic of the conventional wisdom suggests that the open-access nature of the fisheries allows more and more people to enter the fishing sector, which leads to the economic (and possibly biological) overexploitation of the resources—thus the Malthusian dimension of poverty, dilapidation of the economic rent, and finally impoverishment of the fishing community. Based on this argument, fishery resources are, by nature, limited; that these resources are consequently subject to possible overexploitation; and that overexploitation can indeed be a major—if not the major—cause of impoverishment for fisheries-dependent communities (Béné, 2003).

The second logical argument addresses the issue of poverty in the fishery sector is based on the economic concept of ‘‘low opportunity incomes.’’ According to the economic concept of ‘‘low opportunity incomes’’ alternative incomes (outside the fisheries sector) are usually low, this drives (or keeps) fishermen's incomes at low levels through mechanisms of labor transfer between sectors. Within this approach, the roots of poverty ''stem'' from outside the fisheries sector. Thus low income of the fishermen (assumed to be equivalent to poverty) is related to the economic situation outside the fishery (Béné, 2003). The second major idea commonly conveyed in the literature about fisheries and poverty refers to the distributive role of fisheries, namely the fact that fisheries (because of its ''open-access'' nature which leads to dissipation of economic rents) offer poorest people a livelihood through fishing activities. This is the perception of small-scale fisheries as an employer of ''last resort'' or as ''safety valve'' for the poor. This safety valve functions and allows people to enter the fisheries when access to other activities or resources is (economically or institutionally) limited or impeded. In other words, under the ''safety valve'' approach the adage ''they are poor because they are fishermen'' might be reversed to read: ''they are fishermen because they are poor and landless (Béné, 2003).

People living in the coastal zone are particularly subject to poverty because of their vulnerability to shocks from climatic and non-climatic sources. Many authors (Allison *et al.*, 2006; Allison *et al.*, 2009; Béné, 2009) have highlighted the high level of vulnerability faced by fisher-folks, partially due to their high exposure to certain natural, health-related or economic shocks and disasters. Vulnerabilities are risks or shocks that drive welfare of fishers below the minimum welfare threshold almost instantaneously; that is, household vulnerability to poverty (Béné, 2009; Asiedu *et al*, 2013). In accordance with Chambers (1989), vulnerability comes in two parts; external part of shocks or risks to which an individual is subjected to and an internal part pertaining to lack of means to scope with damaging loss. Sources of vulnerability identified in most survey are not independent of one another (Mills *et al.*, 2011). Although McCulloch and

Calandrino (2003) outlined that poverty and vulnerability are not systematically correlated, Adepoju and Yusuf, (2012) alluded that there is close association between poverty and vulnerability; hence efforts aimed at reducing poverty should take into account those factors which exacerbate the probability of being poor (vulnerability).

Many literatures have viewed the dynamics of livelihood through the lens of the poor as a means for enhancing resource productivity (Bebbington 1999; Ellis 2000; Béné, 2003). The concept of livelihood seeks to bring together the critical factors that affect the vulnerability or strength of individual or family survival strategies (Allision & Ellis, 2001). Livelihood as put forward by Ellis (2000) comprises of the assets (natural, physical, human, financial and social capital), the activities, and the access to these (mediated by institutions and social relations) that together determine the living gained by the individual or household. Livelihood sustainability is influenced by external factors, trends and shocks that are beyond the household's control (Allision & Horemans, 2006).

Two of the key features that affect fish-dependent livelihoods are the fugitive nature and perishability of fish. The fugitive nature of fish implies that no coastal state can truly own the fish in its waters prior to capture (Witbooi, 2011) Further, the perishable nature means the spoilage of fish soon after death, due to enzymatic and microbial actions, resulting in disagreeable change in taste, smell and texture; eventually reducing consumer acceptability (Obodai *et al.*, 2009; Tawari & Abowei, 2011). Both these two factors introduce high levels of risk and uncertainty into the livelihoods of the people who depend upon them (Campbell *et al.*, 2006). In the wake of primary livelihood ill-being with regards to degrading natural resources, diversification of livelihoods becomes very essential and beneficial to resource conservation (Deb, 2009; Asiedu & Nunoo, 2013). However, the absence or limited options concerning secondary livelihoods narrows the ability of fishers to make choices with regards to livelihoods outside fisheries as a result deepens the magnitude of poverty in coastal communities (Kraan, 2009). Fisheries especially small scale fisheries contributes to poverty reduction which refers to the process through which people become measurably better off over time due to their involvement/investment in fisheries activities (Béné *et al.*, 2007). In reducing poverty, small-scale fisheries provide a critical safety net for vulnerable households (even those which were not previously poor) when they face a sudden decline in their income. Nonetheless, it is important to realize that open-access is the key mechanism which permits the "safety valve" function of small scale fisheries to operate and allows people to engage, temporarily or permanently, in the sector (Béné *et al.*, 2007).

Ghana is endowed with abundant natural resources, which have played a very important role in the agricultural and industrial development efforts of the country (GoG, 2010). However, constant exploitation of these natural resources to meet socio-economic as well as developmental needs has led to severe degradation, loss of livelihood and poverty (Lawson *et al*., 2012). Trends in economic growth suggest a decline in poverty between 2006 and 2008. Results from the Ghana Living Standard Survey (GLSS 5) indicate that the proportion of Ghanaians described as poor in 2005/2006 was 28.5%, falling from 39.5% in 1998/1999. The proportion of persons described as extremely poor declined from 26.8% to 18.2% (GoG, 2010). In effect, the fisheries sector's economic output provides important contributions to poverty and food security through three main, interlinked pathways: (1) nutritional benefits from the consumption of fish; (2)

income to those employed in the sector and multiplier and spillover effects in fishery-dependent regions; and (3) through generation of revenues from exports, taxation, license fees and from payment for access to resources by foreign fleets (Allision, 2011). In spite of the contribution of fisheries to poverty alleviation, access to detailed data on coastal poverty distribution remains a challenge making coastal poverty analysis in Ghana limited (Lawson *et al*., 2012).

2.6 Assessment of the security of coastal fishing from the perspective of fish catches using fish population parameter indicators

To evaluate the performance of the fishery – whether overfished or not employs both the use of fish population parameters which are indicators calculated from common scientific methods and the catch made overtime. According to Quinn and Deriso (1999), fish population parameters characterize the population dynamics of fisheries stock as well as presents greater insight into fish populations than can indices, which are a static portrayal of the population (Pope *et al.*, 2010) as well as how a population achieved its current state and how it might change in the future.

Pope *et al.* (2010) expanded the categorizations of population parameters as originally outlined by Gibbons and Munkittrick (1994) to include parameters such as growth rate (K), mortality; exploitation rate (E), length at first maturity (Lm_{50}), recruitment pattern and length at first capture (Lc_{50}). The mode of obtaining these parameters are chiefly through fisheries-dependent methods, a method which was used throughout the period of this study. Again, this method is inexpensive and the required data is relatively easy to collect. However, this study will focus on some population dynamics and structure parameters. These include recruitment; mortality; growth; exploitation rates (E) and length at first maturity.

Growth rate (K) and longevity of a fish species indicates whether growth is poor or good (Gheshlaghi *et al.*, 2012). Growth determinations are important in studying longevity, age at first maturity, catchable size and other life history problems in fishes (Lagler *et. al.*, 1977). Regardless of how growth is expressed, it is one of the most important rates estimated during a population assessment (Pope *et al.*, 2010). Age with growth parameters of fishes constitutes essential data to control the dynamic of fish populations. They give an important indication on both the fishery resource management and the level of their exploitation (Summerfelt & Hal, 1975). Estimates of growth drive size and age structured stock assessment models (Quinn & Deriso, 1999), and is related to life history traits such as natural mortality (M) and age or length at maturity (Charnov, 1993).

Mortality can be defined as the death of an organism. Mortality (fishing and natural mortality) rates are important for understanding the rate of population decay. It is also a very important aspect of population biology since it provides information about changes in the population (Naminata *et al.*, 2014). Sarr *et al.* (2013) pointed out that fishing mortality (F) and natural mortality (M) contribute to the total mortality (Z). Fish mortality is caused by several factors including age, fish predators, environmental stress, parasites and diseases and fishing activity (Abowei & Hart, 2009). According to Marshall (1993), mortality rates are of prime importance to fishery scientists in expressing the dynamics of fish population. Fishing mortality is often the focus of fisheries managers because it can be controlled with management actions. However, natural mortality is almost always unobserved and is often outside managers' control hence appear not to be the prime focus of fisheries managers.

The exploitation rate (E) is an index which indicates the level of utilization of a fishery (Abowei & Hart, 2009). The value of the exploitation rate (E) is based on the fact that sustainable yield is optimized when the fishing mortality coefficient is equal to natural mortality (Pauly, 1983). Exploitation is an important part of an assessment of a fished population because of the influence fishing pressure can have on many other population parameters. Exploitation is the portion of the fishing mortality attributed to fishers who harvest what they catch. Also, it is often considered synonymous with fishing mortality because estimation of other forms of fishing mortality, such as bycatch or post release mortality is difficult (Pope *et al.*, 2010).

Besides growth of a species, it is also very important to study about the reproductive cycles for better understanding and management in an ecosystem (Summerfelt & Hall, 1975). Increase in population size may lead to a decrease in per-capita food availability and, thus, a decrease in the size at maturity (Bigler *et al.*, 1996). Environmental conditions also induced phenotypic flexibility in fishes which may change the age and size at maturity (Wertheimer *et al.*, 2004). Correct estimates of size at first maturity (Lm_{50} - length at which 50% of the fish are mature) are useful for fish stock management. Different methods have been proposed to estimate Lm_{50} (Nelson *et al.*, 2009). In this study, the use of a procedure by Hoggarth *et al.* (2006) was applied to estimate Lm_{50}. For a management regime to ensure, in the face of exploitation that a sufficient number of juveniles reach maturity usually requires information on the size and age at first maturation.

The length at first capture (Lc_{50}) depends on the level of fishing pressure. Thus lower value of length at first capture (Lc_{50}) is as a result of high fishing pressure (Etim *et al.*, 1994). Length at first capture indicates the proportion of juvenile to matured fish stock harvested (Udoh *et al.*, 2009). Length at first capture (Lc_{50}) together with length at first mature indicates the sustainability of the stock. Thus if length at first capture is lower than length at first maturity (Lc_{50}), sustainability of the stock is jeopardized as this condition serves as a proxy for growth overfishing (Alhassan & Armah, 2011). Additionally, length at first capture (Lc_{50}) gives a clear idea about the estimate of the real size of fish in the fishing area which is being caught by the specific gear. At the same time, it is an important tool for fisheries managers who, by regulating the minimum mesh size of a fishing fleet, can more or less conclude what should be the minimum size of the target species of a fishery (Nabi *et al.*, 2007).

Recruitment pattern refers to either the addition of new fish to the vulnerable population by growth from among smaller size individuals (Ricker, 1975) and is as a result of the combined effect of recruitment and gear selectivity. Recruitment is the entrance of young fish into the exploited fishing area and became liable to contact with fishing gear (Gulland, 1969). Though recruitment is the major source of variability in fish populations, the mean age of fish at recruitment generally depends on the type of mesh size of the gear used in fishing (Bankole, 1990). Annual recruitment is typically the most variable factor affecting the dynamics of fish populations but can provide substantial insight into why fish populations may vary in size and structure (Maceina & Pereira, 2007). Recruitment pattern provides necessary information for understanding the biological processes of growth, mortality, recruitment, and migration of a fish population (Quinn & Deriso, 1999).

According to John Gulland reported in Saila and Roedel (1980), fisheries managers need to know three things: the catch, the catch, and the catch. This is because it is the catch of commercial fishing vessels that constitutes the basis for estimating past and present biomass, and which then forms the basis for providing advice on next year's catch. Obviously, catch cannot be taken from zero biomass, and in most commercial species the annual catch cannot be larger than the average annual biomass (Froese *et al.*, 2012). Classification for exploitation stages based on catch only interprets the catch in a particular year (relative to the historical maximum in a time-series) as being indicative of stock status as collapsed, rebuilding, over exploited, fully exploited, undeveloped or developed taking into account whether that year happened to be before or after the year of the maximum catch (Daan *et al.*, 2011). According to Kleisner *et al.* (2012), open access to fisheries, increased cost of fishing, regulated fishery, implementation of marine protected areas, by-catch (both reported and unreported) and the market value of certain fish species are some factors that influence the exploitation stages of fish species.

Information on population dynamics as well as literature pertaining to the classification of exploitation stages of individual commercial fish species in Ghana's coastal waters appears to be limited and absent respectively, making fisheries management strategy in Ghana somehow incomplete and dysfunctional.

CHAPTER THREE

3.0 MATERIALS AND METHODS

This chapter deals with the approach and methodologies of the study. Broadly, the study was carried out using both quantitative and qualitative approaches which included analyzing both primary and secondary data.

3.1 Sampling sites strategy

This study focused on the eastern coastline of Ghana comprising of Volta and Greater Accra regions due to accessibility and also, because University of Cape Coast, covered the Western and Central regions. Two sampling fish landing stations were selected from each region, giving a total of four fish landing sampling stations. These were Jamestown and Tema for Greater Accra Region and Vodzah and Denu for Volta Region (Figure 1). Two stage sampling strategy was adopted which involved geographical location and types of fishing fleet deployed by the fishers. The type of fishing fleet considered were: artisanal, semi-industrial and industrial fishing fleet.

3.2 Data sources

3.2.1 Fish catch data

Monthly fish samples were purchased from local fishers who deployed multifilament fishing gears including beach seine, purse seine and bottom set fishing gears at the selected landing sites for eight months from June 2014 to January 2015. At least 30 specimens of each individual fish species collected randomly, were preserved on ice blocks in ice chest and transported to the laboratory at the Marine and Fisheries Sciences Department of the University of Ghana. At the laboratory, samples were sorted into groups based on species and the total weight recorded using the electronic scale to the nearest 0.01g. Individual fishes were counted and weighed using the electronic scale to the nearest 0.01g, while the total and standard lengths were measured to the nearest 0.1 cm using the 100 cm metre rule measuring board. The total length was measured from the tip of the fish snout to end of caudal fin whereas the standard length was recorded from the tip of the fish snout to the base of the caudal fin. Individual fishes were sexed after weighing and measuring of body weights and lengths, respectively. Fishes were identified to the species level using identification keys by Fischer *et al*. (1981) and Kwei and Ofori-Adu (2005).

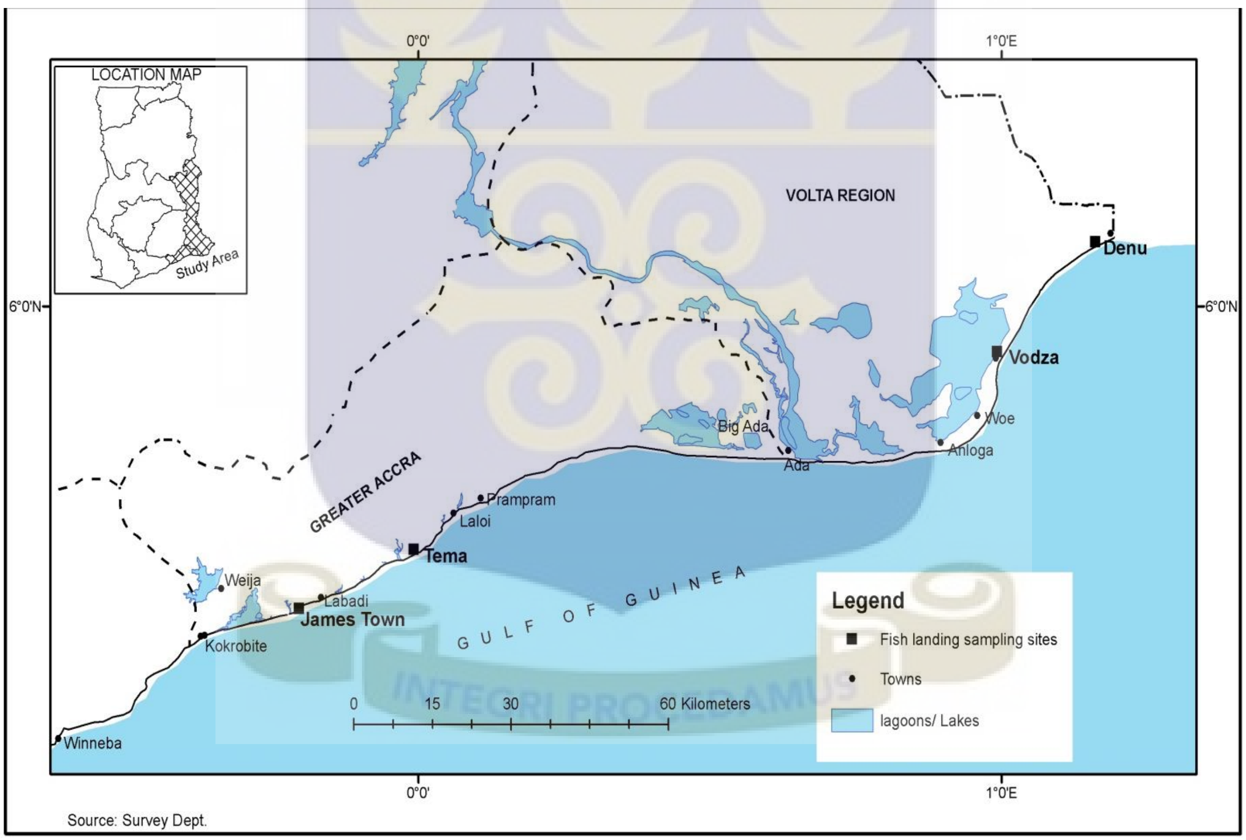

Figure 1: Map showing the four fish landing sampling sites

3.3 Security of coastal fishing operation from the perspective of safety

In order to determine the security of coastal fishing from safety point of fisheries, information on Illegal, Unreported and Unregulated (IUU) fishing, existing fisheries regulations and level of compliance to fisheries regulations were determined as indicated in sections 3.3.1 and 3.3.2.

3.3.1 Illegal, Unregulated and Unreported Fishing (IUU)

Secondary data based on illegal, unregulated and unreported fishing activities occurring in the coastal waters of Ghana from 1997 – 2014 were obtained from the Monitoring, Control and Surveillance Division's (MSCD) Fisheries Enforcement Unit (FEU) of the Ministry of Fisheries and Aquaculture Development (MoFAD), Ghana. Data covering the entire coastline was used due to the migratory nature of fishermen in Ghana as well as the poorly recorded infraction data on regional basis. These data were categorized into the three main fishing levels in Ghana to generate the following:

i. Number of infractions committed against Ghana's fishing regulations at the three fishing levels (artisanal, semi-industrial and industrial).
ii. Correlation between the total fines paid and total number of infractions to identify whether fines do have an impact on the intensity of infractions.

3.3.2 Fisheries management

Information for fisheries management which included existing fisheries regulation measures, level of compliance to fisheries regulations and incidence of arrests were obtained using qualitative method - structured interview guide in Appendix V. (See section 3.4 for details on qualitative method -structured interview guide).

3.4 Use of qualitative method for social data (3.3.2 and 3.5.5)

The aim of qualitative method is to get closer to people in a particular community to know what the community practices (Flybjerg, 2004). The main qualitative method used in the study was structured interview guide (Appendix V). Based on this mode of qualitative data collection, close and open-ended questions were used to obtain information from respondents in the various study areas on the status of coastal fishing in Ghana. From the structured interview guide (Appendix V), the closed-ended questions provided data on demographic characteristics, occupational differentials, educational status, sexual differences, status of fish catches, institutions involved in the regulation of the resources, while the open-ended questions offered detailed insights about the management of the resources, some fisheries regulations, reasons for decline in fish catches, enforcement of the institutions and some illegal fishing practices among others. Respondents were selected randomly from the community, but ensuring that they were all engaged in fishing activities through the use of purposive sampling approach.

The structured interview guide was administered to each respondent separately in a direct face-to-face interview. During the face-to-face interview session, research questions were posed to interviewees, responses obtained were recorded by the interviewer due to the high level of illiteracy among the respondents. Also, responses obtained were transcribed onto an audio recorder with the consent of each respondent. This was to ensure that all information was captured. The respondents were also allowed to freely ask questions and also to contribute their own points of view. However, in fishing communities where language was a barrier particularly in the Volta Region, the assistance of local facilitator was sought.

In all one hundred and twenty (120) respondents (thirty respondents in each study site) were interviewed from July, 2014 to September, 2014 in all the four fish landing sampling sites. The structured interview guide was segmented into three main sections as follows:

i. General information about the fisher
ii. Fisheries management measures
iii. Socio-Economic information

3.4.1 General information about fisher

This section provided information on age, sex, type of gears and mesh sizes used, literacy level, household size, whether migrant or native and the motive if migrant. Information obtained in this session helped in characterizing fishers in general.

3.4.2 Fisheries management measures

Information outlined in this segment included declining fish species, illegal fishing methods, general perception about the status of fish catches, knowledge on any fishing regulations, enforcement bodies and compliance with existing national fisheries regulations measures (if any). Information gained in this session was central in knowing the secured nature of coastal fishing operation in Ghana from safety perspective.

3.4.3 Socio-Economic information

This part covered information on vulnerabilities facing fishers, saving habits among fishers, reasons for occurrence of poverty among fishers, livelihoods and marginalization indicators based on social amenities were provided. Information obtained in this section was vital in highlighting the security of coastal fishing from the perspective of poverty.

3.5 Security of coastal fishing operation from the perspective of poverty

To determine the security of coastal fishing from poverty point of view, information on poverty indices, vulnerability, social amenities and livelihoods were obtained as follows:

3.5.1 Determination of poverty indices

In view of the diverse socio-economic background of fishing communities in Ghana, poverty indices were estimated for the fish landing sampling sites despite earlier estimations by Asiedu *et al*. (2013) in other coastal communities in Ghana. In calculating the poverty indices, the lower international poverty line, lower national and upper national poverty lines provided by Asiedu *et al*. (2013) were used. These poverty lines were used to estimate the relevant poverty indices-namely:

i. Head count (H)

ii. Poverty gap (PG)

iii. Poverty severity(P_2)

3.5.2 Head count

The head-count index is a measure of the prevalence of poverty. This is given by the proportion of the population for whom consumption (y) is less than the poverty line (z). For instance, suppose (q) people are poor by this definition in a population of size (n). Then the head-count index is expressed below as:

H (proportion of total population deemed to be poor) = $\frac{q}{n}$ ………………….. (Foster *et. al.*, 1984)

3.5.3 Poverty-gap

The poverty-gap index is a measure of the depth of poverty. This is based on the aggregate poverty deficit of the poor relative to the poverty line. This gives a good indication of the depth of poverty, in that it depends on the distances of the poor below the poverty line. In measuring the poverty gap, consumptions were arranged in ascending order, the poorest to the least poor having denoted by 'y' which is (by definition) not greater than the poverty line (z) whereas the 'n' refers to the sampled size (n). Then the poverty gap index can be defined as follows:

$$PG = \frac{1}{n}\sum_{i=1}^{q}\left(\frac{z-y}{z}\right)$$ ………………...……………….………………..……. (Foster *et. al.*, 1984)

3.5.4 Poverty severity (P_2)

This poverty index measures the severity of poverty. Foster-Greer-Thorbecke P_2 measure is an additive measure of the severity of poverty, whereby the poverty gaps of the poor are weighted by those poverty gaps in assessing aggregate poverty. Thus Poverty severity (P_2) is measured as:

$$P_2 = \frac{1}{n}\sum_{i=1}^{q}\left(\frac{z-y}{z}\right)^2$$ ……………………………………….……...……… (Foster *et. al.*, 1984)

Similarly, 'y' indicates consumption less than the poverty line (z) with the 'n' referring to the sampled size (n).

3.5.5 Social amenities, source of vulnerabilities and livelihoods

Information on marginalization based on social amenities, source of vulnerabilities and livelihoods were obtained using interview-led structured interview guide provided in Appendix V. (See section 3.4 for details on qualitative method -structured interview guide)

3.6 Security of coastal fishing operation from the perspective of fish catches

In evaluating the security of coastal fishing operation from fish catch point of view, growth and mortality parameters, exploitation rate, length at first maturity, probability of capture, recruitment pattern and exploitation stages were estimated as follows:

3.6.1 Growth parameters

The pooled monthly length frequency distribution data from June, 2014 to January, 2015 of the major fish species in the catches grouped by an interval class of 1 cm were fed into the FISAT II tool to obtain the growth parameters; growth rate (K), asymptotic length (L_∞). This was done using the Von Bertanlaffy Growth Function (VBGF) fitted in FISAT II (Gayanilo *et al.*, 2005). The Wetherall Plot fitted in FISAT II was used to obtain Z/K ratios for the six assessed fish species (Pauly, 1986).

3.6.2 Mortality parameters

Total annual instantaneous mortality rates (Z) were estimated using the Jones and Van Zalinge Plot (Sparre & Venema, 1992). Natural mortality rate, M, was computed by the empirical equation of Pauly (1980) expressed (below) using a mean surface temperature (T) of 25.7°C:

$\log_{10} M = -0.0066 - 0.279 \log_{10} L_\infty + 0.6543 \log_{10} K + 0.4634 \log_{10} T$………….. (Pauly, 1980)

Where M is the instantaneous natural mortality, L_∞ is the asymptotic length, T is the mean surface temperature and K refers to the growth rate coefficient of the VBGF.

Instantaneous fishing mortality (F) was estimated using the relationship;

F = Z –M………………………………………………………… (Beverton & Holt, 1957)

Where Z is the instantaneous total mortality rate, F the instantaneous fishing mortality rate and M is the instantaneous natural mortality rate.

The exploitation level (E) was obtained by the relationship of Gulland (1971):

$E = \frac{F}{Z}$……………………………………………………………………Gulland (1971)

Optimum fishing (**Fopt**) which is a direct related to the natural mortality (M) was calculated for the selected fish species using the expression below:

Fopt = 0.4M ………………………………………………………………. (Pauly, 1984)

3.6.3 Length at first maturity

To estimate the length at first maturity (L_m) for the assessed species, the procedure by Hoggarth *et al.* (2006) below was used. The input parameters for the model included asymptotic length only (L_∞).

Length at first maturity (L_m) = $\frac{2}{3}$ (L_∞)... (Hoggarth *et al.*, 2006)

3.6.4 Probability of Capture

The ascending left arm of the length-converted catch curve incorporated in the FISAT II Tool was used to analyze the probability of capture of each length class according to the method of Enin (1995). By plotting the cumulative probability of capture against mid-length, a resultant curve was obtained, from which the length at first capture was taken as corresponding to the cumulative probability at 50%. Additionally, the length at both 25% and 75% captures were taken as corresponding to the cumulative probability at 25% and 75%, respectively.

3.6.5 Recruitment pattern

The recruitment pattern of the stock was determined by backward projection on the length axis of the set of available length–frequency data as described in FiSAT. This routine reconstructs the recruitment pulse from a time series of length–frequency data to determine the number of pulses per year and the relative strength of each pulse (Nurul *et al*., 2009). Input parameters included $L\infty$ and K. Normal distribution of the recruitment pattern was determined by NORMSEP (Separation of the normally distributed components of size-frequency samples) (Pauly and Caddy, 1985) in FiSAT. The midpoint of the smallest length group in the catch was estimated as the length at recruitment (Lr) length at recruitment (Gheshlaghi *et al*., 2012).

3.6.6 Exploitation stages based on historic catch data

Annual catch data from 1980 to 2010 (making a total of twenty years) for Ghana's coastal fishing were obtained from the Fisheries Scientific Surveys Division (FSSD) of the Ministry of Fisheries and Aquaculture Development (MoFAD), Ghana. The data covered landings from the artisanal, semi industrial and industrial fleet. To establish the status of the treated fish species, the renewed categorization by Froese *et al.* (2012) summarized in Table 1, was used- based on the calculated ratio of catch (C) relative to maximum catch (Cmax).

Table 1: Exploitation stages for all the treated species based on catches (C) relative to the maximum catch (Cmax). Source: Adopted from Froese *et al.* (2012)

Status of fishery	Year	C/C_{max}
Underdeveloped	Before C ≥ 0.5Cmax	< 0.1
Developing		0.1-0.5
Fully exploited	At/after C ≥ 0.5Cmax	> 0.5
Over exploited		0.1-0.5
Collapsed		< 0.1
Rebuilding	**Years between collapsed and first fully exploited status**	
Final year rules		
Developing	If Cmax occurs in the final year, increase Cmax by 50% and set its year of occurrence as final year plus one	
Rebuilding	In the final and preceding year, accept C > 0.28C/Cmax as indicative of subsequent fully exploited status	

3.7 Data analysis

Correlation analysis was conducted between the number of IUU fishing cases (infractions) in Ghana and the total fines (penalties) recorded for IUU fishing cases to show the impact of IUU fishing on the fines recorded (if any) based on the following hypotheses:

1. Null hypothesis (H_0): Fines recorded do not have any impact on the intensity of number of infractions recorded. (Accept when p-value > 0.05)
2. Alternate hypotheses (H_1): Fines recorded do have impact on the intensity of number of infractions recorded. (Accept when p-value < 0.05)

Data assembled from the structured interview guide were coded using the Social Package for Statistical Software (SPSS). Data cleaning in SPSS was done to ensure that values for the right codes were entered before analysis proceeded. Responses from SPSS were then analysed based on demography of fishers, fisheries management and socio-economic information, respectively. Fisheries management and socio-economic responses from SPSS were used to answer research questions concerning security of coastal fishing from safety and poverty, respectively.

Data linked to total infractions, total fines (penalties) and poverty measurements were subjected to Anderson-Darling Normality Tests using Minitab Statistical tool to determine whether or not the distribution of the data was normal. If the data did not follow a normal distribution ($p < 0.05$), non-parametric tests particularly Kruskal-Wallis test was used to test if there were any significant differences. If the data did follow a normal distribution ($p > 0.05$), parametric tests like one-way analysis of variance (ONE WAY ANOVA) and sample T-test were used to test if there were any significant differences. Output of the normality tests are provided in Appendix VI – IX. The level of significance (P-values) used was 0.05. Responses obtained from poverty measurements were used to answer research questions concerning security of coastal fishing from poverty perspective whereas response from total infractions and total fines (penalties) were used to answer research question on security of coastal fishing from safety perspective.

Fish population parameters for the treated fish species, namely *Sardinella aurita*, *Sardinella maderensis, Engraulis encrasicolus, Pagellus bellottii, Scomber japonicus* and *Brachydeuterus auritus* were obtained and analysed using the FISAT II tool. Results obtained from the FISAT II analysis were used to answer the research question pertaining to security of coastal fishing operations from the perspective of catches. Relevant tables and graphs of results were generated using Microsoft Excel and Minitab statistical tool for easy comparative understanding.

CHAPTER FOUR

4.0 RESULTS

This chapter presents the findings from the field and laboratory studies as well as findings from secondary sources. The results are presented on security of coastal fishing operations from three perspectives, namely safety, poverty and fish catches.

4.1 Security of coastal fishing operations from the perspective of safety

This section provides key findings relating to IUU fishing, level of awareness of fisheries regulation measures, compliance with fisheries regulation measures, incidence of arrests arising from non-compliance with fisheries regulation measures and diversity of enforcement authorities or institutions.

4.1.1 Illegal, Unreported and Unregulated (IUU) fishing in Ghanaian waters

Figure 2 shows the scatter plot of total fines in relation to the total number of infractions recorded from 1997-2014 with regression. The low positive value of coefficient of determination (R^2=0.21) indicated a weak correlation between the total fines (GH₵) and the number of infractions (Figure 2). The positive form of regression implied that as the total fines (Y) increases, the total number of infractions (X) also increases according to the regression equation expressed: $Y = 5.302 X - 40.1$**;** where Y = Total fines (x 10^4) and X = number of infractions. In addition to not being normal, there was no significant difference between the total fines and the number of infractions (Kruskal-Wallis; p (078) > 0.05). This indicated that total fines paid had no impact on the intensity of number of infractions recorded.

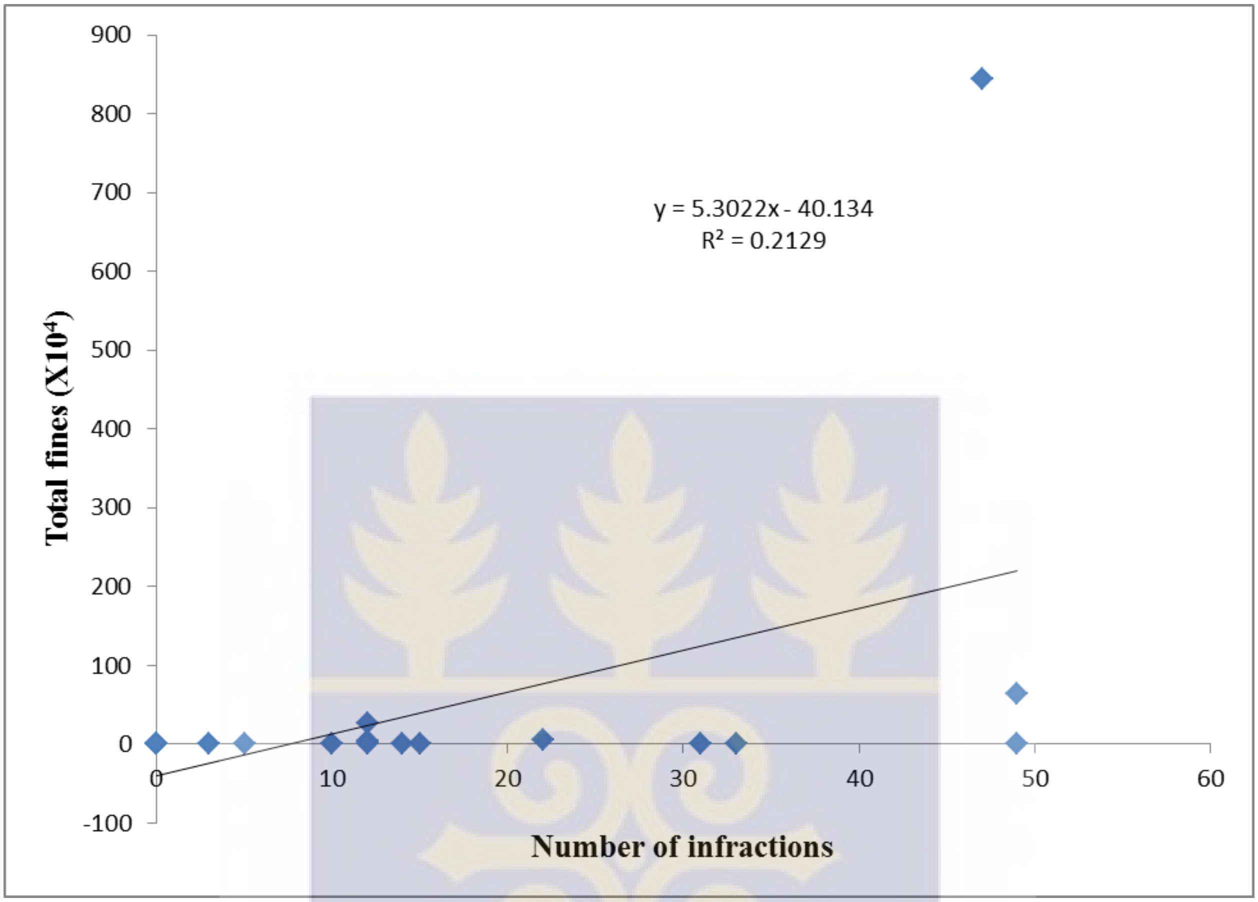

Figure 2: Scatter plot with regression of total fines (GH₵) in relation to number of infractions from 1997-2014. (Data obtained from MCSD, Ghana)

Figure 3 presents the infraction types recorded from 1997-2014 in Ghana's coastal waters by MCSD, Ghana. At least eight key infractions were observed (Figure 5) - namely pair trawling, fishing around the oil rig; fishing with undersized mesh; destruction to VMS inputs; transshipment of catch; light fishing; fishing without license and trawling below 30 m depth. These key infraction types were dominated in order of importance by trawling below 30 m depth (31.8%), fishing without license (29.5%), and light fishing (13.6%). Transhipment of catch (11.4%), fishing with undersized mesh (4.5 %), pair trawling (2.3%) and fishing around the oil rig (2.3%) were the least significant infractions recorded (Figure 3).

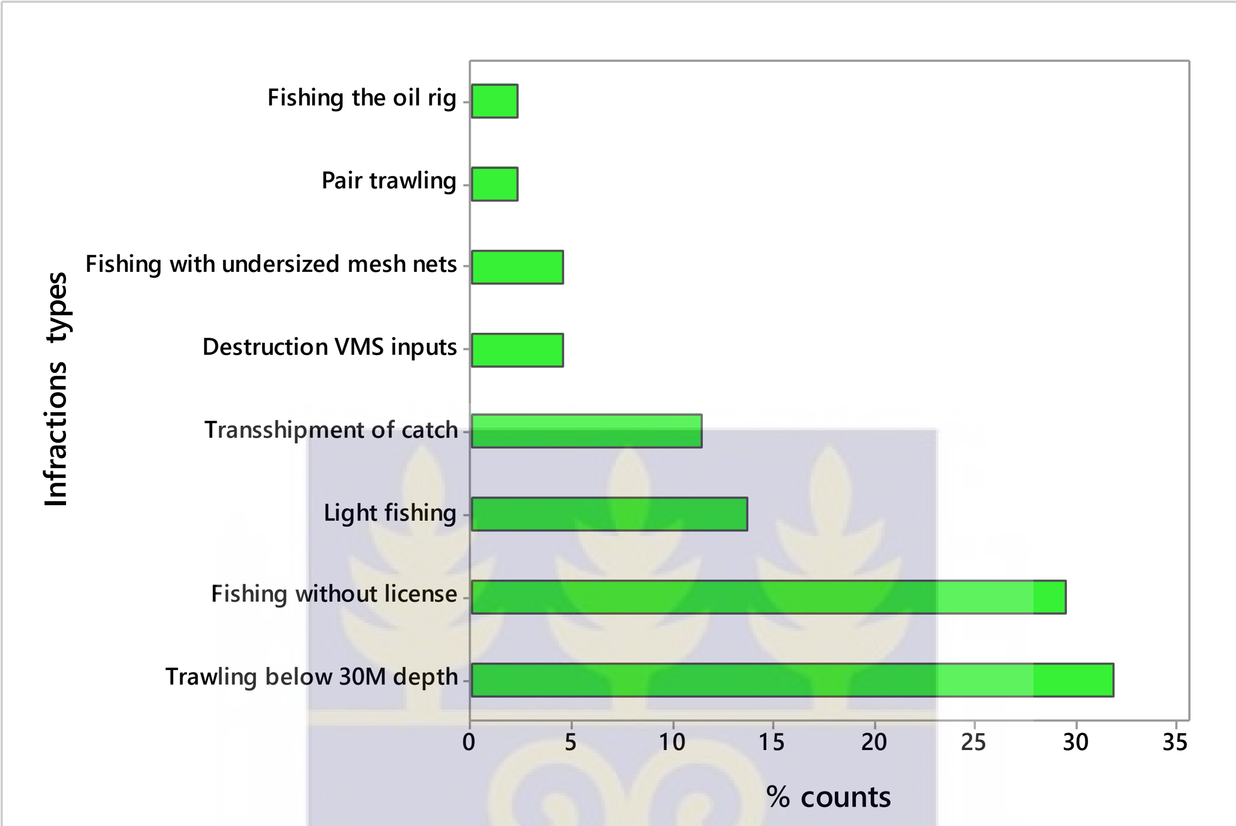

Figure 3: Diversity of infractions recorded in Ghana's coastal waters from 1997- 2014. (Data obtained from MCSD, Ghana)

Figure 4 presents the diverse infractions types occurring from the three marine fishing sectors in Ghana's coastal fishing industry. At the artisanal level, up to two types of infractions were recorded, namely 'fishing with light' and 'transhipment of catch'. Between these two infractions types recorded at the artisanal level, 'fishing with light' appeared as more dominant (75%). Three infraction types were encountered at the semi-industrial level. These recorded infractions included 'fishing with light', 'fishing below the 30 M depth' and 'fishing without license' (Figure 4). However, fishing without license appeared as the most pronounced (57.1 %) form of infraction confronting the semi-industrial sector (Figure 4). The industrial fishing sector which included shrimpers, tuna and trawlers observed the most diverse form of recorded infractions with up to eight (8) infractions recorded (Figure 4). Trawling below the 30 M depth (40%) and fishing without license (25.7%) were the dominant form of infractions facing the industrial fishing sector. Fishing with light (2.9%) and pair trawling (2.9%) as the recorded least infractions confronting the industrial fishing sector (Figure 6).

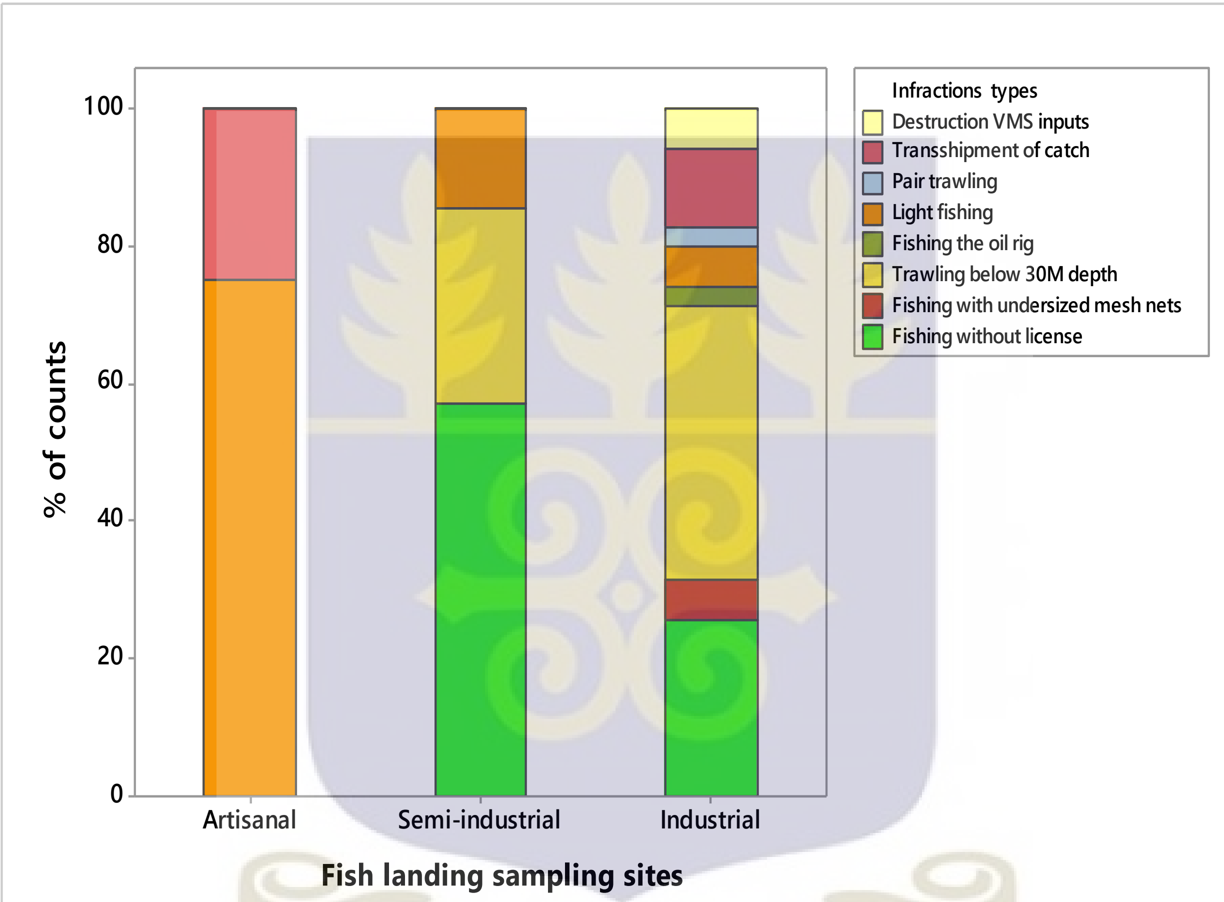

Figure 4: IUU infraction types recorded across the three marine fishing sectors in Ghana. (Data obtained from MCSD, Ghana)

4.1.2 Level of awareness of fisheries regulation measures

Figure 5 displays the degree of awareness of fisheries regulation measures among respondents from the four fish landing sampling stations. A vast majority of the fishers (67%-80%) surveyed appeared to be aware of some fisheries regulation measures whether government or traditional. Relatively, a higher percentage was observed in Tema (80%) and the least in Denu (66.7%).

However, a few of the fishers surveyed (20% - 33.3%) were found to be ignorant of the existence of any fisheries regulation measures. The highest percentage of fishers ignorant of fisheries regulation measures was encountered in Denu (33.3%) and the lowest observed in Tema (20%) (Figure 5).

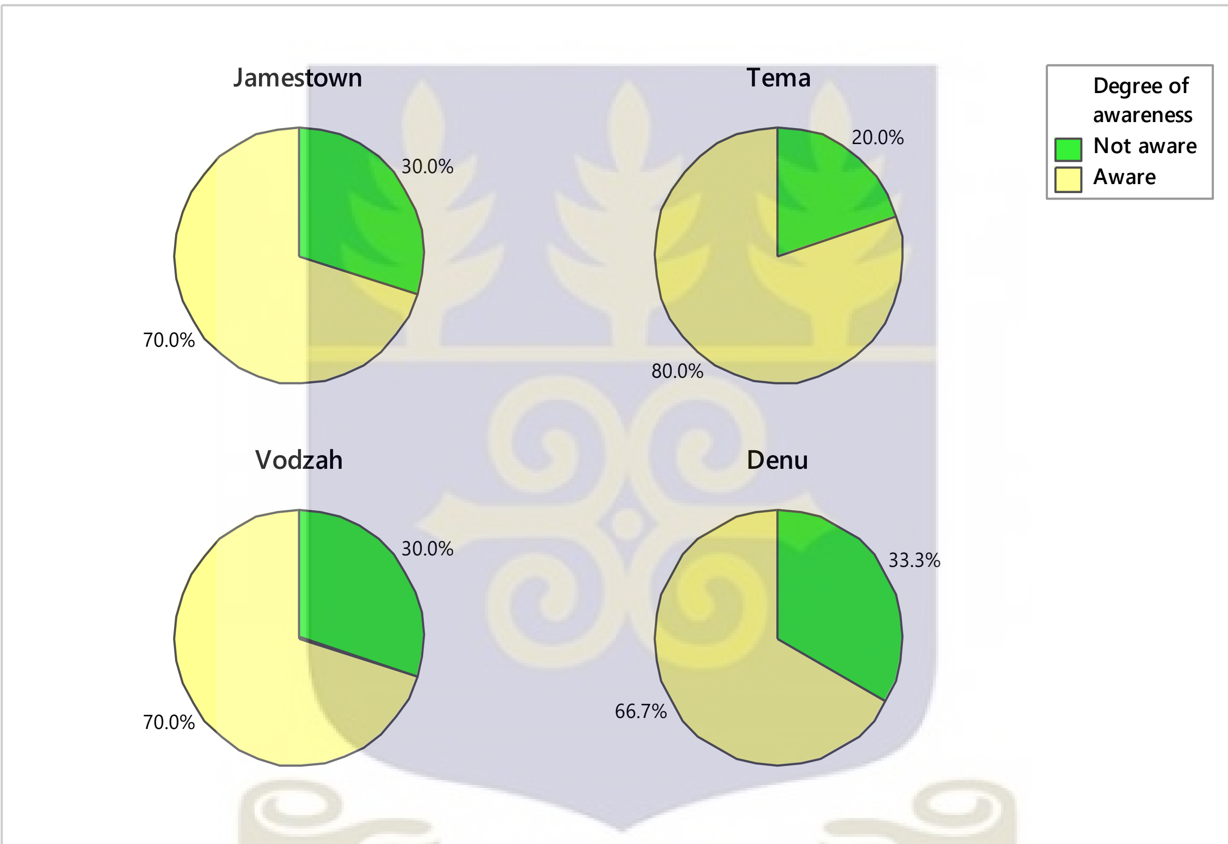

Figure 5: Degree of awareness of fisheries regulation measures by respondents from the four fish landing sampling stations

In order to assess the levels of knowledge of fisheries regulation measures, fishers were made to suggest at least two fisheries regulation measures. Figure 6 gives a comparative knowledge analysis of fisheries regulation measures across the four fish landing sampling stations. From Figure 6, a total of ten fisheries regulation measures were suggested by the respondents. The common dominating fisheries regulation measures suggested from all the sampling stations by the respondents were ‘no light fishing’ (Jamestown-45%, Denu-41%, Tema-40%, Vodzah-23%) and ‘no chemical fishing’ (Jamestown-16%, Denu-22%, Tema-17%, Vodzah-27%). The least commonly suggested fisheries regulation measures included ‘no fighting at sea’, ‘no turtle landings’, ‘no under-aged child in fishing’ and ‘no blast fishing’.

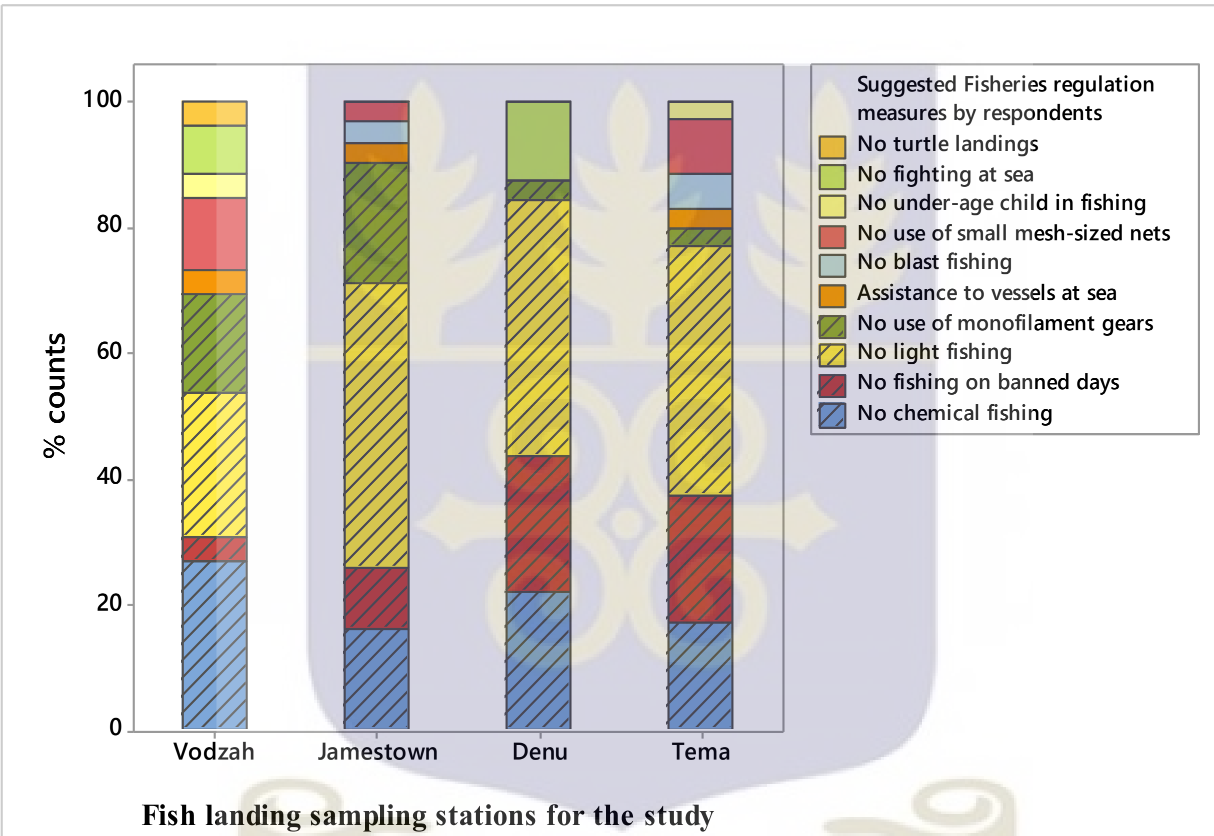

Figure 6: Comparative knowledge analysis of fisheries regulation measures among respondents from the four fish landing sampling stations

4.1.3 Degree of compliance to fisheries regulation measures

Figure 7 provides a presentation concerning the degree of compliance to fisheries regulation measures among fishers surveyed in all the four fish landing sampling stations. A vast majority of fishers surveyed (56.7%-63.3%) with the exception of respondents from Tema accepted that fishers in the corresponding study sites complied with the existing fisheries regulation measures

(Figure 7). In Tema, 40% of the fishers surveyed accepted that fishers comply with existing fisheries regulation measures (whether traditional or official fisheries regulation measures).

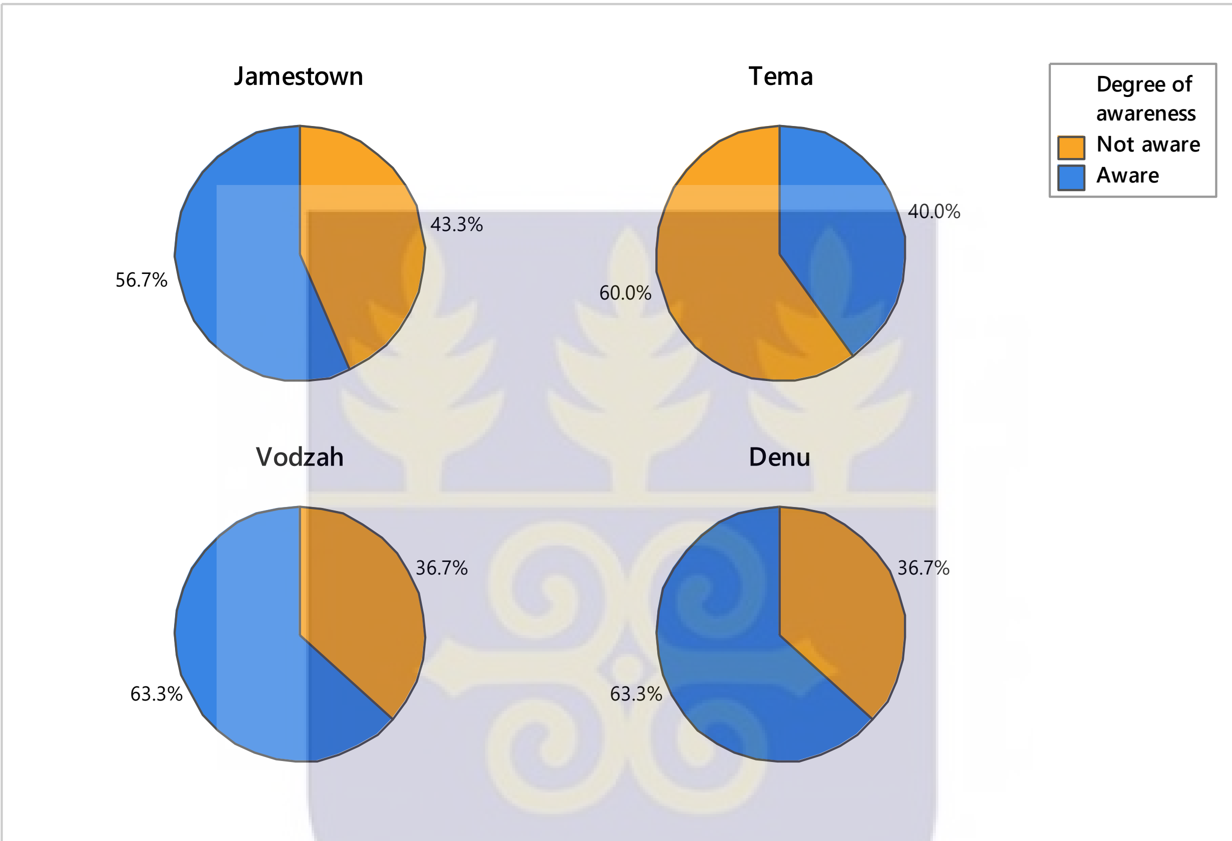

Figure 7: Degree of awareness of compliance to fisheries regulation measures among respondents from the four fish landing sampling stations.

4.1.4 Incidence of arrests emanating from non-compliance

Figure 8 outlines the degree of awareness concerning arrest incidence in the four fish landing sampling stations. This was to serve as an indicator for compliance among respondents who affirmed that fishers comply with fisheries regulation measures were further asked of any recent arrests made in the various fish landing sampling stations. As indicated in Figure 8, a vast majority of fishers surveyed (60%-80%) declined any incidence of arrests made for the past two weeks as at the time of conducting the survey. In addition, a minor section of the respondents

(0%-6.7%) affirmed cases of arrests which mostly centred on seizure of monofilament nets and other fishing inputs (Figure 8).

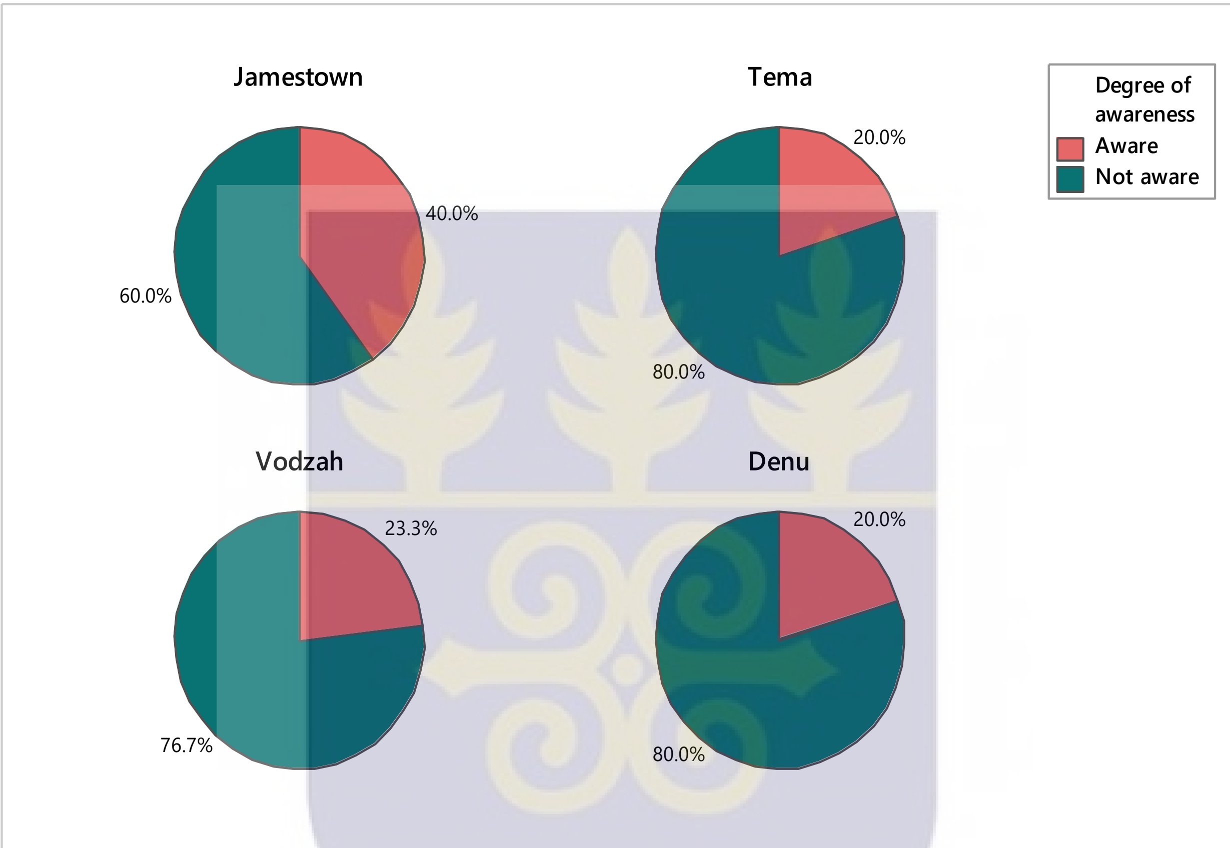

Figure 8: Degree of awareness concerning incidence of arrests at the four fish landing sampling stations

4.1.5 Diversity of enforcement authorities or institutions

Figure 9 shows the various enforcement authorities or institutions for fisheries regulation measures in the four fish landing sampling stations. On the whole, up to six enforcement authorities or institutions were identified, namely; i) the Chief-fisherman; ii) Government, iii) The Ghana Navy, iv) The Ghana Police, v) Local council and vi) Fishers themselves. The Chief-fisherman seems to be the most recognized enforcement authority of fisheries regulation measures with a percentage positive response range of 53.1% - 70.8% (Figure 9).

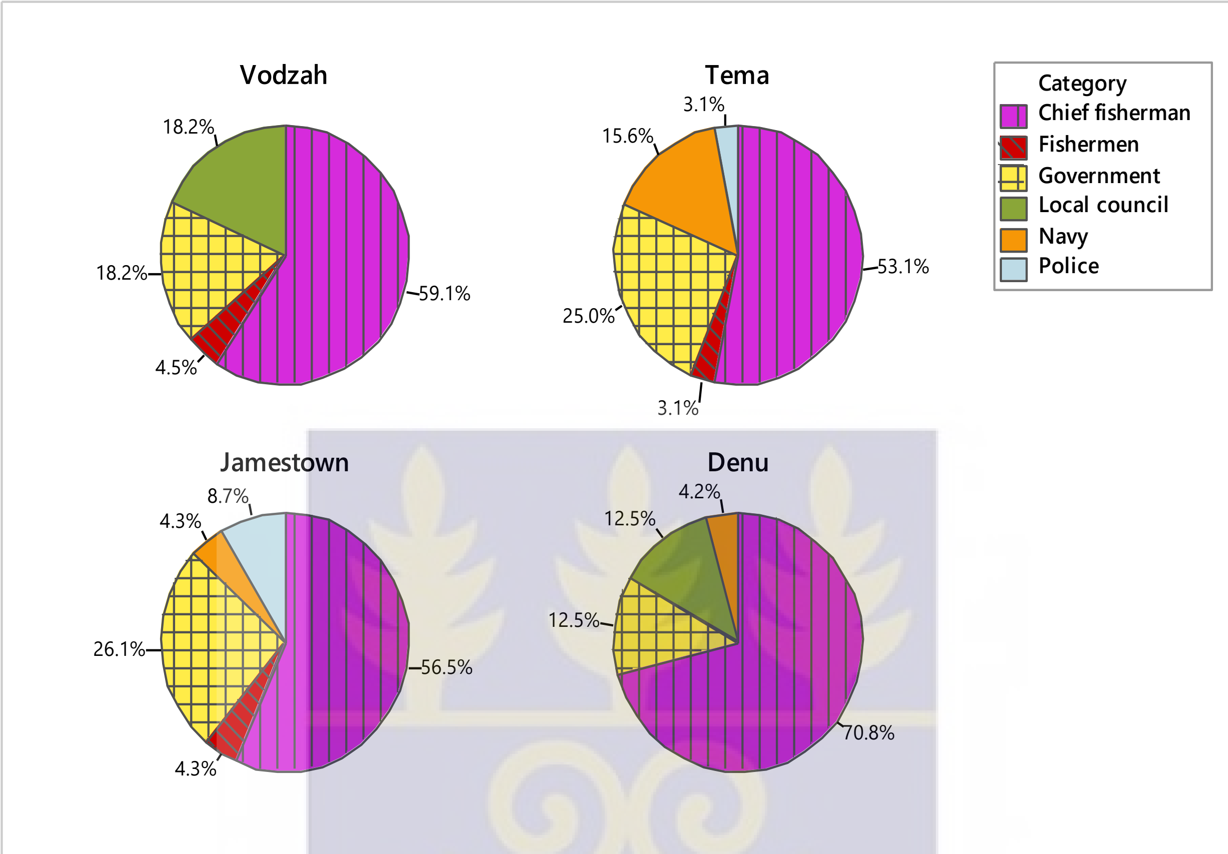

Figure 9: Existing enforcement authorities or institutions for fisheries regulation measures at the four fish landing sampling stations

4.2. Security of coastal fishing operation from the perspective of poverty

Poverty measurement, marginalization due to social amenities, secondary livelihoods, saving habits and vulnerability sources were the main areas of key findings under this section.

4.2.1 Poverty measurement

The head count, poverty gap and severity across the four study sites are outlined in Table 2. With a lower national poverty line of GH₵429 (Asiedu *et al.*, 2013), the incidence of poverty as adjudged from the head count increased with the highest rate at Vodzah (64%) followed by Denu (61%), Jamestown (56%) and Tema (43%). Using the upper national poverty line of GH₵ 632 (Asiedu *et al.*, 2013), the incidence of poverty as adjudged from the head count increased with the lowest rate at Tema (73%) followed by Vodzah (82%), Denu (86%) and Jamestown (90%). Using the lower international poverty line of approximately GH₵688 (Asiedu *et al.*, 2013), the incidence of poverty was Tema (73%), Vodzah (85%), Denu (86%) and Jamestown (93%). Overall, the incidence of poverty is still high and significantly different among the study sites (ANOVA, df = 3, p-value (0.00) <0.05). The head-count indices at both the national upper and international poverty lines were also almost equal- an indication of the closeness of the poverty lines.

The poverty gap was measured as the distance below the poverty line. The distance of the poverty gap saw the lowest rate at Tema (0.11-0.29), followed by Jamestown (0.22-0.43) and Denu (0.28-0.45) with the highest rate at Vodzah (0.28-0.47). The poverty gap was significantly different for all the sites (ANOVA, df = 3, p-value (0.00) <0.05).

Table 2 also shows that the poverty severity (i.e., inequality among the poor) with respect to the three poverty lines, increase with the highest rate at Vodzah (0.15-0.30), Denu (0.16-0.29), Jamestown (0.12-0.15) and the lowest rate at Tema (0.06-0.15). The poverty severity was significantly different for all the sites (ANOVA, df = 3, p-value (0.00) <0.05). From observation, chronic poverty was not identified as fishers were able to make a livelihood from the fisheries resources.

Table 2: Poverty indices based on the three poverty lines used in the four study sites

Poverty line used	Poverty indices	Vodzah	Denu	Tema	Jamestown
Lower national poverty line	Head count	0.64	0.61	0.43	0.56
	Poverty gap	0.28	0.28	0.11	0.22
	Poverty severity	0.15	0.16	0.06	0.12
Upper national poverty line	Head count	0.82	0.86	0.73	0.90
	Poverty gap	0.43	0.41	0.26	0.40
	Poverty severity	0.27	0.27	0.13	0.22
Lower International poverty line	Head count	0.85	0.86	0.73	0.93
	Poverty gap	0.47	0.45	0.29	0.43
	Poverty severity	0.30	0.29	0.15	0.25

4.2.2 Vulnerability of fishers to poverty

Figure 10 provides a comparative analysis of vulnerability sources facing fishers in both Vodzah and Denu. At least nine (9) sources of vulnerability were observed- namely illness, fish catch issues, damage to fishing nets, frequent conflicts; high price of fishing inputs, illegal fishing methods, capital issues and alternative livelihoods. Fish catch issues bordered on low, poor or bad catches whereas capital issues included debts and low profit. However, regardless of their locations, six vulnerability sources appeared to be common. These were capital issues, bad weather, damage to fishing nets; fish catches issues and high price of fishing inputs. The dominant vulnerability sources included fish catch issues (Denu-33.3%, Vodzah-20.0%) and capital issues (Denu-25%, Vodzah-34.3%) (Figure 10).

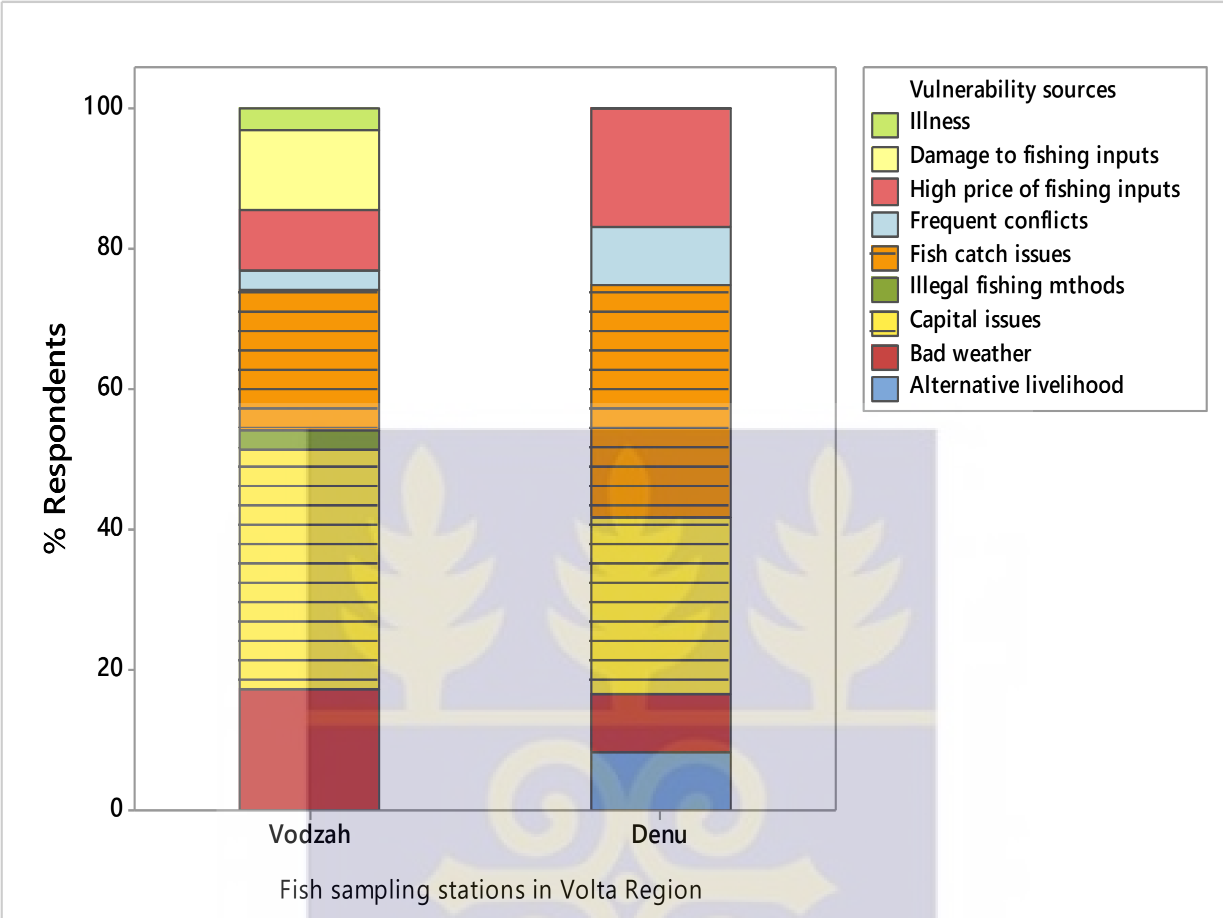

Figure 10: Comparative analysis of vulnerability sources among respondents in Vodzah and Denu in the Volta Region

Figure 11 outlines the comparative analysis of vulnerability sources facing fishers in both Jamestown and Tema. From Figure 13, sources of vulnerability developed from survey responses were up to seven, namely fish catches, bad weather, damage to fishing inputs, frequent conflicts, capital issues, high price of fishing inputs and illegal fishing methods. However, the dominating sources of vulnerability common to these two sampling stations as seen in Figure 11 included capital issues (Jamestown-34.8%, Tema-11.5%), high price of fishing inputs (Jamestown-34.8%, Tema-38.5%) and illegal fishing methods (Jamestown-17.4%, Tema-19.2%).

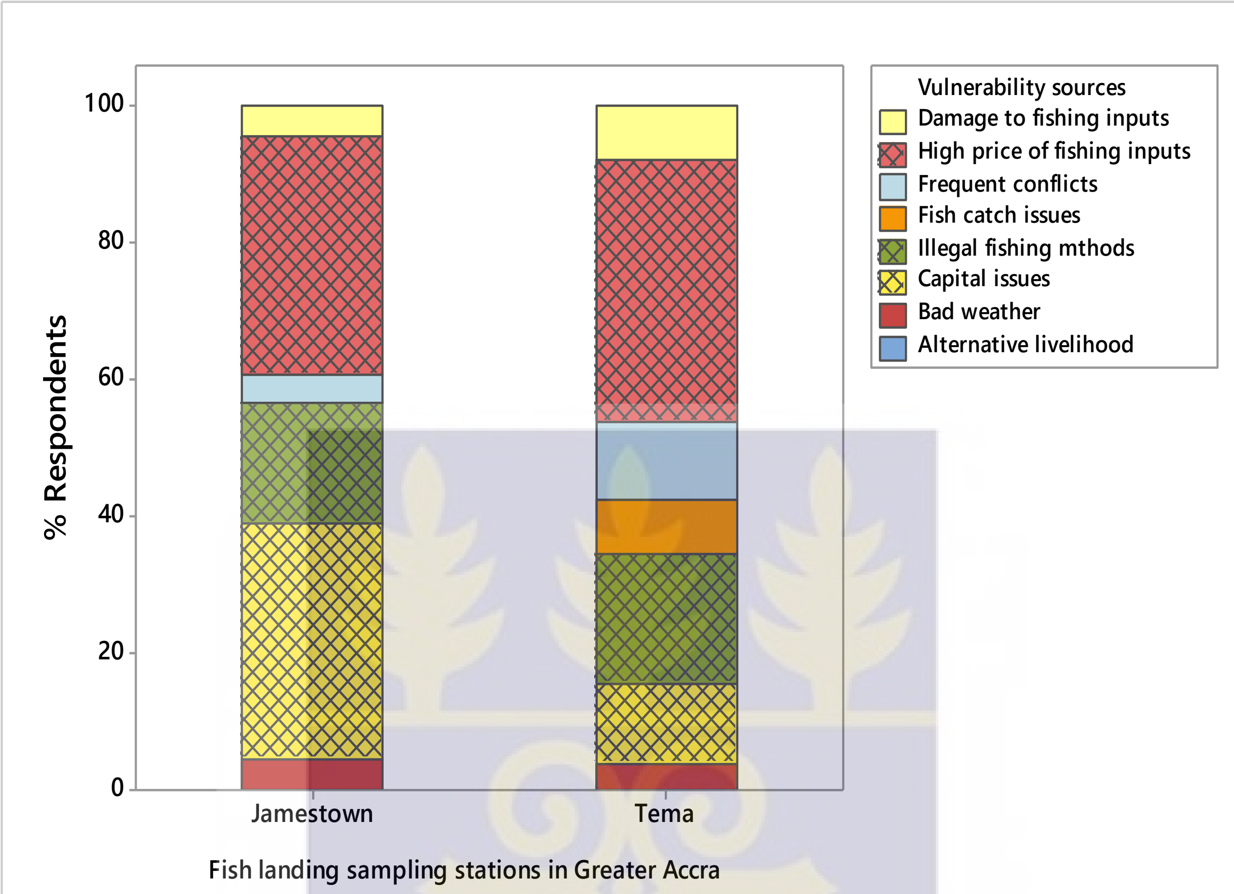

Figure 11: Comparative analysis of vulnerability sources among respondents in Tema and Jamestown in the Greater Accra Region

Considering the four fish landing sampling stations, the most common source of vulnerabilities pertaining to all four of them included; i) high price of fishing inputs; ii) capital issues; iii) bad weather and iv) frequent conflicts.

4.2.3 Secondary livelihoods to fishing

Figure 12 outlines the percentage of secondary livelihoods among fishers surveyed in all the four fish landing sampling stations. As shown in Figure 12, majority of the fishers surveyed (73.3%-86.7%) across the four study sites were without any secondary source of livelihoods indicating that vast majority of fishers surveyed are solely dependent on fishing and its related activities as their only source of livelihood indicating that vast majority of fishers surveyed are solely dependent on fishing and its related activities as their only source of livelihood. A few (13.3%-26.7%) had other source of secondary livelihoods which included driving, farming, weaving, trading and electrical works.

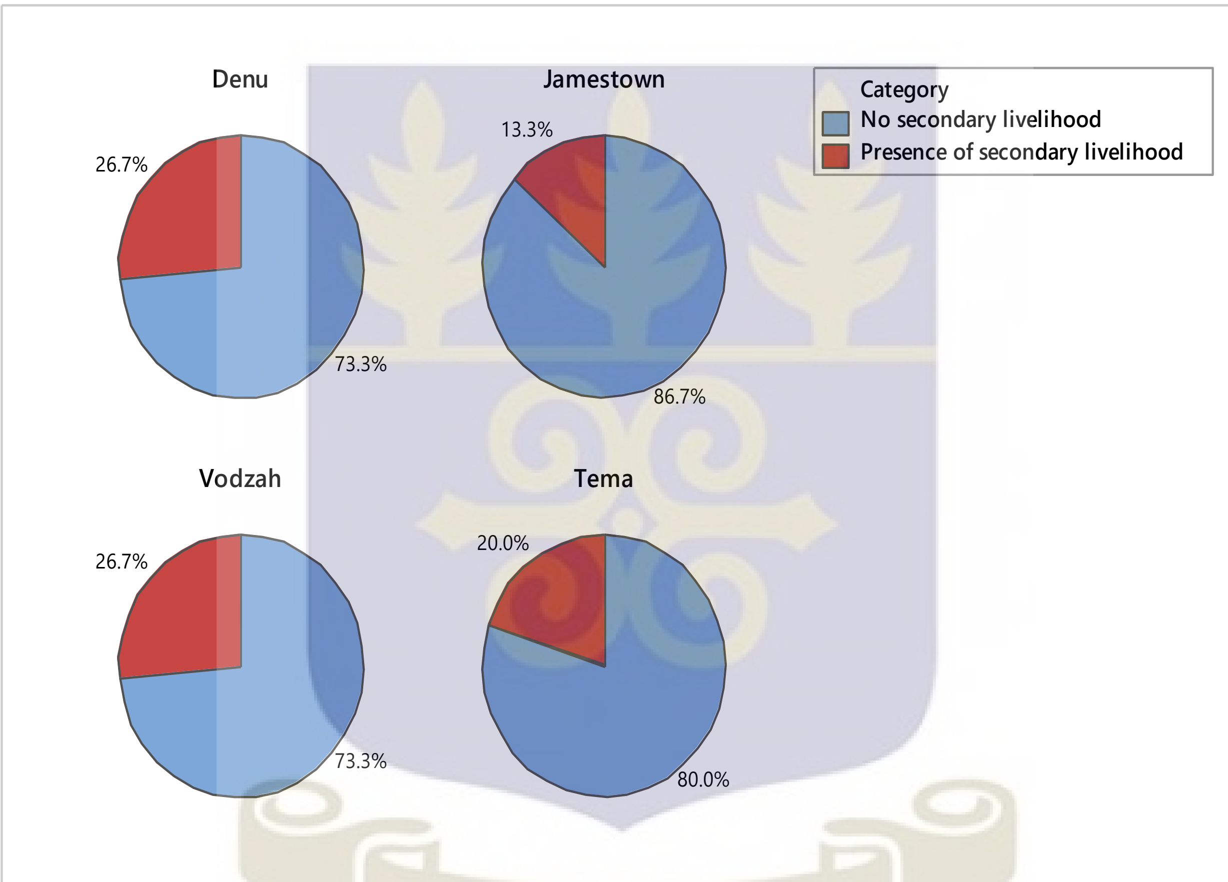

Figure 12: Secondary livelihoods among respondents from the four fish landing sampling stations

4.2.4 Marginalization based on social amenities

Table 3 outlines the presence and absence of social amenities in the four fish landing sampling stations. From Table 6, Tema, Jamestown and Denu (88.9-100%) appeared to be less isolated and relatively better than Vodzah fishing community (66.7.1%) with regard to social amenities.

Accessibility to microfinance institutions was a challenge to fishing communities in the Volta region. Again, Vodzah was not served with coldstore facilities though in Jamestown the coldstorage facility was not functioning. Communication facilities were in the form of mobile phones. From observation, some social amenities like banking facilities, larger markets and health services were not in within the fish landing sampling sites, rather in the communities within which the study sites occurred, approximately 3 km – 10 km from the fish landing sampling sites.

Table 3: Fisherfolks marginalization indicators across the study sites

Social amenities	**Vodzah**	**Denu**	**Jamestown**	**Tema**
Hospital	+	+	+	+
School	+	+	+	+
Clean Water	+	+	+	+
Sanitation facility	+	+	+	+
Microfinance institution	-	-	+	+
Accessible road	+	+	+	+
Coldstores	-	+	-	+
Access to larger market	+	+	+	+
Communication facilities	+	+	+	+
Banking facilities	-	+	+	+
%	**70**	**90**	**90**	**100**

+= Social amenity present - = social amenity absent

4.2.5 Saving habits and forms

Figure 13 displays the degree of savings among respondents from the four fish landing sampling sites. From Figure 13, percentage of respondents having savings habits (occurring in various forms) in decreasing order was highest at Tema (80.0%), Jamestown (76.7%), Denu (70.0%) and Vodzah (60.0%). However, from Figure 13, respondents without saving habits in increasing order was lowest at Tema (20.0%), Jamestown (23.3%), Denu (30.0%) and Vodzah (40.0%).

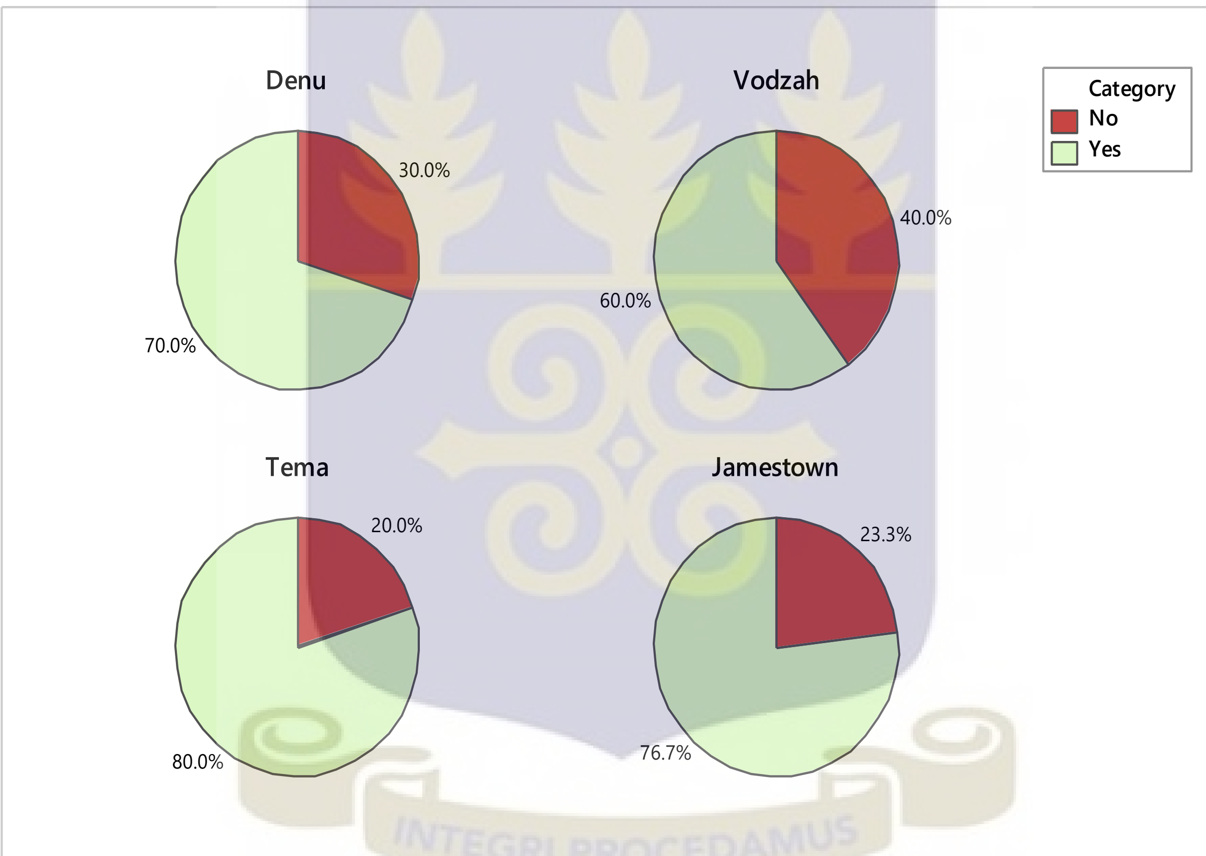

Figure 13: Degree of savings among respondents from the four fish landing sampling stations during the study period

Figure 14 shows the various forms of savings among respondents across the four fish landing sampling sites: four main forms of savings were identified. These were through bank deposits, cash, jewelry and building. Savings in the form of buildings was present only at Tema. Saving in the form of jewelry was only present at Tema and Jamestown fish landing sampling sites.

Concerning saving in the form of bank deposits, Tema and Denu both recorded the highest percentage (28.6%) as a result of the nearness of banking facilities. Vodzah recorded the least percentage of respondents saving through bank deposit (20.4%) due to the absence of banking facilities close by - located in Keta (> 7 km from fish landing sampling sites). Saving was in the form of cash denoted microfinance, credit unions, 'susu' or personal secret locations at respondents' residence. Jamestown fish landing sites recorded the highest percentage of saving through cash (34.3%) chiefly because of the strong and consistent presence of microfinance while the percentages observed in Denu (20%) and Vodzah (22.9%) fish landing sites were mostly due to personal secret locations at their residence. However, the percentage observed in Tema fish landing site (22.9%) was due to loss of interest in banking procedures.

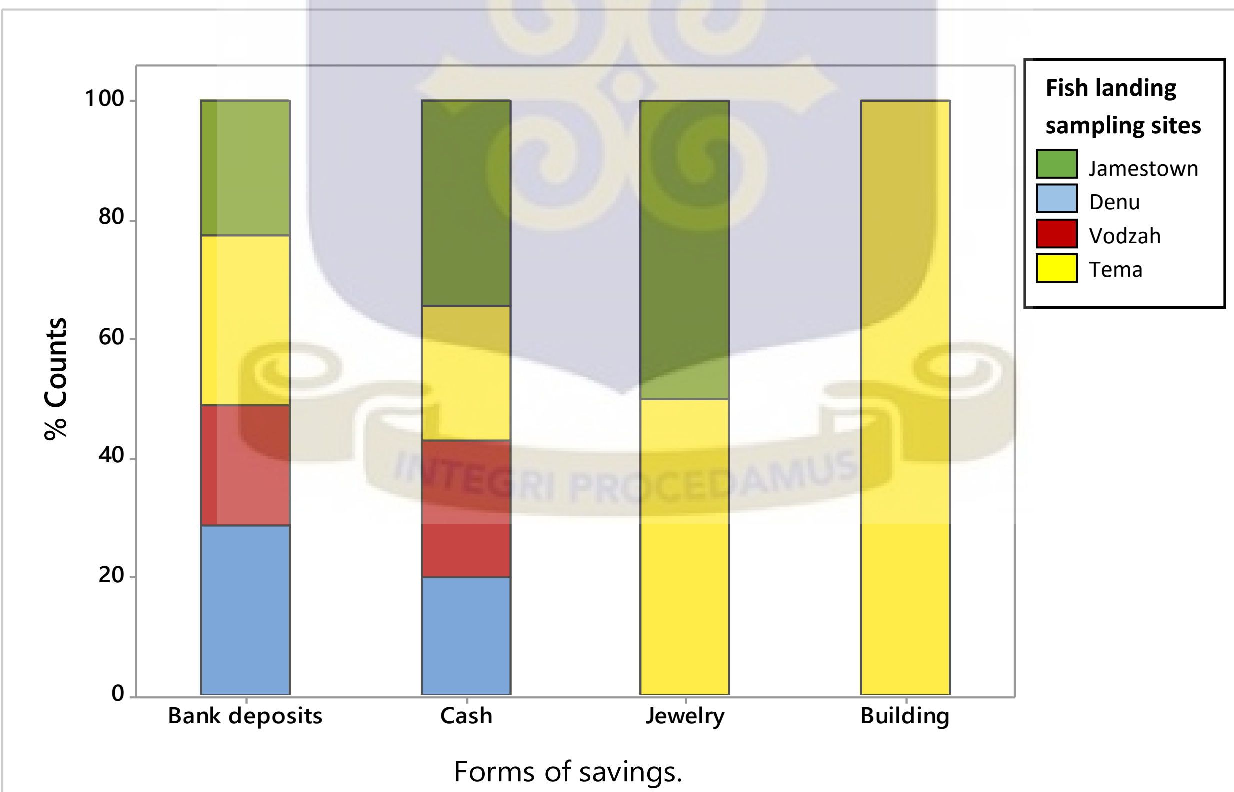

Figure 14: Forms of savings among respondents with saving habits across the four fish landing sampling stations during the study period

4.3 Security of coastal fishing operations from the perspective of fish catches

Key findings under this section focused on growth rate (K), mortality rates, exploitation rates (E), length at first capture (Lc_{50}), length at first maturity (Lm_{50}), recruitment pattern and exploitation stages.

4.3.1 Growth rate (K)

Figure 15 provides the Z/K ratios using the Powell-Wetherall plot for all the assessed species. The estimated Z/K ratios in Figure 15 were greater than one which indicated that the fisheries of assessed fish species are mortality dominated (Montcho *et al.,* 2015). The dark circles in the figure represent the points used in calculating (Z) through least squares regression lines while the yellow circles represent frequencies of fishes discarded from the calculation.

Figures 16a-e, graphically provide the restructured length-frequency data of the assessed species superimposed with the estimated growth curve. From the growth curves (Figure 16 a-e), the estimates of growth rate (K) from the study ranged between 0.25 yr^{-1} and 1.30 yr^{-1}. The highest growth rate (K) estimate was recorded by *Scomber japonicus* (K = 1.30 yr^{-1}) with Sardinella auritus recording the least estimate (K = 0.25 yr^{-1}). Considering estimated growth velocity (K) of 1.30 and 0.78 yr^{-1}, *Scomber japonicus* and *Brachydeuterus auritus*, respectively appeared to be 'fast growing' species (> 0.67 yr^{-1}) (Pardo *et al.*, 2013). The estimated growth rate (K) of *Sardinella maderensis, Engraulis encrasicolus and Pagellus bellottii* were 0.65, 0.58 and 0.42 yr^{-1} respectively, characterizing these species as 'intermediate growing' species (0.34 < K< 0.67 yr^{-1}) (Pardo *et al.*, 2013). The estimate of growth rate (K) for *Sardinella aurita* fell within 0 < K < 0.33 yr^{-1}- categorizing it as a 'slow growing' species (Pardo *et al.*, 2013).

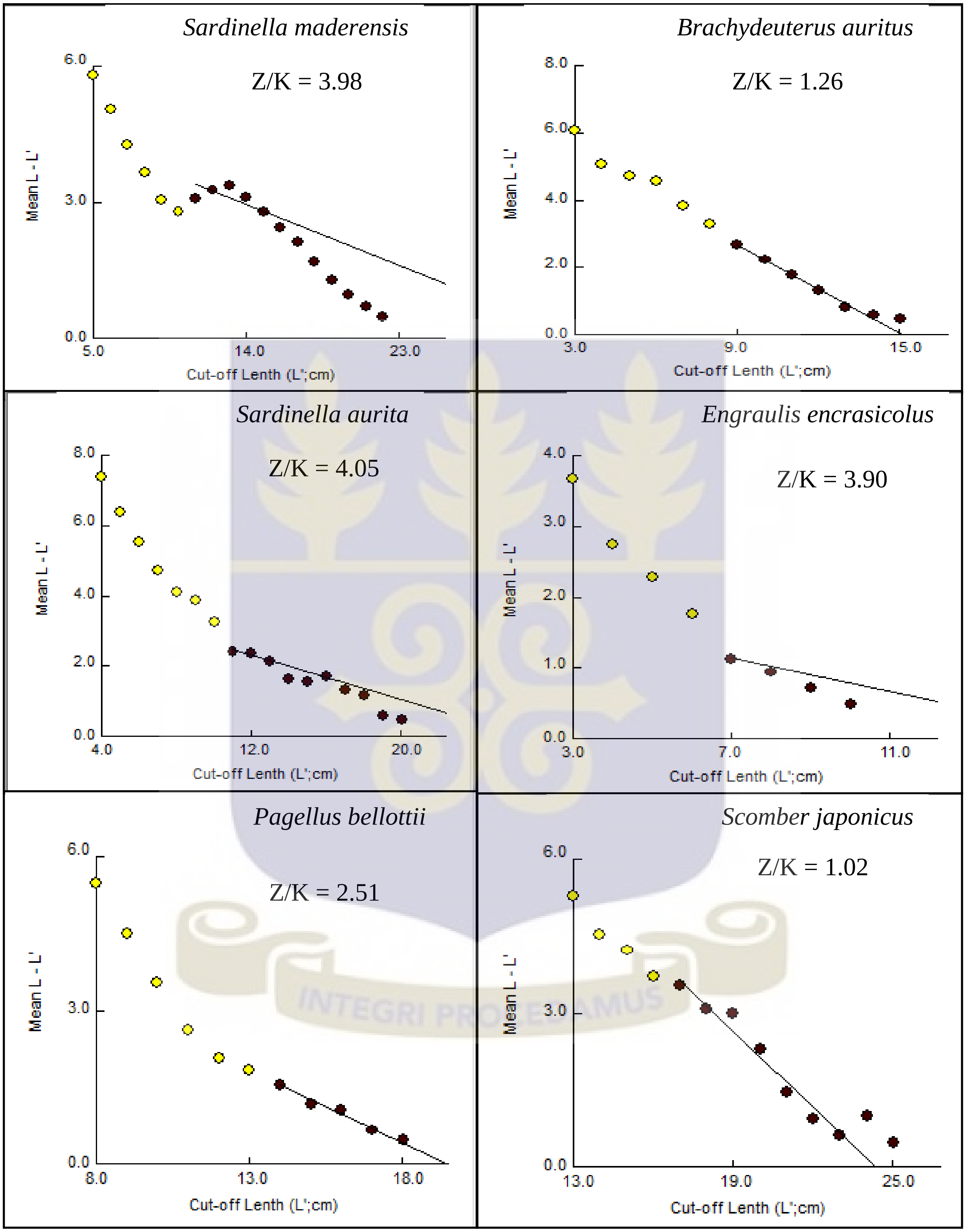

Figure 15: Powell-Wetherall plot for the selected fish species as obtained from FISAT output

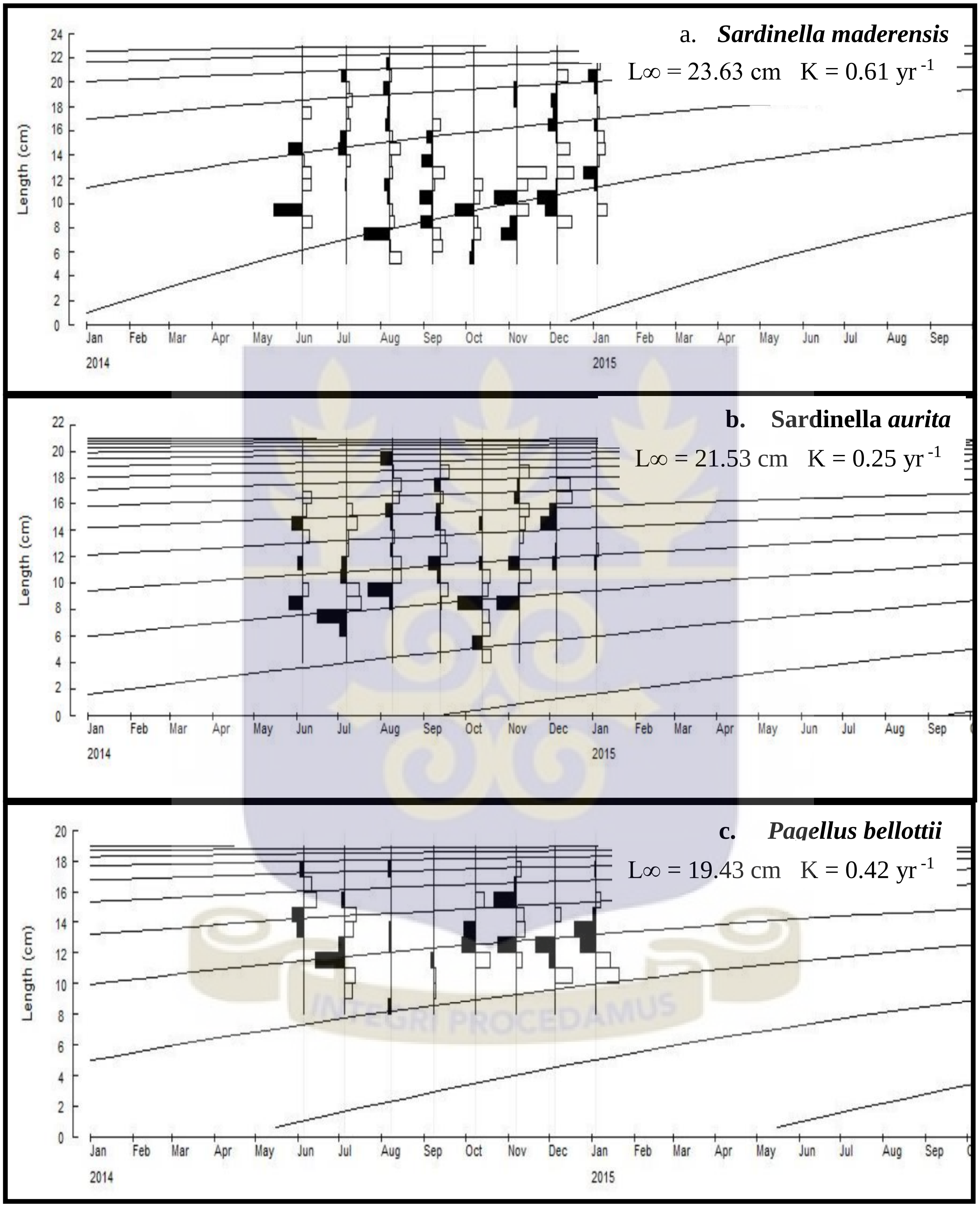

Figure 16: Restructured length-frequency data superimposed with the estimated growth curve as obtained from FISAT output

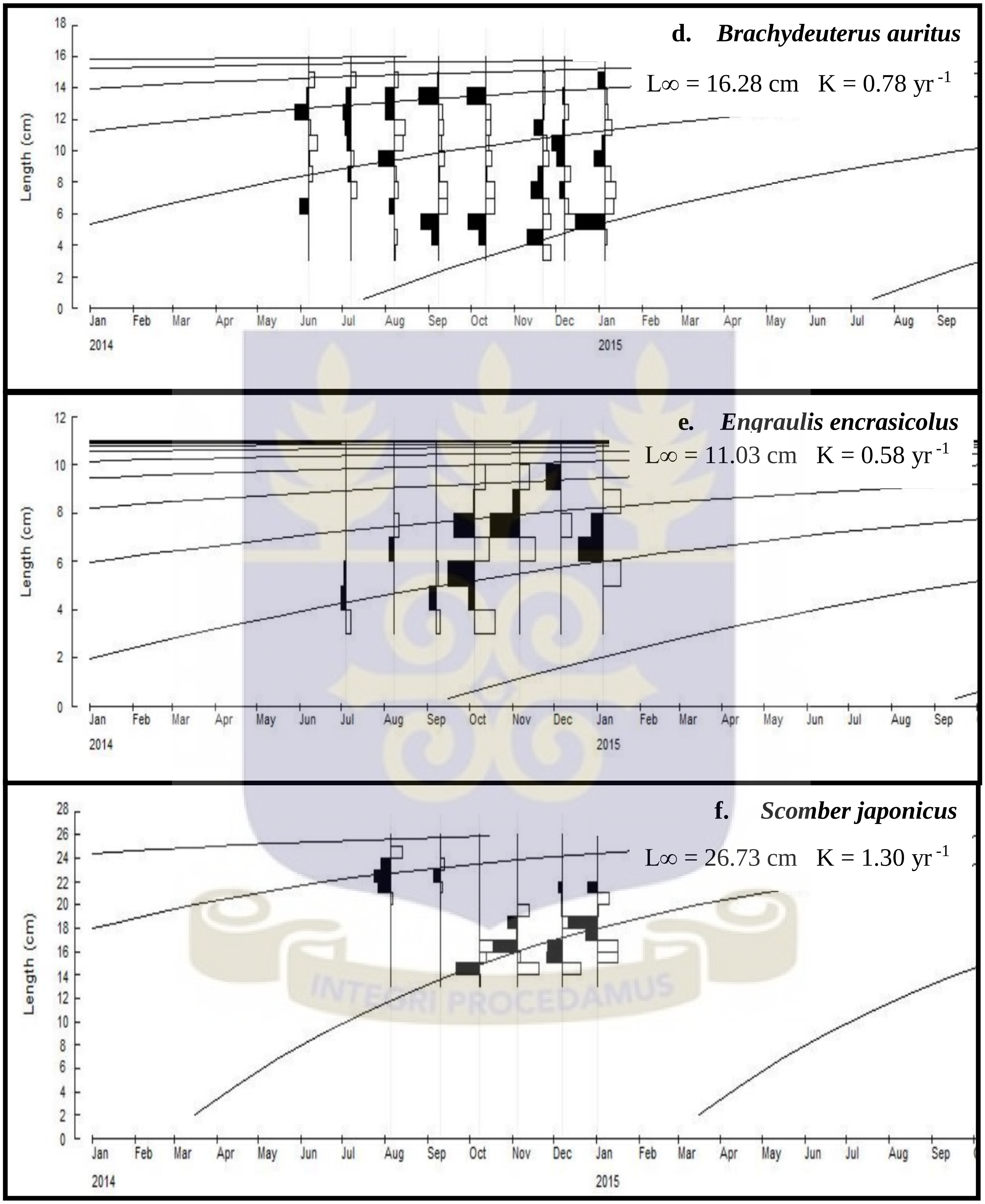

Figure 16: Restructured length-frequency data superimposed with the estimated growth curve as obtained from FISAT output

4.3.2 Mortality coefficients and current exploitation rate (E)

Figure 17, is a graphical representation of the estimation of total mortality (Z) using the Jones and Van Zalinge plot for all the assessed species. The dark circles in the figure represent the points used in calculating (Z) through least squares regression lines. The yellow circles represent frequencies of fishes either not fully recruited or approaching (L∞), and hence discarded from the calculation. *Scomber japonicus* faced the highest total mortality (Z= 5.02 yr^{-1}) while *Pagellus bellottii* had the lowest estimate of 2.58 yr^{-1} (Figure 17).

Using the respective asymptotic length, mean surface temperature and growth rate as the inputs for estimating the natural mortality rate (M), the calculated natural mortality for *Sardinella maderensis*, *Sardinella auritus*, *Brachydeuterus auritus*, *Engraulis encrasicolus*, *Pagellus bellottii* and *Scomber japonicus* were 1.33 yr^{-1}, 0.76 yr^{-1}, 1.73 yr^{-1}, 1.59 yr^{-1}, 1.10 yr^{-1} and 2.10 yr^{-1} respectively (Table 4). The calculated natural mortality (M) from the study spanned from 0.76 yr^{-1} to 2.10 yr^{-1}. *Scomber japonicus* recorded the highest natural mortality (M) value of 2.10 yr^{-1} while least natural mortality (M) value was recorded by *Sardinella auritus* (M= 0.76 yr^{-1}).

Based on the expression by Beverton and Holt (1957) with the corresponding total mortality rate (Z) and natural mortality rate (M) as the only inputs for estimating the fishing mortality (F), the calculated fishing mortality (F) estimates for *Sardinella maderensis*, *Sardinella aurita*, *Brachydeuterus auritus*, *Engraulis encrasicolus*, *Pagellus bellottii* and *Scomber japonicus* were 1.63 yr^{-1}, 2.41 yr^{-1}, 1.48 yr^{-1}, 1.81 yr^{-1}, 1.48 yr^{-1} and 2.92 yr^{-1} respectively (Table 4). The calculated fishing mortality (F) for all the assessed fish species ranged from 1.48 yr^{-1} to 2.92 yr^{-1}. *Scomber japonicus* faced the highest fishing mortality rate (F= 2.92 yr^{-1}) with *Brachydeuterus* *auritus and Pagellus bellottii* both recording the least estimate of F=1.48 yr^{-1}. However, the fishing mortality estimates obtained for all the assessed species were higher than the corresponding calculated optimum fishing mortality level (Fopt) which ranged from 0.30 yr^{-1} to 0.84 yr^{-1}, following the relationship between fishing mortality and Natural mortality (Pauly, 1984) (Table 4). This implies unsustainable level of fishing intensity.

The estimated current exploitation rates (E) using the relationship by Gulland (1971) for *Sardinella maderensis*, *Sardinella aurita*, *Brachydeuterus auritus*, *Engraulis encrasicolus*, *Pagellus bellottii* and *Scomber japonicus* were 0.55, 0.76, 0.46, 0.53, 0.57 and 0.58 respectively (Table 4). The estimated current exploitation rates were above the optimum level of 0.5 for all the assessed species with the exception of *Brachydeuterus auritus* (E = 0.46), *Sardinella aurita* recorded the highest exploitation rate (E) of 0.76, while *Brachydeuterus auritus* recorded the least exploitation rate of 0.46.

4.3.3 Recruitment pattern

Figure 18 illustrates the graphical presentations of the recruitment pattern from FISAT output for the six key species studied. The recruitment patterns were found to be continuous throughout the period of study with two recruitment peaks (major and minor). The calculated length at recruitment ranged from 3.5 cm to 13.5 cm (Figure 18).

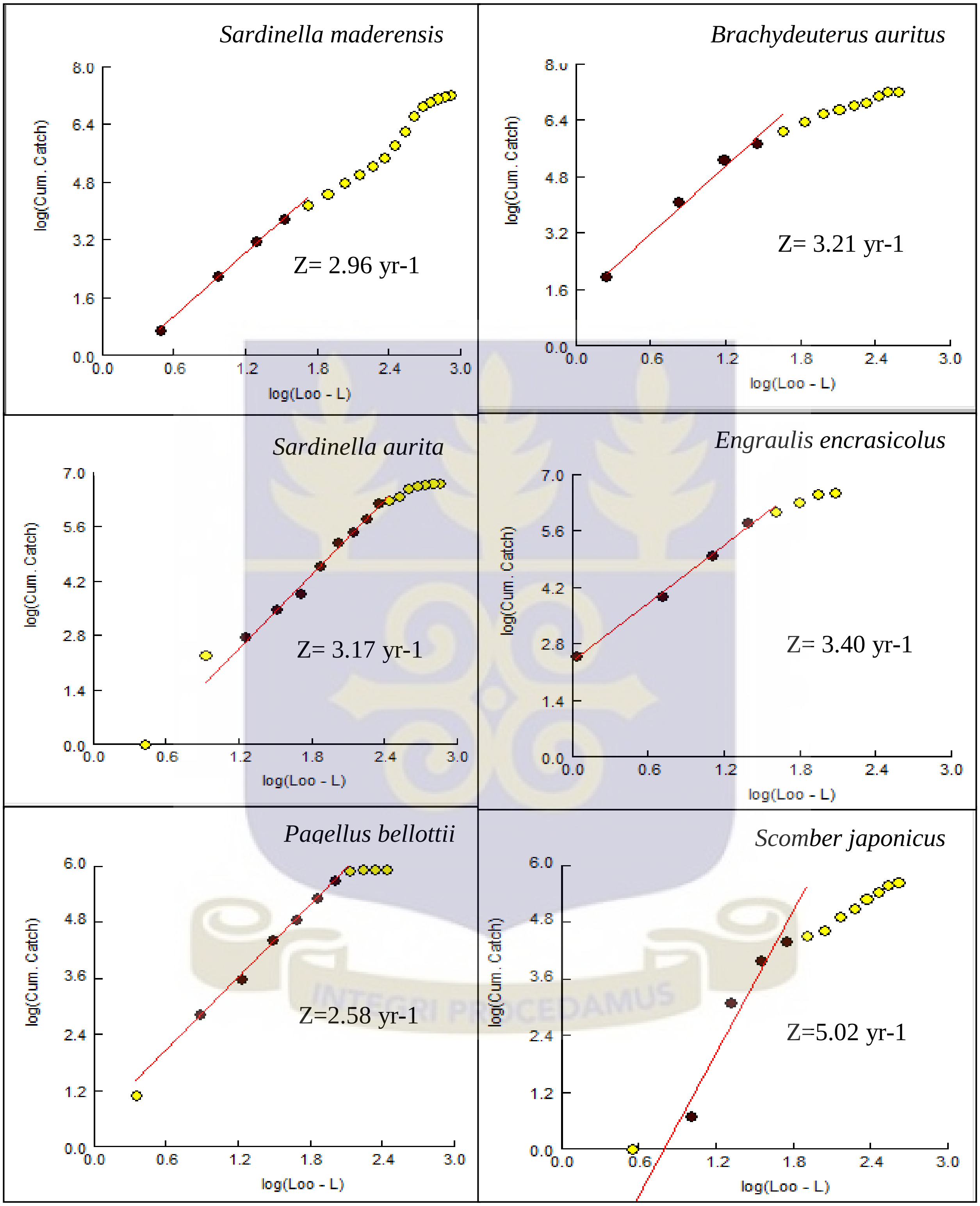

Figure 17: Estimation of total mortality (Z) using the Jones and Van Zalinge Plot for the selected fish species as obtained from FISAT output

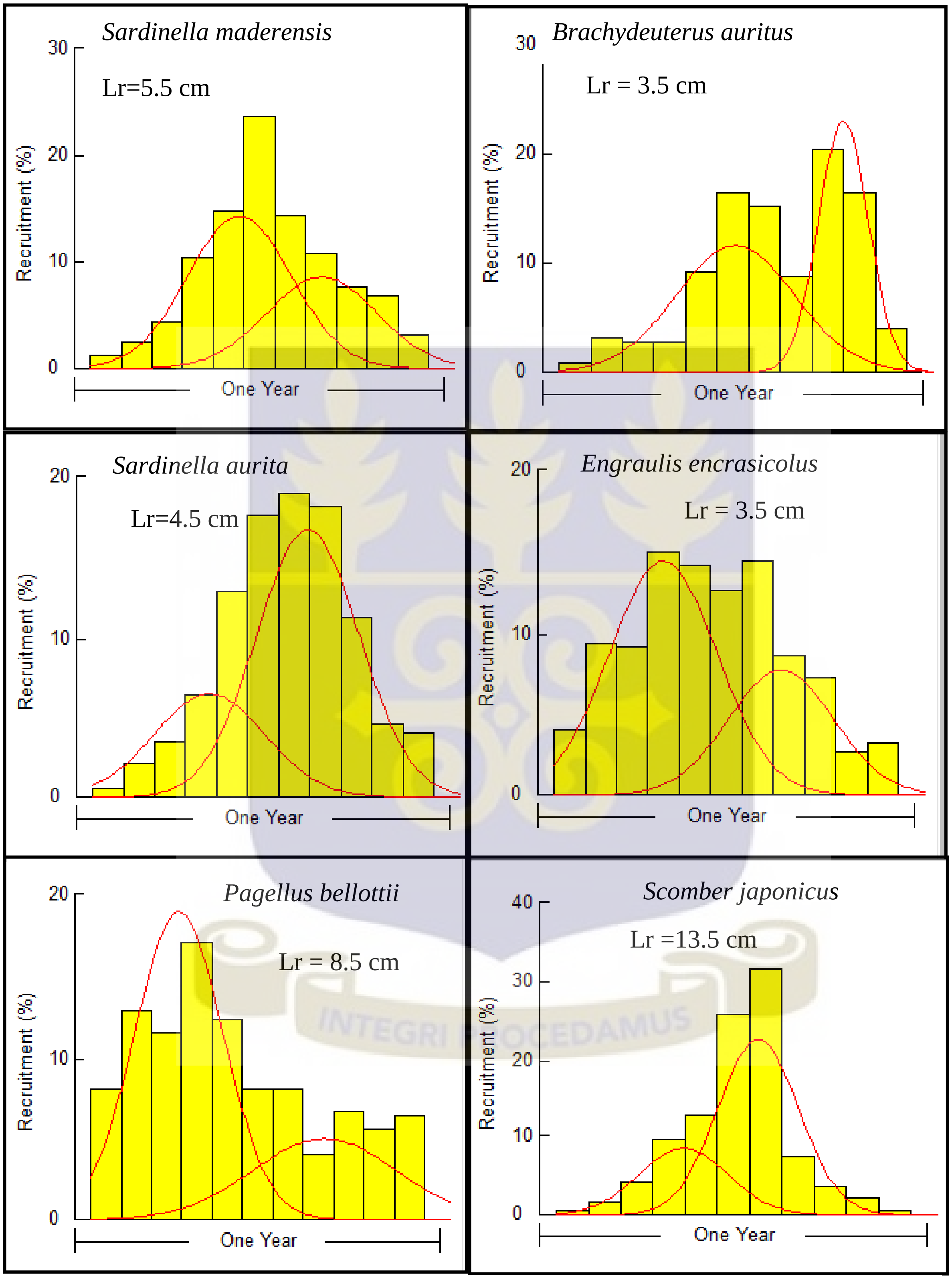

Figure 18: Recruitment pattern for selected fish species as obtained from FISAT output

4.3.4 Length at first capture (L_c)

Figure 19, provides the graphical estimation for the probability of capture for all the treated species which covers length at first capture (L_{c50}), length at 25% ($L_{25\%}$) and length at 75% ($L_{75\%}$) capture. The length at first capture (L_{c50}) estimated for *Sardinella maderensis*, *Sardinella aurita*, *Brachydeuterus auritus*, *Engraulis encrasicolus*, *Pagellus bellottii* and *Scomber japonicus* were 5.30 cm, 5.99 cm, 3.60 cm, 3.71 cm, 9.91 cm and 13.19 cm, respectively (Figure 19). The estimates for the ratio of length at first capture to asymptotic length ($Lc/L\infty$) which indicated the proportion of the asymptotic length before first capture are provided in Table 4. The estimated $Lc/L\infty$ ratios using the relationship between the Length at first maturity (Lc) and the asymptotic length ($L\infty$) by Pauly and Soriano (1986) for all the treated species ranged from 0.22 to 0.51 (Table 4). However, with the exception of *Pagellus bellottii* ($Lc/L\infty$ = 0.51), the remaining assessed species recorded $Lc/L\infty$ ratios less than 0.5 which indicated that majority of the catch landed constituted juvenile fish species. Of the assessed species that recorded a ratio less than 0.5, *Scomber japonicus* recorded the highest ratio ($Lc/L\infty$) estimate of 0.49, while *Sardinella maderensis* and *Brachydeuterus auritus* both recorded the same ratio ($Lc/L\infty$) estimate of 0.22 which was the lowest (Table 4).

4.3.5 Length at first maturity (Lm)

The estimates of the length at first maturity (Lm), for the assessed fish species were calculated and summarized in Table 4. The calculated length at first maturity ranged from 7.4 cm to 17.9 cm. Table 4 presents a summary of the growth parameters and other derived fish population parameters estimated for all the assessed fish species encountered in the catches from June 2014 to January 2015.

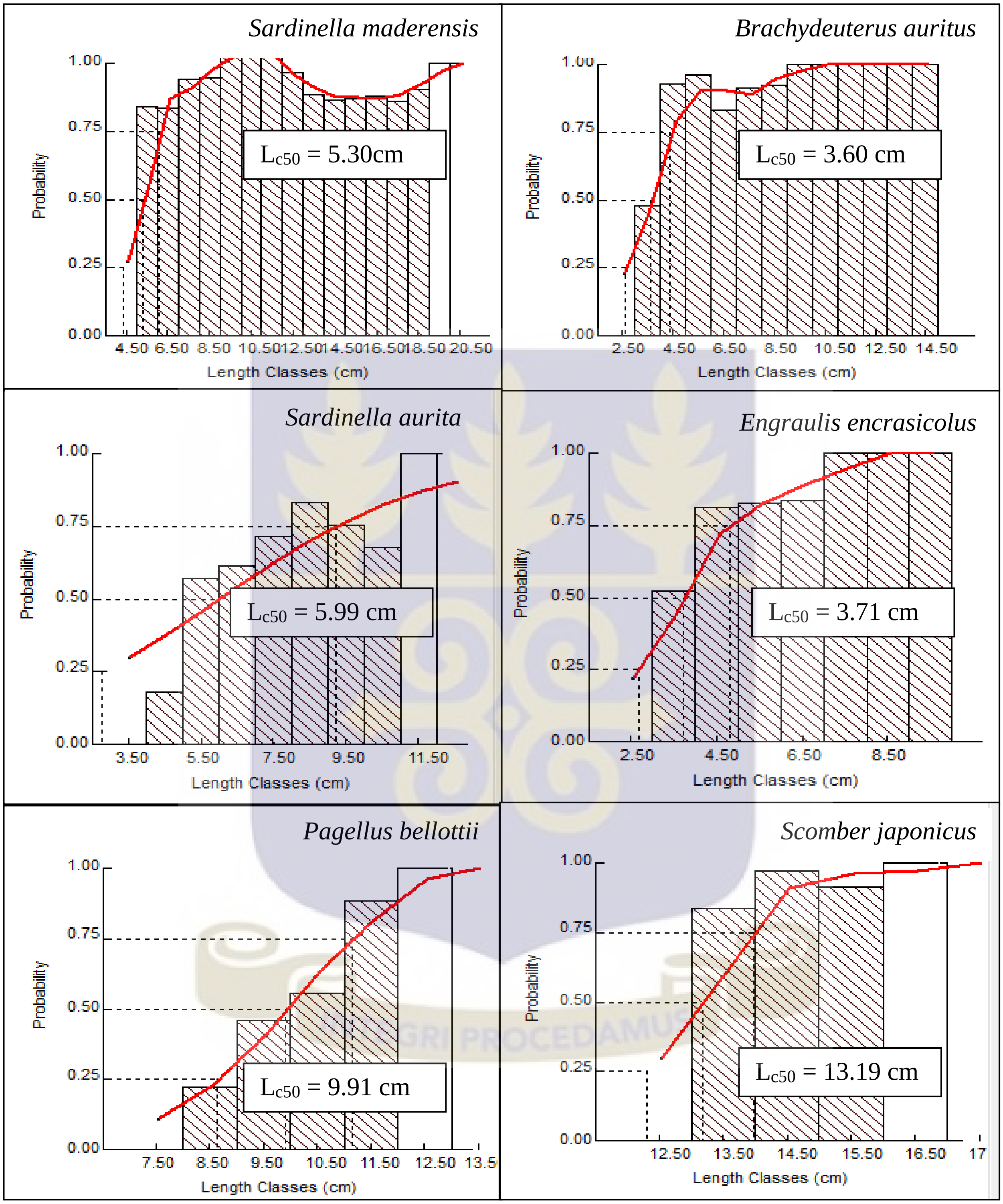

Figure 19: Probability of capture for the selected fish species as obtained from FISAT output

Table 4: Summary of estimated growth and other derived fish population parameters for the key species encountered in the catches from June 2014 to January 2015

Parameters	*Sardinella aurita*	*Sardinella maderensis*	*Brachydeuterus auritus*	*Engraulis encrasicolus*	*Pagellus bellottii*	*Scomber japonicus*
L∞	21.53	23.63	16.28	11.03	19.43	26.73
Growth rate(K)yr-1	0.25	0.61	0.78	0.58	0.42	1.30
M yr-1	0.76	1.33	1.73	1.59	1.10	2.10
F yr-1	2.41	1.63	1.48	1.81	1.48	2.92
Z yr-1	3.17	2.96	3.21	3.40	2.58	5.02
Z/K	4.05	3.98	1.26	3.90	2.51	1.02
Fopt	0.30	0.53	0.69	0.64	0.44	0.84
E	0.76	0.55	0.46	0.53	0.57	0.58
Lm/cm	14.4	15.8	10.9	7.4	13.0	17.9
Lm: L∞	0.67	0.67	0.67	0.67	0.67	0.67
L25%	2.78	4.40	2.60	2.66	8.63	12.39
L50%	5.99	5.30	3.60	3.71	9.91	13.19
L75%	9.20	6.12	4.38	4.81	11.16	13.99
Lc/L∞	0.29	0.22	0.22	0.34	0.51	0.49

4.3.6 Categorization of exploitation stages based on the catches (C) and maximum catch (Cmax) ratios (C/Cmax)

Figures 20a-f provide the scatterplots for C/Cmax ratios from 1980-2010 for the assessed species.

The exploitation stages of *Brachydeuterus auritus* from 1980 to 2001 occurred within the under-developed category with values of C/Cmax ratio ranging from 0.00 to 0.07. However, with C/Cmax ratio values ranging from 0.02 to 0.07, its exploitation stages from 2003 to 2010 attained the collapsed status as categorized after a preceded category of fully' exploited status in 2002 where its C/Cmax ratio was 1.0 (Figure 20a).

With the values of C/Cmax ratio ranging from 0.3 to 0.5, the exploitation stages of *Sardinella maderensis* from 1980 to 1984 were within the developed category. From 1985 to 1990, its exploitation stages alternated between the categories of fully and over exploited (C/Cmax ratios spanned from 0.1-1.0). In 1991, its fishery which was categorized as collapsed with C/Cmax ratio as 0.0 was succeeded by fully exploited status in 1993 (C/Cmax ratio of 0.6). However, its exploitation stage in 1992 was in rebuilding category based on the rebuilding rule that, years between collapsed and first fully exploited status were assigned a rebuilding status. From 1994 to 2010, its exploitation stages oscillated between the categories of 'fully' and 'over' exploited (C/Cmax ratios spanned from 0.2-0.8) (Figure 20b).

The exploitation stages of *Sardinella aurita* fluctuated between the categories of under-developed and developed status from 1980 to 2001 with C/Cmax ratios ranging from 0.0 to 0.3.

In 2002, its fishery attained the category of fully exploited status (C/Cmax ratio = 1.0) followed by the category of over-exploited status from 2003 to 2010 (C/Cmax ratio ranged from 0.1 to 0.2) (Figure 20c).

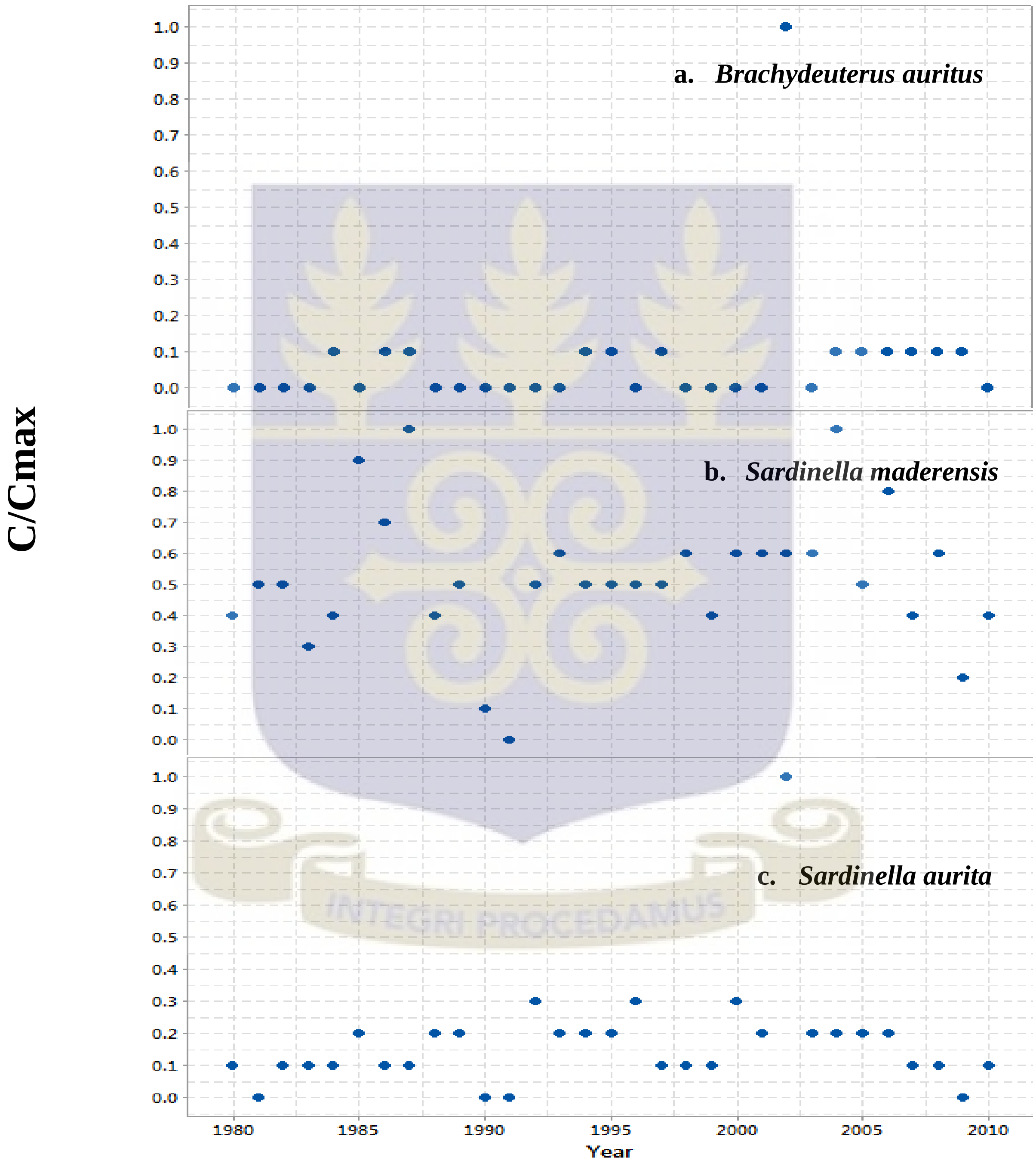

Figure 20: C/Cmax scatterplot from 1980 to 2010 for a) *Brachydeuterus auritus* b) *Sardinella maderensis* c) *Sardinella aurita*

The exploitation stage of *Pagellus bellottii* oscillated between under-developed and developed status from 1980 to 1986 with C/Cmax ratios ranging from 0.0 to 0.4. From 1987 to 1989, its exploitation stage changed to the category of fully exploited status (C/Cmax ratios spanned from 0.6-0.7) followed by a collapsed category in 1990 (C/Cmax ratio was 0.0). However, based on the rebuilding rule that, years between collapsed and first fully exploited status (which occurred in 1992 with C/Cmax ratio of 0.7) are assigned a rebuilding status, its fishery in 1991 attained a rebuilding status although its C/Cmax ratio was 0.0. From 1993 to 2006, its exploitation stages oscillated between the categories of fully and over exploited status (C/Cmax ratios ranged from 0.2-1.0) followed by 'collapsed' category in 2007. However, unable to satisfy the rebuilding rule that, years between collapsed and first fully exploited status are assigned a rebuilding status, its exploitation status retained the category of collapsed status (with C/Cmax ratios ranging from 0.3-0.5) from 2008 to 2009. In 2010, its exploitation stage attained the rebuilding category (with C/Cmax ratio of 0.4) based on the final and preceding year rule that, accept C > 0.28C/Cmax as indicative of subsequent fully exploited status (Figure 20d).

In 1980, the exploitation stage of *Engraulis encrasicolus* was in the developed category (C/Cmax ratio = 0.4). From 1981 to 1983, its exploitation stages oscillated between the categories of fully and over exploited status with C/Cmax ratio ranging from 0.2 to 0.7. However, in 1984, its fishery experienced a collapsed category (C/Cmax ratio was 0.0) followed by a rebuilding from 1985 to 1986 based on the rebuilding rule that, years between collapsed and first fully exploited status (which occurred in 1987 with C/Cmax ratio of 0.9) are assigned a rebuilding status. Nonetheless, from 1988 to 1989 the exploitation stages of its fishery attained the category of fully exploited status (C/Cmax ratio ranged from 0.8). In 1990, its fishery attained the collapsed category with C/Cmax ratio of value 0.0 succeeded by a rebuilding status in 1991 based on the rebuilding rule, that years between collapsed and first fully exploited status are assigned a rebuilding status. In 1992, its fishery attained the first category of fully exploited status with C/Cmax ratio of 0.9 after a collapsed status in 1990. From 1993 to 2010, its exploitation stages had alternated between the categories of fully and over exploited status (C/Cmax ratio ranged from 0.1-1.0) (Figure 20e).

The exploitation stage for *Scomber japonicus* varied between under-developed and developed status from 1980 to 2001 with C/Cmax ratios ranging from 0.0 to 0.4. In 2002, the exploitation stage of its fishery attained the category of fully exploited with C/Cmax ratio of value 1.0. However, with C/Cmax ratio of value 0.1 from 2003 to 2010, the exploitation stages of its fishery attained the category of over exploited status (Figure 20f).

A summary of the C/Cmax values obtained for the selected species and the current exploitation stages based on 2010 as the current year is presented in Table 5. However, it should be noted that 'mt' refers to metric tonnes as indicated in Table 5. From Table 5, the selected species may be placed in three levels of exploitation stages as follows; i) collapsed (*Brachydeuterus auritus*): ii) overexploited (*Sardinella maderensis, Scomber japonicus, Sardinella aurita* and *Engraulis encrasicolus*) and iii) rebuilding (*Pagellus bellottii)*.

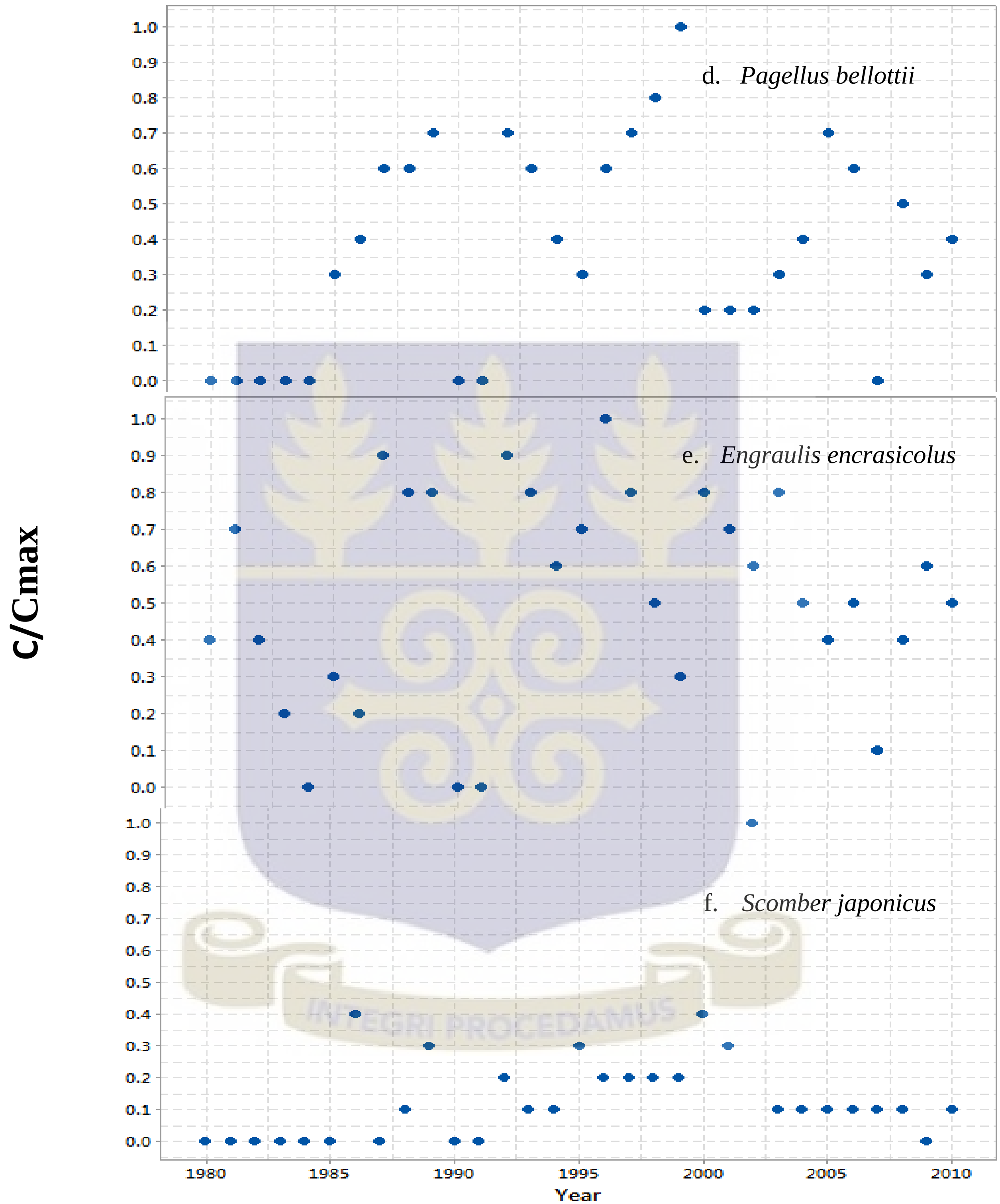

Figure 20: C/Cmax scatterplot from 1980 to 2010 for d) *Pagellus bellottii* e) *Engraulis encrasicolus* f) *Scomber japonicus*

Table 5: Derivative of exploitation stages of the key fish species based on C/Cmax ratios for 2010 (based on catch data obtained from FSSD, Ghana).

Description	*Sardinella aurita*	*Sardinella maderensis*	*Brachydeuterus auritus*	*Engraulis encrasicolus*	*Pagellus bellottii*	*Scomber japonicus*
Recent catch (C) (2010) in mT (x 10^3)	36.7	11.3	13.7	45.1	4.8	3.4
Highest catch (Cmax) in mT (x 10^3)	384.4	27.2	284.2	98.3	13.3	50.7
C/Cmax ratio	0.1	0.4	0.0	0.5	0.4	0.1
Category range	0.1 – 0.5 Cmax	0.1 – 0.5 Cmax	< 0.1 Cmax	0.1 – 0.5 Cmax	> 0.28 Cmax	0.1 – 0.5 Cmax
Category of exploitation stage	Over exploited	Over exploited	Collapsed	Over exploited	Rebuilding	Over exploited

CHAPTER FIVE

5.0 DISCUSSION

This chapter provides discussion of key findings from the study.

5.1 Security of coastal fishing operation from the perspective of safety

From the study, very prominent forms of IUU fishing practices were found to exist within each of the three marine fishing sectors in Ghana, namely light fishing (artisanal level); fishing without license (semi industrial level) and trawling below the 30 m depth (industrial level). This observation could be attributed to the low level of monitoring, low severity of sanctions for illegal activities, intended high income and quantity of catch, the ease with which materials for illegal activities are acquired and the ease of carrying out such illegal activities.

Lack of compliance statistics detailing the intensity, the evolving nature of IUU fishing, and its ecological, economic and societal costs by MSCD of MoFAD, Ghana may have accounted for the poor correlation between total fines and number of IUU infractions recorded in Ghana's coastal waters in (Figure 2). However, countries like Antigua and Barbuda have been able to conduct MCS cost and benefits analysis allowing fisheries administrators to know substantially the portion of fisheries budget to invest into MCS for effective law enforcement (CRFM, 2013).

Weak MCS capacity and inconsistent patrol surveillance by Ghana Navy and Marine Police were identified as two vital facilitators for IUU fishing facing coastal fishing operation in Ghana. This could be attributed to the relatively low allocation of fisheries budget to fisheries law enforcement institutions whereas in countries like Korea and Norway, more than two two-thirds of the fisheries budget is allocated to fisheries law enforcement services (CRFM, 2013; MoFAD, 2014; Petrossian, 2014). Further, the non or slow rate of prosecution of cases concerning arrested fishermen by judicial arm of government dampens the desire of naval officers to continually conduct sea patrols - possibly accounting for the limited sea patrols by Ghana Navy (CRC & FON, 2011; CRC, 2013). Consequentially, limited sea patrols have resulted in increased illegal fishing activities within the inshore economic zone (IEZ) by industrial vessels mostly trawlers (Falaye, 2008).

Lack of effective deterrence strategy promotes continual involvement in IUU fishing at all levels of fishing activities occurring in coastal frontiers of Ghana. For instance, the artisanal sector of fishing in Ghana, confiscation of fishing inputs of low costs due to subsidy may not deter fishers from practising IUU fishing methods as affected fishers will always be able to purchase new ones. However, for deterrence from IUU fishing to be effective, it should be enshrined within the fisheries law of Ghana, the seizure of fishing inputs of higher costs like the outboard motors and the fishing vessel itself as penalties. Additionally, the entire crew could even put behind bars for some days in extreme cases of total defiance. Therefore, there is the need for amendment of the fisheries law to include an increase in the magnitude of penalties for IUU fishing particularly at the artisanal and semi industrial fishing sectors.

Considering the industrial coastal fishing sector in Ghana, penalties maybe regarded as too low in terms of annulling the benefits derived from IUU fishing hence the inability of such sanctions to discourage illegal operators from engaging in IUU fishing (MoFAD, 2014). However, sanctions endorsed in the recent publication of Fisheries Amendment Act, 2014 – Act 880 should be strictly adhered to. Strict enforcement of sanctions in the amended Fisheries Act (Act 880) will not only reduce IUU fishing in coastal fishing operations but also ensure that Ghana joins the few African coastal countries like Namibia and South Africa with reduced IUU fishing due to increased penalties (Pramod and Pitcher, 2006).

Heavy dependence on marine fisheries as ‘foodcrop’ and ‘cashcrop’ by fishing and non-fishing households also has catalyzed IUU fishing in Ghana coastal waters (Varkey *et al.*, 2010). For example, fish processors mostly the ‘fish mammies’ who pre-finance majority of the fishing voyages especially during the lean seasons influence IUU fishing particularly at the artisanal level of fishing since fishermen want to maintain this reliable source of finance for their fishing trips. Further, low fisheries resource abundance during certain periods of lean coastal fishing was found to be another reason for IUU fishing as exemplified by light fishing (Varkey *et al.*, 2010).

The issue of port of convenience which mostly serves as gateways for smuggling illegally caught fish to target markets was observed at the industrial sector where illegally caught fish (mostly smaller than recommended sizes) are smuggled quickly to the market from fishing harbour (EJF, 2007) possibly due to inadequate port State measures (MoFAD, 2014). Access to such port presents a significant problem to the sustainability of Ghana’s coastal fishing as it undermines Government’s initiatives to reduce IUU fishing (Petrossian, 2015).

At the industrial level of coastal fishing in Ghana, it was revealed that measures exist for controlling IUU fishing. For instance, the installation of vessel monitoring systems (VMS) on all tuna vessels, licensing of vessels and observer programmes (Amador, FSSD, pers. comm., 2015).

However, considering observer programmes, familiarity with crew and skipper due to longer fishing periods at sea could prevent observers from reporting any form of IUU fishing that industrial vessels engage in at sea.

Dwelling on fishing regulations, the study indicated that majority of the fishers (80% - 66.7%) were fully aware of the presence of fisheries regulations. The reasons linked to this finding included previous sensitization programmes carried out by Fisheries officials and relevant Non-Governmental Organizations as well as chief-fishermen who are seen as custodian of fisheries regulations measures (Kwarfo, 2014). Regardless of the numerous official fisheries regulations identified, it was not surprising that regulation on light fishing was the most popular. The ease with which materials for light fishing is obtained and the massive focus of enforcement centred on it within coastal fishing communities in Ghana may have accounted for its popularity among artisanal fishers (Mevuta and Boachie-Yiadom, 2013). Minority of the fishers (20%-33.3%) were however, identified to be ignorant of the existence of fisheries regulation measures – a situation which often ends in non-compliance among fishers and subsequently unsustainable management of fisheries resources (Ntiba *et al.,* 2001). Therefore, initiating sensitization programmes on the fisheries regulation measures within coastal fishing communities will ensure effective management and sustainable utilization of fisheries resources (CRC, 2011).

Non-compliance of fisheries regulation measures observed in the study was chiefly driven by the need to ensure continual survival. Other reasons for non-compliance were identified to be due to the absence of fisheries officers at the landing sites, dilution of punishment to offenders (through bribes and familiarity with officials), the desire to increase their fish catches (attributed to migrant fishers by host fishers) and seizure of inexpensive fishing inputs. Additionally, the ecological and economic reasons for certain fisheries regulations were observed as not populous among fishers hence the absence of voluntary compliance. Therefore, as put forward by Bannerman (2014), fishers should be educated of the negative effects of illegal fishing to enhance compliance with the fisheries rules and regulations.

Furthermore, frequent visits by fisheries officers to various landing sites as well as regular awareness programmes focusing on the economic and ecological importance of fisheries regulation measures should be made to prevent further collapse of the marine fisheries in Ghana's coastal waters. Strict, evenhanded and consistent enforcement efforts should be undertaken (if possible simultaneously) in all landing sites as factors driving non-compliant attitudes among fishers are contagious hence the tendency to drive fishers who comply into not complying especially when violators go unpunished with high economic gains from undertaking illegal fishing activities. It is noteworthy that adherence to fisheries regulations will ensure better landings as already seen in neighboring West African coastal states like Liberia (Tsibu, 2015).

The high percentage of non-arrest incidence (60% - 80%) observed in the study did not necessarily indicate compliance; rather it indicated the routine and consistent absence of Government fisheries officials in some fish landing sampling sites especially fishing communities in the Volta Region. Nonetheless, in filling the gap created by the continual absence of Government fisheries officials with respect to enforcement of fisheries regulations, the Chief-fisherman (Traditional authorities) was identified as the most recognized enforcement institution of fisheries regulation measures in all four study sites (Nunoo *et al.*, 2015). This could be due to the high reverence given to them as a result of the authority they possess in pronouncing sanctions for violators at the traditional level. However, the inability of chief-fisherman to make official arrests concerning official national fishing regulations may have also accounted for the high rate of non-arrest incidences prevailing in most fish landing sites in Ghana. The Chief-fisherman can therefore be used as an agent of both social attitudinal change regarding compliance to and enforcement of fisheries regulation measures especially when provided with extra authorities like official license to make arrest.

5.2 Security of coastal fishing operation from the perspective of poverty

The security of coastal fishing operations in Ghana from poverty perspective focused on marginalization based on social amenities, vulnerability sources, secondary livelihoods, poverty indices and saving habits as the key indicators.

Characterized by all-year round access to good road network, functional communication facilities in the form of mobile phones, sanitation facilities, market, education and health services, it was observed from the study that all the four fish landing sampling sites were not remote rural areas (RRAs), probably as a result of infrastructure development occurring in the communities within which these fish landing sampling sites are located (Béné, 2009; Béné & Friend, 2011). Nevertheless, the absence of some fish trade enhancing facilities like microfinance, banking and cold storage facilities within the fishing communities threaten the sustenance of fishing livelihoods for small scale fishing communities (Townsley, 1998). For instance, the inaccessibility to microfinance and banking facilities in some fishing communities limits the fishers' desire to escape poverty through savings. The absence of or dysfunctional coldstorage facility prevents fishers from obtaining better fish prices to compensate for high input cost (Ward *et al*., 2004).

High price of fishing inputs mostly fuel (in the form of premix and outboard motors) was observed to be one of the major sources of vulnerability (constraints) facing fishers regardless of the location of fishing communities. This was attributed to third parties mostly middlemen who take part in the demand and supply chain of these fishing inputs as reported by Kotey (2014). Lack of capital was identified as another major constraint confronting fishers. Marginal profits gained as a result of the high costs incurred in maintaining damaged fishing inputs mostly fishing nets and outboard motors, indiscriminate mismanagement of income gained from fishing expeditions and the high dependency ratio were other reasons fuelling the existence of 'lack of capital' as major source of vulnerability. It was however, observed that in masking the effects of some vulnerability sources, vulnerable fishing communities engage in unsustainable fishing practices such as the use of chemicals like carbide in fishing and small mesh-sized fishing gears.

Minority (13.3% - 26.7%) of the fishers interviewed were found to be with other source of livelihoods (secondary livelihoods) outside their primary livelihoods (fishing and fishing related activities). The unstable nature of the fisheries resources and its related activities may have accounted for the pluralization of livelihoods among these fishers (Allision & Horemans, 2006). Inspite of the desire to diversify livelihoods, the absence of or limited alternate skills, sources of alternate livelihoods and capital to start alternate livelihoods were cited as major barriers which prevented majority (73.3% - 86.7%) of the fishers from engaging in secondary livelihood (Ikiara & Odink, 2000). It is apparent that, in maintaining their welfare, fishing households without alternative source of livelihoods are most likely to put severe pressure on marine fisheries resources through unsustainable fishing practices leading to its degradation – making them prone to poverty (Lawson *et al.*, 2012).

The calculated three indices of poverty measurement, namely poverty severity, poverty gap and head count supported the widely held view that poverty exists in small scale fishing communities. However, the relatively higher poverty gap among fishing households in Volta region (PG= 0.28-0.47) than observed in Greater Accra region (PG= 0.11-0.43) indicated that fishing households in Greater Accra region are living just below the poverty lines used while fishing households in Volta region are living widely below the poverty line. Also, the relatively higher poverty severity (P2) among fishing households in Volta region (P_2= 0.15-0.30) than in Greater Accra region (P_2= 0.06 - 0.25) implied that fishing households in Volta region are poorest among the poor. The relatively higher poverty severity and poverty gap indices among vulnerable fishing households in the Volta Region than in the Greater Accra Region of Ghana could be due to the relatively high intensity of the various forms of vulnerabilities, limited sources of secondary livelihoods and marginalization based on fish trade enhancing social amenities facing fishing communities in Volta Region.

Majority (60% - 80%) of fishers interviewed mostly indulge in saving habits in various forms such as bank deposit, cash, buildings and jewelry in order to escape poverty particularly in the lean season (Asiedu *et al.*, 2013). Nevertheless, minority (20% - 40%) of the fishers interviewed were found to abstain from saving habits. The absence of saving habits among these fishers could be attributed to the fact that these fishers are either crew members or fishwives (who form the bulk of small scale fishing industry) with high debts or very minute profits to save in addition to high dependency ratio. Additionally, the negative perceptions about saving with banks and microfinances, the inability of returns from savings to support vulnerable fishing households on long-term basis especially during the long lean season and the extravagance behaviour of fishers who perceive fish as daily cash crop could also be reasons accounting for the absence of saving habits among some fishers. It is therefore noteworthy that, the absence of sound financial environment among fishers has the ability to create a pathway for vulnerable fishing households to indulge in unsustainable fishing methods in order to sustain their lives till the bumper season returns.

5.3 Security of coastal fishing operation from the perspective of fish catches

In assessing the security of coastal fishing operations from fish catch point of view, the study focused on the estimations of fish growth rate (K), mortality parameters-natural mortality(M) and fishing mortality (F), recruitment pattern, exploitation rates ($E_{current}$,), level of overfishing and exploitation stages based on catch data.

5.3.1 Implications of estimated growth rates (K)

Generally, the six selected species conformed to the rough generalization of Pauly (1983) that species with low growth rate (K) have low natural mortality rate (M) while species with high growth rate (K) have high natural mortality rate (M). Thus *Sardinella aurita* which showed the lowest growth rate (K) of 0.25 yr^{-1} also had the lowest natural mortality rate (M) of 0.76 yr^{-1} while *Scomber japonicus* which recorded the highest growth rate (K) of 1.30 yr^{-1} was also faced with the highest natural mortality rate (M) of 2.10 yr^{-1}. The implication of these observations is that, species with low growth rate (K) cannot contain high natural mortality rate (M) as the presence of such situation has the likelihood to run low growth curvature (K) species into extinction if possible (Pauly, 1984). Although it is not clear yet for the selected species to possibly run into extinction, it is apparent that the current situation could lead to significant decrease in abundance and ultimately a possible long term decline in catches.

On the contrary, high growth rate (K) species facing high natural mortality rate (M) will reproduce at an earlier age or size to compensate for the high mortality rate (M) which confront such species. As an advantage, the spawning stock numbers of such species will increase. However, the disadvantages of this strategy will include reduced length and weight of the spawners, lower fecundity, smaller eggs, with less and smaller viable larvae (Solemdal, 1997) - a competitive disadvantage for survival. Another disadvantage is that fish are spawning at smaller length and lower weight; such that the contribution to the spawning stock biomass is lower than expected, given the large number of spawners (O'Brien, 1999). Therefore, harvesting early spawners will not only reduce the spawning biomass but truncate the age or size structure- such incidences will eventually collapse the fishery. Therefore, regardless of the type of fish species based on growth rate (K), high natural mortality (M) provides a great sense of worry with regard to sustainability of fish abundance and catches.

5.3.2 Implications of the estimated mortality rates

The instantaneous total mortality rate (Z) values greater than about 1.6 are likely to limit sustainability (Patterson, 1992). The levels of total mortality (Z) for the assessed fish species were observed to be greater than 1.6 yr^{-1} as they fell within the range of 2.58 yr^{-1} to 5.02 yr^{-1}.

This finding presents the assertion that the assessed fish species are currently unsustainably exploited possibly due to high fishing mortality. Fishing mortality (F) is mostly reported to cause changes in population parameters such as size ratio, growth rate, size composition and size at first maturity (Chimatiro, 2004). All the selected fish species recorded fishing mortality in the range of F= 1.48 yr^{-1} to F= 2.92 yr^{-1} greater than the corresponding estimated optimum fishing mortality ranging from Fopt = 0.30 yr^{-1} to Fopt = 0.84 yr^{-1} which further supports the assertion that indeed, heavy exploitation currently exists in the fishery of these selected fish stocks (Pajuelo & Lorenzo, 1998).

The estimated Z/K ratios for all the assessed species which were all greater than 1 (Z/K = 1.02-4.05) as outlined in Table 4 also strengthen the presence of heavy exploitation as a result of increased fishing mortality (Etim *et al.*, 1998). The increased fishing mortality could be attributed to increased fishing effort over the years. For instance, the total number of canoes at the artisanal level in Ghana has increased from 8,728 in 1969 to 12,742 in 2013 with the number of fishermen also rising from 81,000 in 1977 to 139,671 in 2013 (Akyempon *et. al.*, 2013). Though there is limited literature on fishing mortality rates for the selected species existing in Ghana's coastal waters, according to the study the six selected fish species are currently facing high fishing mortality rates (F) which are not favourable to the security of coastal fishing operations from the perspective of fish catches and population growth.

5.3.3 Implications of estimated Lc/L∞ ratios and mean length at first maturity (Lm_{50})

The ratio of the length at first capture to the asymptotic length (Lc/L∞) observed provides an insight into whether juvenile or matured fishes are mostly harvested by fishermen. The (Lc/L∞)

ratio calculated for majority of the assessed fish species ($Lc/L\infty$ = 0.22-0.49) which were all lower than 0.5 with the exception of *Pagellus bellottii* as observed in Table 4 indicated that majority of the catch constituted juvenile fish species (Pauly & Soriano, 1986). Consequently, this is an indication of possible existence of growth overfishing within the fisheries of the assessed fish species. The abundance of small-sized fishes in the catches could be explained by indiscriminate use of small mesh sized gears and the non-selectivity of fishing gears especially beach seine whose fishing zone is mostly the nursery zone of juveniles. Similarly, Nunoo (2003) observed that majority (more than 90%) of individuals of fish assemblages were juveniles in the beach seine hauls at Sakumono in Ghana throughout the year indicating the dependence on the nearshore as a nursery for juveniles. However, if left unchecked, the continual use of mesh sizes smaller than the recommended mesh size of 1 inch in diagonal stretch as enshrined in L.I. 1968 (Ghana Fishing regulations, 2010) and the destruction of breeding grounds through the application of illegal fishing gears and methods like beach seining in nearshore marine areas will result in drastic reduction in mean length at first capture of the selected fish species.

The estimated length at first maturity (Lm_{50}) for the assessed species ranging from Lm_{50} =7.4 cm to Lm_{50} =17.90 cm in Table 4 which was higher than the calculated length at first capture ranging from Lc_{50} = 3.71 cm to Lc_{50}=13.19 cm strengthens the assertion that growth overfishing persists in the fisheries of the assessed fish species because the present commercial gears are harvesting higher proportions of immature fish stocks of these species (Agyakwa, 2010). Despite the indication that the fisheries of the assessed fish stock are currently growth overfished, recruitment overfishing was not confirmed for any of the assessed species. This was due to the presence of strong juvenile groups in the length frequency.

5.3.4 Implications from the observed recruitment patterns

The presence of all year round recruitment compensates for the high mortality rates facing the fisheries of the assessed fish stocks (Abowei *et al.*, 2010). The observed recruitment pattern depends on various factors like abundance, the strategy of reproduction of the stock and the variability of their environment (Sossoukpe *et al.*, 2013). Though the presence of two recruitment peaks (one major and one minor) from the study was in line with the description of the recruitment pattern for tropical fishes put forward by Pauly (1982), the observed small length at first recruitment (Lr) ranging from Lr = 3.5 cm to Lr = 13.5 cm (Figure 19) supports the massive use of small mesh sized fishing gears by fishermen in Ghana's coastal fishing operations with no regards to the damage they cause to the fishery (Getabu, 1992). According to Miranda *et al.* (1999) the continual use of small mesh sized fishing gears in addition to high fishing effort can result in diminished economic benefits, reduced catch per effort, and the collapse of the fisheries for the current target species. Therefore, it is mandatory for fisheries managers to appropriately increase the mesh sizes after careful scientific research, while ensuring that fishers comply with the use of the approved appropriate mesh sized fishing gear in order to avert the occurrence of recruitment overfishing. This is because larger mesh sized gears catch large sized fishes, while allowing juvenile fish to spawn at least once before they are harvested (Alagaraja *et al.*, 1986).

5.3.5 Implications of the estimated exploitation levels

In view of the assumption that an exploitation rate of 0.5 indicates optimum fishing level (Pauly, 1984), the study discovered that all the current estimated levels of exploitation ($E_{current}$) for the selected fish species ranged from $E_{current}$ = 0.53 to $E_{current}$ = 0.76 with the exception of

Brachydeuterus auritus ($E_{current}$ =0.46). This indicates that most of the assessed species are currently facing heavy exploitation as the estimated exploitation ratios were above the optimum exploitation rate of 0.5. Possible catalyst for such observed unsustainable exploitation rates included increased fishing efforts especially during the non-upwelling seasons in the form of increased fishing days at seas, increased number of fishing gears per fisherman or fishing vessel and increase in geographical reach through increase in the percentage of motorized canoes within the various coastal fishing communities at the artisanal and semi-industrial level. It is obvious that the current levels of exploitation are unsustainable and unsuitable for the benefits of future generations unless current fishing efforts are reduced.

The trends provided in the plots in Figure 20 reflect changes in the status of the individually assessed stocks. The exploitation stages of most of the assessed fish species provided in this study affirmed the report by Atta-Mills *et al.*, (2004) that on the whole, the Ghanaian marine fishery resources are showing increasing signs of fully or overexploitation. The currently observed exploitation stages for the assessed based on recorded catch relative to maximum catch (Table 5) could be attituded to various factors such as increased fishing effort, high demand for fish as food and cash by consumers, catch composition and the ecosystem which are strongly interlinked.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

Based on the previous chapters, several recommendations may be outlined. This chapter provides the main conclusions and recommendations.

6.1 Conclusions

The study provided insights into assessing the security of coastal fishing operations in Ghana viewed from three key perspectives; namely; safety, poverty and fish catches.

6.1.1 Assessment of security of coastal fishing operations from safety perspective

- IUU fishing was a contributing factor to decline in fish catches and occurs in different forms with pronounced specific forms within each level of coastal fishing operations in Ghana. Weak MCS capacity, less investment in patrol surveillance by government, heavy reliance on marine food, port of convenience and ineffective deterrence strategy were drivers found to compound IUU fishing in Ghana.

- Although fishers including migrant fishers were fully aware of the existence of fishing regulation measures fishers complied particularly with the traditional fishing regulations due the strong presence of the recognized chief-fisherman's authority and the severity of sanctions for violators.

- Non-compliance to fisheries regulation measures among fishers was attributable to a number of factors including the absence of fisheries officials at the landing sites, dilution of punishment (through bribery and corruption), appetite for survival and seizure of inexpensive fishing inputs.

- The high rate of non-arrest incidence (60%-80%) for non-compliance was partly due to the absence of rights to chief fisherman to make arrest of fishers who violate official fisheries regulation measures.

Given the high level of fishers' ignorance on official fisheries regulation measures, the contagious nature of factors promoting non-compliance to fisheries regulation measures to fishers who comply and continual existence of IUU fishing in Ghana's coastal waters, it is obvious that the security of coastal fishing from safety point of view is at a very high risk.

6.1.2 Assessment of security of coastal fishing operations from poverty perspective

- Many fishing households in the coastal communities solely depended on activities connected directly and indirectly to fish resources as their primary source of income. Due to the uncertainty in the fluctuations of the fisheries resources, the fugitive and perishable nature of fish, a few however had secondary source of livelihoods such as trading, farming and driving to complement the primary source of livelihood (fishing and fishing related activities). The absence of secondary livelihood for many (73.3%-86.7%) fishing households made them vulnerable to poverty and unsustainable fishing practices.

- Although chronic poverty was not identified in the coastal community because fishers were mostly making revenue from the fisheries resources, the intensity of poverty indices: head count (H), poverty gap (PG) and poverty severity (P_2) increased with geographic locations, thus higher poverty incidence in Volta Region (PG= 0.28-0.47; P_2= 0.15-0.30) than in Greater Accra Region (PG= 0.11-0.43; P_2= 0.06 - 0.25). Low catch, lack of capital, high dependency ratio, lack of fishing inputs and no alternate skills were the major sources of vulnerabilities increasing the intensity of poverty among vulnerable fishing households.

- Savings in the form of cash, bank deposits, jewelry and building were identified among majority (60% -80%) of the fishers. However, minority (40%-20%) mostly fishwives and crew members had little or no surplus income to save after a fishing period leading to indulgent in unsustainable fishing practices in order to survive especially during the lean fishing season.

- Marginalization based on some physical assets (fish trade enhancing social amenities) in the study sites especially in Volta Region undermined the contribution of fisheries to food security in terms of fish availability and utilization.

In considering the overall negative effects of aforementioned points, it can be argued that the security of coastal fishing from poverty point of view is at a very high risk.

6.1.3 Assessment of security from the perspective of fish catches

- From the study, it was found that regardless of the type of fish species based on the growth rates, increased natural mortalities (M) had the propensity of reducing their stock size leading to a long term decline in their catches.

- The length at first capture (Lc_{50}) of the six selected species were less than the estimated length at first maturity (Lm) suggesting that these species were harvested before they attain the length at first maturity.

- Increased fishing mortality (F> Fopt) and high exploitation rate ($E_{current} > E_{opt}$) also increased the severity of growth overfishing victimizing the fisheries of these fish species.

- However, recruitment overfishing was non-existent in the fisheries of the assessed fish stocks as a result of the strong presence of juveniles within these length frequency data of the assessed fish species.

- Based on the catch only, the study indicated that *Brachydeuterus auritus*, was categorized as collapsed (< 0.1 Cmax); *Engraulis encrasicolus*, *Sardinella aurita*, *Scomber japonicus; Sardinella maderensis* were categorized as over-exploited (0.1-0.5Cmax after > 0.5Cmax) and *Pagellus bellottii* was categorized as rebuilding (> 0.28 Cmax).

The foregoing high mortality rates, high exploitation rates, harvest of higher proportions of immature fish stocks resulting in growth overfishing (because Lc<Lm) indicated that the security of coastal fishing operations in Ghana from fish catch point of view was also at a very high risk.

Overall, the security of coastal fishing operations in Ghana based on evidence from safety, poverty and catches indices were all at a very high risks. Hence, urgent fisheries management strategies are needed to address the security issues regarding coastal fishing operations in the country.

6.2 Recommendations

In order to ensure secured sustainable coastal fisheries in Ghana for both present and future generations, the following are recommended:

1. Fish length frequency data on Ghana's commercial fish species should be carried out at notable landing sites routinely to generate yearly length frequency data in addition to sampling of daily catch. This is because fish length frequency data not only be used to generate yearly population parameters especially fishing mortality parameters but also provide better insights into length-based fish stock assessment and management tool for Ghana's marine fisheries resources.

2. To sustain the fishery resource, imposing the existing ban on use of illegal mesh sizes and other destructive fishing methods need to be urgently enforced by the authorities concerned. The role of international cooperation in enforcing fisheries regulations and rules should be systematically strengthened through international-agreed legislature based on food security, fish recovery, illegal fishing methods and unreported catches. Also beach seine fishing activities should be banned since they harvest juveniles that use nearshore as nursery grounds while providing alternate livelihood interventions for the affected fishermen or fishing households.

3. Fishing gear exchange programme for fisherman should be addressed to control the number of monofilament used in Ghana's coastal fishing. In that regard, gear exchange programme will involve the confiscation of monofilament gears, while replacing half of the total bundle with multifilament gears. However, gear exchange programmes should be carried out only after licensing of canoes and fishing gears.

4. Regular monitoring by fisheries officials of Fisheries Commission (Fisheries Enforcement Unit) is necessary to control and enhance compliance to fisheries regulations and international initiatives (e.g. Code of Conduct) to conserve fisheries among fishers at various landing sites. Also, by-laws should be gazetted to allow Chief-fishermen to make arrest at the various landing sites to enhance adherence to fisheries regulations among fishermen especially migrant fishermen who tend to care less about the ecological conditions in host fishing communities. This is necessary especially in landing sites where fisheries officials tend to have difficulty in visiting as a result of logistic reasons.

5. Adoption of policies that promote interventions to enhance the productivity of the fishing sector. For example, the presence of improved access to formal insurance schemes, micro-credit, post-harvest losses management programmes and improved marketization is essential in improving the contribution of fishers to food security especially at the district level.

6. Marine patrols by Ghana Navy and the Marine Police should be partitioned as it will reduce the monetary logistics needed to monitor the entire fishing levels by Ghana Navy, while ensuring that Ghana Navy, exert the maximum effort in monitoring industrial vessels. Regarding such partition- Marine police should be equipped to monitor the activities of artisanal canoes and semi-industrial boats, at sea while Ghana Navy monitor activities of industrial fleets at sea. Also, marine patrols by Ghana Air force flights as well as AIS monitoring systems should be provided to supplement current VMS.

REFERENCE

Abowei, J., George, A. & Davies, O. (2010). Mortality, Exploitation rate and Recruitment pattern of *Callinectes amnicola* (De Rochebrune, 1883) from Okpoka Creek, Niger Delta, Nigeria. *Asian Journal of Agricultural Sciences.* ISSN: 2041-3890. 2(1), pp. 27 - 34.

Abowei, J. F. & Hart, A. I. (2009). Some morphometric parameters of ten species from the Lower Nun River, Niger Delta. *Research. Journal of Biological Science*, Vol. 4 (3): pp. 282 – 288.

Adepoju, A. O. & Yusuf, S. A. (2012). Poverty And Vulnerability In Rural South-West Nigeria. *ARPN Journal of Agricultural and Biological Science.*, Vol. 7, No. 6, pp. 430-437.

Agnew, D.J., Pearce, J., Pramod, G., Peatman, J., Watson, R., Beddington, J.R. & Pitcher, .T.J. (2009). Estimating the worldwide extent of illegal fishing. *PLoS ONE*, 4(2 e4570): pp. 1-3.

Agyakwah, K. S. (2010). *Catch Assessment and reproductive seasonality of major commercial catfishes in strata II and III of the Volta Lake.* PhD Thesis University of Ghana. 183 pp.

Akinsanmi, G. (2008). *Nigeria: nation loses N25bn to piracy, sea robberies*. Retrieved June 20, 2009, from Allafrica: http://allafrica.com

Akpalu, W. (2002). Compliance To Mesh Size Regulations In Artisanal Marine Fishery in Ghana. *Beijer Research Seminar 28-30 May.* Durban, South Africa. 24 pp.

Akyempon, S., Bannerman, B., Amador, K., & Nkrumah, B. (2013). *Ghana Canoe Frame Survey 2013.* Accra: Fisheries Scientific Survey Division, Ministry of Fisheries and Aquaculture Development. Information Report No 35. 72pp

Alagaraja, K., Suseelan, C. & Muthu, M. S. (1986). Mesh Selectivity Studies For Management Of Marine Fishery Resources In India. *J. Mar. Biol. Ass. India*, 28 (1 & 2) : pp. 202 - 212.

Alhassan, H. E. & Armah, A. (2011). Population Dynamics of the African River Prawn, *Macrobrachium vollenhovenii*, in Dawhenya Impoundment. *Turkish Journal of Fisheries and Aquatic Sciences*, 11: pp. 113-119.

Allision, E.H. (2011). *Aquaculture, Fisheries, Poverty and Food Security*. Working Paper 2011-65. World fish Centre. 62 pp.

Allison, E.H. & Ellis, F. (2001). The livelihoods approach and management of small-scale fisheries. *Marine Policy* , 25(5): pp. 377–388.

Allison, E.H. & Horemans, B. (2006). Putting the principles of the Sustainable Livelihoods Approach into fisheries development policy and practice. *Marine Policy* , 30, pp. 757–766 .

Allison, E.H., Horemans, B. & Béné, C. (2006). Vulnerability reduction and social inclusion: strategies for reducing poverty among small-scale fisherfolk. *Paper presented at the Wetlands, Water and Livelihoods Workshops, 30 January –2 February, Wetland International*. St. Lucia, South Africa.

Allison, E.H., Perry, A., Badjeck, M.-C., Adger, W.N., Andrew, N.L., Brown, K., Conway, D., Halls, A., Pilling, G.M., Reynolds, J.D. & Dulvy, N.K. (2009). Vulnerability of national economies to potential impacts of climate change on fisheries. *Fish and Fisheries*, 10, pp. 173– 196.

Amador, K., Bannerman, P., Quartey, R. & Ashong, R. (2006). *Ghana Canoe Frame Survey, 2004.* Accra: Marine Fisheries Research Division Technical Paper (34): 43 pp.

Anticamara, J., Watson, R., Gelchu, A. & Pauly, D. (2011). Global fishing effort (1950–2010): Trends, gaps, and implications. *Fisheries Research*, 107 (1–3), pp. 131-136.

Asiedu, B. & Nunoo, F. K. E. (2013). Alternative Livelihoods: A Tool for Sustainable Fisheries Management in Ghana . *International Journal of Fisheries and Aquatic Sciences*, pp. 21-28.

Asiedu, B., Nunoo, F. K. E., Ofori-Danson, P. K., Sarpong, D. D. & Sumaila, U.R. (2013). Poverty measurements in small-scale fisheries of Ghana: A step towards poverty eradication. *Current Res. J. Soc. Sci.*, 5 (3): pp. 75–90.

Atta-Mills, J., Alder, J. & Sumaila, U. (2004). The decline of a regional fishing nation: The case of Ghana and West Africa. *Natural Resources Forum 28*, pp. 13-21.

Bank of Ghana. (2008). *The Fishing Sub-Sector and Ghana's Economy.* p. 20.

Bankole, N. (1990). Gillnet monitoring Attiga and Jakaran reservoir in Kano State. National Institute of Fresh Water Fisheries Research (NIFFR). *Annual Report*, pp. 39-42.

Bannerman, P. (2014). *Stop Illegal Fishing.* Retrieved from Ghana's marine sector remains unstable : http://www.ghanaweb.com/GhanaHomePage/NewsArchive/artikel.php

Bebbington, A. (1999). *Capitals and capabilities: a framework for analyzing peasant viability, rural livelihoods and poverty.* World Development ;27(12):2021–44.

Béné, C. (2003). When fishery rhymes with poverty: a first step beyond the old paradigm on poverty in small-scale. *World Development* , 31(6): pp. 949–975.

Béné, C. (2009). Are fishers poor or vulnerable? Assessing economic vulnerability in small-scale fishing communities. *Journal of Development Studies* , 45(6): pp. 911–933.

Béné, C. & Friend, M. R. (2011). Poverty in small-scale fisheries: old issue, new analysis. *Progress in Development Studies*, pp. 119–144.

Béné, C., Macfadyen, G. & Allison, E.H. (2007). Increasing the contribution of small-scale fisheries to poverty alleviation and food security. *FAO Fisheries Technical Paper*. Rome: FAO. No. 481, 125 pp.

Beverton, R. J.H. (1959). *Report on the state of the Lake Victoria Fisheries.* Mimeo. Fisheries Laboratory, Lowesoft. Mimeo.

Beverton, R.J.H & Holt, J. S. (1957). On the dynamics of exploited fish populations. *Fish. Invest. London, Ser.*, II (19), 533 pp.

Bigler, B. S., Welch, D. W. & Helle, J. H. (1996). A review of size trends among North Pacific salmon (*Oncorhynchus* spp.). *Canadian Journal of Fisheries and Aquatic Sciences*, 53, pp. 455–465.

Bjorndal, T. & Munro, G. (1998). The economics of fisheries management: a survey. In T. Tietenberg, & H. Fomer, *The International Year- book of Environmental and Resource Economics 1998/1999,Edward Elgar, Cheltenham*, pp. 153–188.

Black, R. (2007). *Action Urged on Illegal Fishing. BBC News.* Retrieved from http://news.bbc.co.uk/2/ hi/6602639.stm.

Boachie-Yiadom, T. (2013). *Promoting Artisanal Fisheries:Effective Strategies For The Enforcement Of The Fisheries Act 625, Section 81, Sub-Section 5.* Dixcove, Ghana: Fisheries Co-Management Forum. 43 pp.

Campbell, J., Whittingham, E. & Townsley, P. (2006). Responding to coastal poverty: should we be doing things differently or doing differentthings? In C. Hoanh, T. Tuong, J. Gowing & B. Hardy (Eds.), *Environment and Livelihoods in Tropical Coastal Zones* (pp. 230-257). Wallingford UK and Cambridge MA,USA: CABI Publishing.

Chambers, R. (1989). *Editorial introduction—Vulnerability: how the poor cope. IDS Bulletin, 20(2).* Brighton: Institute of Development Studies, University of Sussex.

Charles, T. (2000). Use Rights in Fishery Systems. *IIFET 2000 Proceedings.* Corvalis, USA. 5pp.

Charnov, E. (1993). *Life history invariants.* Oxford, UK.: Oxford University Press.

Chimatiro, S. K. (2004). *The biophysical dynamics of the lower shire river floodplain fisheries in Malawi.* PhD thesis, Rodes University.

Christensen, V., Guénette, S., Heymans, J.J, Walters, C.J., Watson, R., Zeller, D. & Pauly, D., (2003). Hundred-year decline of North Atlantic predatory fishes. *Fish and Fisheries*, 4: pp. 1-24.

Christy, F. (1992). *Territorial use rights in marine fisheries: definitions and conditions.* FAO Fisheries Technical Paper 227. Rome: FAO. 11 pp.

Clark, C. (1990). *The Optimal Management of Renewable Resources. 2nd ed.Mathematical Bioeconomics.* USA: John Wiley and Sons.

Coll, M., Libralato, S., Pitcher, T., Solidoro, C. & Tudela, S. (2013). Sustainability implications of honouring the Code of Conduct for Responsible Fisheries. *Global Environmental Change* , 23: pp. 157-166.

Copes, P. (1989). *Why are fishing incomes often low? A critical review of the conventional wisdom. Discussion Paper 21/89-1, Burnaby.* Canada: Institute of Fisheries Analysis, Simon Fraser University.

CRC. (2013). *Hɛn Mpoano Policy Brief No. 3, January 2013.Integrating Policy Compliance with Effective Enforcement of Fisheries Regulations. USAID Integrated Coastal and*

Fisheries Governance Program for the Western Region of Ghana. Narragansett, RI: Coastal Resources Center, University of Rhode Island. 4 pp.

CRC & FON. (2011). *Hen Mpoano Initiative: Towards Efficient Prosecution of Fisheries Violations in the Western Region.* 14 pp.

CRFM. (2013). *Regional Strategy on Monitoring, Control and Surveillance to Combat Illegal, Unreported and Unregulated Fishing in the CARICOM / CARIFORUM Region.* CRFM Technical & Advisory Document, No. 2013 / 11, 85 pp.

Daan, N., Gislason, H., Pope, J.G. & Rice, J.C. (2011). Apocalypse in world fisheries? The reports of their death are greatly exaggerated. *ICES Jornal of Marine Science*, 4 pp.

Davis, J. (2000). *Monitoring Control Surveillance and Vessel Monitoring System Requirements to Combat IUU Fishing.* Document AUS: IUU/2000/14. 2000. 13 pp.

Deb, K. (2009). *Voices of the Fishantry': Learning on the Livelihood Dynamics from Bangladesh.* PhD Thesis University of Manitoba, Winnipeg, Manitoba Canada. 351 pp.

DEEDI. (2009). *Queensland Fisheries Strategy.* Brisbane: The State of Queensland Department of Employment, Economic Development and Innovation; 2009. 28 pp.

DuBois, C. & Zografos, C. (2012). Conflicts at sea between artisanal and industrial fishers: Inter-sectoral interactions and dispute resolution in Senegal. *Marine Policy* , 36, pp. 1211–1220.

Edame, .G.E., Ekpenyong, .B.A., Fonta, .M.W. & Duru, E.J.C. (2011). Climate Change, Food Security and Agricultural Productivity in Africa: Issues and policy directions. *International Journal of Humanities and Social Science*, pp. 205-223.

EFTEC. (2008). Costs of Illegal, Unreported and Unregulated Fishing in EU Fisheries. . London, UK.: Economics for Environment Consultancy, Ltd.75 pp.

EJF. (2007). *Pirate Fish on Your Plate-Tracking Illegally-Caught Fishfrom West Africa into the European Market.* Retrieved from Environmental Justice Foundation, London,UK: http://www.imcsnet.org/ imcs/docs/pirate_fish_on_your_plate_ejf.p. 28 pp.

Ellis, F. (2000). *Rural livelihoods and diversity in developing countries.* Oxford: Oxford University Press.

Enin, U. (1995). First estimates of growth, mortality and recruitment parameters of *Macrobrachium macrobrachion* (Herklots, 1851) in the Cross River estuary, Nigeria. . *Dana, vol. 11(1),* pp. 29-38.

Etim, L., Sankare, Y., Brey, T. & Arntz, W. (1998). The dynamics of unexploited population of *Corbula trionga* (Bivalvia: Corbulidae) in a brackisk-water lagoon, Cote d'Ivoire. *Arch. Fish. Mar. Res.*, 46 (3), pp. 253-262.

Etim, L., Uwe-Bassey, B. & Brey, T. (1994). Population dynamics of the West African croaker *Pseudotolithus elongatus* in the Cross River Estuary, Nigeria. *Scientia Marina*, 58 (4): pp. 315-321.

Falaye, A. E. (2008). *Illegal Unreported Unregulated (IUU) fishing in West Africa (Nigeria and Ghana).* London: Report of a Study prepared for MRAG. 32 pp.

FAO. (1997). *Fisheries Management. FAO Technical Guidelines for Responsible Fisheries.* 4: 82 pp.

FAO. (2001). *International plan of action to prevent, deter, and eliminate illegal, unreported and unregulated fishing.* Rome: FAO, p. 24.

FAO. (2002). *The State of World Fisheries and Aquaculture 2002.* Rome. p. 70.

FAO. (2004). *Review of the state of world fisheries resources.* FAO Fisheries Technical Paper No.335, FAO, Rome, 2001, 136 pp.

FAO. (2008). *The State of World Fisheries and Aquaculture 2008.* Rome, Italy. 196 pp.

FAO. (2009). *Declaration of the World Summit on Food Security.* Rome. 7 pp.

FAO. (2010). *The State of Food Insecurity in the World—Addressing Food Insecurity in Protracted Crises.* Rome: FAO. 218 pp.

FAO. (2012a). *The State of World Fisheries and Aquaculture 2012.* Rome: FAO. 230 pp.

FAO. (2012b). *The State Of Food And Agriculture. Investing in agriculture for a better future.* Rome. 182 pp.

FAO. (2014). *The State of World Fisheries and Aquaculture 2014.* Rome. 223 pp.

FAO. (2015). *FAO and the 17 Sustainable Development Goals.* Rome, Italy: 8 pp

FAO, IFAD & WFP. (2014). *The State of Food Insecurity in the World. Strengthening the enabling environment for food security and nutrition.* Rome: FAO. 54 pp.

FAO, IFAD & WFP. (2013). *The State of Food Insecurity in the World 2013. The multiple dimensions of food security.* Rome: FAO. 56 pp.

FAO & WWC. (2015). *Towards a water and food secure future. Critical perspectives for policy-makers.* Rome. 74 pp.

Fischer, W., Bianchi, G. & Scott, W. (1981). *FAO species identification sheets for fishery purposes. Eastern Central Atlantic; Fishing area 34, 47 (in part).* Canada Funds n-Trust. Ottawa, Department of Fisheries and Oceans Canada, by arrangement with Food and Agriculture Organization of the United Nations, vols. 1-7.

Flybjerg, B. (2004). Five Misunderstandings about case-study research . In C. Seale, G. Gobo, J. Gubrium, & D. C. Silverman, *Qualitative Research Practice.* London: SAGE Publications.

Foster, J., Greer, J. & Thorbecke, E. (1984). A Class of Decomposable Poverty Measures. *Econometrica Vol. 52* , pp. 761-765.

Froese, R., Zeller, D., Kleisner, K. & Pauly, D. (2012). What catch data can tell us about the status of global fisheries. *Marine Biology*, DOI 10.1007/s00227-012-1909-6. 10 pp.

Gabriel, O., Bivbere, G. & Ugwuadu, I. (2008). *Renewed piracy attacks: fish scarcity looms, Nigeria may lose $600m export earnings*. Retrieved June 20, 2009, from The Vanguard: www.vanguardngr.com

Garibaldi, L. (2012). The FAO global capture production database: a six-decade effort to catch the trend. *Marine Policy* , 36: pp. 760–768.

Gayanilo, F., Sparre, P. & Pauly, D. (2005). *FAO-ICLARM Stock Assessment Tools II (FiSAT II). Revised. User's guide.* Rome : FAO Computerized Information Series (Fisheries). No. 8. Revised version. 168 pp.

Getabu, A. (1992). Growth parameters and total monality in Orochromis niloticw (Linnaeus) from Nyanza Gulf Lake Victoria. *Hydrobiologia*, 232: pp. 91- 97.

Ghana Fishing Regulation. (2010). *Legal Instrument 1968.* Ghana: Assembly Press, Accra. 69 pp.

Gheshlaghi, P., Vahabnezhad, A. & Taghavi Motlagh, S. A. (2012). Growth parameters, mortality rates, yield per recruit, biomass, and MSY of Rutilus frisii kutum, using length frequency analysis in the Southern parts of the Caspian Sea. *Iranian Journal of Fisheries Science*, 11(1), pp. 48 - 62.

Gibbons, W. N. & Munkittrick, K. R. (1994). A sentinel monitoring framework for identifying fish population responses to industrial discharges. *Journal of Aquatic Ecology and Health*, 3: pp. 227 – 237.

GoG. (2010). Medium term national development policy framework: Ghana shared growth and development agenda (GSGDA I). In *Policy Framework*, *vol. I.* NDPC,Accra.p. 3

GSS. (2014). *Gross Domestic Product 2014.* Accra. 9 pp.

Gulland, J. (1969). Manual of Methods for Fish Stock Assessment Part 1. Fish Manipulation Analysis. *FAO manual in fisheries science no. 4.*, 154 pp.

Gulland, J. (1971). *The Fish Resources of the Oceans.* FAO/Fishing News Books, Surrey, 255 pp.

Hanich, G. (2014). *Sustainable fishing is key to food security*. Retrieved from http://media.uow.edu.au/news/UOW173294.html

Hatcher, A., Jaffry, S., Thebaud, O. & Bennett, E. (2000). Normative and Social Influences Affecting Compliance with Fishery Regulations. *Land Economics Journal*, 76(3): pp. 448 - 461.

Hɛn Mpoano (2013). *Solving the Fisheries Crisis in Ghana: A Fresh Approach to Collaborative Fisheries Management. USAID-URI Integrated Coastal and Fisheries Governance (ICFG) Initiative.* Coastal Resources Center, Graduate School of Oceanography,: University of Rhode Island. 21 pp.

Hoggarth, D.D., Abeyasekera, S., Arthur, R.I., Beddington, J.R, Burn, R.W., Halls, A.S., Kirkwood, G.P., McAllister, M., Medley, P., Mees, C.C., Parkes, G.B., Pilling, G.M., Wakeford, R.C. & Welcomme, R.L. (2006). *Stock Assessment for fishery management - A framework guide to the stock assessment tools of the Fisheries Management Science Programme (FMSP).* Fisheries Technical Paper. No. 487. Rome. FAO. 261 pp.

IFPRI. (2006). *Annual report 2005-2006.* Washington, D.C.: IFPRI.

IICA. (2009). *IICA's Definition of Food Security. Sowing innovation to harvest prosperity.* 2 pp.

Ikiara, M. M. & Odink, J. (2000). Fishermen resistance to exit fisheries. *Marine Resource Economics* , 14: pp. 199 – 213.

Jayne, T., Mather, D. & Mghenyi, E. (2010). *Principal challenges confronting small-holder agriculture in sub-Saharan Africa.* World Development 38(10), pp. 1384 - 1398.

Jenny, A., Fuentes, H. F. & Hans-Joachim, M. (2006). Psychological Factors Determining Individual Compliance with Rules for Common Pool Resource Management: The Case of a Cuban Community Sharing a Solar Energy System. *Human Ecology*. 12 pp.

Kleisner, K., Zeller, D., Froese, R. & Pauly, D. (2012). Using global catch data for inferences on the world's marine fisheries. *Fish and Fisheries*, 14, pp. 293 – 311.

Koranteng, K. (1998). *The importance of Environmental Forcing on the Dynamics of Demersals Fisheries Resources of Ghana.* PhD Thesis, University of Warwick (UK). 360 pp.

Kotey, I. (2014). *Fishermen Cry Over High Price Of Premix Fuel*. Retrieved May 5, 2015, from The chronicle: http://thechronicle.com.gh/fishermen-cry-over-high-price-of-premix-fuel/

Kraan, M. (2009). *Creating space for fishermen's livelihoods. Anlo-Ewe beach seine fishermen's negotiations for livelihood space within multiple governance structures in Ghana.* Ph.D. Thesis, African Studies Centre African Studies Collection, Leiden. 360 pp.

Kwadjosse, T. (2009). *The Law Of The Sea: Impacts On The Conservation And Management Of Fisheries Resources Of Developing Coastal States – The Ghana Case Study.* 88 pp.

Kwarfo, E. (2014). *Ghana: 26 Arrested For Engaging In Illegal Fishing.* Retrieved from Stop Illegal Fishing: http://talkafrica.co/gh/p/16090/ghana26arrestedforengaginginillegal-fishing

Kwesi, E. & Ofori-Adu, D. (2005). *Fishes in the coastal waters of Ghana.* Tema: Ronna Publishers. 108 pp.

Lagler, K. F., Bardach, J. E., Miller, R. R. & May Passino, D. (1977). *"Ichthyology" 2nd ed.* New York: Wiley. 506 pp.

Lawson, E., Gordon, C. & Schluchter, W. (2012). The dynamics of povertye environment linkages in the coastal zone of Ghana. *Ocean & Coastal Management*, 67, pp. 30-38.

Ludi, E. (2009). *Climate change, water and food security.* London: Overseas Development Institute, 8 pp.

Maceina, M. J. & Pereira, D. (2007). Recruitment. In C. S. Guy, & M.L. Brown (eds) *Analysis and interpretation of freshwater fisheries data* (pp. 121–185). Bethesda, Maryland: American Fisheries Society.

Marshall, B. (1993). *The biology of the African Clupeid Limnothrisa miodon with special reference to its small size in artificial lakes.* Retrieved from Reviews in Fish Biology and Fisheries 3,17-38:http://dx.doi.org/10.1007/BF00043296.

McCulloch, N., & Calandrino, M. (2003). Vulnerability and chronic poverty in rural Sichan. *World Development* , 31(3), pp. 611– 628.

Mensah, M. A. & Konnteng, K. (1988). A review of the oceanography and fisheries resources in the coastal waters of Ghana. *Mar. Res. Rep. Fish. Res. & Util. Branch, Tema, Ghana*, 8,35. 104 pp.

Mevuta, D. & Boachie-Yiadom, T. (2013). *Joining Forces to Collaboratively Manage Ghana's Fisheries Resources; the role of a Fisheries Working Group.* Friends of the Nation, USAID Integrated Coastal and Fisheries Governance Program for the Western Region of Ghana. 22 pp.

MoFAD. (2014). *Natioanl plan of action to prevent, deter and eliminate illegal, unregulated and unreported fishing.* Repbulic of Ghana: Ministry of Fisheries and Aquaculture Development. 30 pp.

MFMR. (2007). *National Plan of Action To Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing.* Republic of Namibia. 25 pp.

Mills, D., Béné C., Ovie, S., Tafida, A., Sinaba, F., Kodio, A., Russell, A., Andrew, N., Morand, P. & Lemoalle, J. (2011). Vulnerability in Small-Scale Fishing Communities. *Journal of International Development.*, 23, pp. 308–313.

Miranda, L., Agostinho, A. & Gomes, L. (1999). Appraisal of the selective properties of gill nets and implications for yield and value of the fisheries at the Itaipu Reservoir, Brazil–Paraguay. *Fisheries Research* , 45, pp. 105–116.

Montcho, .A.S., Agadjihouèdé, .H., Montchowui, .E., Lalèyè, .A.P. & Moreau, .J. (2015). Population parameters of Oreochromis niloticus (Cichlidae) recently introduced in lake Toho (Benin, West Africa). *International Journal of Fisheries and Aquatic Studies* , p. 143.

Mora, C., Myers, R. A., Coll, M., Libralato, S. & Pitcher, T. J. (2009). Management effectiveness of the world's marine fisheries. . *PLoS Biol* , 7(6): pp. 1 – 11.

MRAG. (2008). *Study and Analysis of the Status of IUU Fishing in the SADC Region and an Estimate of the Economic, Social and Biological impacts.*London. 35 pp.

Munro, G. & Sumaila, U. R. (2012). Subsidies and the Sustainability of Offshore Fisheries: An Economist's Perspective. *Forum: Dialogue on Fisheries Subsidies.* Mexico La Paz, Baja California Sur, Mexico. 15 pp.

Nabi, M., Hoque, M., Rahman, A., Mustafa, S. & Kader, M. (2007). Population Dynamics of *Polynemus paradiseus* from Estuarine Set Bag Net Fishery of Bangladesh. *Chiang Mai Journal of. Scienc*e, 34(3) : pp. 355-365.

Naminata, K., Boutonner, L., FranckHervis, B., Siaka, B., Mamadou, B. & Paul, K. E. (2014). Length-weight relationship and population parameters of *Pellonula leonensis* Boulenger, 1916 (Clupeidae) in man-made Lake Taabo (Bandama basin; Côte d'Ivoire) . *International Journal of Biosciences* , Vol. 5, No. 4, pp. 149-158.

Nelson, F. F., Aloísio, S. B. & Paulo, C. M. (2009). Estimating size at first maturity (L_{50}) from Gonadossomatic Index (GSI) data. *Neotropical Ichthyology* , 7(2): pp. 217-222.

Nincic, D. (2009). Nigeria: the 'other' maritime piracy hotbed. *Journal of Ocean Technology* .

Norman-Lopez, A. & Pascoe, S. (2011). Net economic effects of achieving maximum economic yield in fisheries . *Marine Policy*, 35, pp. 489–495.

Ntiba, M., Kudoja, W. M. & Mukasa, C. (2001). Management issues in the Lake Victoria watershed. *Lakes & Reservoirs: Research and Management* , 6: pp. 211–216.

Nunoo, F. K. E. (2003). *Biotic, abiotic and anthropogenic controls of nearshore marine fish assemblage caught in beach seines in Sakunono, Ghana, and their management implications.* Ph.D. Thesis, University of Ghana, Legon, 155 pp.

Nunoo, F. K. E. (2015). *Mid-Term Review Report For West Africa Regional Fisheries Programme For Ghana.* Accra-Ghana. 77 pp.

Nunoo, F. K. E. & Asiedu, B. (2013). An Investigation of Fish Catch Data and Its Implications for Management of Small-scale Fisheries of Ghana. *International Journal of Fisheries and Aquatic Sciences*, 2(3): pp. 46-57.

Nunoo, F. K. E., Asiedu, B., Amador, K., Belhabib, D., Lam, Vicky., Sumaila, U.R. & Pauly, D. (2014). Marine Fisheries Catches in Ghana: Historic Reconstruction for 1950 to 2010 and Current Economic Impacts. *Reviews in Fisheries Science & Aquaculture*, 22:4, pp. 274-283.

Nunoo, F. K. E., Asiedu, B., Olauson, J., & Intsiful, G. (2015). Achieving sustainable fisheries management: A critical look at traditional fisheries management in the marine artisanal fisheries of Ghana, West Africa. *JENRM, Vol. 2, No. 1, 15-23*, 9pp.

Nurual - Amin, S., Arshad, A., Siraj, S. & Japar – Sidik, B. (2009). Population structure, growth, mortality and yield per recruit of sergestid shrimp, *Acetes japonicus* (Decapoda: Sergestidae) from the coastal waters of Malacca, Peninsular Malaysia. *Indian Journal of Marine Sciences.* Vol. 38(1), pp. 57-68.

Obodai, E., Muhammad, B., Obodai, G. & Opoku, E. (2009). Effect of Fuel wood on the Quality of Smoked Freshwater Fish Species Sold in Tamale Central Market, Northern Region, Ghana. *Ethiopian Journal of Environmental Studies and Management*, Vol.2 No.2., p. 27.

O'Brien, L. (1999). Factors Influencing the Rate of Sexual Maturity and the Effect on Spawning Stock for Georges Bank and Gulf of Maine Atlantic Cod Gadus morhua Stocks. *Journal of Northwest Atlantic Fisheries Science*, Vol. 25: pp. 179–203.

OECD. (2001). *Development Action Committee's Guidelines on Poverty Reduction.* Organisation for Economic Co-operation and Development. Paris (available at www.oecd.org). 131 pp.

OECD. (2013). *Fishing for Tomorrow: Managing fisheries for sustainable development.* Paris, OECD.12pp.

Pajuelo, J. & Lorenzo, M. (1998). Population biology of the common pandora *Pagellus erythrinus* (Pisces: Sparidae) off the Canary Islands. *Fisheries. Research*, 36: pp. 75-86.

Pardo, A.S., Cooper, B.A., Dulvy, K.N. (2013). Avoiding fishy growth curves. *Methods in Ecologyand Evolution*, 8 pp.

Patterson, K. (1992). Fisheries for small pelagic species: an empirical approach to management targets. *Reviews in Fish Biology and Fisheries*, 2, pp. 321–338.

Pauly, D. (1980). A selection of simple method for the assessment of tropical fish stocks. *FAO, Fish. Circ.*, (729), 54 pp.

Pauly, D. (1982). Studying single species dynamics in a tropical multi-species context. In: Pauly, D., Murphy, G.I. (Eds.), Theory and Management of Tropical Fisheries. *Proceedings of the ICLARM Conference*, No. 9, pp. 33-70.

Pauly, D. (1983). Some simple methods for the assessment of tropical fish stocks. *FAO Fish Technical Paper*, 234.52 pp.

Pauly, D. (1984). Fish population dynamics in tropical waters: a manual for use with programmable calculations. *ICLARM Stud. Rev.*,8, 325 pp.

Pauly, D. (1986). On improving operation and use of the ELEFAN programs. Pt. II. lmproving the estimation of L∞. *Fishbyte*, 4(1): pp. 18-20.

Pauly, D. & Caddy, J. F. (1985). *A modification of Bhattacharya's method for the analysis of mixtures of normal distributions.* FAO Fish. Circ. (781): 16 pp.

Pauly, D., Christensen, V., Guanette, S., Pitcher, T. J., Sumaila, U. R., Walters, C. J., Watson, R. & Zeller, D. (2002). Towards Sustainability in World Fisheries. *Nature*, 418 : pp. 689–695.

Pauly, D. & Soriano, M. (1986). Some practical extensions to Beverton and Holt's relative yield-per-recruit model. In D. L. Maclean JL, *The First Asian Fisheries Forum* (pp. 491-496). Manila, Philippines,: Asian Fisheries Society.

Petrossian, G. (2015). Preventing illegal, unreported and unregulated (IUU) fishing: A situational approach. *Biological Conservation*, pp. 1-10.

Pitcher, T. & Cheung, W. (2013). Fisheries: Hope or despair? *Marine Pollution Bull*etin, 11 pp.

Pitcher, T., Kalikoski, D., Pramod, G. & Short, K. (2008). *Safe Conduct? Twelve Years Fishing under the UN Code.* WWF, Gland, Switzerland. 63 pp.

Pope, K. L., Lochmann, S. E. & Young, M. K. (2010). *Methods for Assessing Fish Populations. Nebraska Cooperative Fish & Wildlife Research Unit* . Staff Publications. Paper 74. 29 pp.

Pramod, G. & Pitcher, T. (2006). *An Estimation of Compliance of the Fisheries of Namibia with Article 7 (Fisheries Management) of the UN Code of Conduct for Responsible Fishing.* University of British Columbia: Fisheries Center Research Reports. p. 19.

Quaatey, S. (1997). Synthesis of recent evaluations undertaken on the major fish stocks in Ghanaian waters. *A working document for the eleventh session of the CECAF Working Party on Resource Evaluation*, (p. 35). Accra, Ghana.

Quinn, T. J. & Deriso, R. B. (1999). *Quantitative fish dynamics.* New York: Oxford University Press.

Ray, D.K., Mueller, N.D., West, P.C. & Foley, J.A. (2013). *Yield Trends Are Insufficient to Double Global Crop Production by 2050.* PLoS ONE 8(6), pp. 1 – 8.

Ray, D.K., Ramankutty, N., Mueller, N.D., West, P.C. & Foley, J.A. (2012). *Recent patterns of crop yield growth and stagnation.*Nature Communications 3, pp. 1 – 7.

Ricker, W. E. (1975). *Computation and interpretation of biological statistics of fish populations.* Fisheries Research Board of Canada Bulletin 191. 401 pp.

Saila, S. & Roedel, P. (1980). Stock Assessment for Tropical Small-Scale Fisheries. *Proceedings of International Workshop, Sept. 19–21 (1979).* University of Rhode Island. Internatioanl Center Marine Research and Development.

Sarr, S., Kabre, T. & Philippe, C. (2013). Recruitment, mortality and exploitation rates estimate and stock assessment of *Mugil cephalus* (Linnaeus, 1758 Mugilidea) in the estuary of the Senegal River. *International Journal of Agricultural Policy and Research. Vol.1 (1)*, pp. 001-010.

Shah, M., Fischer, G., & van Velthuizen, H. (2008). *Food Security and Sustainable Agriculture. The Challenges of Climate Change in Sub-Saharan Africa.* Laxenburg: International Institute for Applied Systems Analysis. 40 pp.

Solemdal, P. (1997). Maternal effects – A link between the past and the future. *Journal for Sea Research*, 37: pp. 213–227.

Sossoukpe, E., Nunoo, F. K. E. & Dankwa, H. R. (2013). Population structure and reproductive parameters of the Longneck croaker, *Pseudotolithus typus* (Pisces, Bleeker, 1863) in nearshore waters of Benin (West Africa) and their implications for management. *Agricultural Sciences 4* , pp. 9-18.

Sparre, P. & Venema, S. C. (1992). *Introduction to tropical fish stock assessment. Part I. Manual.* FAO Fish. Tech. Pap. 306(1), 376 pp.

Sumaila, U. R. (2003). *A fish called subsidy*. Retrieved from downtoearth: http://www.downtoearth.org.in/node/13721

Sumaila, U.R., Alder, J. & Keith, H. (2006). Global scope and economics of illegal fishing. *Marine policy*, 30: pp. 696-703.

Sumaila, U. R., Lam, V., Le Manach, F., Swartz, W. & Pauly, D. (2013). *Global fisheries subsidies*. Brussels, Belgium: European Parliament, Directorate General for Internal Policies. Policy Department B: Structural and Cohesion Policies—Fisheries. 48 pp.

Sumaila, U.R., Teh, L., Watson, R. & Munro, R. (2010). A Bottom-up Re-estimation of Global Fisheries Subsidies. *Journal of Bioeconomics*, vol. 12: pp. 201-225.

Summerfelt, R. C. & Hall, G. E. (1975). *Age and growth of fish", Iowa State University Press.* Iowa State University Press. Ames.

Sundström, A. (2012). Corruption and regulatory compliance: Experimental findings from South African small-scale fisheries. *Marine Policy* , 36, pp. 1255–1264.

Sutinen, J. G. & Kuperan, K. (1999). A socio-economic theory of regulatory compliance. *International Journal of Social Economics*, 26 (1/2/3): pp. 174-193.

Swartz, W., Sala, E., Tracey, S., Watson, R. & Pauly, D. (2010). The spatial expansion and ecological footprint of fisheries (1950 to present). *PLoS ONE 5*, pp. 1 – 6.

Tawari, C. & Abowei, J. (2011). Traditional Fish Handling and Preservation in Nigeria. *Asian Journal of Agricultural Sciences* , 3(6): pp. 427-436.

Townsley, P. (1998). Livelihoods and aquatic resource management. In Carney D, *Sustainable rural livelihoods: what contribution can we make?* (pp.139–54.). London: Department for International Development.

Tsamenyi, M. (2014). *The Case Of Ghana: Sharing Challenges In Implementing Legislation To Combat IUU Fishing.* 14pp.

Tsibu, B.G. (2015). *Ghanaians Consume 1m Tonnes Of Fish Annually*. Retrieved from The Ghanaian Times: http://www.ghanaiantimes.com.gh/ghanaiansconsume1mtonnesoffish-annually/

Udoh, J. P., Nlewadim, A. A. & Ofor, C. (2009). Maturity estimation in male swimming brachyuran crab, *Callinectes amnicola* (de rocheburne, 1883) (decapoda , portunidae) in the Imo river estuary, Nigeria. *Nigerian Journal of Agriculture, Food and Environment.*, 5(2-4): pp. 61-71.

UNCTAD. (2014). *Maritime Piracy. An Overview of Trends, Costs And Trade-Related Implications. Studies in Transport Law and Policy–2014/No.1.* New York and Geneva. 54 pp.

UNDP - Ghana and NDPC/GOG. (2015). *2015 Ghana Millennium Development Goals Report.* Accra: Republic of Ghana. 113pp.

UNEP. (2009). *The environmental food crisis – The environment's role in averting future food crises. A UNEP rapid response assessment.* Norway: Birkeland Trykkeri AS. 104 pp.

UNICEF & WHO. (2014). *Progress on sanitation and drinking-water.* Geneva, Switzerland: WHO Press. 74 pp.

United Nations. (2014). *The Millennium Development Goals Report 2014. We can end poverty 2015.* New York: United Nations. 59 pp.

UNODC. (2011). *Transnational Organized Crime In The Fishing Industry. Focus On: Trafficking In Persons Smuggling Of Migrants Illicit Drugs Trafficking.* . United Nations, Vienna. 144 pp.

UNODC. (2013). *Transnational Organized Crime from East Asia and Pacific.* . Retrieved from 'www.unodc.org/documents/Publications/2013/TOCTA_EAP_web.pdf'

Varkey, D., Ainsworth, C., Pitcher, T., Goram, Y. & Sumaila, U.R. (2010). Illegal, unreported and unregulated fisheries catch in Raja Ampat regency, Eastern Indonesia. . *Marine Policy*, 34, pp. 228–236.

Veitch, L., Dulvy, N.K., Koldewey, H., Lieberman, S., Pauly, D., Roberts, C.M., Rogers, A.D., Baillie, J.E.M. (2012). *Avoiding empty ocean commitments at Rio+20.* Science 336, pp. 1383–1385.

Ward, A. R., Bortey, A., Whittingham, E., Braimah, L., Ashong, K. & Wadzah, N. (2004). *Poverty and Post Harvest Fishery Livelihoods in Ghana.* Exeter, UK: Output from the Post-Harvest Fisheries Research Programme Project R8111. IMM Ltd, 110 pp.

WARFP. (2014). *Mid-Year Project Implementation Report (January – June 2014).* Accra. 68 pp.

Wertheimer, A. C., Heard, W. R., Maselko, J. M. & Smoker, W. W. (2004). *Relationship of size at return with environmental variation, hatchery production, and productivity of wild pink salmon in Prince William Sound, Alaska: does size matter?* Reviews in Fish Biology and Fisheries, 14, pp. 321–334.

Witbooi, E. (2011). *Fisheries and sustainability. A legal analysis of EU and West African agreements.* Martinus Nijhoff Publishers : Leiden, The Netherlands, 271 pp.

World Bank. (2004). *Saving Fish and Fishers. Toward Sustainable and Equitable Governance of the Global Fishing Sector.* The World Bank Agriculture and Rural Development Department. Report No. 29090-GLB, 109 pp.

World Bank. (2009). *The Sunken Billions: The Economic Justification for Fisheries Reform.* The World Bank Agriculture and Rural Development Department,Washington. 130 pp.

Worm, B., Barbier, E.B., Beaumont, N., Duffy, J.E., Folke, C., Halpern, B.S., Jackson, J.B.C., Lotze, H.K., Micheli, F., Palumbi, S.R., Sala, E., Selkoe, K.A., Stachowicz, J.J. & Watson, R. (2006). Impacts of biodiversity loss on ocean ecosystem services. *Science*, 314, pp. 787–790.

APPENDICES

Appendix I: Plate A showing the species used in the study

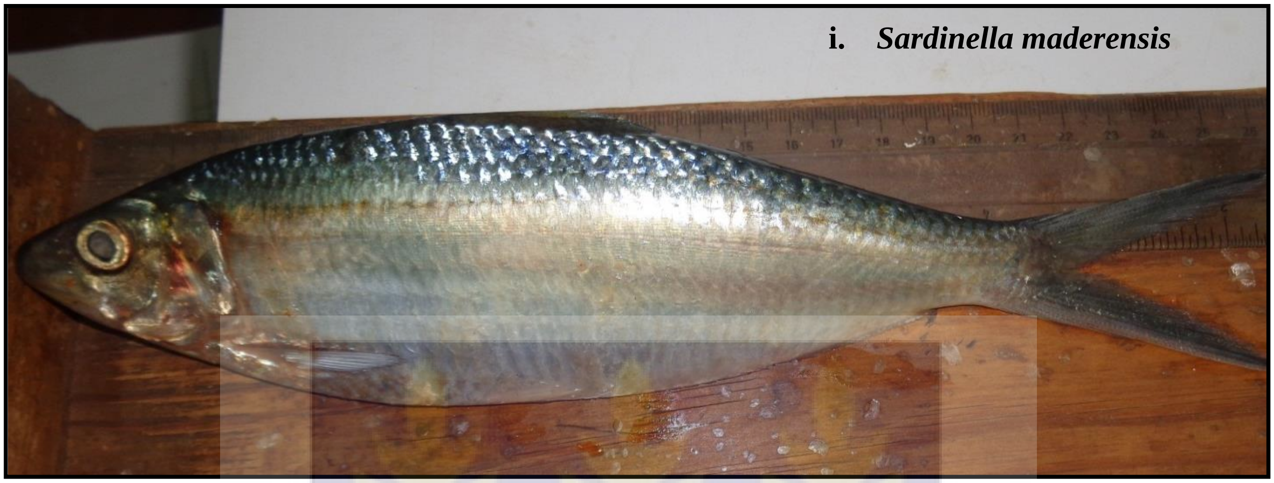

Plate A: Species used in the study i) *Sardinella maderensis* ii) *Sardinella auritus* iii) *Pagellus bellottii*

Appendix I: Plate A showing the species used in the study-continued

Plate A: Species used in the study iv) *Brachydeuterus auritus* v) *Engraulis encrasicolus* vi) *Scomber japonicus*

Appendix II: ANOVA of incidence of poverty (Head count) across the four study sites

ANOVA: Two-Factor Without Replication

SUMMARY	*Count*	*Sum*	*Average*	*Variance*
1	4	2.24	0.56	0.01
2	4	3.31	0.83	0.01
3	4	3.37	0.84	0.01
Vodzah	3	2.31	0.77	0.01
Denu	3	2.33	0.78	0.02
Tema	3	1.89	0.63	0.03
Jamestown	3	2.39	0.80	0.04

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	0.20	2	0.10	61.77	0.000	5.14
Columns	0.05	3	0.02	10.70	0.008	4.76
Error	0.01	6	0.00			
Total	0.26	11				

Appendix III: ANOVA of poverty gap across the four study sites

ANOVA: Two-Factor Without Replication

SUMMARY	*Count*	*Sum*	*Average*	*Variance*
1	4	0.89	0.22	0.01
2	4	1.5	0.38	0.01
3	4	1.64	0.41	0.01
Vodzah	3	1.18	0.39	0.01
Denu	3	1.14	0.38	0.01
Tema	3	0.66	0.22	0.01
Jamestown	3	1.05	0.35	0.01

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	0.08	2	0.04	318.07	0.00	5.14
Columns	0.06	3	0.02	151	0.00	4.76
Error	0.00	6	0.00			
Total	0.14	11				

Appendix IV: ANOVA of poverty severity across the four study sites

ANOVA: Two-Factor Without Replication

SUMMARY	*Count*	*Sum*	*Average*	*Variance*
1	4	0.49	0.12	0.00
2	4	0.89	0.22	0.00
3	4	0.99	0.25	0.00
Vodzah	3	0.72	0.24	0.01
Denu	3	0.72	0.24	0.00
Tema	3	0.34	0.11	0.00
Jamestown	3	0.59	0.20	0.00

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	0.035	2	0.02	92.65	0.00	5.14
Columns	0.03	3	0.01	56.63	0.00	4.76
Error	0.00	6	0.00			
Total	0.07	11				

Appendix V: Interview guide for obtaining social information from respondents

DEPARTMENT OF MARINE AND FISHERIES SCIENCE

UNIVERSITY OF GHANA, LEGON

ASSESSMENT OF THE SECURITY OF COASTAL FISHING OPERATIONS IN GHANA

INTERVIEW GUIDE

The aim of this study is to identify the social component of fishers engaged in coastal fishing operations in Ghana in order to assess coastal fishing operations in Ghana. The study is strictly for research purpose and I will appreciate, if you could help by responding to this interview guide to the best of your knowledge. All information provided in this study will be treated with confidentiality. **Thank you**

Target group: Fishers living in coastal fishing communities

Serial no: ………………………………… Sex: …………………………………..

Date: …………………………………….. Ethnicity: ……………………………

Coastal community: ……………………..

Name of interviewer: ……………………………………………………………...…….

Name of interviewee: …………………..……………………………………….……

A. **GENERAL INFORMATION ON FISHER**

1. What is your primary occupation? ....
2. Do you have any secondary occupation? If yes, specify all) ………………………
3. For how long have you been in the primary occupation?…………………………..
4. How old are you? ……………………………………………………
5. Have you been to school before? If yes, what is your highest level of education?.......
6. What fishing gear type do you use? ……………………………………………………..
7. What is the size of your household? …………………………………………………..
8. Are you originally from this community? Yes or No? ………………………………..
9. If No, what is your area of origin? ……………………………………………………..
10. If No, why did you migrate? ………………………………………………………..

B. FISHERIES MANAGEMENT ISSUES

11. In your opinion, are the fish catches increasing or declining? ………………………………
12. What do you think are the causes for your answer above?..
13. List any two illegal fishing activities occurring in your fishing community? ………………
14. Who sells materials used for this illegal fishing activity in your answer above? ……………
15. Are this illegal fishing materials sold in the Open or undercover? …………………………...
16. Do you know of any fisheries regulation measures? Yes or No …………………………….
17. If yes, state any two of the fisheries regulations? ……………………………………………...
18. Who are responsible for the enforcement of the fisheries regulations? …………………….
19. Do fishers in the fishing community adhere to the rules and regulations under the management practices? Yes or No? ………………………………………………………

20. If No, why: …………………………………………………………………….

21. How many persons using illegal fishing methods have been arrested in the past month?.....

C. SOCIO ECONOMIC ISSUES

22. Do you have any savings from your fishing activities? Yes or No …………………………

23. If yes, in what form do you save? ……………………………………………………….

24. Would you say fishermen are poor? Yes or No ……………………………………………

25. What are the main causes of poverty in fishing communities? Pleases give at least five…...

26. What are some of the constraints you face as a fisher? …………………………………….

27. List all the known social amenities in this community. ……………………………………

THANK YOU

Appendix VI: Output of normality test for head count (H) poverty index across the four fish landing sampling sites

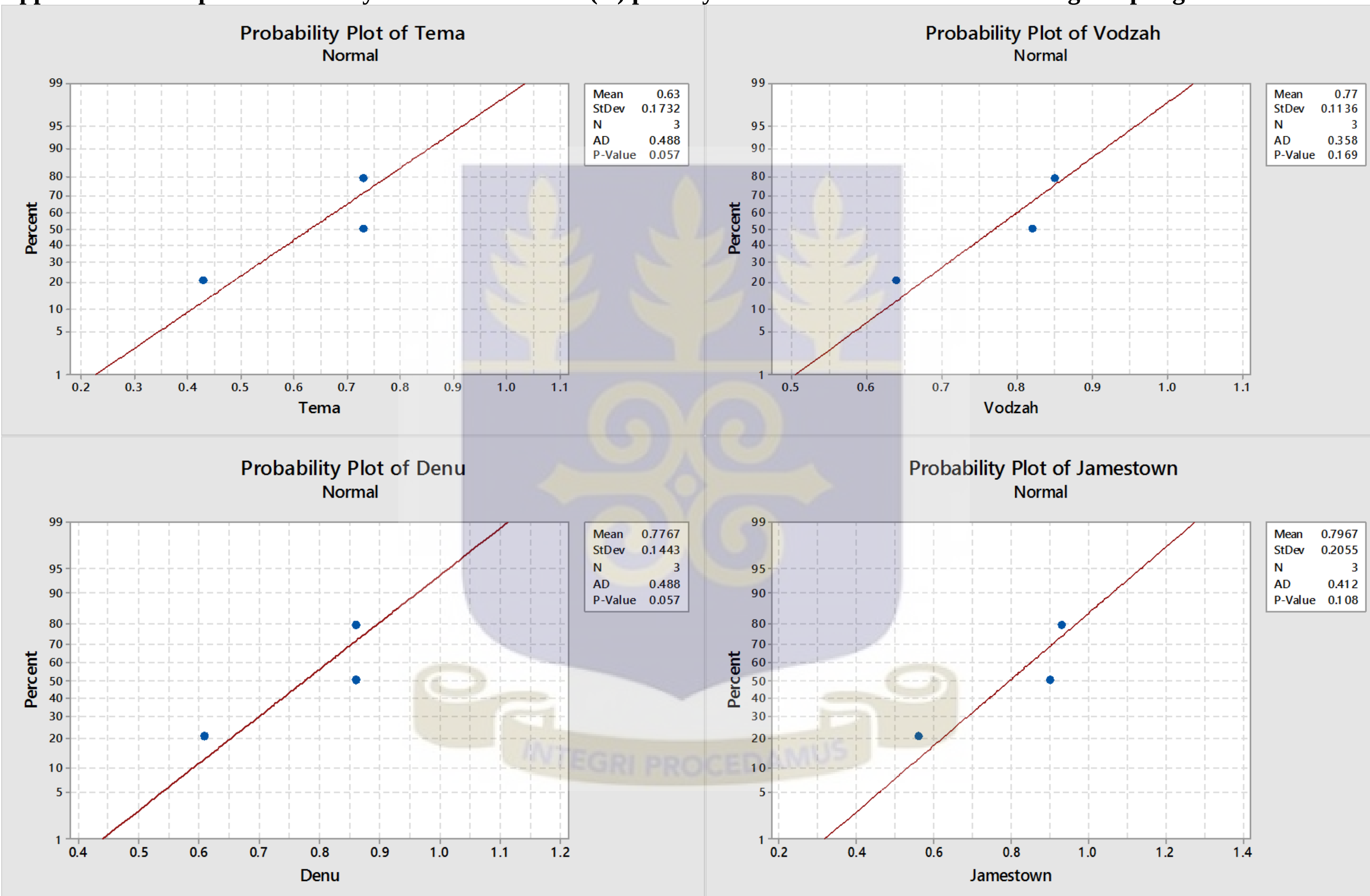

Figure 21: Normality test for head count (H) poverty index across the four fish landing sampling sites from Minitab output

Appendix VII: Output of normality test for poverty gap (PG) poverty index across the four fish landing sampling sites

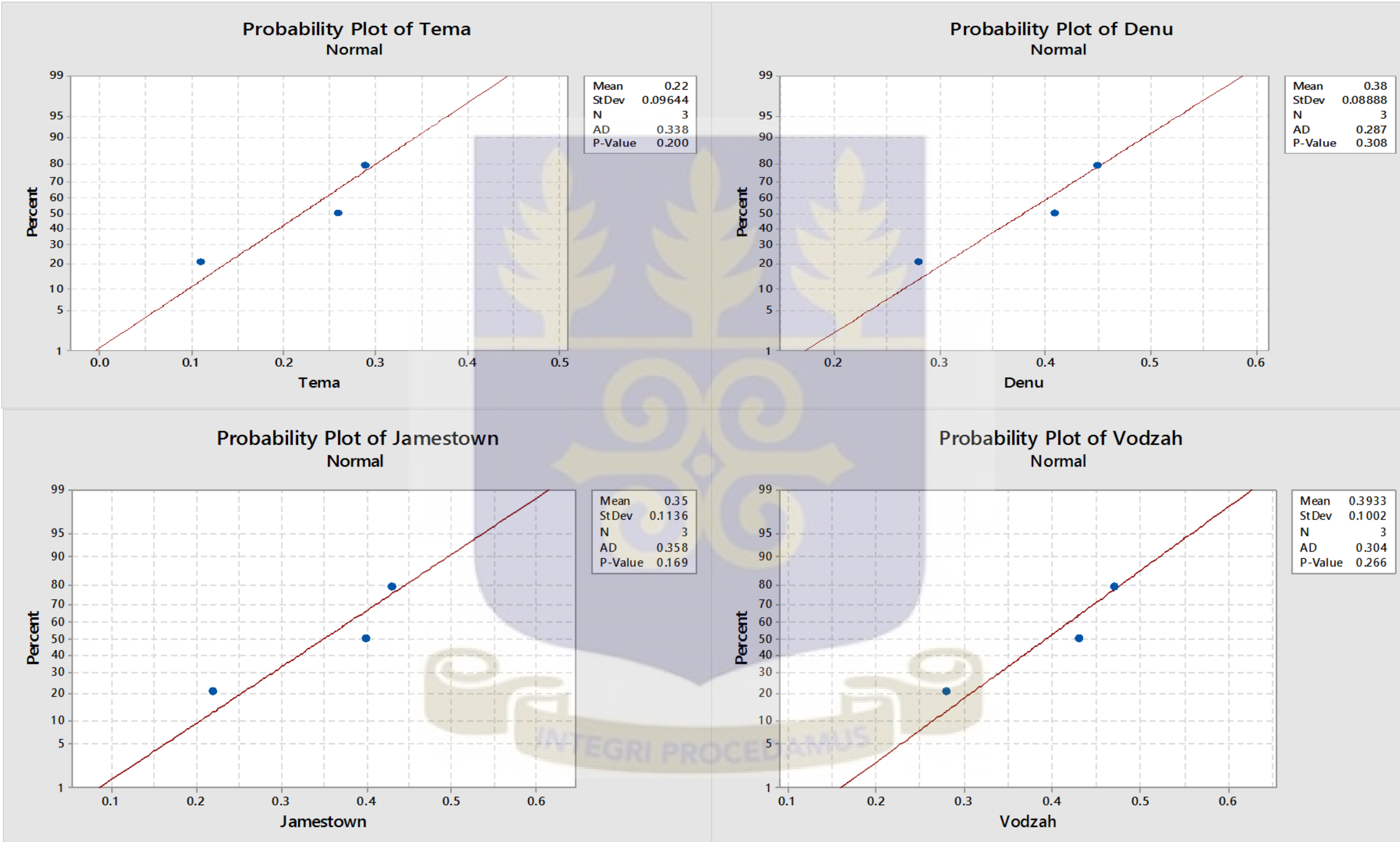

Figure 22: Normality test for poverty gap (PG) poverty index across the four fish landing sampling sites from Minitab output

Appendix VIII: Output of normality test for poverty severity (PS) poverty index across the four fish landing sampling sites

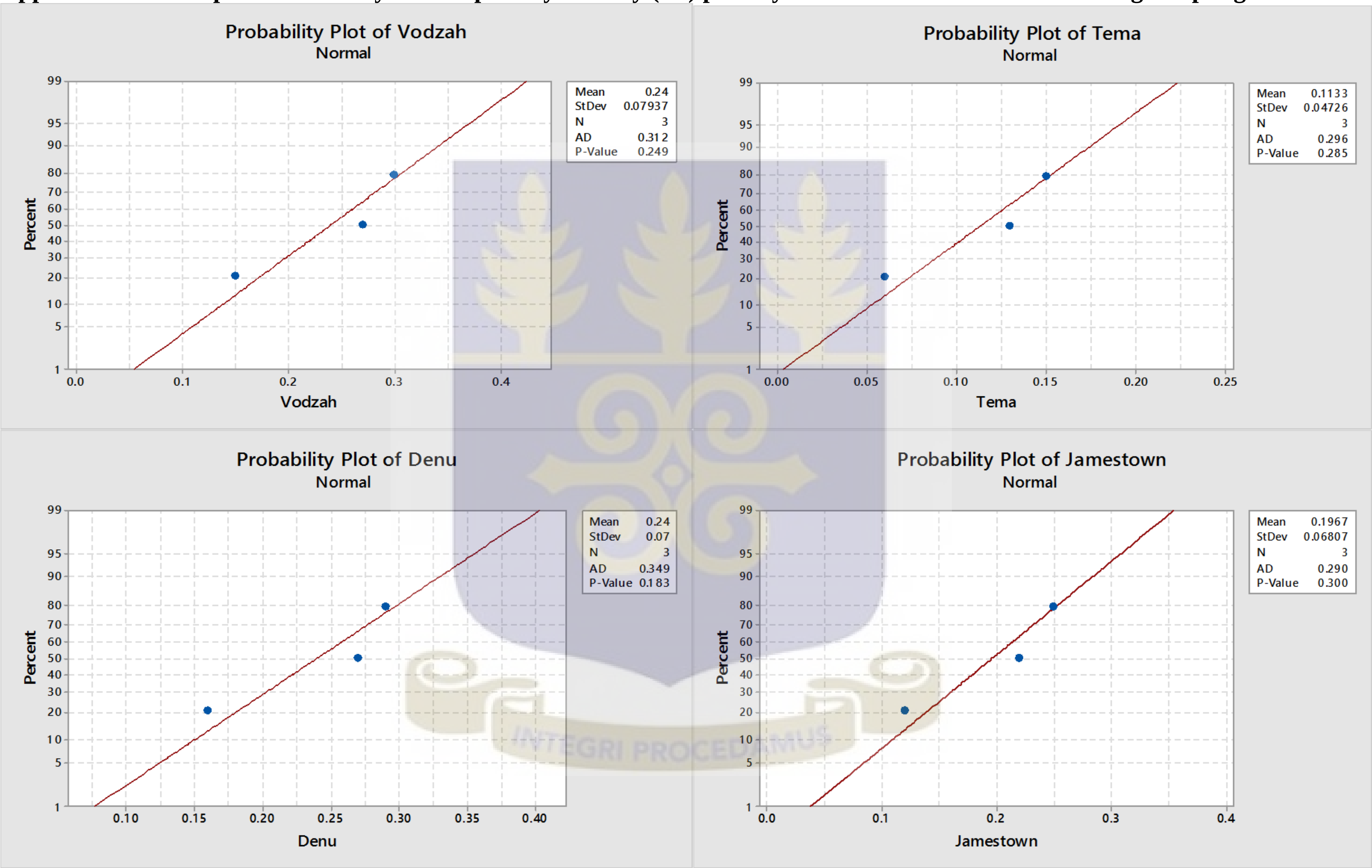

Figure 23: Normality test for poverty severity (PS) poverty index across the four fish landing sampling sites from Minitab output

Appendix IX: Output of normality test for total infractions and total fines (penalties)

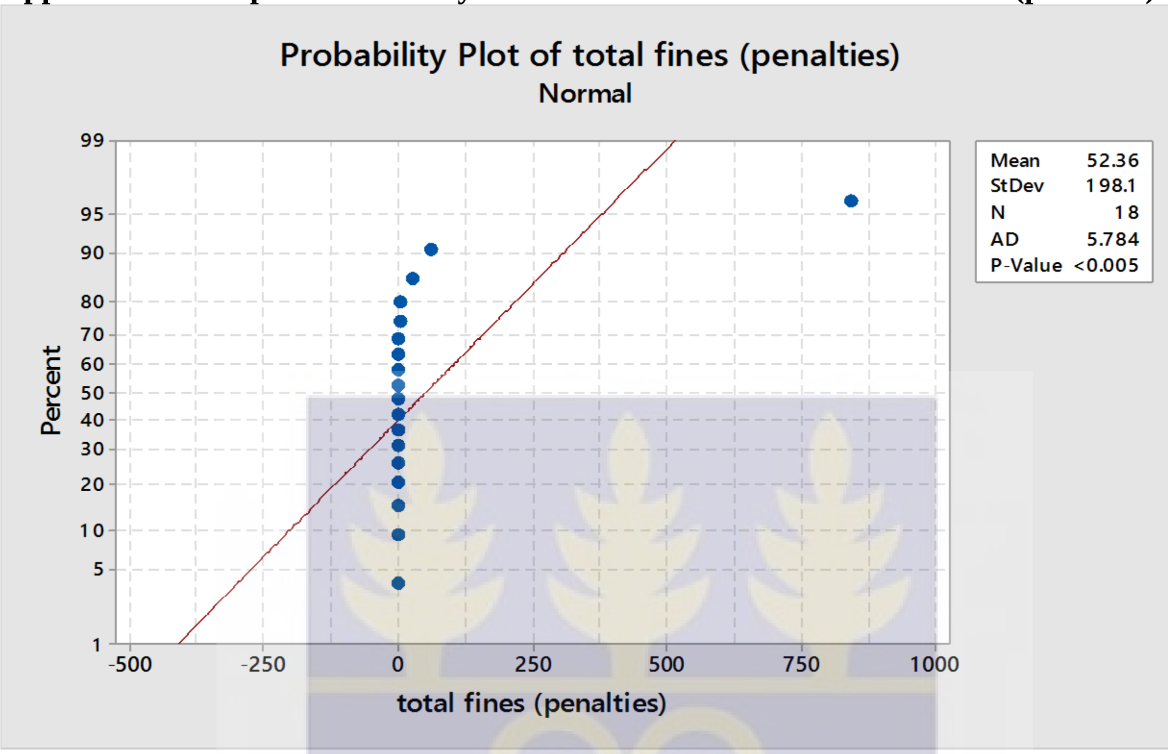

Figure 24: Normality test for total fines (penalties) from Minitab output

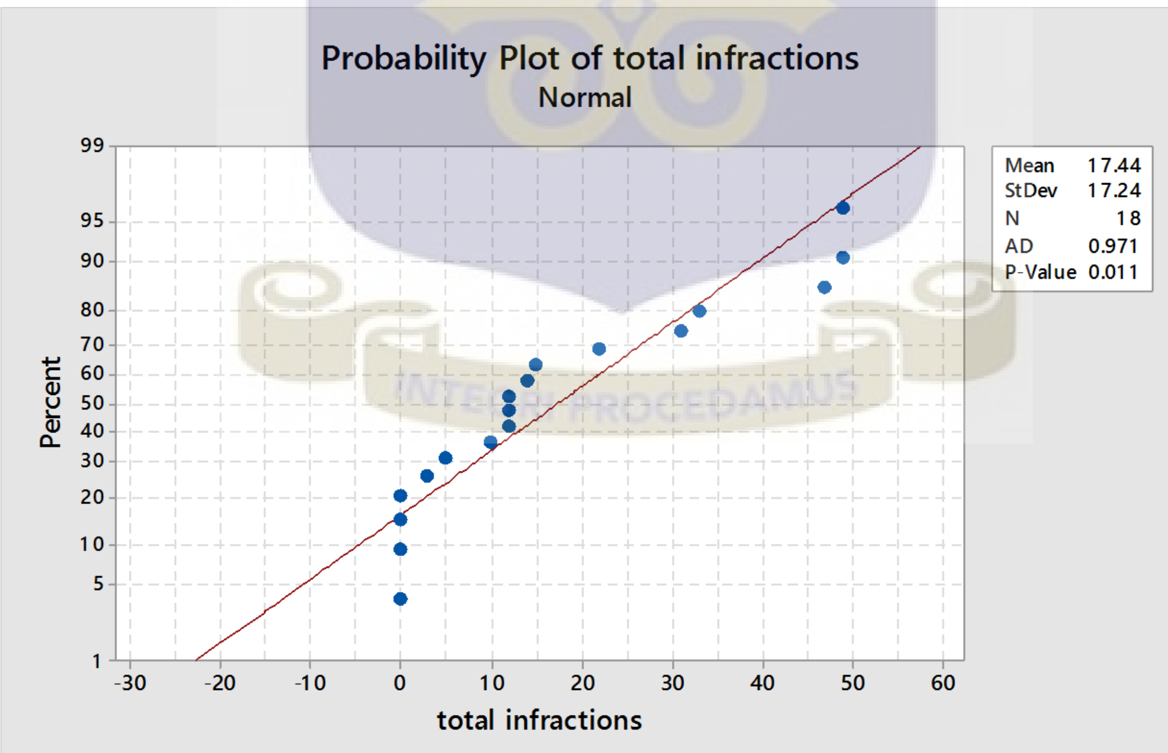

Figure 25: Normality test for total infractions from Minitab output

Appendix X: Kruskal-Wallis Test for total fines (penalties) versus total infractions

Kruskal-Wallis Test on total fines (penalties)

Total infractions	N	Median	Ave Rank	Z
0	4	0.000000000	7.0	-1.06
3	1	0.000000000	7.0	-0.48
5	1	0.000000000	7.0	-0.48
10	1	0.000000000	7.0	-0.48
12	3	3.511800000	12.3	1.01
14	1	0.000000000	7.0	-0.48
15	1	0.000000000	7.0	-0.48
22	1	5.690000000	15.0	1.06
31	1	0.000000000	7.0	-0.48
33	1	0.000000000	7.0	-0.48
47	1	8.43768E+02	18.0	1.64
49	2	3.16500E+01	12.0	0.70
Overall	18		9.5	

H = 7.29 DF = 11 P = 0.775
H = 11.68 DF = 11 P = 0.388 (adjusted for ties)