UNIVERSITY OF CAPE COAST

DATA QUALITY OF CAPTURE FISHERIES MANAGEMENT IN DEVELOPING COUNTRIES: A CASE STUDY OF GHANA

TEMILOLUWA JESUTOFUNMI AKINYEMI

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BY

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A thesis presented to the Department of Fisheries and Aquatic Sciences, School of Biological Sciences, College of Agriculture and Natural Sciences, University of Cape Coast, in partial fulfillment of the requirements for the award of a Master of Philosophy (Honors) Degree in Fisheries Science

DECEMBER 2022

DECLARATION

Candidate's Declaration

I hereby declare that this thesis is the outcome of my original study and that no portion has ever been submitted for credit toward another degree at this university or anywhere else.

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

Name: Temiloluwa Jesutofunmi Akinyemi

Supervisors' Declaration

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

Principal Supervisor's Signature _____________________ Date _____________

Name: Prof. Denis Worlanyo Aheto

Co-Supervisor's Signature _________________________ Date ________________

Name: Prof. Wisdom Akpalu

ABSTRACT

Quality fisheries data is critical to sustainable fisheries management. Yet, gathering quality national fisheries data for fisheries management remains a huge challenge in many developing countries such as Ghana. This study assessed the quality of marine fisheries data, the methods used in generating the data, and how it influences Ghana's fishery's sustainability. The FAO standard protocol for national fisheries data collection was used to evaluate the kind of fisheries data collected and the sampling methods. The results indicated that different data sets were collected in different districts and regions of the country showing several discrepancies in the data sets used for developing management plans and policies. 50 landing sites were sampled out of 292 landing sites in Ghana, instead of 166 landing sites. For canoes, 290 were sampled out of 11,583 canoes instead of 372 canoes. Additionally, the results of bioeconomics analysis revealed the underestimation of catch potentials which has implications on the policy and management system. The situation eliminates potentially valuable data samples that could be crucial for the management process, which has an impact on the precision of the estimated catch and effort. This would thus make it more difficult to develop relevant regulations for the fisheries industry because the knowledge gained from this data might result in incorrect conclusions, unwise policy, and irresponsible fisheries management. It is suggested that, for the governance and sustainability of the fish stock, fisheries managers, and policymakers, including all pertinent stakeholders diligently collaborate to strike a balance between sampling techniques, needs, and the understanding of the data required. This should also give a balance collection by field and office staff, as this is essential to producing reliable statistics all year long.

LIST OF PUBLICATIONS

1. Akinyemi, T.J.; Aheto, D.W.; Akpalu, W. Sampling Error and Its Implication for Capture Fisheries Management in Ghana. Fishes 2022, 7, 333. https://doi.org/10.3390/fishes7060333 (Published: fishes-2005859)

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KEYWORDS

Fisheries data quality

Fisheries data monitoring

Fisheries Sustainability

Ghana

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DEDICATION

I devote this thesis to my mother, Bosede Amudat Akinyemi, who helped me in many ways while I was pursuing my education. Additionally, I dedicate it to my siblings Kemi, Femi, and Toluwanimi Taiwo Akinyemi. Most of all, I devote it to Almighty God, whose Love and Compassion have allowed me to advance so far.

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LIST OF ACRONYMS

ACECoR	Africa Centre of Excellence in Coastal Resilience
CFS	Canoe Frame Survey
CPUE	Catch per Unit Effort
EEZ	Exclusive Economic Zone
E_{MSY}	Effort corresponding to Maximum Sustainable Yield
FAO	Food and Agriculture Organisation
FSSD	Fisheries Scientific and Survey Division
GDP	Gross Domestic Product
IUU	Illegal Unreported and Unregulated
MDPI	Multidisciplinary Digital Publishing Institute
MoFAD	Ministry of Fisheries and Aquaculture Department
MSY	Maximum Sustainable Yield
SFC	The State Fishing Corporation

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

Millions of people who live along coastlines depend on fisheries resources for their food security, economic growth, and eminence of life (Andrew *et al.*, 2007). These resources provide a huge contribution to the world economy, especially in developing nations. Global marine fisheries contribute more than US$ 270 billion yearly to the global GDP (World Bank, 2012). According to FAO estimates, 10 to 12% of the global populace relies on fisheries and fish farming for their livelihoods. Nearly 17% of the animal protein ingested by the world's populace and 6.7% of all protein ingested in 2013 came from fish. Additionally, for more than 3.1 billion individuals, fish provided nearly 20% of the average daily consumption of animal protein (FAO, 2016).

Ghana as a sovereign state has a long fishing tradition with a rigorous and diverse spectrum of fishing activities ranging from subsistence (motorized and unmotorized canoes), semi-industrial (wooden-planked vessels), and to the industrial fishery (tuna, shrimpers, and trawlers) (Afoakwah et al 2018). These fisheries sectors have made significant contributions to Ghana's economy, as fish alone provides over 60 percent of the nation’s protein requirements. The average Ghanaian eats about 25 kg of fish per year (FAO, 2016). Moreover, over US$1 billion in revenue (about 1.5 percent of GDP) is generated each year from fisheries (Quagrainie J and Chu K 2019). However, Ghana's fisheries resources have been seriously threatened for the past two decades, with several experts reporting recurring declines in total fish landings despite increased efforts (Lazar et al. 2017). This decline is attracting a lot of attention around the country as many stakeholders involved in fisheries resources, whether directly or indirectly, have resolved to work together to preserve and manage national fishery resources to ensure that there is enough fish for both present and the future (Stöhr et al. 2014).

The regulation of Ghana's marine resources and sectors is therefore very important as the population need fish-based protein, and it is well understood that sustainably managed fisheries can provide this service in perpetuity and also assist in meeting economic goals while also conserving the aspects of society and culture of fishing (Farmery *et al*., 2021). Therefore, the importance of credible data in fisheries management cannot be overemphasized. Without accurate data, a capture marine fishery cannot be kept healthy and sustainable, as the collection of quality data will aid in the early detection of under-exploitation (underutilization of fisheries resources) and overexploitation symptoms such as decreased fish size, biomass, and total catch (Brewin, 2018). Quality local data will contribute to regional and global fish stock assessment, maintenance, and monitoring systems, as well as give more realistic national economic stability and growth indicators. As a result, providing high-quality data will aid in making well-informed judgments and suggestions both locally and globally.

The best available scientific data must be used as the foundation for fishery management, according to the FAO Guidelines for Responsible Fishery (FAO, 1995). This shows that the quality of the finest scientific data is directly related to managing choices for a fishery because even a small omission or inaccurate information in the dataset could lead to overfishing or underfishing, both of which have major economic and environmental effects.

This omission, however, could be the consequence of several things, such as illegal, unreported, and unregulated (IUU) fishing practices and unreported catches from "Saiko" or fish transshipment fishing, unreported portions of fish taken by the fishing crew at the end of each trip, waste and discarding of spoiled fish, unstainable resources exploitation techniques and the method for collection of data (biological and economic) for management (see Astrid et al., 2020; Aheto et al., 2020). Therefore, it is essential to evaluate the data used by the Fisheries Commission and other stakeholders to regulate the status and true state of the fishery, allowing management strategies to be developed that will improve the fishery while causing the least amount of inconvenience to the fishing community.

Statement of the Problem

Access to high quality data is critical for sustainable fisheries management. Yet, the critical hurdle to Ghana's sustainable fisheries management are data availability and quality. Reports and data from the Fisheries Commission and MoFAD show a declining trend of total catch and catch per unit effort beginning 1992. However, there are data gaps of unreported catch from “saiko” fishing activities, dumping at sea, crews’ share of harvested fish (Aheto et al., 2020), undocumented data on the exploitation of shell fishery, estuarine and lagoon fishery in the data used by Fishery Commission (Atta-Mills et al., 2004). For instance, Nunoo et al. (2015) indicated that Ghanaian vessels' total landing in domestic coastal waters were 1.8 times higher than the catches the country's FAO reported. These gaps in the Fishery Commission's data could have led to inaccurate estimates of the economic rents from the resource, as well as less-than-ideal information on resource availability, allocation, or extraction. Moreover, an overcapitalized fishery owing to erroneously or over-exaggerated catch potentials is likely to collapse the fishery. It is therefore expedient to investigate the extent to which the management practices and by extension, the policies of Ghana's capture marine fisheries deviate from the maximum sustainable and economic yield levels by comparing estimates from the official and reconstructed data sets.

Research Questions

1. How do the types and sources of data based on the national data and FAO toolkit for small-scale fisheries routine data collection compare?
2. How do the methods in the national data collection differ from FAO toolkit for small-scale fisheries routine data collection?
3. What are the limiting factors associated with the collection of data?
4. How do the trends in fish catches based on the official data and reconstructed data in Ghana compare?
5. How do the Maximum Sustainable Yields (MSY) and the corresponding fishing effort levels based on the official data and the reconstructed data differ?
6. What are the potential losses in rents based on the official data and reconstructed data?
7. What is the effect of the data quality on the socio-economic contribution of the fisheries sub-sectors?

Research Aim

The aim of this study is to assess the currently used fisheries data, bringing to light the gaps in the data (in terms of effort and catch), identifying the sources, forms, and scale within the fisheries sectors of Ghana and evaluating the eventual implications on fisheries resources and the nation's economy.

Research Objectives

The study's key objectives are to:

1. assess the types and sources of data used based on the national data and FAO toolkit for small-scale fisheries routine data collection
2. evaluate the data collection techniques based on the national data and FAO toolkit for small-scale fisheries routine data collection
3. evaluate the limitations associated with data fisheries quality
4. examine the patterns in total catch and Catch per Unit Effort (CPUE) for the artisanal subsectors based on the official data and reconstructed data on Ghana from 1990 to 2018.
5. estimate and analyse the maximum sustainable yields and the corresponding fishing effort levels for Ghana's artisanal fisheries using the official and reconstructed data.
6. compare the resource rent deficits based on the official data and reconstructed data.
7. analyze the effect of data quality on the fisheries management practices and policies in Ghana

Significance of the Study

Fishing resources are a limited resource even though they are renewable. Therefore, to stop the depletion of the marine resources as reported by various scientist, sustainable exploitation, adequate management, and conservation are required. Over the years, there has been inherent difficulty in the management of fisheries due to the gaps and errors in the data used for management. Data quality is however very important as it aids in the early detection of over exploitation or under exploitation symptoms.

To effectively manage fisheries resources and stop further decline of fisheries so that fish will be available now and, in the future, it is necessary to have clarity regarding the data collection process, the gaps and errors in the data, and the effects of these errors on the fisheries resource, the national economy, and policy making. Doing so will provide broad-based scientific baseline understanding to inform country-level policy decision-making to improve fisheries management through the provision of a more reliable and realistic information for accurate estimation of the magnitude of production. Doing so will also shore up Ghana's international data credibility to global fisheries statistics. The work will also support further research studies.

Delimitations

Twenty-nine data gatherers were chosen for this study from Ghana's coastal regions. Four geomorphologic zones, the Greater Accra Coast, East Coast, Central Coast, and West Coast, are used to categorize Ghana's coastal regions. The study locations were Abutiakope, Lighthouse (Volta), Gbegbeyise, Botianor, Agjivompanye, Odin-nyonma, Osu alata, Teshie, Ga mashie, Awudun (Greater Accra), Saltpond, Kromantse, Apam main, Elmina main, Elmina, Ayipey, Abrofo mpoano, Mumford main, Enfano (Central Region), and Dixcove, Sekondi, Fante line (Axim), Akyinim, Ewe line, Fante line (Half Assini), Sharma Apo, Sekondi-Takoradi, Akwadae, Adjua (Western). These sites were picked because they include all of the significant fishing landing points where data on fisheries is being gathered for fisheries management. In this study, catch and effort data were used instead of other valuable and standard information about fisheries and aspects of fish stock assessment, such as gonad weight, sex, salinity, temperature, and dissolved oxygen, because these data offer useful indicators of population trends that can be used to reform the distribution of fishing activity and achieve sustainable fisheries.

Limitation

While conducting the study, several limitations were found, although they are of no consequence. One of the data collectors who was scheduled for an interview could not be made available because of his hearing issue. The study's quality was unaffected despite this constraint.

Definition of Terms

The following descriptions of terminology used in the study are provided to facilitate readers' comprehension. These are:

Data: Data is a collection of information gathered by observations, measurement or analysis.

Data quality: A way of describing the state of data based on criteria including accuracy, completeness, consistency, reliability, and if the data is recent. Measuring levels of quality data can assist organizations or managers in identifying data mistakes that need to be fixed and determining whether the data they already have is suitable for its intended use.

Saiko: Trans-shipment of fish from commercial trawlers to canoes

Respondents: Used to describe the enumerators employed by FSSD to collect catch and effort data.

Fisheries data: a broad term for information that could be useful for managing fisheries.

Organization of the Study

Five chapters make up the format of this study. Background information for the research, the problem statement, the research questions, the relevance of the study, as well as its delimitation, constraints, definition of terms, and organizational structure, are all provided in the first chapter, which is named Introduction. A theoretical foundation for the study is presented in Chapter 2. It discusses the fundamental ideas and theories that this study is based on and provides a thorough analysis of the literature pertinent to this investigation. It emphasizes global discoveries on fisheries, fisheries status, fisheries management, fisheries data, the quality of such data, and data gathering guidelines. Chapter Three covers the first article from the research titled "Sampling Errors and its Implication in Capture Fisheries Management in Ghana", which is published in the Journal of Fishes, an open access journal by MDPI. The study evaluated data type and sampling methods in Ghanaian fisheries, evaluated errors in data collection and its implication on management policy. Chapter Four presents the second article submitted to Fish and Fisheries Journal, titled "Fisheries data quality errors in marine sectors of Ghana". The sustainability and catch patterns of the marine fisheries sectors were evaluated in this study. The overview, conclusions, and recommendations are found in chapter five. Just after chapter five, a list of all the references used to support the thesis is provided.

CHAPTER TWO

LITERATURE REVIEW

This chapter summarizes key review from the literature on national fisheries data and other pertinent information. In relation to the goal of this study, it also offers a constructive appraisal of the outcomes and methodologies of other investigations. In this section, the fisheries sector, its management, the caliber of data used for fisheries management, and the procedure for data gathering in Ghana, other developing nations, and other regions of the world are discussed.

Overview of Fisheries industries in developing countries

It is impossible to emphasize the significance of fisheries as a source of nutrients, employment, and revenue for many coastal and rural populations across the world because it is the most traded food product and over 800 million people rely on its capture, processing, production, and sale. Their contribution to the livelihood strategies of millions of households in developing nations, as well as their involvement in poverty alleviation, are particularly noteworthy. (SADC 2003). According to a recent study, the world's 6 billion people consume 15.4 kilograms (nearly 34 pounds) of fish on average annually from industrial, recreational, and subsistence fisheries as well as aquaculture (Bennett A. et al. 2018). Ghana is among the few poor nations in the world with a lucrative fishery that brings in up to $1 billion every year. Only the marine subsector of the fisheries sector, which employs 135,000 people, accounts for about 10% of the workforce in the nation (BOG, 2008) and the activities of four different groupings within the industry, namely the Artisanal, Semi-Industrial (inshore sector), Industrial (deep sea), and Tuna fleets, demonstrate how this subsector is organized in Ghana. (Amadou T. & Pierre F. 2012).

The Ghanaian government adopted a policy after the country's independence in 1957 with the intention of bolstering the fishing industry by building fishponds as part of all irrigation projects conducted within the nation (BoG, 2008). The State Fishing Corporation (SFC), which was established in 1961, and the construction of Tema Harbor in 1962 were two additional initiatives to boost mechanized fishing using huge fishing trawlers, inboard motors, and outboard motors (BoG, 2008). The number of marine fish caught increased significantly as a result of these and other strategies from the late 1960s, going from 105,100 tons to 230,100 tons in 1971 (Amos A. A. 2020), but the nation's fisheries started to decline in 1999, especially the marine fisheries. These decreased from about 420000 to about 202 000 tonnes in 2014 (FAO, 2016), even though fish catches appeared to have been increasing steadily in nominal terms. Mismanagement, overfishing, and the harmful effects of climate change all contributed to this collapse (FAO, 2016). The Ghanaian government implemented certain efforts in 2005 to address this. It has led to a rise in the number of fish farmers from 1,200 in 2005 to 38,500 in 2014. (FAO, 2016). As a result, Ghana's total catch fisheries production increased from 231,600 tonnes in 1980 to 293000 tonnes in 2014. (FAO, 2016). Despite the increasing availability, the nation was forced to import fish in 2013, which cost USD 373 million. This enables to meet the expected 24.2 kg annual per capita intake of fish. (FAO, 2016). Due to this, the fish trade balance changed from being in surplus in 1997 to being in deficit in 2013 by USD 319 million. (FAO, 2016).

Fisheries sectors in Ghana

Ghana's fisheries productivity is built on its 550 km of coastline and its 228,000 km^2 maritime domain, which includes the territorial sea and the Exclusive Economic Zone (EEZ) (MOFAD 2015). Artisanal, industrial, lagoon, and inland fisheries are among Ghana's five different types of fishing. Contrarily, the the information provided by the Fisheries Commission did not specifically cover lagoon and inland fisheries. Since the sea provides most of the fish caught in Ghana, it is the primary source of national fish production and data. (Afoakwah R. et al. 2018).

Marine Fisheries subsectors

About 80 out of every 100 fish supplies in Ghana come from the maritime subsector, which covers about 225000 km^2 of the country's total land area. Around 77000 people were employed in this sector in 2014, and there were 304 landing centers which composed 189 fishing settlements across the coast. The subsector still produces an annual average catch of over 300,000metric tonnes, even though its catch has dropped from roughly 420 000 tonnes in 1999 to 202 000 tonnes in 2014 (FAO, 2016). Marine fishing is a major component of Ghana's economy. It increases GDP, creates jobs and revenue, helps fight poverty, and ensures food security. Marine fisheries primarily come from the sea, but some lagoons are also involved. The yield of marine fisheries depends on the upwelling process, a trend in which nutritionally cool water is lifted to the ocean's surface to boost the ecosystem. The main season, which occurs from July to September, and the trifling season, which also occurs as of late December to early February, are the two upwelling seasons on Ghana's continental shelf. (MoFAD, 2015). There are many fish to catch during these seasons. Artisanal or small-scale, semi-industrial or inshore, industrial, and tuna fisheries are the four subsectors of the marine fisheries sector. Trawl boats and shrimpers are part of the industrial sector. All sectors' catches, with the exception of the tuna fleets', are dominated by small pelagic fish species. According to data, total fish landings usually rose starting in 1970, peaked in 1996, and then started to drop through 2016 (Quaatey 1997; Amador et al. 2006)

Artisanal Fisheries sector

Artisanal fisheries are known for their use of wooden canoes (motorized or unmotorized). With 292 landing beaches in 186 fishing villages, this subsector currently employs over 200,000 fishermen and over 13,000 artisanal canoes. (MoFAD 2015). An outboard motor with an engine output of up to 40 hp powers about 50% of these canoes. (2006) Amador et al. Among the most popular fishing techniques used in this sector are beach seines, set nets, drift gillnets, and hook and line. In 2017 (Lazar et al. 2017). In waters that are 80 meters deep and have a hard bottom, hook and line canoes are used. Fish can be stored for up to three days using the ice storage features found in some hook and line canoes. The canoe owner is escorted by four men, each bearing its own nets. The nets are combined then utilized as a single large net, with every crew member carrying back home the catch from their individual portion of the net once payment of a share of between one-fifth and one-third has been made to the canoe owner (Afful & Osafo-Gyimah, 1979). Some canoes stay out at sea all night while others depart in the morning or the afternoon and return in the evening or morning, respectively. These expeditions leave in the evening and arrive the next day. According to various profit- or loss-sharing agreements, the amount and worth of fish landed determines how much money the artisanal fishermen make. The cuts are typically computed, and profits allocated weekly, frequently on Tuesdays, a prohibited fishing day that is typically reserve for this, along with taking care of mundane jobs, such mending nets (Mensah & Antwi 2002). Over 254,000 metric tons of fish are believed to have been taken by the artisanal subsector, which makes up about 73% of all fish landings in the ocean. (MoFAD 2015). In addition to making up 2.5% of the entire population, this also accounts for over 20% of the workforce (Atta Mills et al., 2004). With a few prized demersal fish species tossed in for good measure, the target species are primarily small pelagic fish. The main species being pursued are mackerel, anchovies, and sardines. In Ghana, artisanal fisheries confront many difficulties, including overexploitation, and have recently experienced a decline in catch. Also, to overexploiting the targeted bottom-dwelling stocks, trawlers in Ghana vigorously participate in IUU fishing practices. Prior till recently, many trawlers engaged in inshore exclusive zone fishing, vying with artisanal fishers for the diminishing stocks of tiny pelagic fish species. These species are concealed as by-catch (referred to locally as saiko), refrigerated in blocks, and transshipped at sea to artisanal boats. According to landings and fleet capacity, the artisanal fishery is Ghana's dominant fishery. Data readily available show that since 1992, when the maximum catch of 308,000 metric tons was reported, catch levels have been dropping. The lowest catch was noted in 1999, but it appears to have steadied since 2013 at around 180,000 metric tons. Like how fishermen's capture rates have generally decreased, canoe catch rates between 1992 and 2016 were 35.44 metric tons and 15.5

metric tons, respectively. Recent stock assessment reports show that small pelagic stocks are severely depleted, and stocks are obviously overcapitalized.

Semi-industrial (inshore) fleets

A total of 403 locally manufactured wooden boats makes up the semi-industrial fleet. Inboard engines ranging from 90 to 400 horsepower are installed in the boats. Purse seines and trawl gears are among the fishing gears used by the vessels. The estimated yearly capture is 6,000 metric tons, or 1.8% of all marine fish landings (MoFAD, 2015). Among the species being targeted are sardinellas and mackerels.

Industrial fisheries

Large, foreign-built vessels operate in Ghana's industrial fishing industry from Tema and Takoradi, both of which have berthing facilities. Ghanaian trawlers fished in more productive waters such as Angola and Mauritania prior the UN Convention on the Law of the Sea, that authorized coastal countries an Exclusive Economic Zone of 200 nautical miles (Mensah and colleagues, 2006). The EEZ permits vessel operation in Ghanaian waters beyond the Inshore Exclusive Zone (IEZ), which includes waters deeper than 30 meters or the six nautical mile offshore border. Trawlers may then fish for demersal fish in these deeper areas (Fisheries Act 625 of 2002). The industrial fleet, also referred to as offshore/distant waters, consists of 48 trawlers, 7 pair trawlers, 2 shrimpers, 26 tuna bait boats, and 10 tuna purse seiners. Trawlers are often over 35 meters long with engines producing over 600 horsepower, whilst shrimpers are up to 30 meters long with engines producing over 350 horsepower. (Nunoo et al. 2014) Industrial fleets are estimated to collect around 18,500 metric tons of fish, accounting for around 5.4 percent of all fish production (MoFAD, 2015). Sparids, groupers, snappers, and cuttlefish are among the species targeted by industrial fleets.

Tuna fleet

A typical tuna fleet consists of about 26 vessels and uses pole and line fishing. Tuna fleets catch bigeye tuna, yellowfin tuna, and skipjack tuna. In a recent study of tuna resources in the Atlantic, the International Commission for the Conservation of Atlantic Tunas (ICCAT) came to the conclusion that yellowfin and bigeye tuna resources are being used to their fullest potential whereas skipjack tuna resources are being underutilized (Nunoo et al., 2015). It is anticipated that the annual sustainable tuna catch will range between 90,000 and 100,000 metric tons (Rurangwa et al., 2015). Contrarily, 65,000 metric tons of tuna are collected annually, making up 18.9% of all marine capture (MoFAD, 2015). The biggest processing company, Pioneer Food Cannery, MYROC, and GAFCO are just a few of the companies that process tuna mostly for export to the EU.

Exploitation and utilization of fisheries in Ghana waters

From 1950 to the present, we have steadily worked our way down the food chain, catching all of the top predators one by one. Every year, the total amount of fish that man takes from the system and consumes increases. In 2005, 95 million tonnes of fish were consumed worldwide, 86 million of which came from marine fisheries and 9 million from inshore ones. Another 50 million tonnes (43 percent) of production came from fish farming, with a large portion of it supplied indirectly by fish from maritime fisheries (Pauly D. et al. 2005). For billions of people worldwide, fish is their main source of protein, and for millions, fishing is their main source of income. Our seas and oceans have long been considered to be a never-ending supply of sustenance. But during the past 50 years, increased fishing activity and unsustainable fishing methods have brought a number of fish stocks dangerously close to extinction (Hauge et al. 2009). Fish is becoming less important in rich countries' diets, and the linked industry contributes only a small portion of their Gross National Product. However, in developing countries, fisheries are projected to contribute significantly to GNP, providing protein for the human population, and frequently serving as a source of foreign exchange (Payne A. I. 1976).

Ghana produced averagely 441,000 tons of fish and fishery products from catch fisheries. Production from marine capture fisheries totals 291,000 tons, while production from inland capture fisheries makes 150,000 tons. In 2008, Ghanaian fish consumption was estimated to be over 540,000 tons, resulting in a fish import imbalance (Edward E.O. et. al. 2020). In terms of absolute output, fish landings were once presumed to be 800,000 metric tons annually, but this has now dropped to 480,000 metric tons per year, and with over 75% of all or extensively exploited fish stocks depleted, we are rapidly emptying fish and edible marine life forms (BOF GHANA 2008). More than 30% of fisheries have been exploited beyond what is ecologically possible, demanding drastic management actions to restore their biological balance. Several key commercial fish populations (such as sardines and anchovies) have dwindled to the point of extinction (Roberson et al. 2020). Aside from overfishing and catastrophic stock depletion in Ghana's fisheries, illegal, unreported, and unregulated (IUU) fishing is widespread, causing a significant loss of potential income for coastal communities (Stein S. E. 2019)

Management of Fisheries in Ghana

The nation's economy has long been supported by Ghana's fishery resources, which have greatly aided the socioeconomic growth of the nation. However, it has been apparent over the past two decades that the nation's catch fisheries resources are seriously threatened, as several studies have confirmed by reporting falling fish landings despite increased effort (Astrid E. H. et al. 2020). As a result, marine fisheries are catching fewer fish than they were at recent peaks. (Asiedu et al. 2021).

There are a number of plausible explanations for this terrible situation. However the following are the main factors contributing to the decline:

- Limited nature of fish resource
- Open access
- Increasing population and over-dependence on fish.
- Overcapacity and advances in technology,
- Overfishing,
- Illegal, Unreported and Unregulated fishing
- Employing damaging fishing techniques, environmental degradation
- Poor fisheries governance leading to non-compliance with fisheries regulations.
- Catch by Unauthorized distant water fleet

The poor situation is reflected in the small size of landed fish, a high number of discarded fish, high fishing input costs, and low profitability. Studies on the artisanal fisheries show that over the past ten years, the average income per canoe has fallen by up to 40%. This foretells trouble and raises the possibility that the more than 2.4 million Ghanaians who depend on fishing for a living may be in risk. (Quagrainie & Jingjie 2019). A concerted effort must be made to conserve fish through management strategies in light of these discoveries and the significance of fisheries in order to guarantee that there will be adequate food for both the present and future generations.

Processes involved in Fisheries Management

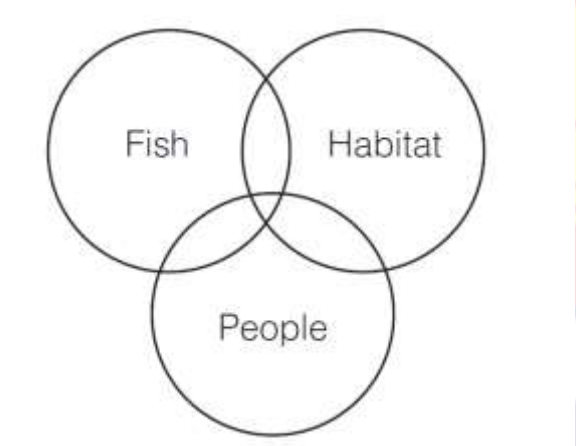

Figure 1: Interconnection of processes involved in fisheries management

Fisheries management is a multi-step process that entails developing and implementing strategies to influence fish populations, ecosystems, and humans to achieve specific human objectives that benefit everyone. The graphical representation of fisheries management depicted shows the circles surrounding populations, habitat, and people overlapping because, most issues require that fisheries managers simultaneously deal with two or all three of those areas (Steve L. M. & Edmund P. 2021). This process is challenging since individuals participating in management must be aware of who they are dealing with, who has access to the fisheries, who is permitted to fish, who the fishermen perceive to be a part of them, and other pertinent information etc (Randall M. P. 2004). The process starts with managing people as it is one of the difficult parts of management. (Ahmad H. 2019).

To handle these three components, a management process involving six key activities is required, including scoping, setting operational objectives, data collection and analysis, strategy creation and implementation, enforcement, and monitoring. Because it is impossible to plan for every difficulty that the sectors will confront, this management process does not have to begin with scoping and continue through each phase until the established goals are met. Due to unanticipated situations, changes and amendments are made as the management process advances, but data collection cannot be omitted or substituted (Thomas M. T. 1998). These processes, particularly data collection and analysis, are critical to fisheries management because any flaw or inaccuracy can result in fisheries stock mismanagement, resulting in overexploitation of fisheries resources, as well as unjustified lost revenue or civil misery for communities along the coastline that rely on fish (Hilborn and Walters, 1992). Many studies have been done on the effects of gaps occurring at various phases of the management process (Hilborn and Walters, 1992; McAllister and Kirkwood, 1998), but the evaluation of data quality on capture fisheries management is of importance to this study.

Data for Fisheries Management

Fisheries data is a broad term that refers to information that can be used in fishery management, as well as for economic, cultural, societal, and intellectual objectives (Garry, 2001). Fisheries management must prioritize providing reliable evidence on the status of fish stocks. This information is acquired using a number of sampling techniques, and the findings are used to offer guidance on how to manage fish stocks in a sustainable way, which is essential to the sustainability of the sector. These data, which are gathered from a variety of sources, typically consist of biological information about the exploited fish and related species, economic information about the fishermen and the markets for the catch, and environmental data about the factors affecting the species' productivity. (Marine Institute 2020).

Fisheries scientists acquire and use data from two primary sources. These can be separated into data that is not reliant on the fishery and data that is dependent on the fishing. The first often involves using fisheries surveys to monitor changes in the relative or definitive abundance of fish populations over time in a fashion that is free of the prejudices associated with data from commercial fisheries (National Academy Press, 1998). Fishery-dependent data includes things like biological samples from commercial fisheries and the gathering of catch and effort data (CPUE). Typically, logbooks are used to collect CPUE data. Variations in CPUE accurately reflect changes in fish stock quantity, which is the fundamental principle (Najmudeen & Wilson 2019). Observers remain stationed on industrial fishing boats to provide statistics on fishing operations that aren't generally documented in record books, like the effect of fishing on threatened species and the amount and outcome of bycatch and dumping. Samples can be used to determine the catch's species composition, sex ratio, and age distribution (National Academies of Sciences, Engineering, and Medicine. 2000).

To effectively manage human resource exploitation, it is often required to understand how much can be taken without endangering the environment or depleting resources. The notion of maximum sustainable yield (MSY) is considered a vital tool used for fisheries management in the case of fishing when discussing the limits of exploitation of the fish populations. For a particular fish stock, MSY refers to the largest annual catch that may be sustained over time by maintaining the stock at the level causing the most growth (Sparre & Venema 1998). The MSY designates a fictitious situation in which fishing activity and population exploitation are at an equilibrium. When data on fishing effort and catch are available, allowing for analysis of catch per unit effort (CPUE) throughout a variety of fishing seasons, MSY as a technique for stock evaluation is easily adopted (Sparre & Venema 1998). To create a four-year Fisheries Management Plan in Ghana, the Ministry of Fisheries and Aquaculture Development (MOFAD) maintains a fishery data bank including information on weighted catches and the number of fishing boats (fishing effort). In numerous earlier research, MSY and surplus production models were covered and used in fishery management. (Punt & Szuwalski 2012)

Data quality

The fundamental limitation in fisheries management decisions, according to Milo Adkison 2007, is the lack of quality data, as successful managing of numerous species is frequently hampered by the dearth of such data and its poor quality. The paucity of life-history data, fishery-independent data, and species-specific catch statistics combined with the fact that many commercially fished populations lack reliable evaluations and precise stock status estimations make management difficult (Patricia A. et al. 2021). Quality data is critical for achieving the UN Sustainable Development Goal because it is the only way to make informed decisions about fisheries, leading to proper monitoring of the health and sustainability of fisheries through timely identification of symptoms of overfishing, such as decreasing fish sizes, productivity, and total capture (Brewin, 2018). Finally, robust high-quality data will serve as the foundation for management goals such as guaranteeing sustainability of fish and fishing, efficient consultation, and increased possible economic development. Additionally, they will contribute to local and global stock management and monitoring programs and promote more accurate national economic stability and development measures (Menasveta D. 2000). By providing the best possible data, local and global decision-making and guidance will be supported.

The FAO Code of Conduct 1995 says that "Conservation and management choices for fisheries should be based on the best scientific data available," acknowledging both the value of and difficulties in employing high-quality data. This indicates that the management of fisheries is directly impacted by the quality of the data. Precise estimations are necessary for all structured assessment models that scientists use to manage fisheries since distorted data sets can cause fisheries to malfunction. Both landed and discarded fish should be included.

However, unreported catches from fish transshipment, known as Saiko fishing, illegal unreported unregulated (IUU) fishing activities, unreported catch by distant water fleet, an unreported portion of fish collected by the crew at the end of each trip, waste, and discarding of spoiled fish, unstainable resources exploitation techniques, the method for collection of data (biological and economic) for management to name a few, have all been reported as gaps in the data used by the fisheries commission to inform fisheries management plans (see Astrid et al., 2020; Aheto et al., 2020), undocumented data on the exploitation of shell fishery, estuarine and lagoon fishery in the data used by Fishery Commission (see (Atta-Mills et al., 2004).

These gaps noticed has called for indicators by FAO to guide the types of information that should be gathered and used for fisheries management. They are:

a. Relevance: refer to the extent to which statistics satisfy users' present and future needs. This refers to the extent to which concepts utilized (definitions, classifications, etc.) reflect user needs as well as whether the necessary statistics are supplied.
b. Accuracy: the degree to which computations or estimations are accurate or represent true values.
c. Timeliness: refer to the amount of time that has passed between the time that the information was made available and the event or phenomenon it describes.
d. Punctuality: refer to the amount of time that passed between the time the data was released and the intended delivery date.
e. Accessibility: This refers to the actual circumstances under which consumers can acquire data, such as the methods for accessing the data, the turnaround time, potential price and marketing policies, the availability of micro or macro data, and the formats that are offered.
f. Clarity: refer to the data's information environment, specifically relevant metadata, graphics like graphs and maps, details on the data's quality, and potential extra help.
g. Comparability: when statistics are compared between geographic areas, sectoral domains, or through time, to quantify the influence of

variations in applied statistical ideas, measurement methods, and procedures.

h. Coherence is the capacity to be consistently combined in varied ways and for multiple uses.

Since there is no precise way to measure the indicators, they are arbitrary to the user.

Data required for fisheries management

Many fisheries sectors pay little attention to data and information collecting, and as a result, their attempts to manage their fisheries are problematic from the beginning. Many of these companies spend a lot of money and effort gathering data about their fisheries, but when it comes down to processing, preserving, and analyzing the data, they often fall short (Cochrane K.L. 2002). While others are unsure of the data they should gather for effective management. The collection of data about fisheries is not a purpose in and of itself; if the data are not utilized, they represent a squandered resource (FAO 1997). For responsible fishing management to take place, the necessary data needs to be gathered and be used to inform the decisions necessary to efficiently manage the fishery and so improve the long-term benefits received from it (Cochrane K.L. 2002). In most cases, different data is required for management. The issues and operational goals that the management must evaluate dictate these requirements. In the case of Ghana, the operational goal of collecting data is to guarantee the lengthy conservation of its fish populations while also helping to enhance diet and nutritional safety on a national scale. The FAO categorizes the information to be gathered for this purpose into biological, ecological, economic, social, and institutional categories.

Table 1: Demonstrates some key data needs for providing data to fisheries officials and decision-makers to assist them in selecting the best management strategies.

Objectives	Data requirement
Biological	Total annual landings by key species by fleet Total annual effort by fleet Length and/or age distribution of significant species landings Major species discarded annually per fleet Length or age distribution of discards by species, fleet, and/or year Fishing grounds for each fleet
Ecological	Total annual catches per fleet of bycatch species (including rejected species) or chosen indicator species Composition of captures bycatch species or chosen indicator species by length and/or age Effects of fishing equipment and activities on the habitat's physical features Critical habitat modifications carried on by non-fishing activities
Economic	The average annual revenue per fishing unit for all fleets Annual costs per fishing unit Financial success of each fleet (in the absence of detailed economic data this could be based on interviews or similar information) Location of landings from each fleet and an indicator of how much other sections of the society depend on the fisheries (e.g., processors, wholesalers, etc.)
Social	Fishing personnel employed by each fleet Total number of individuals working in fishing or shore-based jobs each fleet, broken down by gender and age group as necessary Each fleet's reliance on shoreside employees and fishermen for a living

Source: Technical Guidelines (FAO, 1997)

These requirements are frequently the most important source of data for monitoring and assessment. These data, alternatively, must be correctly collected (considering every change that each industry has experienced) and evaluated to extract useful and relevant information for management.

CHAPTER THREE

SAMPLING ERROR AND ITS IMPLICATION FOR CAPTURE FISHERIES MANAGEMENT IN GHANA

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Abstract

Capture fisheries in developing countries provide significant animal protein and directly support the livelihoods of several communities. However, the misperception of biophysical dynamics owing to a lack of adequate scientific data has contributed to the suboptimal management of capture fish stocks. This is because yield and catch potentials are sensitive to the quality of catch and effort data. Yet, studies on fisheries data collection practices in developing countries are hard to find. This study investigates the data collection methods utilized by fisheries technical officers within the four fishing regions of Ghana. We found that the officers employed data collection and sampling procedures which were not consistent with the technical guidelines curated by FAO. For example, 50 instead of 166 landing sites were sampled, while 290 instead of 372 canoes were sampled. We argue that such sampling errors could result in the overcapitalization of capture fish stocks and significant losses in resource rents.

Keywords: fisheries data quality, fisheries management, Ghana.

Introduction

Millions of people around the world depend, directly or indirectly, on capture fisheries for their food security, income, and livelihoods (FAO 2018). This dependence is particularly strong in coastal communities in developing countries where the sector employs 97% of the 50 million people who make up the world's fishing workforce (Béné et al. 2007). Ghana, as one of the developing countries, is home to a wide variety of biodiversity, including small pelagic species such as anchovies, sardinella, and chub mackerel and larger pelagic fish such as yellowfin, skipjack, and big-eye tuna. There are also demersal fish such as grouper and snapper, and other seafood such as shrimp and squids (Perry and Sumaila 2007). For sustenance and the eradication of poverty, many coastal dwellers are solely dependent on the exploitation of these fisheries, with over 60% of the population relying on fish as their primary source of protein and about 10% of the population (2.6 million people out of a total population of 26 million) believed to be directly or indirectly dependent on fish resources (UNFAO 2019).

The Ghanaian marine fishing industry is divided into three primary sectors: small-scale artisanal fishers, semi-industrial fisheries, and large industrial fisheries, with over 300 fish landing sites spread throughout its coasts (Ameyaw 2017). The vessels used in Ghana's marine capture fishery include dugout canoes, canoes with outboard motors, trawlers, and large steel-hulled foreign-built vessels. The dugout canoes and canoes fitted with outboard motors are primarily utilized by artisanal fishers while trawlers and steel-hulled vessels are used mainly in the semi-industrial and industrial marine fisheries (Afoakwah 2018). There is currently a total of 11,583 licensed marine artisanal canoes operating along the coast, 150 semi-industrial vessels, and 84 licensed industrial trawlers in Ghana's marine waters (Amador and Dovloo, 2016).

Despite the importance of the fisheries sectors, according to various experts, fish stocks have been declining rapidly due to the overcapacity of fleets, excessive fishing quotas, illegal fishing practices, and the generally poor management of fisheries, which poses existential threats to coastal communities (Worm et al. 2009). This has necessitated the formulation and refinement of existing management policies with the aim of limiting fishing efforts to optimize the economic, social, and ecological sustainability of capture fisheries (AUC-NEPAD 2014). The effectiveness of effort-limiting policies, however, depends on the availability and quality of the relevant fisheries data used for decision-making (Dowling et al. 2015).

National governments and international organizations have been working hard at collecting fisheries data to inform sustainable and long-lasting management plans and strategies (Mangubhai and Lawless, 2021). However, this remains a daunting task due to the complex interactions among species and marine ecosystems, and the wide distribution and migration of pelagic stocks across national jurisdictions. These complexities of biophysical dynamics make fisheries management difficult (Bradley et al. 2019). Nevertheless, management decisions must be made as livelihoods and incomes depend on wise decisions made by the managers, and they can only make wise decisions if they have sufficient knowledge of the ecosystem and fishery to understand the causes of the current fisheries situation and predict how the resource and fishery will change in response to management actions (Cochrane, 2002).

Accurate and consistent knowledge about how a fishery is doing, as well as what, where, and how much of a species is being captured requires more precise data collection and faster and more advanced reporting, processing, and analysis, as well as more efficient mechanisms to disseminate the results to enable close to real-time analysis (Wilson et al., 2018). The fisheries data collected is usually the manager's major source of information, which is essential in developing appropriate management tools to support the sustainable use of the stock (Cochrane, 2002; Collie et al., 2016). However, the data quality is low in many developing countries owing to inadequate resources, including skills and funding.

Although the FAO Code of Conduct (Paragraph 6.4) has stated that the conservation and management of fisheries must be based on the best scientific knowledge available at any point in time. Unfortunately, many fisheries agencies lack sufficient data, making attempts at managing fisheries difficult. For instance, the reconstruction of catches carried out by Nunoo et al., (2015); Pauly and Zeller (2017) revealed that the catch and effort data compiled by FAO were deficient. As noted by Ye et al., (2017), the unavailability and suspicion of errors in catch data due to lack of skills and resources in member countries have resulted in the complementation or replacement of countries' data with data from other sources. These omissions or errors in data collection could lead to erroneous fisheries management policies, which in turn could result in suboptimal extraction, losses in resource rents, and eventual collapse of capture fisheries. It is therefore expedient to assess how catch and effort data are collected to better inform management policies.

An analysis of the national fisheries data collection protocols in Ghana suggests that the Fisheries Scientific Survey Division (FSSD) is mandated to conduct scientific research and deploy surveys on marine environments and fisheries to inform the formulation and management of policies aimed at the sustainable management of Ghana's marine fisheries resources. The FSSD is under the Fisheries Commission (FC), which was established in 1962 with technical assistance from the Food and Agriculture Organization (FAO). Due to limited human and financial resources, the FSSD has not been able to provide adequate monitoring of the data collection activities of the technical officers. Thus, any errors that occur on the field are ignored. To the best of our knowledge, no study has been undertaken to investigate whether the recommended sampling procedures are followed by the field enumerators.

Materials and Methods

Study Area

This aspect of the study was carried out in the following twenty-nine fish landing sites out of thirty representing the four coastal administrative regions in Ghana: Abutiakope, Lighthouse (Volta), Gbegbeyise, Botianor, Agjivompanye, Odin-nyonma, Osu alata, Teshie, Ga mashie, Awudun (Greater Accra), Saltpond, Kromantse, Apam main, Elmina main, Elmina, Ayipey, Abrofo mpoano, Mumford main, Enfano (Central Region), Dixcove, Sekondi, Fante line (Axim), Akyinim, Ewe line, Fante line (Half Assini), Sharma Apo, Sekondi-Takoradi, Akwadae, and Adjua (Western) (See Figure 1 for the geographical location of the landing sites). These twenty-nine sites chosen for primary data collection were selected based on the total number of enumerators in Ghana and where they are assigned along the coast.

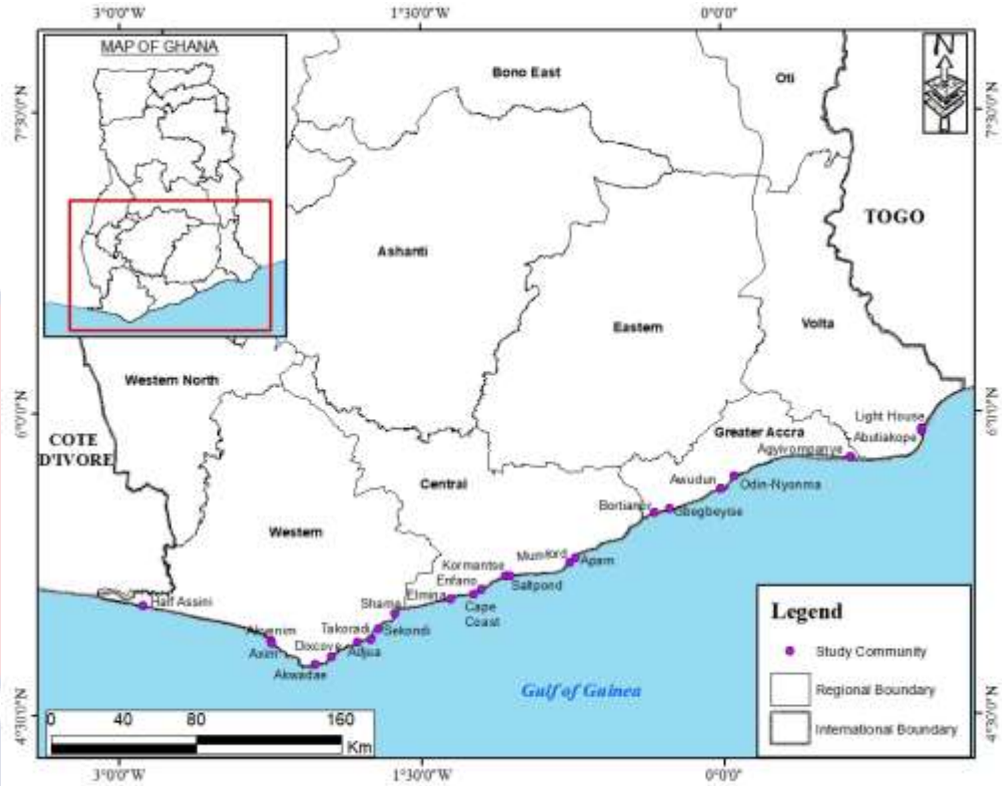

Figure 2: Map showing the twenty-nine landing beaches in Ghana.

Research Design

This study used a quantitative survey design to examine the types of data collected and the methods associated with the data collection in Ghana. The data were gathered between May and June 2022 at all the landing sites. A structured questionnaire was used for data collection. Field assistants were trained on the administration of the questionnaire, ethical standards, and COVID-19 safety protocols. The respondents included 29 Fisheries Commission field enumerators and 1 Field Scientific Survey Division data manager. The surveys were conducted in English and local languages, including Fante, Ga, Nzema, and Twi. Each interview lasted between 40 to 60 min.

Research Instrument

The questionnaire used was made up of three sections. The first part of the questionnaire (Section A) consisted of an introductory statement and questions about the relevant sociodemographic characteristics of respondents. Some of the variables included age, years of experience in data collection, the number of landing sites, gender, fishing experience, and level of education (basic education, secondary, and tertiary). The next two sections highlighted the types of fisheries data gathered using the FAO data collection guidance as a benchmark (FAO, 1997). The data was classified as biological, ecological, economic, or social. A total of 24 questions were developed through an extensive review of the literature (Cochrane 2002; de Graaf et. al 2015; EDF. 2013). For the evaluation of the data collection procedure, the questions comprised five categories. These categories were based on the source of the data on fish production, the type of effort data gathered, the type of capture data gathered, and the frequency of data collection.

Data Analysis

Responses from interviews were coded using the IBM Statistical Package for Social Scientists (SPSS) computer software version 20.0. (2012) and analyzed for trends in response to research questions using Software for Statistical Analysis (STATA SE 15.0) (STATA Corp, College Station, city, TX, USA) and Microsoft excel. To understand the distributions of all relevant variables, descriptive statistics (frequencies and percentages) were generated. The summaries of the results are presented in tables (Tables 1–3). To check for sampling error, this study compared the capture fisheries data collection procedures in Ghana to the recommended best practices (i.e., the FAO guidelines) along the entire coast of Ghana using the FAO toolkit for small-scale fisheries routine data collection (de Graaf et. al 2016) and the FAO data collection guidelines (de Graaf et. al 2015). The sample size formula developed by Yemane (1967) was used to estimate the actual sample size for comparison with the number sampled.

Table 2: Catch data collection by Ghana's Fisheries Commission enumerators

Variables	Collected (%)	Not Collected (%)
Biological data		
Total fish landings by major species	66	34
Total fish landings by canoes	69	31
The total effort by canoes	86	14
Length and/or age composition of fish landings	21	79
Discards of fish species per canoe	0	100
Length and/or age composition of discards	0	100
Areas fished by each canoe	17	83
Ecological data		
Total catches of bycatch species	17	83
Length and/or age composition of bycatch	3	97
Economic data		
The average income per fishing unit	52	48
The cost of premix fuel	7	93
Price of fish landed per canoe	93	7
Social data		
Crew size within each canoe	93	7

Table 3: Type and method of catch data collected by enumerators

Variables	Freq	Percent
Type of catch data collected		
Multi-species (all species)	15	51.72
Single-species (only one species)	10	34.48
Single-species and multi-species	4	13.79
Data collection method		
By canoes	10	34.48
By gear	5	17.24
By species	10	34.48
By species and gear	4	13.79

Table 4: Type of effort data collected by enumerators in each district (□= data collected; □= Data not collected)

District	Number of Canoes	Size of Fishing Gear	Type of Fishing Gear	Number of Trips	Trip Duration	Size of Canoe
Keta	✓	×	✓	×	✓	×
Ada East	✓	✓	✓	×	✓	×
Kpone Ketamanso	✓	×	✓	×	✓	×
AMA	✓	✓	✓	✓	✓	×
TMA	✓	×	✓	×	✓	×
Ga South	✓	×	✓	✓	✓	×
Efutu Municipal	✓	×	✓	✓	✓	×
Gomoa West	✓	×	✓	✓	✓	×
Ahanta West	✓	×	✓	✓	✓	×
Abura-Asebu Kwamankes	×	×	×	✓	✓	×
Cape Coast	×	×	✓	✓	✓	×
Nzema East	✓	×	✓	×	✓	×
Jomoro	✓	×	✓	✓	✓	×
Komenda-Edina-Equafo	✓	×	✓	×	✓	×
Ledzokuku	✓	✓	×	✓	✓	✓
Mfantseman	✓	×	✓	✓	✓	×
Sekondi-Takoradi	✓	×	✓	✓	✓	×
Shama	✓	×	✓	×	✓	×

To enhance visualization and appreciation of the study context, graphs are used in the representation. The landing sites and canoes sampled across the whole district were compared with the landing sites and canoes that were required to be sampled. Summaries of the results are presented in Figures 2 to

5. The chi-square test was then used to verify whether there was a significant difference between the actual and the expected sampled landing beaches.

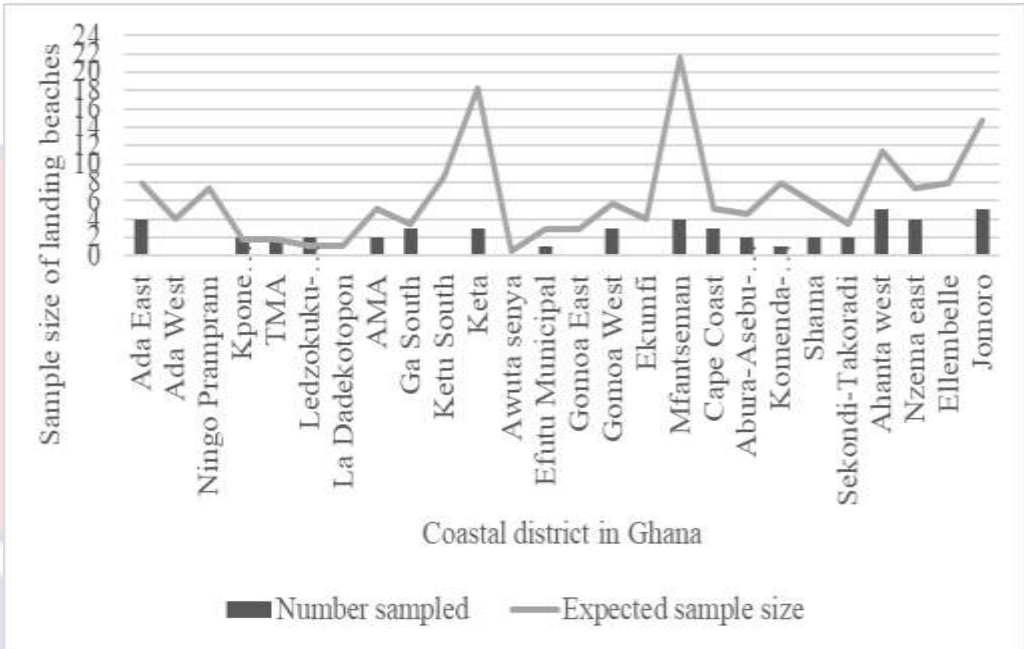

Figure 3: Comparison between the observed sample size of the Fisheries Scientific Survey Division (FSSD) and the expected sample size of landing beaches according to the districts in Ghana.

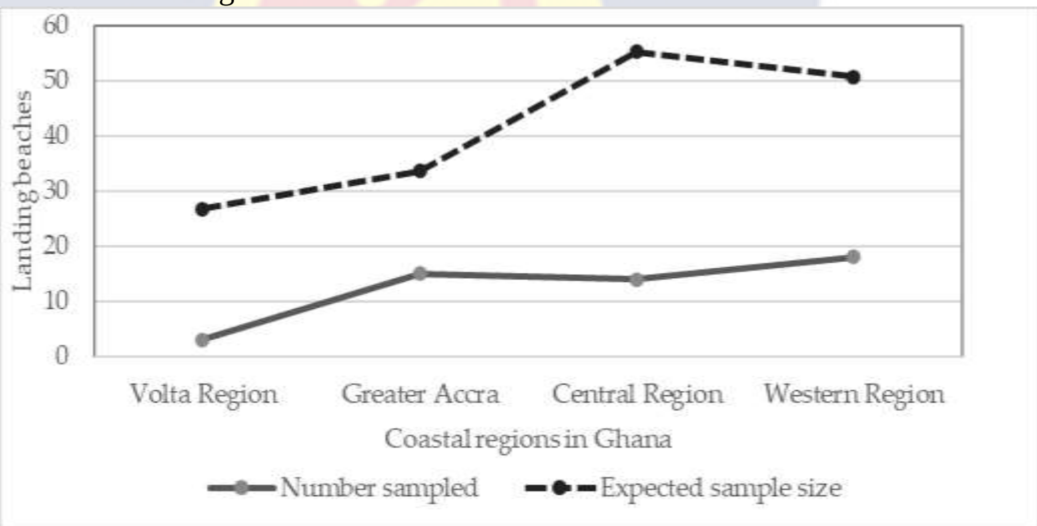

Figure 4. Comparison between the observed sample size of the Fisheries Scientific Survey Division (FSSD) and the expected sample size of landing beaches according to the coastal regions in Ghana.

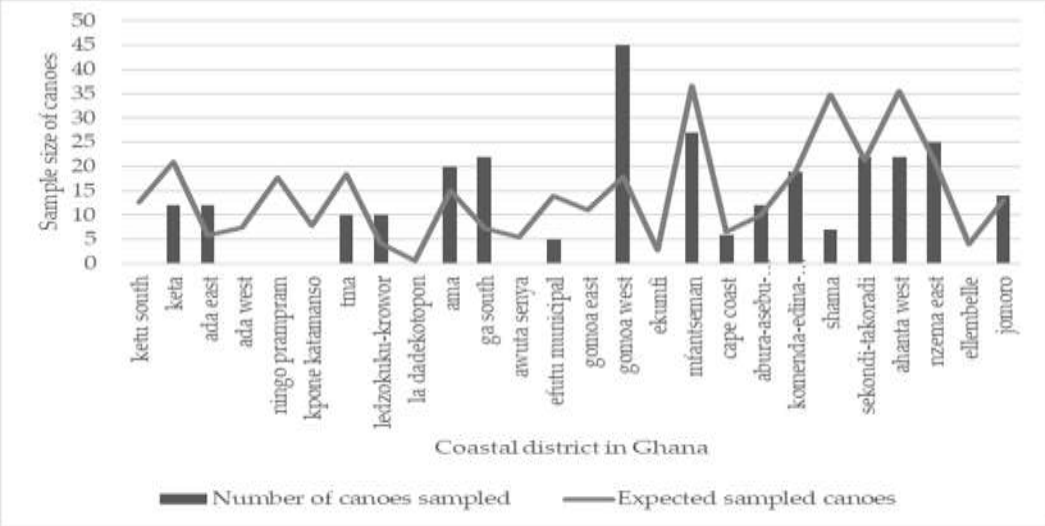

Figure 5. Comparison between the observed sample size of the Fisheries Scientific Survey Division (FSSD) and the expected sample size of canoes according to the districts in Ghana.

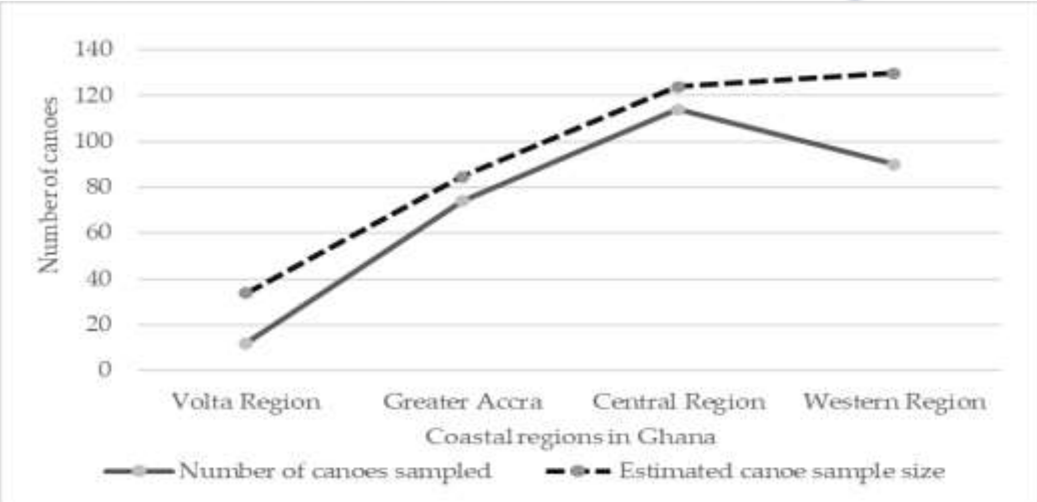

Figure 6. Comparison between the observed sample size and the expected sample size of canoes according to the coastal regions in Ghana.

Results

This section presents the data collection procedures of the FSSD and the results of the study. FSSD employs 30 enumerators to collect artisanal fisheries data from 50 landing beaches out of approximately 292 landing beaches (CFS, 2016). These 50 landing beaches were obtained using the three-stage sampling survey by dividing the whole coastal area into four regions (i.e., Major strata) and the four regions into districts (Minor strata). Sampled canoes and landing sites were selected within the minor strata (districts) based on the canoe frame survey for the sole purpose of increasing the accuracy of the derived estimates using the proportional stratified sampling method.

The equation for the sampling is $n_k = \frac{n}{N} * N_k$, with a maximum of 12 canoes sampled daily, where N and n are the total population and sample sizes, respectively, k is the number of strata, N_k is the number of units in stratum k, and n_k is the number of sampled units in stratum k. To calculate the sample size of the total population, sample size formula $n = \frac{N}{1+N(e^2)}$ is used (Yemane 1967), where e is the level of precision. The FSSD employ 95% as the confidence interval and +/−5 as the degree of accuracy.

The sampling procedure is adopted from the FAO toolkit for small-scale fisheries routine data collection (de Graaff et al. 2016) and, as stated in the toolkit, enumerators at the landing beaches sample data for 14 days/gear/month with each enumerator having two gears which in some cases spill over to two landing sites each, depending on the size of the landing site and the abundance of fishing gears. For the recording of data, two forms are provided by the Fisheries Commission, Forms 1a and 1b, with each performing a different function. Form 1a is used to record daily information on fishing activity at the landing site, and Form 1b is used to record information and data collected. The data collected by FSSD are placed into three categories: the fisheries statistical data, i.e., the catch and effort data; the biological data; and the environmental data.

The fisheries data expected to be recorded at each landing beach are catch and species composition (single species), fishing effort, price of fish, number of operating fishing crafts, types and sizes of fishing crafts, types of gears and their target species, areas of operation of fishing crafts, number of fishermen on fishing crafts, and information on landing sites. The biological data to be collected are fish length, fish weight, gonad weight, and sex. The environmental data are salinity, temperature, and dissolved oxygen.

The data is collected by the 30 enumerators at all fifty landing sites but due to the shortage of resources and intellectual capacity, the biological data is collected at four landing sites across the four coastal regions, and the environmental data is collected at six landing sites. These sites were selected based on the abundance of fish species and the flow of water, respectively. After the data are recorded, the zonal officials (supervisors) in charge of the enumerators receive the records from each landing site and transmit them to FSSD, where they are compiled. For this study, since 1 of the enumerators had hearing loss, only 29 were interviewed. These enumerators had a male-to-female ratio of 25:4, an average age of 37 years, and an average of 10 years of data collection experience.

Sampling of Landing Beaches in the Coastal Districts of Ghana

Ghana has 292 landing beaches. This means that the calculated sample size is 166 (Yemane 1967). However, only about a third of these beaches are sampled by enumerators. Each of the 26 fishing districts should have at least 1 landing beach sampled based on ratio and proportion, but as can be seen in Figure 2, the enumerators cover 18 out of the 26 fishing districts, resulting in an under-sampling of 8 districts. The data gatherers also stated that they sample a total of 50 landing beaches from the 18 districts they work in, which is 80 beaches less than what should be sampled from those 18 districts (assuming the sampling of the 18 districts is desirable). However, they over-sample in Ledzokuku-Krowor by 1 landing beach.

To determine whether there is a significant difference between the number of landing beaches sampled and the number of landing beaches expected to be sampled, a chi-square test was undertaken, and we found a significant difference (93.87276, *p*-value of 0.001). The low coverage of landing beaches is attributed to a lack of human and financial resources.

Sampling of Landing Beaches in the Coastal Regions of Ghana

On a regional level, it was discovered that a considerable discrepancy between the actual and expected landing beaches sampled, as shown graphically in Figure 3. This was found using the same methodology (sampling, ratio, and proportion). It was discovered that the Central Region has a more pronounced under-sampling of 41 landing beaches as compared to Greater Accra which is under-sampled by 19 landing beaches.

Sampling of Canoes in the District of Ghana

Ghana had 11,583 canoes in total as of 2016, according to MoFAD. Out of this total, 372 canoes were to be sampled. Based on a proper sampling procedure, at least 1 canoe should be sampled from each coastal district. We also discovered from our research that the 290 canoes from 18 districts that the enumerators collectively sample are either under- or over-sampled. Figure 4 indicates that canoes are over-sampled in approximately half of the district, with Gomoa West and Ga South oversampled by 27 and 15 canoes, respectively. However, the canoes were under-sampled by 28 and 14 canoes in Sharma and Ahanta West districts, respectively. The over-sampling of canoes was found to be attributable to misalignment of incentives: i.e., compensation for the district from which data is not being collected or the district with a smaller number of canoes.

Sampling of Canoes in the Coastal Regions of Ghana

As presented in Figure 5, there are variations in the number of canoes sampled and the expected sample in each region. Clearly, there is under-sampling, with the Western region having the highest proportion of under-sampled canoes (40 canoes) as opposed to the other regions, especially the Central region which is under-sampled by 10 canoes.

Percentage Contributions

Each coastal region's contribution to the under-sampling of canoes and landing beaches is shown in Figure 6. Using the differences between the actual sampled with the estimated sample across the coastal regions, we found that the Western region contributed the most to the under-sampling of canoes (49%) and slightly less than the Central region to the under-sampling of landing beaches (28%), with the Central region contributing the most to the under-sampling of landing beaches (35%) and the least to the under-sampling of canoes (12%).

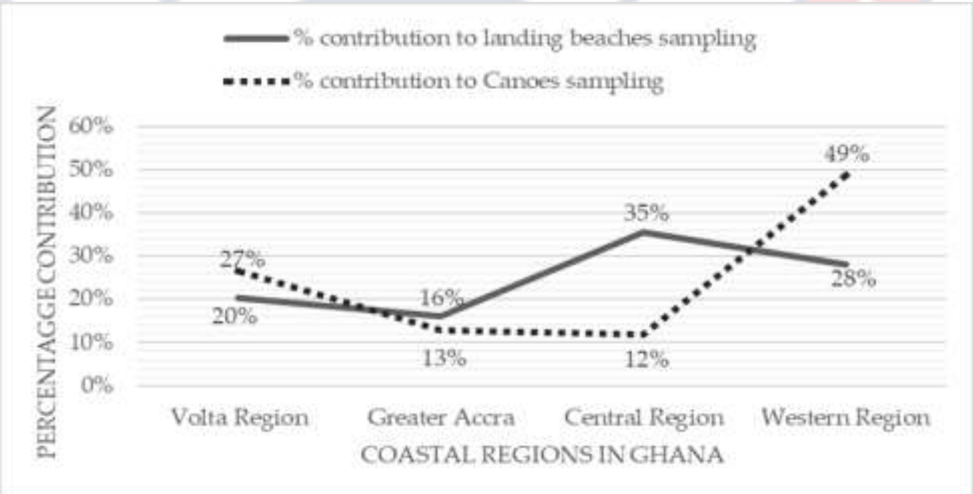

Figure 7. Percentage contribution of coastal regions to under-sampling of Canoes and Landing beaches in Ghana.

Catch Data

The four catch data categorizations (i.e., biological, ecological, economic, and social) were analyzed (Cochrane, 2002). Each category has various components as presented in the first column of Table 1. The results revealed that none of the components under each thematic area show 100% data collection among the enumerators.

Out of the seven components under the biological category, the enumerators do not collect data on discards of fish species per canoe and the length and/or age composition of discards. However, 86% of the enumerators collect information on fishing effort. Only 17% of them indicated that they collect information on bycatch species, while 93% collect data on the price of fish and crew size of each canoe. These inconsistencies discount the reliability of the data aggregated by the FSSD for effective fisheries management.

Some of the enumerators collected data on single species and others on multiple species. The multi-species and single-species data indicate an ecosystem-based approach and a precautionary approach, respectively (Howell et al. 2021). Due to the establishment of an ecosystem-based approach in national and international law, the authors of (Collie et al. 2016; Tallis et al. 2010) suggested an ecosystem-based approach as the appropriate starting point for management; however, as indicated in Table 2, we can establish that there has been no consensus on which approach to use. About 52% of the enumerators collect multi-species (i.e., collect data by canoes and by gear) while 14% collect both single-species and multi-species (i.e., collect by either species or by both). The Fisheries Commission, on the other hand, indicated that the enumerators were instructed to collect only single-species data.

Effort Data

Regarding data on fishing effort, differences in the frequency across the enumerators were found. Comparing results from the 50 landing sites (Table 3), 86% of the enumerators collect data on the number of canoes and the type of gear, while only 16% indicated that they collect data on the size of a canoe.

Conclusions

From the survey on data collection practices by technical officers at the landing beaches, evidence of under-sampling and over-sampling has been found. This implies that the FAO toolkit for best practice is not being followed in practice in Ghana. This may be due to a lack of financial resources and the requisite skills to follow the desired protocol for fishery data collection. The sampling procedure deviates significantly from the ideal, which has implications for the quality of data generated.

A sample size that is too small might result in a Type I error (Sekaran 2013), which is the likelihood of incorrectly rejecting a certain discovery when it should be accepted. Additionally, the author argued that an excessively high sample size is not appropriate due to the potential for type II error, which involves accepting a certain finding when it should be rejected. Thus, the relevant data needed for the formulation of management policies could be erroneous, thereby affecting the accuracy of the estimated catch and effort data.

The collection of catch and effort data sets and the method by which they are collected were different at some landing beaches. This discrepancy contrasts with FSSD's objective of collecting reliable data guided by scientific procedures. As noted by the authors (Fitzgerald 2007), components of each thematic area should be the same at every landing site (beach) to ensure accurate data for fisheries management.

Errors in the sampling of landing beaches and canoes, as well as discrepancies in data sets gathered, could lead to the exaggeration of catch potentials, resulting in erroneous estimates of the maximum sustainable yield level (MSY) and the effort corresponding to maximum sustainable yield (F_{MSY}). These wrong estimates could lead to over-exploitation or over-capitalization of fisheries and their eventual collapse, as suggested by many studies.

To improve the quality of data collection, proper monitoring of the field enumerators should be incorporated as part of the Ministry's activities and the use of the FAO Open Data Kit (ODK) mobile phone application should be reviewed, upgraded, and its usage continued to ensure accurate collection of data. National service personnel from fisheries academic departments should also be employed to ensure better coverage of landing sites in the country. This suggestion comes with limited cost implications. In addition, there should be a balance between an understanding of the sampling techniques, the need for data, and the kind of data to be collected by the field enumerators and office staff.

CHAPTER FOUR

FISHERIES DATA QUALITY ISSUES IN THE ARTISANAL FISHERIES SECTOR OF GHANA

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Writing and compilation of manuscript, established methodology, data collection and analysis, preparation of tables and figures

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Abstract

In Ghana, it has been discovered that marine fisheries are crucial for generating money, jobs, and food supply. However, dependence on insufficient and largely unreported national statistics has resulted in a mismanagement of marine fisheries, which has been exacerbated by the ignorance of the true situation of fisheries. To demonstrate how the national data differs from the Maximum Sustainable yield levels, this study compares reconstructed data with the national data for Ghana's artisanal fisheries. We found that fish production is underestimated due to significant data gaps in the national data. We argue that such error could result in decisions and policies that underutilize and under exploit fisheries resources, which may have an impact on national food security

Introduction

Food security and sustainable livelihoods are immediately threatened by the expanding fish stock depletion in emerging coastal nations where the fishing sector directly employs major portions of the population and controls are typically insufficient. (Arnason et al., 2009). This situation is because of extreme fishing pressure leading to diminished catch per unit effort, disputes among fishers, and low output of fisheries resources.

Fishing in Ghana has been a popular pastime, especially among rural people along the coast and large rivers (Atta-Mills et al., 2004). With around 500,000 fisherman, fish processors, traders, and boat builders involved in

Ghana's fisheries industry, fishing serves as a significant source of both employment and revenue as well as nourishment for people all over the nation. The fishing sector provides employment for 10% of Ghana's population, including their dependents (Okyere et al. 2020).

Ghana's local demand for fish has been increasing due to rising earnings, urbanization, and a growing population. Despite an overabundance of policies intended to sustain captured fish stocks in Ghana, evidence abounds that fishing capacity continues to expand and the level of exploitation of fish stocks continues to rise. As a result, fish and fish products are gradually becoming more expensive and inaccessible in comparison to other animal protein sources. Most fish stocks are outside safe biological limits, and in many cases, they are on the verge of extinction (FAO, 2007). This has raised concerns and called for interventions from many international organizations and national governments to curb activities causing the decline so that the fisheries resources would be sustainably harvested.

To achieve this, new approaches to fisheries management were recommended and implemented (Hawkins, 2002). These new approaches require collection of quality data as the understanding of fisheries' state and trends helps in using aquatic resources sustainably by providing basis for developing solid policies, making smarter decisions, managing fisheries responsibly, and monitoring the performance of fisheries management. However, the data required are specific to the type of management strategy and policy instrument to be used for management of resources. For example, a tax on the cost per unit of labor or harvest is one of the necessary policy instruments to restrict fish catches to levels that are sustainable. This demonstrates that understanding the biophysical dynamics of the stocks is crucial to the effectiveness of such a policy instrument (Akpalu, 2009).

According to Fisheries Management Plan of Ghana, 2015, a formal harvest strategy (management strategies) requires specific data to allow sustainable exploitation based on defined objectives. The data needed are the fishery-dependent data, which typically include information on the capture of each species, including fish brought to the shore, fish obtained from the sea, and fishing effort (the number of nets, boats, and hours spent fishing). This information is gathered and evaluated to monitor fish stocks and predict stock levels and this is mostly done by matching data to population models, also identified as stock assessments.

Fisheries data has been facing several challenges and these difficulties are particularly severe in Ghana because there are currently no credible estimates of the status and sustainability of the fisheries there (Hilborn et al., 2020, Akinyemi et al., 2022). For instance, reliable estimations of effort (=E), yield (=Y), catch per unit effort (=CPUE), and areas from which catches are obtained (=CPUA) are deficiencies in fisheries catch statistics (Dalzell, 1996; McClanahan, 2018; Pauly & Zeller, 2016). Also, reports and data from the Fisheries Scientific Survey Division (FSSD) of the Fisheries Commission of Ghana have shown some data gaps or omission of unreported catch from “saiko” fishing activities, dumping at sea, crews’ share of harvested fish (Aheto et al., 2020), sustenance, and other non-commercial marine sectors (Pitcher et al. 2002; Agnew et al. 2009; Pauly and Zeller 2016).

This has led to a dependence on insufficient and largely unreported national data, putting the fisheries agencies at serious risk of over-licensing fishing access, undervaluing Ghana fisheries' contributions, and improperly managing marine ecosystems. This makes sustainable fishing, one of the main objectives of fisheries management, challenging. Additionally, changing projections of overall production and making it more difficult for managers to reconcile conservation and food security objectives. As a result, it is necessary to assess the fisheries data used for management, investigating the extent to which the management practices and by extension the policies of Ghana’s capture marine fishery deviate from the maximum sustainable yield levels by comparing estimates from the official and reconstructed data sets. This study seeks to: (i) Examine the patterns in total catch and Catch per Unit Effort (CPUE) for the artisanal subsectors based on the official data and reconstructed data on Ghana from 1990 to 2018. (ii) estimate and analyse the maximum sustainable yields and the corresponding fishing effort levels for Ghana’s artisanal fisheries using the official and reconstructed data. (iii) Analyze the effect of data quality on fisheries management practices and policies in Ghana.

Materials and Methods

Study Area

Ghana, a country in West Africa, shares borders with Burkina Faso to the north, Côte d'Ivoire to the west, Togo to the east, and the Gulf of Guinea to the south. The nation, which has a population of about 25 million and a land area of about 240,000 km2, became independent from Britain in 1957. With latitudes ranging from 4.5°N to 11.5°S and longitudes from 3.5°W to 1.3°E, Ghana is located north of the equator. From New Town in Half Assini in the west to Aflao in the eastFish resources are extracted from Ghana's Exclusive Economic Zone, which covers up to 200 nautical miles. (Nunoo et al. 2015). With the exception of few sizable lagoons at the extremes of its east and west, Ghana's coastline in the Gulf of Guinea Extensive Coastal Ecosystem is incredibly monotonous. The oceanic crust (waters below 200 meters), which extends 24 to 80 kilometers offshore, is rather small. The existence of two powerful tides, the Guinea Current to the east and the South Equatorial Current to the west, encourages two seasonal upwellings as well as significant biological and fishing productivity. (FRU/ORSTOM, 1976; Longhurst and Pauly, 1987; Mensah and Koranteng, 1988).

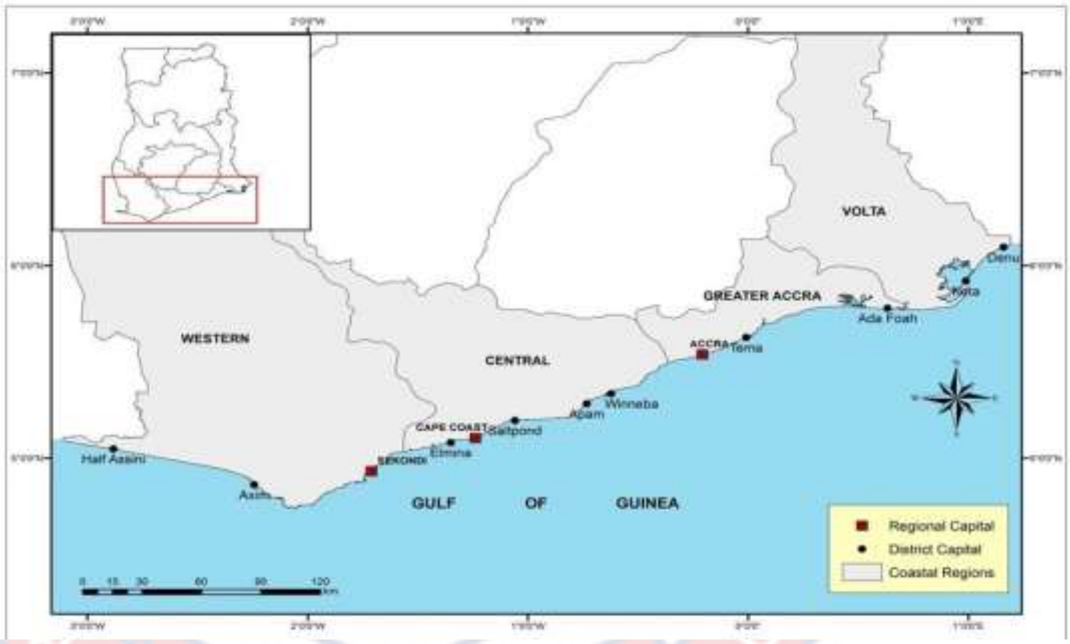

Figure 8. Map of the Coastline of Ghana showing Ghana’s Coastal Regions
Source: Ameyaw, 2017

Sources and methods of data collection

Data for this study was acquired from Sea Around Us and the Fisheries Scientific Survey Division of the Ghanaian Fisheries Commission. The necessary information was divided into biological (catch), effort, and economic categories.

The Fish Scientific Survey Division (FSSD) of the Fisheries Commission (FC), under the Ministry of Fisheries and Aquaculture Development of Ghana, provided historical statistics on catch and effort from 1990 to 2020. FSSD uses a stratified sample plan to carry out a canoe catch assessment survey of common fish species in Ghana. The sampling approach uses both spatial and temporal sampling.

Out of 292 fish landing locations, FSSD uses records of fish catches and fishing efforts from 50 of those sites to estimate annual fish landings. A canoe frame survey that gives an inventory of the distribution of canoes/gear in 292 fish landing sites was used to determine the 50 fish sampling locations. With the exception of fishing holidays, FSSD enumerators sample at least five days per week at a sampling location, typically on Tuesdays. For the purpose of estimating monthly fish landings for each monitored species per canoe/gear, the catch and effort data collected for each month is sent to FSSD and entered into the ART FISH software. The estimated monthly catches of each species are added to determine the total fish landings for that species during a given year.

Data from Sea Around Us was used to rebuild the original data. The University of British Columbia's The Sea Around research initiative evaluates the effects of fisheries on the world's marine ecosystems and provides alleviating solutions to a variety of stakeholders. The initiative is housed at the Institute for the Oceans and Fisheries, formerly known as the Fisheries Centre. Comprehensive databases of catches, distribution of commercial marine species, fishing access agreements between nations, ex-vessel pricing, marine protected areas, and other information have been compiled by the researchers.

An email was sent to the University of British Columbia's Sea Around Us Directorate requesting data from the Sea Around Us, and a meeting was scheduled to present my research proposal and discuss the kind of data I required.

Data Analysis

Analysis of trends in Total Catch and Catch per Unit Effort (CPUE)

Current fisheries data were evaluated using the Catch per Unit Effort (CPUE) to identify trends in catch (production) and effort (number of vessels) through time.

CPUE was be calculated using the following formulas:

$$CPUE_t = \frac{Catch_t}{Effort_t} \text{ (Quinn, 1999)}$$

Where $CPUE_t$ represent fish catch per effort in year t_o- t, $Catch_t$ represent the fish catchment in year t_o- t as well as E_t is the effort in year t_o- t.

To calculate for the degree of change in CPUE for a specific yearY_1, the variation in CPUE of that year ($CPUE_1$) and the former year,Y_o, ($CPUE_0$) divided by $CPUE_1$, would be used and expressed in decimals.

Thus, the rate of change in $CPUE_1$ can be expressed as $CPUE_1 = \frac{CPUE_1 - CPUE_0}{CPUE_1}$

Analysis of Maximum Sustainable Yield and the corresponding Fishing Effort

Estimation of parameters

Three key functional relationships would be required in this fisheries model, which includes: biomass growth function, and harvest function. The most popular surplus production models, Fox's and Schaefer's, are known to yield estimates that are nearly identical, with neither model being significantly better than the other (FAO 2014). In this study, the MSY and the fishing effort, E_{MSY}, required to create the MSY for the Ghanaian artisanal fisheries under the equilibrium assumptions were estimated using the Schaefer's model, as proposed by Graham (1935). The assumption is that under equilibrium conditions, the biomass does not change across two successive time periods, therefore the production is equal to the deduction in the form of annual yield (Masters 2007). The Schaefer model presupposes a symmetrical parabola-shaped relationship between yield and fishing effort. Regression from STATA is utilized, using intercept (a) and slope (b). We employed the subsequent equations: The key functional relationships in the fisheries model employed can precisely be expressed as;

i. Biomass growth function

$$x = G\ (x) - y \quad (1)$$

In which x denotes biomass, $G\ (x)$ represents growth in biomass and y is the yield or harvest from fishing. Natural biomass growth is the function G(x)

ii. Harvest function

$$y = Y\ (e, x) \quad (2)$$

where, y, represent yield or harvest which is dependent on fishing effort, e, and x for the biomass that fishing is applied to.

For the long-term harvest function, the catch effort data can be expressed as follows:

$$H\ (E) = aE - bE^2 \quad (3)$$

Where $a = qK$ and $b = \frac{q^2K}{r}$. are the two parameters to be estimated, and t denote time (year).

Due to the artisanal fishery's availability of catch and effort data across time, the parameters a and b could be determined by a linear regression of the catch per unit effort on the relative fishing effort data.

The intrinsic growth rate is used to calculate the catchability coefficient and environmental carrying capacity for each sector or species.

Parameters *K* and *r* can be calculated from the estimated *a* and *b* as follows:

$$K = \frac{a}{q} \tag{4}$$

$$r = \left\{\frac{q^2 K}{b}\right\} \tag{5}$$

Hence $CPUE = \frac{H}{E}$ can be expressed as follows:

$$CPUE = a - bE \tag{6}$$

Maximum Sustainable Yield (MSY)

In equation (7), the partial derivative of *H* with respect to *E* is set to zero to obtain the effort at maximum sustainable yield:

$$\frac{H}{E} = 0 \Rightarrow E_{MSY} = \left\{\frac{-\alpha}{2\beta}\right\} = \frac{r}{2q} \tag{7}$$

And the output at MSY is:

$$MSY = Y(E_{MSY}) = \left\{\frac{-a^2}{4b}\right\} = \frac{rk}{4} \tag{8}$$

Results

3.1. Trends in the artisanal fisheries' overall catch and catch per unit effort

National surveys estimated that between 1990 and 2018, artisanal catches were around 6,416894 metric tonnes, which is less than the 6,918727 metric tonnes of catch that SeaAroundUs reconstructed. Overall catches increased with variance, rising from 242000 mt in 1990 to a peak of 308,000 in 1992. It has since dropped to 159723 mt. The reconstructed data showed a similar trend. Reconstructed data, however, indicates steadily higher and stable landings for Ghana starting in 1994, with the maximum peak being 319199 mt in 1996 which is 20,950 mt greater the was recorded in the national data.

The under-reporting component increased between 1997 and 2000, which may have been caused by a staffing deficit and illegal, unreported, and unregulated fishing (Eriksen et al. 2018). Following that, the under-reporting declined, especially after 2001. Overreporting of the catch was seen from 2010 to 2012 as well as from 2014 to 2018, following the drop in catch.

In contrast to the 30.05 and 13.8 metric tons obtained from the national fisheries data, the capture figures per canoe for 1990 and 2018 show 29.7 and 15.9 metric tons, respectively, suggesting a continual drop in catches per boat. Figure 3 illustrates the comparable trend of rising effort from 1990, when yield decreased (Figure 2), to 1992, when catch increased. This tendency was evident in both the national data and the reconstruction data. Reconstructed data from 2006 to 2016 as well as statistics at the national level demonstrate an overall decline in catch per unit effort (CPUE).

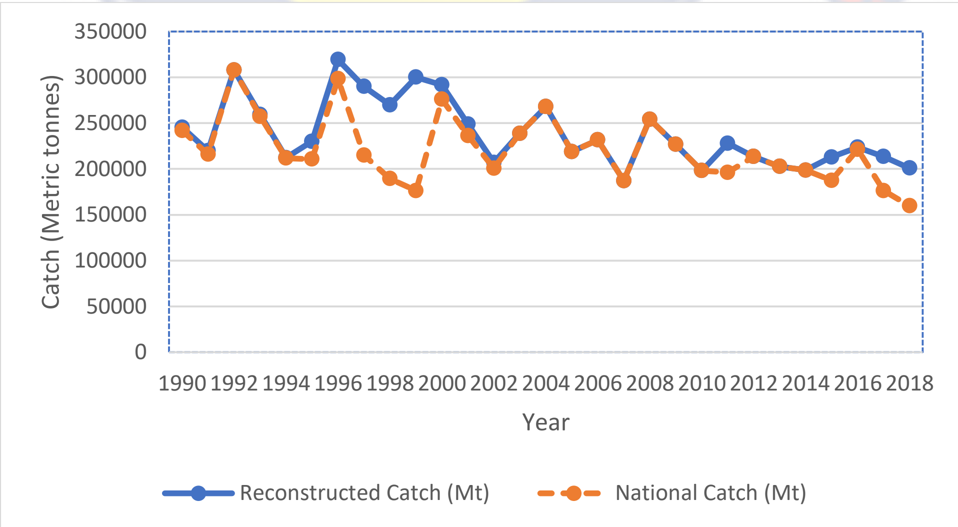

Figure 9. The trend in total catch for Artisanal fisheries based on the official data and reconstructed data

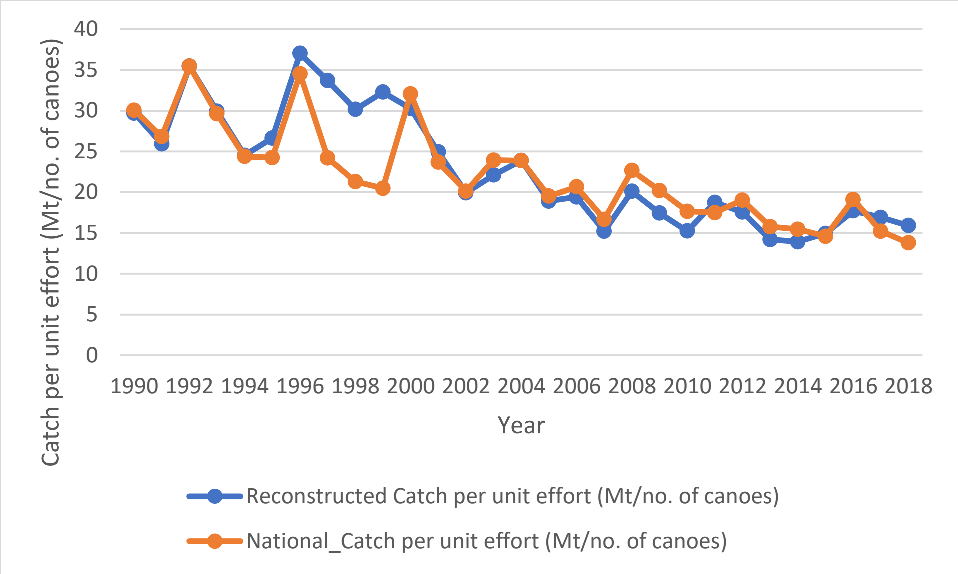

Figure 10. The trend for artisanal fisheries' capture per unit effort based on official data and reconstructed data

Maximum sustainable yield and Effort at Maximum Sustainable yield

In comparison to the national data, which shows MSY and EMSY at 234,485MT and 8797canoes, respectively, the reconstructed data indicates higher MSY and EMSY (258,584MT and 9253 canoes, respectively). Figure 9 illustrates that the effort used was greater than what was necessary because, from 1997, the effort applied based on national data has continuously exceeded the E_{MSY}, while also the effort estimated from the reconstructed data shows a consistently higher than E_{MSY} from 1999 to 2018.

Additionally, the computed maximum sustainable yield (MSY) for both the national data and the rebuilt data is likewise shown to be higher than the average catch for each data set, and the effort level to obtain this maximum yield has also been exceeded. Nevertheless, the reconstructed data still indicates that the maximum catch that can be removed per year has been underestimated by 10%, reducing the catch potential of the artisanal fisheries.

Table 5: The MSY and E_{MSY} for Ghana's Artisanal sector

Parameters & Variables	Reconstructed catch data	National catch data
α	55.89	53.31
β	0.00302	0.00303
r	1.052	1.052
$q = \frac{\beta r}{\alpha}$	5.68445E-05	5.97929E-05
$k = \frac{\alpha}{q}$	983208.3008	891577.288
$E_{MSY} = \frac{r}{2q}$	9253.311258	8797.029703
$MSY = \frac{rk}{4}$	258583.7831	234484.8267

Note: (1) The intrinsic growth rate (r) for the reconstructed and National catch data are sources from the literature (Akpalu et al. 2015). The two parameters α and b are estimated from the yield functions; q is the catchability coefficient; k is environmental carrying capacity; MSY is maximum sustainable yield and E_{MSY} is the effort (no. of canoes) corresponding to the MSY.

Conclusion

From the report's findings, landings both from the reconstructed and national data are declining. However, there is an indication that the fish population is being underestimated given the reconstructed catch is 1.1 times greater than the catch from the national data. This underestimation may be caused by a significant volume of unreported data from saiko fishing, crew shares, and other illicit fishing activities (Nunoo et al 2014).

The Maximum Sustainable Yield and the effort required to produce the maximum sustainable yield were underestimated because of the underestimation of catch potential, which reduce comprehension of the true potential of artisanal fisheries. This puts the fisheries manager at risk of underestimating the contribution of artisanal fisheries, which could result in decisions and policies that underutilize and under exploit fisheries resources, which could have an impact on national food security.

A miscalculated catch could also result in an unsustainable management strategy for fisheries. For instance, if catch limits are too low, legitimate fishers lose out on money; conversely, if they are too high, fish may not be able to reproduce quickly enough to survive the pressure of fishing, potentially leading to the collapse of the population (Merrill 2020).

Data misrepresentation or underreporting is one of the apparent problems with fisheries sustainability. According to Chen (2003), fisheries management and stock estimates are both significantly influenced by the quality of available fisheries data. Therefore, Ghana's institutions for fisheries management must create a plan and techniques for gathering data that is both of high quality and suitably representative of artisanal fishing.

Similarly, when compared to the E_{MSY}, the number of canoes currently operating in artisanal fisheries exceeds 31% showing an overcapitalized fishery (presuming the national data is admissible). This explains the downward trend observed in the catch per unit effort (CPUE). Therefore, the effort level needs to be decreased by 24% to sustain or rebuild stocks to levels that can generate the highest sustainable yield.

CHAPTER FIVE

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

Assessment of data quality of capture fisheries management in Ghana is presented in this study. The importance of data from managing fisheries to sustaining fisheries was discussed. Their importance was highlighted, and the implication of data quality on fisheries management practices and policies in Ghana was also discussed.

It is important to note that prior research on fisheries management and sustainability was focused on the general overview of the kind data for stock assessment, the subjective way of assessing fisheries data, and the management strategies. However, the health and sustainability of captured marine fisheries are maintained by understanding the complex social and biological systems of fisheries. Research in this area, therefore, needs to focus on the sustainability of these systems through assessment of the quality of data used for capture fisheries management. Thus, the current study addressed the gap by assessing the data collection methods and the national data used by the Fisheries Commission to determine the status and true state of the fishery.

The research was aimed at assessing the currently used fisheries data, bringing to light the gaps in the data (in terms of effort and catch), identifying the sources, forms, and scale within the fisheries sectors of Ghana, and evaluating the eventual implications on fisheries resources and the nation's economy. Specifically, the research was to (i) assess the types and sources of data used based on the national data and FAO toolkit for small-scale fisheries routine data collection (ii) evaluate the methods used in the data collection based on the national data and FAO toolkit for small-scale fisheries routine data collection (iii) assess the limiting factors associated with data fisheries quality (iv) analyze the trends in total catch and Catch per Unit Effort CPUE for the artisanal subsectors based on the official data and reconstructed data on Ghana from 1990 to 2018 (v) estimate and analyze the maximum sustainable yields and the corresponding fishing effort levels for Ghana's artisanal fisheries sector using the official and reconstructed data (vi) compare the resource rent deficits based on the official data and reconstructed data (vii) analyze the effect of data quality on the fisheries management practices and policies in Ghana. The significance of the study in addressing data quality and its importance to sustainable fisheries were listed in Chapter One. Some of the findings from the study were discussed in the two articles drafted, the titles of the articles are presented below with the summarized outcomes. However, the article on the resource rent deficit and its effects on management practice and policy is still in progress, and the study was not presented in this report.

a. *Sampling errors and their implication in Capture fisheries management in Ghana*

The analysis of how catch and effort data are gathered to properly inform management policies is included in the paper. The FAO toolset for routine data collecting in small-scale fisheries (de Graaff et al. 2016) was compared with the way data is collected by Fisheries Science Survey Division field enumerators and a case of undersampling and oversampling of landing beaches and canoes was found. Out of 292 landing beaches, 166 landing sites were supposed to be sampled. However, enumerators only sample about a third of these beaches. Additionally, based on ratio and proportion, each of the

26 fishing districts should have at least one landing beach tested; yet the enumerators only cover 18 of the 26 fishing districts, undersampling the remaining 8 districts.

Moreover, 372 canoes out of 11,583 were supposed to be sampled. At least one canoe from each coastal district should be sampled using an appropriate sampling technique. This study showed that the 290 canoes that the enumerators jointly sample are either under or over-sampled.

Furthermore, the four categories of catch data—namely, biological, ecological, economic, and social were examined (Cochrane, 2002). The findings showed that none of the components under each thematic area under each category demonstrate 100% data collection among the enumerators. Each category comprises a variety of components.

b. *Fisheries data quality concerns in the Marine sector of Ghana*

The paper presents the findings of national data deviates showing the true state of artisanal fisheries by comparing with the reconstructed data. The results showed that the total catch from the reconstructed data is higher than the total catch from the national data. Also, despite the general decline from the reconstructed and the national data, an underreporting of the catch was observed between 1997 and 2000.

The calculated maximum sustainable yield (MSY) for both the national data and the reconstructed data was higher than the average catch for each data set, and the effort level to achieve this maximum yield has also been exceeded. Nevertheless, the reconstructed data still indicates that the maximum catch that can be removed per year has been underestimated by 10%, reducing the catch potential of the artisanal fisheries.

Conclusions

The assessment data quality of Capture Fisheries Management in Ghana was presented in the articles above. The following conclusions were drawn from the studies:

1. Technical officers' data collecting methods at the landing beaches display signs of both under and over-sampling. This suggests that Ghana does not implement the FAO toolkit for best practices (de Graaf et al. 2016, for example). The quality of the data obtained is affected because the sampling method differs greatly from the ideal.
2. At various landing beaches, the methods used to collect the data sets for catch and effort were distinct. This mismatch runs counter to the FSSD's goal of gathering trustworthy data using scientific methods.
3. Inaccurate estimations of the maximum sustainable yield level (MSY) and the effort required to achieve the maximum sustainable yield could emerge from errors in the sampling of landing beaches and canoes and variations in the data set acquired (FMSY). As demonstrated by numerous studies, these inaccurate estimates might result in the overexploitation or overcapitalization of fisheries and ultimately their collapse.
4. There is an indication that the fish population is being underestimated given the reconstructed catch is 1.1 times greater than the catch from the national data.
5. The MSY and the effort required to produce the maximum sustainable yield were underestimated as a result of the underestimation of catch potential, which reduce comprehension of the true potential of artisanal

fisheries. This puts the fisheries manager at risk of underestimating the contribution of artisanal fisheries, which could result in decisions and policies that underutilize and under exploit fisheries resources, which could have an impact on national food security.

6. Finally, when compared to the EMSY, the number of canoes currently operating in artisanal fisheries exceeds 31% showing an overcapitalized fishery (presuming the national data is admissible). This explains the downward trend observed in the catch per unit effort (CPUE).

Recommendations

The followings are the recommendations from the studies.

1. To ensure accurate data collection, the Ministry's efforts should include proper field enumerator supervision, and the use of the FAO Open Data Kit (ODK) mobile phone application should be evaluated, updated, and sustained.
2. To provide better coverage of the nation's landing locations, national service personnel from fisheries academic departments should also be hired. Cost-related ramifications for this recommendation are minimal.
3. There should be a coherence between knowledge of sampling methods, the requirement for data, and the type of information to be gathered by field enumerators and office personnel.
4. Ghana's fisheries management institutions must develop a plan and strategies to collect data that is both high-quality and sufficiently representative of artisanal fisheries.

5. The effort level needs to be reduced by 24% to preserve or rebuild stocks to levels that can generate the highest sustainable yield.

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APPENDICES

Appendix A: Structured Interview Schedule

Confidentiality Statement: Please kindly note that data provided in this study shall be handled with the utmost confidentiality and used solely for academic purposes. Your participation in the study is completely voluntary.

Date_____________ Landing site______________ District______________

Sector______________

Instruction:

This instrument is to be administered to Fisheries commission agents who work directly with Fishermen.

SECTION A: SOCIO-DEMOGRAPHIC DATA

1. Gender: (1) Male () (2) Female ()
2. Name ……………………..............
3. Industry ………………..................
4. Organization………………………
5. Department ……………………………...
6. Job title …………………………………
7. Years of Experience ……………………………….

SECTION B: ASSESSMENT OF THE KIND OF FISHERIES DATA COLLECTED

What kind of fisheries data do you collect?

B Data collected

8. Biological () Total fish landings by major species

() Total fish landings by canoes

() Total effort by canoes

() Length and/or age composition of fish landings

() Discards of fish species per fleet

() Length and/or age composition of discards per species per canoe per year

() Areas fished by each canoe

9. Ecological () Total catches of bycatch species (including discarded species)

() Length and/or age composition of catches of bycatch species

10. Economic () The average income per fishing unit

() Costs of premix fuel

() Price of fish landed per canoe

11. Social () Crew size within each canoe

SECTION C: ASSESSMENT OF DATA COLLECTION METHOD

12. What is the source of fish production data?

o Catch

o Landing

13. How do you collect your data? Data collection method

o By species

o By gear

o By canoes

14. What kind of effort data do you collect?

o Size of canoe

o Trip duration

o Number of Trips

o Type of fishing net

o Size of fishing net

o Number of canoes

o The usage of outboard motor

o Other: _______________

15. What kind of catch data do you collect?

o Single species

o Multispecies (aggregated species)

16. How often do you typically collect data?

o Daily

o Weekly

o Monthly

o Bimonthly

o Annually

17. How many times per month do fishermen go fishing?

....

18. What type of data do you collect from them?

i………………………………………………………………………………

ii………………………………………………………………………………

iii……………………………………………………………………………

iv……………………………………………………………………………

v………………………………………………………………………………

19. How do you collect the data?

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20. How many canoes operate on your landing site?

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21. On average, how many canoes do you collect data from?

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22. What determines the number of canoes you collect data from?

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23. What determines which canoe you collect data from?

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24. How do you sample the canoes from which the data is taken?

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25. What is the crew size on each canoe per gear type at the landing site?

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26. Is the total number of registered vessels consistent with the data? () Yes () No

27. What are the major fish species landed?

i……………………………………………………………………………………

ii……………………………………………………………………………………

iii……………………………………………………………………………………

iv……………………………………………………………………………………

v……………………………………………………………………………………

28. What is the average weight of the major species mentioned

i……………………………………………………………………………………

ii……………………………………………………………………………………

iii……………………………………………………………………………………

iv……………………………………………………………………………………

v……………………………………………………………………………………

29. What is the cost of the quantity of premix fuel used per trip?.....................

30. How many landing sites do you collect data from?....................................

31. Name them

i…………………………………………………………

ii…………………………………………………………

iii…………………………………………………………

iv…………………………………………………………

v…………………………………………………………

vi…………………………………………………………

vii…………………………………………………………

32. If you are responsible for several landing sites, what determines the number of landing sites you sample from?

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33. Describe how you sample from each landing site?

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……………………………………………………………………………………

34. What is your perception about the quality of the data you collect?

o Very Good
o Good
o Acceptable
o Poor
o Very Poor

35. What are the challenges you encounter while gathering data? () Yes () No

36. If yes, what challenges do you have when gathering data?

i..……………………………………………………………………………
ii.……………………………………………………………………………
iii……………………………………………………………………………
iv……………………………………………………………………………
v.……………………………………………………………………………

Appendix B: Catch and Effort data from FSSD

National data			
Year	Catch (MT)	Effort (no of vessels)	CATCH PER UNIT EFFORT (Mt/no. of vessels)
1990	242020	8052	30.05712866
1991	215847	8052	26.80663189
1992	307931	8688	35.44325506
1993	257237	8688	29.60831031
1994	211747	8688	24.37235267
1995	210659	8688	24.24712247
1996	298249	8641	34.51556533
1997	215125	8895	24.18493536
1998	189459	8895	21.2994941
1999	176237	8610	20.4688734
2000	275965	8610	32.05168409
2001	236355	9981	23.68049294
2002	200824	9981	20.1206292
2003	238861	9981	23.93156998
2004	267910	11219	23.88002496
2005	218871	11219	19.50895802
2006	231681	11219	20.65077101
2007	187088	11219	16.67599608
2008	254133	11219	22.6520189
2009	226755	11219	20.21169445
2010	198152	11219	17.66218023
2011	196200	11219	17.48818968
2012	213451	11219	19.02584901
2013	202602	12847	15.77037441
2014	198656	12847	15.46324827
2015	187401	12847	14.58715965
2016	221356	11583	19.11038246
2017	176398	11583	15.2290771
2018	159723	11583	13.78943279

Appendix C: Reconstructed data obtained from SeaAroundUs

Reconstructed data			
Year	Catch (MT)	Effort (no of vessels)	Catch per unit effort (MT/no. of vessels)
1990	245459.878	8264	29.70230851
1991	219754.83	8476	25.92671424
1992	307931	8688	35.44325506
1993	259422.401	8672	29.91379499
1994	212260.533	8657	24.51989211
1995	230110.773	8641	26.6301091
1996	319199.356	8626	37.00647566
1997	290000.105	8610	33.68177758
1998	269836.876	8953	30.14011074
1999	299972.998	9296	32.27077599
2000	291690.852	9638	30.2638811
2001	248851.496	9981	24.93252135
2002	207070.417	10392	19.92658385
2003	238796	10802	22.10596476
2004	267910	11213	23.892803
2005	218872	11570	18.91654567
2006	231681	11928	19.42361542
2007	187088	12285	15.2287305
2008	254133	12643	20.10132409
2009	226755	13000	17.44269231
2010	198152	13000	15.24246154
2011	228000	12161	18.74896898
2012	213452	12161	17.55265319
2013	202602	14259	14.20856748
2014	198656	14259	13.93183276
2015	213005.443	14259	14.93816552
2016	223651.918	12630	17.70818553
2017	213554.642	12630	16.90870912
2018	200856.673	12630	15.90331644