UNIVERSITY OF CAPE COAST

# BIOECONOMIC ANALYSIS OF THE SEMI-INDUSTRIAL FISHERY IN GHANA

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# BIOECONOMIC ANALYSIS OF THE SEMI-INDUSTRIAL FISHERY IN GHANA

BY

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# DECLARATION

## Candidate's Declaration

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

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

Name: David Siaw Gyimah

## Supervisors' Declaration

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

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

Name: Professor Emmanuel Ekow Asmah

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

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## ABSTRACT

The biological and economic factors that influence the semi-industrial fishery, one of the three major subsectors of the fishing industry in Ghana, was studied from November 2020 to May 2021, in order to determine the most efficient management and optimize policy for the fishery. Historical catch, effort and revenue data from 1980 to 2019 were obtained from the Fisheries Scientific Survey Division (FSSD), Ghana. Structured questionnaire and interviews were used in collecting primary data from fisher folks, some key informants and stakeholders along the value chain. The Gordon Schaefer surplus production model based on the empirical data on the semi-industrial fishery, was applied to determine the static reference points of the model and the results were discussed. Gross Margin analysis was also used to evaluate for the profitability of the fishery at each node of the value chain.

The results revealed a steady decline in CPUE over the period (1980-2018) which may be symptomatic of overexploitation of the fishery. In spite of the fact that the current (2018) fishery reference situation had not exceeded optimum level yet, the trends revealed that, in the past years the fishery had experienced gross economic overfishing. The poor economic conditions forced most of the fishers to move out of the fishery, thereby reaching the current reference point. Illegal, unreported and unregulated fishing activities (e.g. Saiko) and high cost of fuel (marine gas oil) have been the major challenges impeding the proper management of the fishery, putting the fishery at the verge of vulnerability against changing climatic and economic conditions. Hence, the current study calls for policy intervention to rescue the stock from the existing high fishing pressure that would lead to depletion.

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# DEDICATION

To my family:

Mr. & Mrs. Gyimah, Prince, Philip, Zipporah and Kwaku

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| | |
|---|---|
| ABS | Albert Bosomtwi Sam fishing harbor |
| ADR | Alternative Dispute Resolution |
| AfDP | African Development Programme |
| AU | African Union |
| BCR | Benefit Cost Ratio |
| BoG | Bank of Ghana |
| CBFMC | Community-Based Fisheries Management Committees |
| CCRF | Code of Conduct for Responsible Fisheries |
| CEMARE | Centre for the Economics and Management of Aquatic Resources |
| CPUE | Catch per Unit Effort |
| CYP | Clarke, Yoshimoto and Pooley |
| DoF | Directorate of Fisheries |
| EEZ | Economic Exclusive Zone |
| EMEDO | Environmental Management and Economic Development Organization |
| ESR | Expense Structure Ratio |
| FAO | Food and Agriculture Organization |
| FSSD | Fisheries Survey and Scientific Division |
| GDP | Gross Domestic Product |
| GEPC | Ghana Export Promotion Council |
| GIFA | Ghana Inshore Fisheries Association |
| GM | Gross Margin |
| GTZ | German Technical Cooperation |

| | |
|---|---|
| IEZ | Inshore Exclusive Zone |
| IOC | Intergovernmental Oceanographic Commission |
| IPCC | Intergovernmental Panel on Climate Change |
| IUU | Illegal Unreported and Unregulated fishing |
| KEEA | Komenda - Edina-Eguafo-Abrem |
| LOA | Length Over All |
| MEY | Maximum Economic Yield |
| MoFA | Ministry of Food and Agriculture |
| MoFAD | Ministry of Fisheries and Aquaculture Development |
| MRFD | Marine Research Fisheries Division |
| MSY | Maximum Sustainable Yield |
| NAFAG | National Fisheries Association of Ghana |
| NFI | Net Farm Income |
| NPM | Net Profit Margin |
| NPOA_IUU | National Plan of Action to Prevent, Deter and Eliminate Illegal Unreported and Regulation fishing |
| NPV | Net Present Value |
| NROI | Net Returns on Investment |
| OAE | Open Access Equilibrium |
| PAH | Polycyclic Aromatic Hydrocarbons |
| SDGs | Sustainable Development Goals |
| SSF | Sustainable Small-Scale Fisheries |
| TC | Total Cost |
| TFC | Total Fixed Cost |
| TR | Total Revenue |

| | |
|---|---|
| TSR | Total Sustainable Revenue |
| TVC | Total Variable Cost |
| UNDP | United Nation Development Programme |
| UNFSA | United Nations Fish Stocks Agreement |
| USAID | United States Agency for International Development |
| USD | United State Dollar |
| VCA | Value Chain Analysis |

# CHAPTER ONE

# INTRODUCTION

Globally, fishery resources contribute significantly to the livelihoods of millions of coastal inhabitants, food and nutrition security, and economy growth (Andrew et al., 2007). The capture fishery, as opposed to capital-intensive aquaculture activities, is one of the most essential activities related to fish resources that makes a significant contribution to the livelihood of most fishing communities (Anna et al., 2017). Capture fishery is usually done on subsistence, commercial and recreational purposes which in some ways have impact on the growth dynamics, availability, carrying capacity and sustainability of fish stock under exploitation. With the introduction of information about price, cost and the relationship between profit and output, a model could be developed that could aid policy makers in forecasting the likely level of effort and associated outputs required to sustain the contribution these resources provide to both humans and the ecosystem.

The contribution of fisheries resource to the global economy is enormous, especially in developing countries. It has been estimated that the marine fisheries contribute over $270 billion to global Gross Domestic Product (GDP) each year, making sustainable fishery resource exploitation a crucial component of a flourishing blue economy (World Bank, 2012). Therefore, a sudden decline of these resources would have a significant impact on the many livelihoods that directly or indirectly depend on them. According to Akpalu (2002), fishing activities provide a major source of employment to inhabitants in the coastal communities of Ghana. In the face of near-collapsed commercial marine fish stocks off the coast of Ghana, policy makers are drawn into a situation whereby they have to ensure increasing productivity and stabilize livelihoods (employment) on one hand, while also ensuring sustainable exploitation of stocks to prevent the risk of industry collapse as a result of resource depletion in the near future on other hand. Management of the fisheries system is surrounded by several uncertainties and risk due the its dynamics (Évora & Kristófersso, 2016).

Therefore, fisheries management, however would necessitate the incorporation of several components of the resource (biology, ecology and economic factors) in order to predict fishers' behaviour over space and time (Anderson & Seijo, 2010). Even though both the biological and ecological health assessment of different marine species in Ghanaian waters and other part of the world have been undertaken by several researchers (Amponsah et al., 2017; Kassah, 2020; Bannerman & Cowx, 2020), there seems to be very little information on the bioeconomic analysis of Ghanaian fisheries. Taking into account the numerous challenges facing the fishery industry Ahiable (2015), especially with regards to the semi-industrial fishery, it is prudent to undertake a current research to help develop a bioeconomic model for such fishery in Ghana. This will help guide stakeholders to make informed decisions on sustainable management policies to avoid the risk of the collapse of this sector of the Ghanaian fishery.

### 1.1 Background of Study

In many developing coastal countries, such as Ghana, fishery resources are a major component of animal protein. It accounts for approximately one-third of animal protein in the West African region. Fish protein is estimated to account for approximately 60% of Ghanaians' animal protein intake (FAO, 2016). Of the total annual domestic fish production, it is estimated that 75% is consumed domestically, accounting for approximately 22.4% of total household consumption expenditure (Nunoo et al., 2015). Additionally, the fisheries sector further employs and sustains a sizeable portion of the active labor force, including women who perform critical responsibilities in post-harvest activities on-shore such as fish trading, processing and storage (Ameyaw et al., 2020).

Ghana’s fishing industry revolves around the marine and inland (freshwater), coastal lagoons and estuaries. Ghana as a sovereign state has a long fishing history and heritage, with a vibrant and diverse variety of fishing activities extending from subsistence (motorized and unmotorized) to semi-industrial (including the “china-china” boats) as well as the industrial fisheries (shrimpers, tuna and trawlers) (MoFAD, 2015). Of the three subsectors, the artisanal fisheries are the most important of all in terms of its contribution to production and local fish supply of about 60% - 70% of total annual fish landings (MoFAD, 2015; Ashitey, 2019). The fishing industry also plays a pivotal role in the eradication of poverty in Ghana, with approximately 10% of the population reliant on the sector for their livelihood (BOG, 2008).

Following the assertion of an Exclusive Economic Zone in many of the nations where Ghanaian fleets fished in the 1980s, Ghana's distant-water fleet came back to its home waters, instigating a drastic decline of some domestic stocks. Contributions derived from the inshore fisheries to Ghana’s economy is gradually declining as a result of the use of primitive technology and the activities of industrial vessels, which further impoverish already threatened communities, while industrial fisheries (specially tuna vessels) are increasing their profit margins due to the adoption of advanced technology and operations in less exploited areas of Ghana's continental shelf (Nunoo et al., 2014).

It must be emphasized that the decline in fisheries resources is of global concern, and Ghana cannot be exempted from this crisis. Ghana's national fisheries statistics show that marine fish production has generally been on the decline for the last decades (STWG, 2015; Lazar et al., 2016). This is demonstrated by the fact that the contribution of fisheries to the country's GDP has declined from approximately 6% in 1993 to 4.5% in 2015 (MOFAD, 2015; FAO, 2016). According to recent estimates, the fisheries sector contributes approximately 1.2% of the nation's GDP (Quagrainie et al., 2019). Ghana, as an importer of fish in 2018, imported $311 million in seafood and fish products, an estimated 48% of its total demand, compared to an estimated 35% in 2010 (Ashitey, 2019). These parameters indicate the current status and economic contribution of the sector to the nation and the urgency for effective management regimes.

Some fish production policies and regulations geared towards revamping collapsed and dwindling fisheries, developing fish stocks, as well as improving the yield of aquaculture have been enacted both globally and locally. As shown in the FAO Guidelines for Responsible Fisheries (FAO, 1995), the 2030 Agenda for Sustainable Development aims at contributing towards food security and nutrition through aquaculture and fisheries in a manner that would ensure sustainable development in economics, environmental and social development (FAO, 2018a). Moreover, as presented by FAO (2017), the Sustainable Development Goal (SDG) 14 calls for the conservation and wise use of the oceans, seas, and marine resources for sustainable development. The implementation of the SDGs is to be carried out by countries through the application of the best scientific information available. Several international instruments contain this principle, including the (a) Sustainable Small-scale Fisheries (SSF) Guidelines, the (b) Code of Conduct for Responsible Fisheries (CCRF), and the (c) United Nations Fish Stocks Agreement (UNFSA). The SSF Guidelines focus on the recognition of small-scale fishing communities as "holders, providers, and receivers of knowledge." Furthermore, the scientific information available should be coupled with existing traditional knowledge in policy making, management, and sustainable use of small-scale fisheries (FAO, 2020b).

Locally, the Ghana Fisheries Act 625 (2002) requires that the resources (marine, inland, and aquaculture) in Ghana be regulated and well managed. Ghana's Fisheries Act 625 (2002), PART IV – Fisheries Management and Development, Sub-Part – Fishery Plans, "A fishery plan prepared by the Commission for the management and development of fisheries shall (a) be based on the best scientific information available; (b) ensure the optimum utilization of the fishery resources but avoid overexploitation; and (c) be consistent with good management principles." As part of the content of a fishery plan, fishery resources and their characteristics are to be identified, assessed to ascertain the current state of exploitation based on relevant social, economic, and biological factors to determine potential average annual yields; and the measures taken to promote the development of the resources specified.

According to King (2013), the depletion and eventual collapse of fish stocks is a major concern for social welfare and global food security. Pillay and Kutty (2005) highlighted the overfishing and depletion of fish stocks as a living reality. They pointed out the recognition by management bodies in appreciating the necessity to recover or create new stocks by human intervention. According to FAO (2018a), the state of fisheries resources in 2017 indicates that SDG Target 14.4 (which aims to climax overfishing in the marine sector by 2020) is unlikely to achieve its target. In general, well-managed fisheries have produced significant results, such as a reduction in the total fishing effort and increasing stock sizes, with some reaching their optimal sustainable limit, as opposed to poorly managed or unregulated fisheries, which have seen some collapse and, in extreme cases, extinction. To effectively implement the legal and regulatory framework in fisheries, developing mechanisms capable of effectively replicating successful policies and measures in fisheries with minimal management is critical.

According to FAO (2020a), capture fisheries and aquaculture provided approximately 179 million tonnes to the world in 2018. Finfish accounted for 85% of total marine capture production, with gadiforms and tuna-like species coming in second and third, respectively. The total size of Africa's fleet now accounts for 20% of the global total. Based on FAO’s evaluation of assessed commercial fishery resources, the percentage of biologically sustainable fish stocks has decreased from 90% in 1974 to 65.8% in 2017. The percentage of stocks fished at biologically unsustainable levels increased from 10% to 34.2% between 1974 and 2017 (FAO, 2020a). The increasing proportion of overfished stocks and decreasing percentage of non-fully exploited species around the world serve as a warning that global fisheries are declining, hence negatively impacting fishery production. Overfishing have negative ecological consequences as well as a reduction in fish production, both of which has negative social and economic implications. Illegal, unreported, and unregulated fishing, which generates between USD 10 and USD 22 billion in undocumented revenue, has a negative impact on fish stocks. According to the World Bank, poorly managed fisheries and regulations results in annual revenue losses of more than USD 80 billion, which could be retrieved if global fisheries were significantly reformed, including a 44% reduction in fishing intensity (World Bank, 2017).

Several studies (Keen et al., 2018; Sumaila et al., 2020) have shown that only well-managed and governed fisheries can add value to the blue economy in the long term, making governance reform an integral element of the transition to a blue economy. The "blue economy" concept aims to boost and stimulate economic growth, social integration, and livelihood preservation and improvement while also ensuring the environmental sustainability of the oceans and coastal areas (Hasan et al., 2018; Karani & Failer, 2020).

In addition, the FAO Code of Conduct for Responsible Fisheries (CCRF) and related international agreements provide such a strong framework for the industry that it can and should be used more widely. The SSF Guidelines complement the Code of Conduct for Responsible Fisheries (CCRF), which takes a comprehensive perspective on the small-scale fisheries governance system. This implies that small-scale fisheries resource management, social and economic development must all be addressed simultaneously and given equal relevance (FAO, 2020b). The African Development Program (AfDP), African Union (AU) Commission, and United Nation Development Programme (UNDP), through the execution of its Ten-Year Strategy, outline the aspiration of Africa to become economically integrated and a major global partner (2013-

2022). This Agenda ranked "Feed Africa" (through fisheries, aquaculture, and agriculture) as its second prioritized area. The five prioritized areas, which are also referred to as the "High Fives" are closely linked to the SDGs and the continental framework, Agenda 2063. (Africa, UNDP, 2017).

### 1.2 Statement of the Problem

According to several experts, many US and global fisheries are afflicted by a combination of poor economic sustainability, low stock abundance, discarding, by-catch, and fishing's impact on marine ecosystems (Squires et al., 1998; Hilborn, 2007; Rutherford, 2008). In Ghana, the semi-industrial is one of the sub-sectors of the fishery industry that lands very economically viable species such as snappers, sea bream, burrito and cuttlefish, contributes significantly to the fishery's GDP of the country and also supports over 150,000 livelihoods in the country. However, this sector has over the years suffered economic woes due to high cost of fishing inputs (operational cost: fuel, gear, marine engines), lack of capital, trade agreements, climate change, global economic integration of the fisheries sector, and the prevalence of foreign industrial trawlers in the inshore zone of Ghana and their use of unauthorized gears (Koranteng, 1998).

The decline of the semi-industrial sector has had a significant economic impact, leading to a reduction in fishing investment, GDP contributions, and employment (Atta-Mills et al., 2004). The numbers in terms of the fleet shrank from 248 vessels in 1980 to 165 vessels in 1996. (Koranteng, 1998). Many of the local fishing companies that thrived in West Africa in the 1960s and 1970s, such as Mankoadze Fishing, Ocean Fisheries, Commodore, Obuorwe, and Obedru, have either terminated or shifted their focus to the importation of fish and retailing. Some of the semi-industrial fishers have been absorbed into the artisanal fleet, where they fish for subsistence and a little extra income (Atta-mills et al., 2004).

According to MOFAD (2015), there are approximately 403 boats in the semi-industrial sector along Ghana's coast. Regardless of the fact that overall numbers have more than doubled in the last ten years, catches have decreased by half and are now reported to be less than 10,000mt (MOFAD, 2015). For a decade now, the economic rent on fishing operations in this sector has been reported to be the lowest of the three sectors of the Ghanaian fishing industry (MOFAD, 2015). Recently, the number has again been drastically reduced due to high economic losses incurred through their operations. It has been estimated that just about 10% of the inshore fleet are able to make returns on their operations, while a percentage of them also break even on their cost of inputs and revenue (perscomm, GIFA secretariat). Some boat owners have even been forced to dock their boats and sell their gear due to the high cost of debt incurred from operations.

According to the World Bank, the semi-industrial segment shrank by half (from 401 to 201 vessels) in the year 2016 to 2018 during the Ghana-West Africa Regional Fisheries Program (WARFP) project's lifetime due to competition from the industrial sector, which targets and exploits the same species and fishing zones (World Bank, 2011). Although this trend is positive in terms of effort reduction, it is negative in terms of domestic ownership because the industrial sector is characterized by foreign investors in partnership with some Ghanaian stakeholders, whereas the semi-industrial segment is dominated entirely by Ghanaians (World Bank, 2011). This industrial fleet harvests highly commercialized fish for export, whiles low-value fish are imported into Ghana. In 2007, Ghana imported three times more protein than it exported in an effort to match its protein deficit (GEPC, 2008; MRFD, 2008). This presupposes that local fisheries are not meeting consumer demands, and it serves as a signal to the government and other stakeholders that fishery resources must be managed sustainably. Mauritius as a small island nation, has been able to manage its semi-industrial fleets to land a total catch of about six tons of fish per trip. Access to semi-industrial fisheries has caused a shift from family livelihood to business management (European Commission, 2021).

Although several reports on the biological and ecological health assessment of different marine species in Ghanaian waters has been undertaken by several researchers (Amponsah et al., 2017; Kassah, 2020; Bannerman & Cowx, 2020), information on the bioeconomic analysis of the semi-industrial fishery seem to be very scarce, except few (Bortier-Verstraaten, 2000; Bailey et al., 2011) mostly dealing with the artisanal and industrial fishery resources. Over the years, Ghana’s fisheries management policy has emphasized much on artisanal (contribution to food security and livelihood) and industrial fleets (export for foreign exchange) as compared to inshore fleet, despite the fact these fleets are capable of exploiting both demersal and pelagic stocks. However, a proper and detailed understanding of bioeconomic resources and its utilization is an urgent need to promote sustainable development of the fishery resources exploited by the semi-industrial fishery. It has therefore become prudent to investigate the biological and economic factors that influence the profitability and long-term viability of Ghana's semi-industrial (inshore) fishery using the empirical data.

## 1.3 Purpose of the study

The purpose of this study is to furnish stakeholders with the necessary information on the economic and biological reference points of Ghana's semi-industrial fishery under changing climatic and economic conditions, profitability associated with these reference points, challenges facing the sector, and the need for interested stakeholders to make informed decisions on optimal and sustainable management regimes which would help increase the annual production, profitability, and also sustain this sector.

## 1.4 Research Objectives

The overarching goal of this study was to examine the biological and economic factors that affect or influence the semi-industrial fishery in order to determine the most efficient management options for optimizing outputs from the fishery.

The study's specific objectives were to:

1. Examine the annual trends of catch and catch per unit effort of the semi-industrial fishery (1980 - 2019).
2. Analyse the biological and economic reference points and conditions of the semi-industrial fishery.
3. Evaluate the profitability of the fishery and suggest optimal utilisation policy.

The following hypotheses helped in guiding this study:

1. The biological and economic reference points of the semi-industrial fishery have been exceeded.
2. There are economic losses incurred along the value chain of the fishery which might lead to the collapse of this sector.

**1.5 Significance of the study**

The problems in Ghanaian fisheries surpass policy implementation. There is a wide data gap that results from the interplay between climate change, unsustainable resource exploitation techniques, a lack of fisheries management systems, bioeconomic analysis and modeling of resources, increasing population, and the overall quantification of fishery resources. This has led to the gradual collapse of our fisheries. Ghanaian marine commercial fishery like any other fishery worldwide, is undertaken for profitability purposes. As a result, just like every other economic actor, boatowners and fishermen are motivated by the short-term maximization of profit (Conrad & Clark, 1987). Thus, fishing effort and fishermen can be considered rational economic agents that, collectively, will make decisions in order to improve their well-being within the restrictions of the institutional and legal incentive schemes foisted on them (Hilborn, 2007). These challenges, coupled with other failures in existing management measures, could possibly be the cause of the gradual collapse of the semi-industrial fishery.

It is therefore timely to use a bioeconomic model approach to investigate the effects of stock decline and its economic implications on the profitability of stakeholders and fishers in the industry. Bioeconomic analysis and models are extremely useful for simultaneously addressing both the economic and biological components of a fishery. They are also employed to test the performance of management techniques and to provide a discussion forum among the diverse participants in the fishing industry.

Furthermore, because fisheries resources are both biological and food-supply resources, their decline and eventual collapse will pose a substantial economic challenge to fisherfolk and many others who make a living from fishing. To avoid this tragedy, it is clearly desirable and necessary to establish biologically and economically sustainable fisheries. Biological and economic management options should be combined to better understand how they interact within a fishery (Anderson & Seijo, 2010). As a result, the purpose of this study is to use bioeconomic analysis to determine the most effective management and the effective fisheries policy for Ghana's semi-industrial fishery.

## 1.6 Delimitations

The study was carried out to examine the biological and economic factors that influence the semi-industrial fishery along the coast of Ghana in order to determine the most efficient management options for optimizing outputs from the fishery. Moreover, a structured questionnaire and an interview guide were used to elicit socioeconomic information from the actors along the fisheries value chain to help evaluate the profitability of the fishery.

## 1.7 Limitations

The unavailability of data on catch, effort, and the economics of the semi-industrial fishery posed a challenge in this research. Due to this limitation, only the effort (number of licensed vessels) was used in the overall estimation of the Maximum Economic Yield, Maximum Sustainable Yield, and Open Access Equilibrium, although effort (days spent at sea) was also used in the estimation of Maximum Sustainable Yield only.

Again, the lunar cycle affected the collection of socioeconomic data from the actors of the fishery. Fishermen involved in inshore fishing did not often operate during this season. They explained that during this period, fish are able to detect their fishing gears and boats and evade capture during operations. They intend to stay home or sometimes come to the landing to repair their gears and boats. This “break” in some way also affected the subsequent actors in the fishery, since they got their supplies from the fisherman.

The model (Gordon-Schaefer) employed in this study assumes a constant environmental condition. However, the fishery is a dynamic system which involves the interaction of several components (biological, environmental, and technical). In Ghanaian multispecies fisheries, there is a high degree of biological and technical interaction, resulting in untargeted species mortality from fishing gears. As a result of the model's sustainable effort level for exploitation, some species may be overfished while others remain unaffected (Jennings et al., 2001). In spite of the usefulness of this model, there are some limitations in managing tropical fisheries that have varying maturity ages. However, this model can help determine optimal fishing effort levels and be used to compare other large-data modeling approaches (Hannesson, 1993).

**1.8 Definition of Terms**

**Maximum Sustainable Yield** – the level at which the largest average catch can be exploited from the biomass under existing environmental conditions.

**Maximum Economic Yield** – the level of sustainable catch which coincides with the effort that allows for returns to be maximized from the fishery.

**Open Access Equilibrium** – the level at which the total revenue derived from the fishery is equal to the total cost of operation.

**Intrinsic growth rate** – the rate at which the stock would grow with no external effects.

**Mortality rate** – the portion of the stock that is taken either naturally or by fishing operation

**Carrying capacity** – the largest size of the stock that a specific ecosystem can support

**Cost Benefit Analysis -** a technique, that is used to compare, the various cost associated with the investment of the company with the benefits that is proposes in return.

**Catch per Unit Effort** - an indirect measure of the abundance of a target species that is used in long term monitoring of a fishery.

**Value Chain -** full range of activities performed to add value to a product or service from conception to final disposal.

### 1.9 Organization of the Study

This study is structured into six chapters. The first section entails the study's background, problem statement, justification, purpose, research objectives, hypothesis, and organization. A review of literature is presented in Chapter Two, which summarizes current status of fishery management in Ghana, along with the models used to measure the profitability of the semi-industrial fishery. Chapter three constitutes the materials and methods of the study with a focus on the study area, data collection, and data analyses to mainly address the research objectives. The findings are presented in Chapter Four, which comprises figures and tables with statistical analyses as well as comments on the results. Chapter Five is a discussion of the results with reference to relevant literature. Chapter Six presents the summary, conclusions of the findings, and recommendations from the study.

# CHAPTER TWO

# LITERATURE REVIEW

This study focuses on the aspect of the biological and economic reference points to inform policies and strategies for the optimization of yield, sustainable management, and an increase in economic rent of the semi-industrial fishery. The chapter two of this research work constitutes a comprehensive review of relevant literature on the subject under investigation. The following thematic areas are used to organize the literature review: a general overview of the fishery sector of Ghana, current fishery management options, theoretical perspectives of bioeconomic models in fisheries, the concept of fishery value chain, and an empirical review. Except for the general overview of the fishery sector of Ghana and current fishery management options, the thematic areas are structured by way of introduction, body (background to methodology, theories/concepts, and past and current research), and conclusion (literature gaps).

## 2.1 An overview of Ghana's fishing industry

Ghana as a nation is endowed with rich fishery resources which can be broadly classified into two categories, namely, the inland and marine fisheries. There are three major subsectors within the marine fisheries sector (Amador et al., 2006), which includes the artisanal (motorized and unmotorized canoes), semi-industrial (wooden planked boats) and industrial (shrimpers, trawlers, and tuna) fisheries. Fishing activities of these subsectors takes place within 200 nautical miles of the nation's waters exclusive economic zone (EEZ), authorizing them to exploit both pelagic and demersal fishery resources. The inland fisheries encompass the Volta Lake and aquaculture subsectors. (MOFA,

2012) and are mostly exploited at subsistence and artisanal levels. Amongst these fishery resources, the marine, inland and aquaculture contributes 70.1%, 17.1% and 12.8% respectively (MOFAD, 2017).

### 2.1.1 The marine fisheries sector

This subsector accounts for roughly 80% of all fish produced in Ghana (FAO, 2016), with an annual catch of around 300,000 mt. The Ghanaian fisheries sector has three subsectors: industrial (shrimpers, trawlers, and tuna), semi-industrial (inshore) and artisanal (canoe) fleets (Amador et al., 2006). The Fisheries Act 625 of Ghana authorizes the small-scale fishery (except trawlers) to operate within a 30m depth limit, while the large-scale fishery is eligible to operate in waters deeper than 30m depth. Seasonal upwelling in the Gulf of Guinea affects this industry. Biological activity increases during upwelling seasons (December/January–February and July–September), increasing fish food production and abundance.

### 2.1.2 Artisanal fishery

This subsector involves dynamic activities that range from subsistence to commercial fishing activities and from traditional to advanced (motorized) methods of exploiting the fishery resources. The motorized canoes, which are usually known as the "lagas canoes," possess insulated containers and ice for the preservation of highly valued fish at sea. A variety of fishing gears are used in the artisanal sector, including purse seine nets (for adult sardinellas and chub mackerel), drifting gill nets (for large pelagics), beach seines (for adult and juvenile fish species such as red snapper, grey snapper, mullet, and ribbonfish), and hook and line (targeting demersal resources including, seabreams and snappers). It employs around 1.5 million people in 189 fishing villages with 304 landing sites along the coast. The greater proportion (60%-70%) of the total annual catch of small pelagic species (sardinellas, mackerels, and anchovies) is caught by this subsector (NAFAG, 2007). Outboard motors with up to 40 hp are installed in about half of the dugout canoes (Armador et al., 2006). The artisanal fisheries according to FAO (2007) accounts for roughly 90% of all small pelagic resource landings each year in terms of volume.

### 2.1.3 Semi-industrial fishery

They are usually locally built wooden hulled dual vessels with 90 – 400 hp inboard diesel engines (Nunoo et al., 2009; Bannerman & Cowx, 2002; DoF, 2003) and vary from 8m to 37m in length overall. The semi-industrial fleet berth at Winneba, Mumford, Apam, and Elmina (in the Central Region), Tema (in Greater Accra), Axim, Sekondi, and Takoradi (in the Western Region). They are classified by their size and the gears they use. The size classification includes large semi-industrial vessels (10 to 37m long) and small semi-industrial vessels (8 to 10m long) (Quaatey, 1997), and the gear classification includes purse seines and trawlers. Purse seine nets are typically 400–800 meters long, 40–70 meters deep, and 25–40 millimeters wide in terms of mesh size, though larger vessels use nets up to 2 kilometers long.

During periods of major and minor upwelling, the semi-industrial vessels employ the purse seine and trawl nets, respectively. The purse seiners have about 20 to 25 crews, while the trawlers have about 7 to 10 crews. Semi-industrial purse seiners operate in the same waters as the artisanal fishery, but trawling by semi-industrial takes place beyond 30m of water depth (Koranteng, 1997b). Operating within the same waters as the artisanal fishery frequently leads to disputes among these fleets (Marquette et al., 2002). The purse seiners mainly exploit chub mackerel, sardinellas, and other carangidae species. The small-sized trawlers also exploit Grey triggerfish while the others exploit seabreams, cassava fish, snappers, burrito, red mullet and groupers. Bottom trawling targets shrimps, seabreams and cuttlefish for export in waters deeper than 30m (Heinbuch, 1994). Because most of these vessels have inboard freezing facilities for preserving fish, fishing trips typically last three to five days (FAO, 2004).

### 2.1.4 Industrial fishery

These are large steel-hulled foreign-built vessels that operate from Tema and Takoradi fishing harbors, which have appropriate berthing infrastructure (NAFAG, 2005). These vessels are managed by companies and are run through joint ventures between foreigners and Ghanaians. The fisheries law requires that at least 75% of the crew be Ghanaians (Directorate of Fisheries, 2004). Tuna bait boats, pair trawlers, industrial trawlers, shrimpers, and tuna purse-seiners are the different types of vessels in this sector. These vessels, by law, are mandated to operate in waters deeper than 30m because of how sophisticated they are built (Fisheries Act 625, 2002). Demersal species are targeted by trawlers and shrimpers. These vessels have freezers installed for fish preservation during operations, which increases their propensity to stay at sea for months. Trawlers are typically over 35 meters long and have engines that produce over 600 hp, whereas shrimpers are up to 30 meters long and have engines that produce over 350 horsepower. Trawlers initially fished off the west and south coasts of Africa, particularly between Sierra Leone and Mauritania, as well as between Angola and Namibia. These vessels have been forced out of these waters as a result of these countries' approval of the 200-nautical mile EEZ

Law. Shrimpers are also permitted by law to operate in waters deeper than 30 meters. These vessels export all of the shrimp they catch. These shrimpers catch finfish such as soles, seabreams, cassava fish, cuttlefish, and red mullet as by-catch.

The tuna fleets target mainly yellowfin tuna, skipjack tuna, and bigeye tuna. The majority of tuna vessels are operated as part of a joint venture, with at least half of the shares held by Ghanaian owners, as required by the Fisheries Act 625. In general, the number of industrial fleets has increased substantially since 1984, when the Ghanaian government's policy targeted industrial fishing as a way of enhancing non-traditional exports (Quaatey, 1997; FAO, 2007).

### 2.1.5 Brief history of the semi-industrial fishery

Ghana's commercial fishing began in the 19th century when river boats were modified to handle the rough waves and currents (Agbodeka, 1992). Ever since these boats provided accessibility to coastal resources, Ghana's inshore artisanal and commercial (semi-industrial) fishing sectors grew rapidly. The high demand for fish in the late 19th and early 20th centuries led to the formation of fishing companies, with foreign offices directing semi-industrial fishing operations in distant waters. Ghanaian companies recruit native fishermen to crew their sea-faring vessels. Ghana had become a fishing power in West Africa by the mid-20th century due to the advancement of a semi-industrial fleet in foreign waters (Agbodeka, 1992).

The Ghanaian semi-industrial fleet was not equipped to fish offshore in the early 1960s, making it difficult to explore new inshore fishing areas. In Ghana, accessible fishing grounds were already heavily exploited, and Ghana's newly independent government recognized it as such. As a result, the new government and private industry heavily invested in offshore industrial fishing vessels in the 1960s and 1970s (Adjetey, 1973). In 1961, Ghana established the State Fishing Corporation to encourage local entrepreneurs to start fishing businesses. While Ghana's politics became more stable in the 1990s, the economy remained unstable, and access to distant fishing grounds was prohibitively expensive. Marine resources were overexploited in the 1990s, contributing to the decline of semi-industrial fleets. From 1980 to 2019, catch per unit effort declined in both semi-industrial and industrial fleets. Small pelagic species such as sardinellas and chub mackerel (Scomber japonicus) were overexploited, according to an IOC report (1997). These trends have hampered the sector's performance.

Fishing, particularly artisanal and semi-industrial fishing, was a major source of employment for unskilled young men (Pauly, 1976). In 1992, Ghana's fishing industry employed around 500,000 people (IOC, 1997), but by 1996, that number had declined to 400,000. (FAO, 1998). Up to 100,000 jobs lost in four years is a significant shift in the labor force. Some of the fishermen who lost their jobs in the semi-industrial sector have been absorbed into the artisanal sector, where they fish for subsistence and extra money. However, the resource is overfished and cannot support any additional effort.

**2.1.6 The Fishery Sector's Economic Contribution**

Fish is Ghana's most important non-traditional export commodity, accounting for over 50% of export earnings (Bennett, 2000; Sarpong et al., 2005). Annual national fish production is estimated at 420,000 metric tons, which is 460,000 metric tons short of national needs, a more than 50% deficit. Fish imports worth over $200 million annually help balance the deficit (Ministry of Food and Agriculture, 2012). Fish imports surged to $373 million in 2013. (FAO, 2016). Fisheries are vital to Ghana's economy, livelihoods, nutrition, wealth creation, and food security. Fishing activities are important livelihoods in Ghana (Pittaluga et al., 2003). The coastal economy of Ghana is based on marine fisheries (Hen Mpoano, 2013). It generates over $1 billion annually (World Bank, 2009). Ghana's fisheries employ an estimated 210,000 people. Directly or indirectly, the sector employs 2.2 million Ghanaians, or roughly 20%. (Atta-Mills et al., 2004; World Bank, 2009). According to FAO (2016), the fishing industry employ over 250,000 people and over 29,300 fishing vessels. The fisheries sector employs 372,049 people according to the World Bank (2011). Despite its importance, the fishing industry's economic contribution has declined.

**2.2 Current Fishery Management Options**

To sustainably benefit from Ghana's fisheries, traditional (local authorities) or formal (government of Ghana) management must be improved. The traditional government regulates access to Ghanaian fisheries, contributing to sustainable fish stock utilization. In almost every fishing village, non-fishing days are observed on which fishers maintain gear and equipment, resolve conflicts, rest, and socialize. Also, some fishing communities or ethnic groups have a two-week fishing ban prior to and during annual festivals (Nunoo et al., 2015).

Several decades ago, the Ministry of Food and Agriculture had a Directorate of Fisheries and a Fisheries Commission that was responsible for policy formulation and implementation. Under the direction of the Fisheries Commission, this directorate managed and controlled the fishing industry. The

Commission was established by the Fisheries Act 625 (2002) to regulate and manage Ghana's fisheries and to coordinate related policies. It also ensured proper conservation of fishery resources by reducing overfishing. It also reports to and advises the Ministry on all fishing-related matters. As a result of these global trends and innovations in fisheries management, Community-Based Fisheries Management Committees have been established and operated since 1997. (CBFMC). Ghana's fisheries co-management system is currently fragile and unsustainable (Nunoo et al., 2015). The newly established Ministry of Fisheries and Aquaculture Development (MOFAD) is mandated to carry out development interventions to move the fisheries sector and industry to contribute efficiently to the Ghanaian economy. Post-harvest losses are reduced by reducing effort and fishing capacity control, biological/stock assessment, marine habitat and biodiversity protection, social interventions, and inter-agency linkages (MoFAD, 2015). The sector is divided into five divisions: Marine Fisheries Management, Marine Fisheries Research, Inland Fisheries Management, Monitoring, Control and Surveillance, and Operations and Administration. The current management options in this sector can be broadly categorized under five key components; effort and fishing capacity control, biology/stock assessment, marine habitat & biodiversity protection, post-harvest losses reduction, and social interventions and inter agency linkages (MoFAD, 2015). To effectively and efficiently perform the mandate assigned to the sector, there are five (5) divisions, namely; Inland Fisheries Management Division, Marine Fisheries Research Division, Operations and Administration Division, Monitoring, Control and Surveillance Divisions and Marine Fisheries Management Division.

The Fisheries Act 625 (2002) was enacted in 2002 to consolidate and amend all fisheries laws. In addition to the Fisheries Act, the Fisheries Regulations (LI 1968) were passed in 2010 to complete Ghana's legal framework for fisheries management. The Fisheries Act 625 (2002) and the Fisheries Regulations, LI 1968, currently govern fishing in Ghana (2010). The Ghana Shared Growth Development Agenda II, the Republic of Ghana National Fisheries and Aquaculture Policy (2008), the Republic of Ghana Fisheries and Aquaculture Development Plan 2011-2016, the Ghana National Aquaculture Development Plan, and the Fisheries Management Plan of Ghana (Marine Fisheries Sector) 2015-2019 are all existing fisheries policy documents. Management strategies based on these instruments that have been implemented over the years to manage fisheries are geared toward limiting fishing methods and gears, regulating mesh sizes, and assessing stock status to set targets and thresholds for fishing mortality rates and other biological reference points.

The overarching goal of these strategies was to keep fish stocks at their current levels in order to achieve maximum sustainable yield (MSY). However, due to poor governance as a result of a lack of resources (both human and financial) and political will to deal with the issue of increasing fishing effort and capacity as a result of the open access nature of the fishery, these options have not been very effective for managing the stocks.

## 2.3 Theoretical Approach in Bioeconomic Models and Value Chain Analysis

### 2.3.1 Theoretical Perspective of Bioeconomic Models in Fisheries

Regardless of the negative economic consequences of closures, there is a perceived risk of extinction associated with allowing a fishery to remain open during periods of low stock levels, which is high enough to justify a closure. The phenomenon known as the “tragedy of the commons” is one of the most common challenges in fisheries management (Hardin, 1998). Fishermen operate under the assumption that the fishery resource is fugitive and that fish that are not caught today may be caught tomorrow by someone else. This logic among fishermen may inevitably lead to the extinction of the very resource on which they rely. Overfished stocks have historically failed to recover (Safina et al., 2005; Rosenberg et al., 2006; Worm et al., 2009). However, as Larkin et al. (2006) demonstrated, rebuilding stocks as quickly as possible has social consequences. Bioeconomic models that explicitly evaluate biological and economic risks can assist in balancing these costs with the risk of stock growth or extinction that is less than expected.

Several studies (Sumaila & Suatoni, 2005; Gates, 2009) have found that delaying rebuilding can increase average harvest levels and benefits significantly. The Gordon-Schaefer model is the most commonly used bioeconomic model. This model selects a harvest and effort level that maximizes the net present value of harvests over time. This "equilibrium" solution maximizes economic yield (MEY) as opposed to maximizing harvest level over time or sustainable yield (MSY). The divergence of these two solutions provides recommendations for bioeconomic policy. This method is useful for rebuilding, but it lacks information on the optimal time horizon or time path. Because they omit information on transition and reasons for rebuilding, static models are insufficient for addressing fisheries rebuilding (Clark, 2006a). Sustainable fisheries, particularly commercial fisheries, are a global concern (Hilborn et al., 2005; Worm et al., 2009). To rebuild fisheries, some countries and international organizations have revised management plans and established specific protocols (Khwaja & Cox, 2009). Calculating reference points can help manage and rebuild fish stocks. These rules ignore fisherman's behavior and economic conditions (Hilborn, 2002; Clark, 2006b). Global management ignores local biological realities. Reference points frequently stifle management innovation (Hilborn, 2002). While reference point-based management may aid in stock recovery, it is difficult to determine whether the stock has met its fishing objectives.

To achieve a biological rebuilding target, many efforts first estimate it. This approach is often mandatory, but it is incompatible with long-term fishery management. A fishery or community may not be stabilized if the MSY is not economically viable. The sustainable yield curve is used to determine a target stock level, but it ignores the economy. When it comes to economics, the benefits and costs must be balanced. The widespread assumption is that economics should be used only after determining a rebuilding target or resolving any imbalances between stock size and fishing capacity (Penas, 2007; Khwaja & Cox, 2009). Even in a stable economy, determining a target MSY level for rebuilding is difficult. The MSY is a long-term concept that will change as biological parameters, fishing effort, or the relationship between stock and harvest level change. If the general economic conditions or technology change, fishing effort may vary (Whitmarsh et al., 2000). Exogenous factors can have an impact on fishing mortality and, therefore, MSY estimation, or they can change MSY during the rebuilding process. These variations are feasible, but they are not covered by a guideline that calls for a ten-year target. Caddy & Agnew (2004) argue that stock calculations, which are frequently overestimated, are less important than the management infrastructure and socioeconomic context.

Establishing an MSY target above current stock levels shows future resource productivity and how management can improve a fishery. For sustainable fisheries and stock rebuilding, Munro (2010) contends that harvest timing is as important as stock size. Without endangering the lost potential in fisheries, Homans and Wilen (2005) modeled potential market effects of changing harvest schedules and their impact on optimal management. An MSY target with zero or negative profits may not be sustainable for the community (fishery) (Kompas et al., 2009). However, MSY is still used to rebuild stocks. They show that harvesting below the MSY maximizes benefits. However, compared to MEY, MSY biomass size depends on species growth rate rather than traditional economic factors like prices, costs, or discount rates. Ward and Kelly (2009) argue that even if simple biological stock assessments are accurate, they are not good indicators of fisheries management success or failure because managers must balance multiple objectives. Bioeconomic models can require a lot of data and advanced problem-solving skills (Smith & Wilen, 2003). While applied bioeconomic models require more data, the level of data required varies by model.

MEY can be calculated using simple surplus production models and fish prices (Milon et al., 1999). A fishery with distinct cohorts may need price and yield data by age and size, as well as seasonal data (Larkin & Sylvia, 1999). Bioeconomic models can help evaluate alternative rebuilding targets and approaches. That is, short-term policies justified by economic concerns contradict biological advice (Aps et al., 2007). A range of policy-relevant analyses can be conducted using bioeconomic modelling (Whitmarsh et al., 2000; CEMARE, 2009). Less focus on target stock level determination and more on management tools that best account for fishermen's incentives while maximizing net societal benefits. The question of whether such systems are universally beneficial (despite the bioeconomic evidence) remains unanswered.

Deterministic bioeconomic models can forecast sustainable harvest levels or the best exploitation path for stocks. This may not be the case in overfished stocks. Establishing explicit management objectives and valuing a fishery's rents can be difficult. De facto, adjusting model-predicted harvest or effort levels may jeopardize the fishery's ability to achieve (Milon et al., 1999; Kompas & Che, 2004). Misuse of the models to support a policy can lead to the unjustified dismissal of the bioeconomic technique. As a result of the uncertainty, it is not reasonable to approach an estimated target slowly (Kompas et al., 2009).

**2.3.2 Concept of Value Chain**

A value chain connects all production, processing, and distribution steps of a product, allowing each step to be evaluated in relation to the previous and following steps (Russel & Hanoomanjee, 2012). The value chain has vertical relationships as the product moves through various processing stages and horizontal relationships as it moves to various markets (Hempel, 2010). A key idea is that all decisions have consequences, regardless of their direction (Hempel, 2010). Equipment suppliers and research organizations produce inputs for upstream activities. Downstream activities include harvesting, processing, and shipping (Hempel, 2010). Each player or actor in the value chain plays a distinct role in the value chain (NiMble, 2005). Legislation, trade agreements, policies, and infrastructure are examples of value chain enabling environments. As a result, the product can advance up the value chain (Hellin & Meijer, 2006). Supporting organizations are institutions, associations, or businesses that help in the efficient operation of a value chain (Hellin & Meijer, 2006).

The Value Chain concept was introduced by Michael Porter in his 1985 book, *"Competitive Advantage: Creating and Sustaining Superior Performance"*. According to Michael Porter, a value chain is a series of activities that work together to provide value to a consumer, whereas a value system is a link between value chains (Porter, 1998). The value chain approach takes into account the value created by a product or service as it moves from raw material to finished product for consumers. According to Kaplinsky and Morris (2000), the value chain is "the full range of activities performed to add value to a product or service from conception to final disposal." It is critical to understand the market before engaging with value chain operators. To approach the value chain, one must first comprehend the interdependence of consumer demands, distribution, and marketing. GTZ (2007)

A Value Chain Analysis is a method for mapping and analyzing value chains (VCA). Figure 2.1 reveals a value chain map that depicts the typical activities that take place along the semi-industrial fishery. A value chain analysis (VCA) is a systematic and analytical tool for understanding the processes at work in an industry or system, as well as highlighting the costs at each stage of the system or chain (Russel & Hanoomanjee, 2012). A well-designed economic study, such as the VCA, can provide a thorough understanding of an industry. Constraints and major issues can be identified, and a general overview of the revenue flow from production to retail can be provided. The VCA can be used to characterize a process from beginning to end and allocate cost proportions, or it can be used as a model in more analytical studies (Porter, 1985). Finally, it is a diagnostic tool that can help with the design of projects and programs that support a value chain. The goal is to achieve a specific development outcome, which can be purely business-related, such as lowering processing costs in a company, or it can be for social development, such as identifying where value addition is needed in the agricultural value chain of a developing region.

According to Gooch (2005), value chain management practices can help businesses improve their competitiveness and stay in business. Based on his research, Porter (1980) discovered that organizations must coordinate operational and support services to be profitable. As a result of these activities, a product's value is increased as it moves downstream to the end market (Gooch, 2005). The value chain model is used to identify sources of competitive advantage. On the other hand, Porter, on the other hand, argued that these sources can only be identified by breaking the firm down into activities. There are two types of activities: primary and secondary activities (M4P, 2008), which assist in increasing the customer's profit margin (Roduner, 2004).

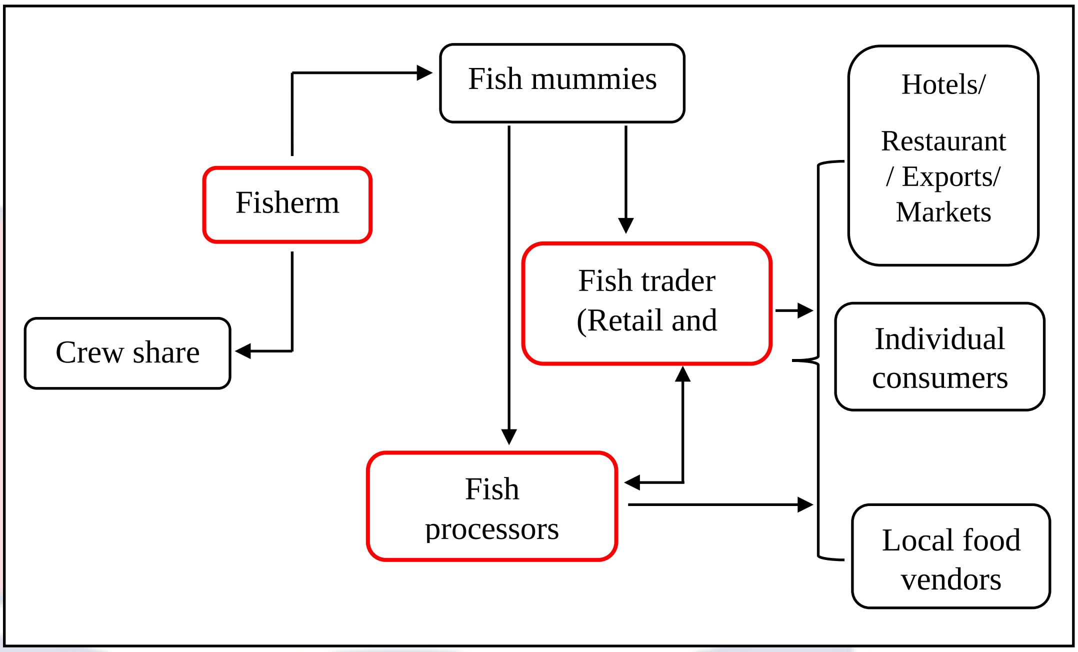


*Figure 1:* A value chain map showing the main actors of the semi-industrial fishery. Source: Field survey, (2020-2021)

Several researchers have recently used the VCA in the fisheries sector. The majority of studies are recent, indicating that this method is still relatively new in fisheries science. Aquaculture, as well as artisanal and industrial fisheries, are examples of applications for the VCA. In developing countries, the VCA is now widely used to study value addition in fisheries. Increased economic benefits and job opportunities are critical concepts that encourage value addition (Rosales et al., 2017). As a result, VCAs may assist researchers in better understanding a commodity chain and, as a result, identifying realistic opportunities to increase income or profit. When the value chain is mapped, certain aspects, such as revenue distribution, can be examined in greater depth. Prices and costs show how much actors earn, spend, and occasionally lose in their business (O'Neil, 2013). The distribution of profits, losses, and costs can be seen by examining the finances at each stage of the value chain. In revenue distribution studies, the total cost, the purchase price, the selling price, the profit, the margin, and the added cost are all important concepts to understand. Fisheries value chain analysis and bioeconomics are linked because they both aim to understand and optimize the use of fishery resources. A value chain analysis can help identify ways to improve the efficiency of the production and distribution of fishery products, which can increase the economic benefits of the fishery sector. However, this must be done in a way that takes into account the ecological sustainability of the fishery resources, which is the focus of bioeconomics

The fishery value chain actors and their roles in Ghana have received the attention of researchers and practitioners over the years as shown in *Fig.1* (Odotei, 1991; Overa, 1993; Gordon et al., 2011; Aheto et al., 2012; Entee, 2015b; Nunoo et al., 2015; Samey, 2015; Torell et al., 2015; Quagrainie & Chu, 2019; Ameyaw et al., 2020). The actors in the semi industrial value chain play different roles, even though some of these roles are minor. Yet, each actor has a different interest, which makes management of the sector a complex task. The actors include boat owners, fishers, fish mummies, fish processors, and traders. The chain of supply builds on the gender sharing of work tasks. The harvesting aspect is primarily done by men, while women control the post-harvest part of the value chain (Overa, 1993).

**Boat owners and operators**

Semi-industrial fleet owners are currently dominated by men. The boat operators purchase the inputs (boats, engines, and gear) for the fishing operation. They also employ fishers for the harvesting activities, and some of them participate in fishing (Gordon et al., 2011). The number of crew employed per vessel ranges between 8 and 24 based on the size and purpose of the boat

(Tobey et al., 2016). The boatowner foots the cost of fishing operations (fuel, food, water, and other miscellaneous) through the support of the fish mummies, family, friends, and, in rare cases, bank loans.

**Fishermen**

The fishers are the crew employed by the boat owners. Fishing is traditionally carried out by men. They typically fish daily, except on Tuesdays, which are observed as traditional fishing holidays in most fishing communities (Gordon et al., 2011). A fishing trip can take 1 to 3 days, depending on the amount of fuel and ice for catch preservation (Gordon et al., 2011; Tobey et al., 2016). Fishers operate throughout the year and are known to land large sums of catch during the upwelling seasons. The major upwelling season is from July to September, and the minor bumper season is February and March. The fishers' fish little or not at other times when catches do not cover fishing expenditure. However, in recent times, there has been an increase in illegal activities. Fishers use light to attract fish and nets with tiny mesh sizes to catch even juveniles in reasonable quantities all year round (Gordon et al., 2011; Samey, 2015; Dovlo et al., 2016; Afoakwah et al., 2018).

**Fish processors**

Processing of fish is traditionally done by women in the coastal communities. Basically, all species of fish caught in the country can be smoked, and an estimated 70-80% are marketed locally by the processors (Samey, 2015). During the lean season, fish processors buy cold-storage fish and process them or travel to other landing sites where there is the availability of fish for purchase. Fish processors employ manual labor to help in fish processing. The most commonly used processing kilns are the Chorkor kilns, which are easy to use, cheap to build, and fast in smoking, but produce fish with high concentrations of polycyclic aromatic hydrocarbons (PAH) and consume a lot of fuelwood as compared with other kilns (Gordon et al., 2011; Samey, 2015; Kwarteng et al., 2016b). Fish processors find it difficult to adapt to the newly modified kilns known as Ahotor smokers because of their slow rate of heating, hence the relatively shorter shelf life of smoked fish. Although these advanced kilns have been experimented to produce very low PAH and a lower risk of health conditions (Beran, 2018), it has been observed that fish processors along the coast of Ghana resort to the Chorkor smoker as compared to the Ahotor smoker.

**Fish traders**

Fish transported to the market is normally sold to wholesalers or retailers who then sell it to the consumers. Even though fish processors transport the fish to the market, they do not sell it directly to the consumers. There are mostly women who serve as intermediaries (wholesalers and retailers) between consumers and fish processors. In some cases, the fish is sold to wholesalers who then sell it on to retailers before it reaches the final consumer (Overa, 1993; Tetteh, 2007; Gordon et al., 2011).

## 2.4 Empirical Review

Several attempts to conserve renewable natural resources have been initiated using various management tools, from which bioeconomic models cannot be exempted. The mathematical and dynamic bioeconomic models concerning the management of fisheries resources have been systematically developed by Clark (1990, 2006b) based on Schaefer (1954) and Gordon (1954). Clark and Munro (1975) extended the Gordon-Schaefer model by making it non-autonomous and nonlinear, which was static in nature. Studies conducted by Lleonart and Merino (2010) also extended the G-S model by proposing an alternative way to unregulated or poorly managed fisheries by modeling the biomass yield using a time series data. The conclusion of this study suggested that poorly managed or unregulated fisheries tend to be overexploited but not at a level sufficient to dissipate the net revenue in its entirety.

Bioeconomic models have been used to manage both the single and multi-species fisheries over the years. Saha Ray and Chaudhuri (1996) studied the exploitation of a two-species prey-predator fishery, considering the effects of environmental perturbations on the populations. A study conducted by Waileruny et al. (2014), which employed the surplus production model combined with the Fox algorithm, was used to determine the bioeconomic equilibrium of the skip jack fishery in Banda Sea. The results of the study revealed that, utilization at MEY and MSY level had a narrow range with a small profit difference, which attracted the fishermen to expand the effort. As a result, the skip jack fishery in the Banda Sea may exhaust and this may affect the skip jack business activities. Studies conducted in a single-species fishery by Chaudhuri and Johnson (1990) show that the use of the catch-rate function is more realistic as compared to the CPUE, which is widely used in developing a bioeconomic model for a fishery. The conclusions of this studies suggest that a suitable tax on the landings should be imposed as a tool for governing and regulating the exploitation and optimal harvest policy.

Gumulira et al. (2019) used a simple biomass dynamic model, thus the ASPIC software and Schaefer's (1954) model, to determine the biological and economic reference points of the Usipa fishery in Lake Malawi. The results of the model suggest that the fishery is overexploited and that the catch from recent years is above the MSY and MEY. This informs policymakers to reduce effort to as close as the calculated MSY reference point and possibly to the effort at MEY as calculated in the model. This would aid sustain the exploitation of stock and increase economic rent as well. Aswathy et al. (2009) analysed the bioeconomic condition of the marine fish production in Kerala using the Fox model by assuming the Gompertz function. Recommendations made from this study include improvement of stock through community-based fishery management practices such as marine protected areas and the promotion and expansion of mariculture and aquaculture. Christensen (2009) conducted a study using the revenue and cost from the value chain of a fishery instead of considering only that of the fishing fleet, which has been accepted worldwide. Findings of the study shows that the MEY-level moves closer to, but slightly below, the MSY-level, which indicates that the MSY-level is the more appropriate target to manage a fishery.

Pitcher et al. assessed 33 countries' performance in ecosystem-based fisheries in three fields (principles, criteria and implantation) using quantitative ordination including uncertainty (2009). This 33-country EBM fisheries performance was not evaluated empirically. For example, Pomeroy et al. (2009) advocated for improved fisheries statistics, a coordinated and integrated approach to resource management, resource restoration, economic and community development, and new governance. The recommendations were made without using any fisheries statistics.

# CHAPTER THREE

# MATERIALS AND METHODS

The chapter provides an in-depth description and explanation of relevant methods that were employed in carrying out the research. These methods were used to test the hypotheses that the biological and economic reference points of the semi-industrial fishery have not been exceeded; that there are no differences in resource economic rents between MSY and MEY of the fishery; and that there are no economic losses incurred along the value chain of the fishery, which might not lead to the collapse of this sector. The chapter is divided into four sections, covering: (i)Study Area; (ii) Data sources and collection, which describes the procedures and processes that were used in obtaining the data; (iii) Fisheries and bioeconomic model details some models adopted and used to estimate some parameters and conditions: (iv) Data analysis which describes in detail how catch-effort data, bioeconomic data, and value chain analysis were analyzed, including some computer programs.

## 3.1 Study Area

Ghana's coastline extends for 550 km which lies between latitudes of 4° and 12° N and longitude 4°W and 2°E (Koranteng, 2001). The Exclusive Economic Zone of Ghana is about 218,100 km$^2$ (DoF, 2003) and has a continental shelf with a length of 24,300 km (Ayivi, 2012) which serves a fishing population of over 107,518 (Amador et al., 2006). The semi-industrial fishery has eight (8) landing sites along Ghana's coast. The study was conducted within three (3) selected landing sites of the semi-industrial fleets, namely, Tema Fishing Harbor, Elmina fish landing quay, and Sekondi Fishing Harbor (also known as Albert Bosomtwi-Sam (ABS) Fishing Harbor). These landing sites are known to be the largest along the coast of Ghana and contribute significantly to the fisheries industry (Okpei et al., 2020). Moreover, they are also characterized by well-structured facilities that enable a high number of fleets to berth in these communities as compared to the other communities. The coastal zone of Ghana may be divided into three geomorphological areas, which are: the Eastern coast (128 km), the Central coast (330 km) and the Western coast (93 km) (Yankson & Obodai, 1999).

The study of the eastern coast of Ghana's shoreline was conducted at Tema Fishing Harbor with geographical coordinates of 5.6333° N, 0.0167° W. Fishing and its related activities form the primary livelihoods of most inhabitants around the Tema fishing harbor with few engaged in alternate livelihoods such as petty trading. On the central coast of Ghana, the study focused on Elmina landing beach, which is located at 5.0931°N, 1.3383°W. It is the third largest landing site in Ghana after Tema and Sekondi fishing harbors, making a significant contribution of about 15% of the country's total fishery production (Doortmont, 2003). On the western coast, the study was carried out at the Albert Bosomtwi-Sam fishing harbor. The harbor is characterized by a 200m long breakwater and a 76m long groyne, which helps in the berthing of fleets. It lies at longitude 4° 92'N and latitude 1° 77'W.

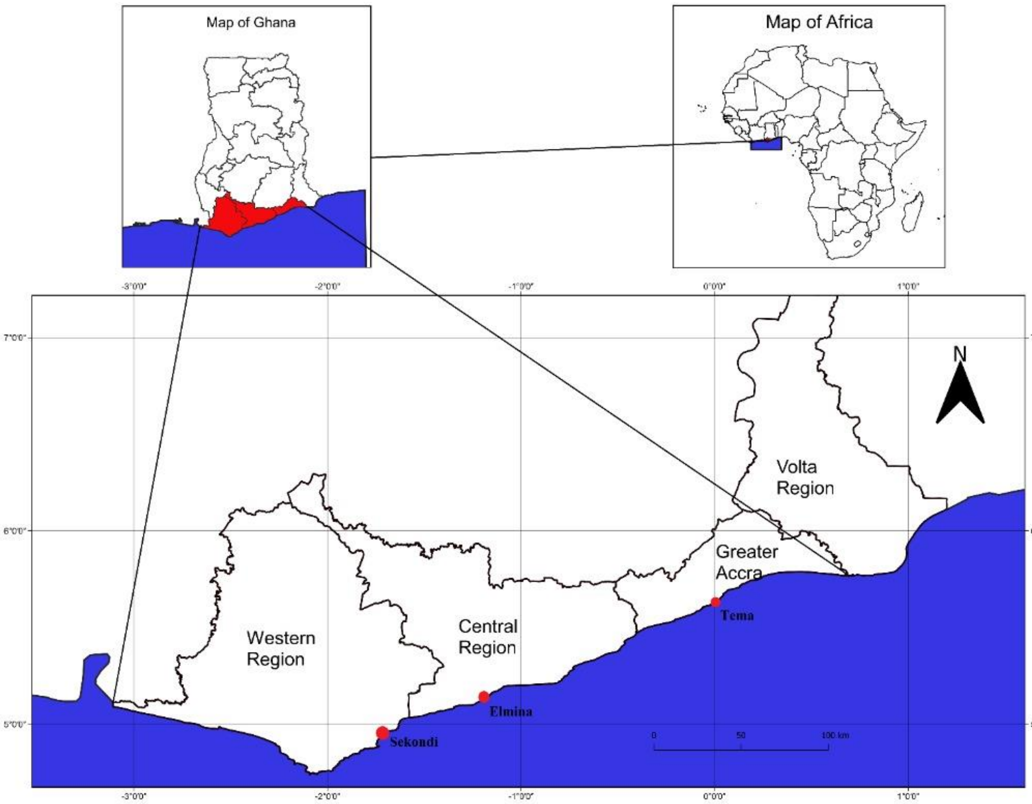


*Figure 2:* Map of the study area, showing the sampling sites

### 3.2 Data Collection

For the purpose of this research, data was gathered from a variety of sources. The data required was classified into three categories: biological, effort, and economic information.

*Biological data*

Historical production and annual catch data (in tonnes, T) of semi-industrial vessels, for the period 1980 to 2018 were collected from the Fisheries Scientific and Survey Division (FSSD) of the Fisheries Commission (FC), under the Ministry of Fisheries and Aquaculture Development of Ghana.

*Effort data*

The fishing effort used in this study was based on data on the number of licensed vessels as reported by FSSD from 1980-2018 and the number of days spent at sea (2005-2019). For semi-industrial fleet, both the number of licensed vessels and days spent at sea were used as measures of fishing effort. The number of fishermen in each active licensed vessel was recorded at each landing during the survey. These were used to calculate each vessel's CPUE.

*Economic data*

Evaluation of the economics of the semi-industrial fishery was estimated based on the total costs, revenues, and profits, which included the harvest effort and fish price from data from the field and FSSD collected. However, the costs incurred by the "typical" vessels were used in calculating the total costs incurred by other vessels. The "typical" vessels selected for the study had comparable technical characteristics (engine horse power, length overall (LOA) and gear type). "Typical" vessels carry out fishing expeditions or trips 15 to 18 days per month with an average of two days at sea. They tend to carry out fishing expeditions for 11 months a year, with one month designated for "closed season". Therefore, the number of fishing days per year was 182 days.

In order to select fisherfolk (fish traders, fish processors, and fishermen) in the three coastal communities for the collection of socioeconomic data, a simple random sampling approach was employed. The socioeconomic data was collected through structured interviews with a total of 100 fishermen and 50 fish processors. Also, a total of 100 fish traders were purposively selected at the landing site and near-by markets, adding up to a total of 250 respondents. Lastly, to complement the field data undertaken, a focus group discussion with the major actors and stakeholders of the coastal fisheries value chain was held.

A survey with closed and open-ended questions about the respondents' socioeconomic profile (e.g., work experience, fishing income, and alternative livelihoods) and fishing activity (e.g., characteristics of boats and gears, trip length, exploited species, fish price, processing, and marketing) guided the interviews. The average price per kilogram of each species, at the first-hand market, was recorded in the national currency (GHC). The interviews took place at the respondents' workplaces, at the landing sites, and at the fish markets.

### 3.2.1. Sample size

A multi-stage sampling technique was deployed, where Greater Accra, Central Region and Western Region were purposively selected. Three landing harbors were systematically selected which included Elmina fishing harbor, Sekondi fishing harbor, and Tema fishing harbor. Simple random sampling was employed in the selection of the 250 respondents. 100 fishermen, 50 fish processors and 100 fish traders were randomly selected from the study area. A pilot survey was carried out in the study are to pre-test questionnaires. New information from the pilot survey were used to update questionnaires before moving to the field for data collection.

## 3.3 Data Analysis

### 3.3.1 Catch Per Unit Effort (CPUE)

CPUE is an indirect measure of the abundance of a target species that is used in long term monitoring of a fishery. The CPUE was calculated in order to ascertain the abundance and level of fishery resource utilization in the system. The data on both production (catch) and efforts were computed. The number of fishing days and licensed fishing boats were the focus of this effort. The CPUE was 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, $Catch_t$ represent the fish catchment in year, t as well as $Effort_t$ is the effort in year t.

The rate of change in CPUE for a particular year $Y_1$ was calculated as the difference between the CPUE of that year ($CPUE_1$) and the previous year, $Y_o$, ($CPUE_0$) divided by $CPUE_1$, and expressed in decimals.

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

### 3.3.2 Fisheries and Bioeconomic Models

Cochrane (2002) describes fisheries management as an integrated procedure that aims to attain economic, ecological, biological, and social objectives. As a result, predictive fisheries models are used to forecast the evolution of a resource's abundance and provide management guidance for a fishery (Defeo & Seijo, 1999; Ulrich et al., 2002). This is needed in order to take timely development and management measures (Garcia, 1981). In cases where comprehensive population dynamic model data is not readily available (e.g. mortalities, fish growth, age, class structure, and recruitment), simple biological predictive models like the Gordon-Schaefer Model could be employed, since they only utilize historical catch and effort data, which are most often available to analyse fishery dynamics (Sparre & Venema,1992).

**Estimation of parameters**

Three key functional relationships are required in this fisheries model, which include: i. biomass growth function, ii. harvest function and iii. fisheries profit function. Nonetheless, “the Gordon-Schaefer Model” (Graham, 1935; Gordon, 1954; Anderson, 1979; Anderson & Seijo, 2010) were used in the estimation of MSY. The modelling approach employed in this study is based on the works of Verhulst (1838), but often associated to Gordon-Schaefer (1954) because of the earlier works done in bioeconomic modeling.

**Specific functional forms**

The key functional relationships in the fisheries model employed can precisely be expressed as;

i. Biomass growth function

$$\dot{x} = G\,(X) - Y \qquad \text{(Net Biomass growth)} \qquad (1)$$

where *X* denotes biomass, $\dot{x}$ represents the biomass growth, and *Y* is the yield or harvest from fishing. Natural biomass growth is the function G(*X*)

ii. Harvest function

$$Y = y\,(E, X) \qquad \text{(Harvesting function)} \qquad (2)$$

where, *y*, represent yield or harvest which is dependent on fishing effort, *E*, and the biomass, *X* to which the fishing is applied.

iii. Profit function

$$\pi = p.Y\,(E, X) - C\,(y,E) - fk \quad \text{(Net Benefit or Profit function)} \qquad (3)$$

where *p* denotes the landed fish unit price, *C (y, E)* represents the variable cost, and *fk* is the fixed cost. The revenue for the fishing activity is also denoted by the expression *p.Y* (*E, X*). The profit function is based on the price of the harvested fish landings, the sustainable fish yield and the fishing operation costs.

The natural growth function *G (X)*, the harvest function *Y (E, X)* and the cost function *C (e)* are the three basic functions deployed in the model and expressed as follows.

*The biomass growth function*

The fish stock, measured in terms of biomass, is the system's natural capital. Its potential to procreate and provide new recruits, as well as growth rates, natural mortality rates, and fishing mortality rates, are all important factors to consider. These populations cannot grow indefinitely due to the constraints in environmental factors and food availability. This has to do relation with population size and marginal growth. Thus, when the population size increases, marginal growth decreases and vice versa. This is known as density-dependent growth. Such populations' biological growth functions can be expressed as follows:

$$G(X) = rX - sX^2 \qquad (4)$$

Where *X*, is stock size, *G (X)* represents natural biomass growth, *r* represents the population's intrinsic growth rate, and *s* represents the growth rate to carrying capacity ratio. This is the logistic growth equation, also known as the parabolic equation (Anderson & Seijo, 2010).

The parameter *s* can be expressed in terms of environmental carrying capacity, *K*, and intrinsic growth, as follows:

$$S = -\frac{r}{K} \qquad (5)$$

Substituting *S* in equation (5) into equation (4) the expression of the logistic growth equation is derived and expressed as:

$$G(X) = rX\left\{1 - \frac{X}{K}\right\} \qquad (6)$$

The term *rX* in the equation, reveals that growth is proportional to stock size, whereas the term ($1-\frac{X}{K}$) introduces the complexity that growth declines with stock density, $\frac{X}{K}$ , and eventually falls to zero when the stock size equals the carrying capacity. By setting the first order derivative of equation (6) to zero and solving for X, the maximum natural growth and corresponding stock size were calculated mathematically:

$$\frac{dF(X)}{dX} = r\left\{1 - \frac{2X}{K}\right\} = 0 \qquad (7)$$

Stock size at maximum sustainable yield is:

$$X_{MSY} = \frac{K}{2} \qquad (8)$$

Because recruitment increases with stock size, the effect on individual growth increases with stock size. Recruitment and individual growth slow as the stock approaches environmental carrying capacity. It is proportional to stock size and eventually reaches zero. This equation assumes that effort removes a fixed proportion of the stock.

$$H(E, X) = qEX \qquad (9)$$

*H (E, X)* is the biomass catch per unit effort; *E* represents fishing effort, and *q* is a constant catchability coefficient.

When population and harvest are equal, surplus growth is expressed as a rate of change of biomass, $\frac{dx}{dt} = G(X) - H(E, X) = 0$

Based on equation (6) and (9) it implies that, $qEX = \left\{1 - \frac{X}{K}\right\}$ , thus, biomass at equilibrium, X is expressed as:

$$X = K\left\{1 - \frac{qE}{r}\right\} \qquad (10)$$

Equation (10) is inserted into equation (9) to give the long-term catch equation.

$$H(E) = qKE\left\{1 - \frac{qE}{r}\right\} = qKE - \frac{q^2KE^2}{r} \qquad (11)$$

To derive the relationship between CPUE and fishing effort, which is linear, both sides of (10) were divided by effort (E) and expressed as:

$$\text{CPUE} = \frac{H}{E} = qK - \frac{q^2KE}{r} \qquad (12)$$

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

$$H(E) = aE + bE^2 \qquad (13)$$

Where $a = qK$ and $b = \frac{q^2K}{r}$. Using a linear regression of $\frac{H}{E}$ against E (Conrad and Clark, 1994), the estimated coefficients a and b can be derived, where: $a$ = intercept of plot; $b$ = slope;

The availability of catch and effort data over a period of time of the semi-industrial fishery allowed the parameters $a$ and $b$ to be estimated through a linear regression of the catch per unit effort on the relative fishing effort data.

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

$$K = \frac{a}{q} \qquad (14)$$

$$r = \left\{\frac{q^2K}{b}\right\} \qquad (15)$$

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

$$CPUE = a + bE \qquad (16)$$

*Estimation of reference points*

The MEY, OAY, and MSY were calculated using biological and economic parameters. These performance measures were analyzed for future fisheries and ecosystem development.

*Maximum Sustainable Yield (MSY)*

In equation (13), the partial derivative of *H* with respect to *E* is set to zero to obtain the effort at maximum sustainable yield:

$$E_{MSY} = \left\{\frac{-a}{2b}\right\} \quad (17)$$

And the output at MSY is:

$$\text{MSY} = \left\{\frac{-a^2}{4b}\right\} \quad (18)$$

*The Harvest Function*

The deliberate effort in exploiting fishery resources by fishermen leads to the catch per vessel. Taking into account how exploitation impacts fish population dynamics, thus, the changes in stock size in relation to harvest can be expressed as:

$$X_{t+1} = X_t + G(X_t) - Harvest_t \quad (19)$$

This indicates that the stock size for the subsequent year will be at equilibrium with the stock size this year minus the catch of this year and expressed as $G(X_t) = Harvest_t$.

Supposing each unit of effort harvested equals the desired amount of stock size, the stock size (x) at equilibrium can be expressed in the form of carrying capacity (K), catchability coefficient (q), and fishing effort (E) for the harvesting model in conformance with the generalized (Schaefer, 1954) (Anderson & Seijo, 2010) model, represented in short-term yield as;

$$Y_t = qE_t X_t \quad (20)$$

Where q denotes the catchability coefficient and $E_t$ also represents the fishing effort. The catchability coefficient is a physical representation of the technology used to catch fish. Because of technological and management changes, the catchability coefficient evolves over time.

Generalized Schaefer:

$$Y(x, e) = qE^{\alpha} X^{\beta} \quad (21)$$

Thus, coefficient β, denotes the degree of schooling behavior by the fish, where β Є [0, 1] and 0 < α ≤ 1

*The cost and profit function*

As a result, the cost of fishing operation (effort) will be a linear function of the magnitude of effort. The annual cost, *C(e)* of fishing, is proportional to effort (e). The fishing boats were assumed to be homogeneous for this study. The cost function is written as:

$$C(e) + fk \quad (22)$$

Where *C* represent the marginal costs and *f k* represent the fixed costs

The net benefits function assumes a constant price p, which when multiplied by harvests yields the fishery revenues (*R*). Profits ($\pi$) however are calculated by deducting total costs (*C (e)*) from the marginal revenues (R) resulting in the following:

$$R = py(e, x) \quad (23)$$

$$C\ (e) = c\ e + f\,k \tag{24}$$

$$C = \frac{c_1 e + c_2 e + c_3 e + c_4 e + \cdots}{e_{no.of\ fishing\ day\ per\ vessel}}$$

Where $c_1$ represents the fuel cost and engine oil, $c_2$ denotes the cost of ice for fish preservation at sea, $c_3$ denotes the cost of food, $c_4$ is the cost fresh water and $c_5$ is the wages of crew

$$f\,k = \sum(f\,k_1 + f\,k_2 + f\,k_3 \ldots \ldots .) \, E$$

Where $f\,k_1$ is the value of vessel depreciation, $f\,k_2$ is the value of boat registration and license, and $f\,k_3$ is the cost of maintaining a vessel and fishing gear and $E$ represents the effort (number of licensed vessels).

The short-run total cost $C_s$ may be represented:

$$C_s\ (e, y) = C_s\ e + \delta\ (p\ y\ e\ \text{-}C_s\ e) + f\,k \tag{25}$$

Where $\delta$ $(p\ y\ e\ \text{-}C_s\ e)$ represents the share of the crew, and $1 > \delta \geq 0$, and $C_s\ e$ represents the variable cost per fishing day in a short-run option, the following is represented:

The long-run total cost $C_l$ can be expressed as:

$$C_l\ (e, y) = C_l\ e + \delta\ (p\ y\ e\ \text{-}C_l\ e) + f\,k_l e \tag{26}$$

Where $C_l\ e$ represents the variable cost per fishing day in a long-run option, and the $f\,k_l$ represents the fixed cost in a long run option that can be expressed:

$$f\,k_l = \frac{fk}{E}\frac{1}{DAS}$$

DAS represents the average number of days spent at sea per vessel each year; which is estimated to be 182 days at sea per vessel each year based on available fishing effort data.

The profit is a function of total revenue, $R = py(e)$ minus the total cost $C(e)$ which is expressed as:

$$\pi(e,x) = p\,y(e,x) - C(e,y) \tag{27}$$

Or, the profits at Short-run $\pi_s$ can be expressed:

$$\pi_s(e,x) = p\,(y(e,x)) - (1\text{-}\delta).(py(e,x) - C_s\,e) - C_s\,e - fk \tag{28}$$

The profits at long-run $\pi_l$ can be expressed:

$$\pi_l(e,x) = p\,(y(e,x)) - (1\text{-}\delta).(py(e,x) - C_l\,e) - C_l\,e - fk_l\,e$$

Economic Model

Biological models of fisheries support economic models, which makes it an important component for the development of an effective economic model for managing a fishery (Munro, 1982). The catch-effort function (equation 13) can be converted to define the revenue as a function of standardized effort units based on constant price and unit cost of effort. In other words, the total revenue (TR) in equilibrium was estimated using the formulae as follows

$$TR(E) = p.\,H(E) \tag{29}$$

Where $p$ represents the average price per kilogram of fish.

From the mathematical equation, $p$, denotes the constant price per unit of the harvest. Similarly, total cost (TC) of fishing effort is given as follows:

$$TC(E) = c\,.\,E \tag{30}$$

Where, $c$ is the unit cost of effort. The cost constitutes the fixed, variable, and opportunity costs of capital and labor. Fixed cost is cost incurred independent of the fishing operation whereas the variable costs is dependent on the fishery.

Resource rent at equilibrium is expressed as a function of fishing effort and can be derived from equations (30) and (31) as follows:

$$\Pi(E) = TR\ (E) - TC(E) \qquad (31)$$

*Open Access Equilibrium*

In the case of OAE, the total cost of fishing operation would be at equilibrium to the total revenues generated from the fishery since vessels are considered to be homogenous. The effort at open access was calculated by equating *TC(E) = TR (E)* which yields:

$$E_{OAY} = \frac{\left\{a - \frac{c}{p}\right\}}{b} \qquad (32)$$

*Maximum Economic Yield*

At this point, returns from the fishery is achieved with lower fishing effort. This is because positive economic rent can only be achieved with efforts lower than effort at open access yield. The effort at which profit is maximized at Maximum Economic Yield is obtained by using equation (31), $\Pi(E) = 0$ or $\frac{dTR(E)}{dE} = \frac{dTC(E)}{dE}$.

Therefore, the effort at maximum economic yield is:

$$E_{MEY} = \frac{\left\{a - \frac{c}{p}\right\}}{2b} \qquad (33)$$

**Trend analysis of annual economic rent**

To maximize economic efficiency, both fishing costs and total catch revenues must be considered. The catch-effort relationship must be used to define revenues and costs. According to Seijo et al. (1998), the annual economic rent can be interpreted as follows: Given a price, *p*, as per unit of fish harvested each year, the total revenue, TR, was calculated as follows:

$$TR = pH \tag{34}$$

where *TR* denotes the total revenue, *p* represents the average price of landed fish per year and *H* is the harvest/yield per year.

The total costs of fishing operation, *TC* (including TVC and TFC) of can be estimated when cost, *c*, per unit of effort per year is given. Thus, TC can be expressed as:

$$TC = c. E \tag{35}$$

Where *TC* represents the total cost of fishing, *c* denotes the unit cost of fishing per year and *E* denotes the effort level of fishing per year.

The sustainable economic rent generated by a fishery at any given level of fishing effort can be described as the variation between total revenue and total cost of fishing.

$$\Pi(E) = TR(E) - TC(E) \tag{36}$$

The total revenue function was based on actual catch and price data per year. The total cost function included fuel, crew wages, food, annual license, maintenance, gear, and boat costs. Semi-industrial fleet is estimated to operate 15–18 days per month and, as such, 182 days per year, which was used in calculating the annual variable cost for the fishery.

**Estimation of present value**

To compare money over time, the present value of a future revenue stream was estimated. Because the future sum could not be invested immediately, the estimated values were discounted. The study used the Bank of Ghana's (BoG) discount rate (13.5%) for 2021. Discounting does not mean future earnings are lost, but that they are not worth the same now as they will be in the future due to future catch risk and uncertainty. The present value of future revenue was estimated for a 12-year period from 2018 to 2030. Seijo et al. (1998) defined present value as follows:

$$PV_{\pi} = \frac{TR\ (t) - TC\ (t)}{(1+i)^t} = \frac{\pi\ (t)}{(1+i)^t} \qquad (37)$$

Where *i* denotes the social rate of discount and PV represents the present value profit.

Net present value (NPV) which ascertains the viability of semi –industrial fishing through time was estimated. The NPV was obtained according to Sumaila and Suatoni, (2005):

$$PV_{\pi} = \frac{P_1}{(1+i)^1} + \frac{P_2}{(1+i)^2} + \frac{P_3}{(1+i)^3} + \frac{P_4}{(1+i)^4} \ldots\ldots\ldots + \frac{P_{10}}{(1+i)^{12}} \qquad (38)$$

where *P* denotes the present value from 1 to 12 years

**Sensitivity Analysis**

The sensitivity analysis involves changing the model and management measure parameters and observing the results. The model used to measure short- and long-term sustainable fisheries is surrounded with risk and uncertainties. The model's parameters, for example, may be inaccurate. A sensitivity analysis of short-run and long-run sustainable fisheries to parameter values was performed to assess the robustness of the parameter misspecification. The levels of variables were defined by variations between -10 % and 25% around the reference value of the main parameters, total cost, unit price, growth rate, and carrying capacity, in analysing the effect of each parameter independently on the response variables (maximizing net benefits).

**Assumptions for the production model**

In most surplus production models, environmental factors are found to be ignored over time. However, this is evident that climatic variables as well as anthropogenic factors driven environmental variability have a notable impact on fisheries stock and its growth. The increasing human activities have become a major factor in progressive environmental degradation on the global scale, particularly biological structures and ecological processes that mean a reduction in the ecosystem's carrying capacity (Zalewski, 2002). Therefore, in the present model, nine environmental scenarios have been considered, including the present situation (Scenario 0). The scenarios were based on the current model where each scenario represents possible climate change and anthropogenic consequences. Recent studies (Alison et al.,2009, Muringai et al., 2021) have shown that the subsequent decline of marine fish stock in Ghanaian waters is as a result of the effect of climate changes. Changes in the physico-chemical parameters of the marine ecosystem can alter productivity and growth rate of the fish stock (Munday et al., 2008; Bajaj, 2017; Sanon et al., 2020). The authors in (Eiden & Heen, 2002) described environmental scenario and possible growth rates. As Ghana is also prone to climate change impact, therefore, we assume that the following nine scenarios are included:

(0) current situation (i.e., *r* and *K* as now),

(1) growth rate change by 10% (i.e., *r*-10% and *K* as now),

(2) growth rate and carrying capacity both change by 10% (i.e., *r*-10% and *K*-10%),

(3) carrying capacity change by 10% (i.e., *r* as now and *K*- 10%),

(4) growth rate change by 25% (i.e., *r*-25% and *K* as now),

(5) carrying capacity by 10% and growth rate by 25% (i.e., *K*-10% and *r*-25%),

(6) carrying capacity change by 25% (i.e., *r* as now and *K*-25%),

(7) growth rate change by 10% and carrying capacity by 25% (i.e., *r*-10% and *K*-25%),

(8) growth rate and carrying capacity both change by 25% (i.e., *r*-25% and *K*-25%).

### 3.3.3 Profitability along the Value Chain of the Industry

*Analytical Procedures*

The data was analyzed using a combination of statistical, budgetary, and parametric analysis. Descriptive analysis, inferential statistics, and profitability indicators are examples of these.

*Descriptive Statistical Tools*

The socio-economic characteristics of the respondents were characterized using frequencies, tables, bar charts, and percentages. Fishing income, alternate source of livelihood, source of capital, working experience, impact of industrial and artisanal fishing activities, etc. were among the characteristics.

*Gross margin analysis* (GM)

The budgetary method was employed to determine the gross margin income at each node of the value chain. The gross margin is described as the variation between total revenue and variable costs incurred (GM). A straight-line method was used to depreciate fixed items. The gross margin was calculated using the budgetary technique.

This technique includes the cost and return analysis at each node of the actors along value chain to determine the profitability of the fishery in the study area.

$$GM = \sum TR - \sum TVC \qquad (39)$$

GM denotes gross margin, TR denotes total revenue, TVC is the total variable cost

$$TR = P_y \cdot Y_i \quad (40)$$

$P_y$ is the unit price of output produced (GHC) and $Y_i$ is the quantity of output

$$TVC = P_x \cdot X \quad (41)$$

$P_x$ is the unit price of variable input (GHC) and $X$ is the quantity of variable input.

$$TC = TVC + TFC \quad (42)$$

TC is the total cost (GHC), TVC is the total variable cost (GHC) and TR is the total revenue (GHC).

$$NFI = GM - TFC \quad (43)$$

NFI is the net farm income (GHC) and TFC is the total fixed cost

$$NROI = \frac{NFI}{TC} \quad (44)$$

NROI is the net returns on investment (GHC)

$$NPM = \frac{NFI}{TR} \quad (45)$$

NPM is the net profit margin (GHC)

$$ESR = \frac{TFC}{TC} \quad (46)$$

ESR is the expense structure ratio (%)

$$BCR = \frac{TR}{TC} \quad (47)$$

BCR is benefit cost ratio (%)

Depreciation values of respondent fixed items were calculated using this formula:

$$D = \frac{c - s}{n} \qquad (48)$$

Where, *S* is the salvage or scrap value, *n* is the estimated life of years, *D* is the annual depreciation and *C* is the cost of asset.

**Statistics and statistical packages**

A confidence interval of 95 % and an alpha level of 0.05 was employed for all inferential statistics. The study also employed the use of descriptive statistics, 1-sample t-test and linear regression for analyses of the data. A number of statistical packages where used in the various analyses, these are Microsoft Excel 2019, Minitab (version 19) and SPSS (version 20).

# CHAPTER FOUR

# RESULTS

The findings originating from the study which focuses on the examination of the annual catch and catch per unit effort, estimation of the biological and economic reference points and conditions, and evaluation of the profitability of the semi -industrial fishery are presented in this chapter. The data have been analyzed and shown in tables and figures and arranged in a sequence that addresses the study objectives. It must be noted that due to unavailability of time series data, the data on number of vessels begins from 1980 to 2018, whereas that of days spent at sea starts from 2005 to 2019. The data on the value of the catch landed also began in 2005 and ended in 2018.

## 4.1 Catch and Catch per Unit Effort (CPUE) Analysis

### 4.1.1 Trends of fishing vessels and total landings of semi-industrial fishery

The number of fishing fleet for the first eight years (1980 to 1988) tended to be fairly stable between 238 and 244. The number of fishing boats decreased sharply from 1989 to 1991, from 244 to 146, a reduction of about 98 fishing boats accounting for 40% decrease in fleet numbers. There was a rise in the number of fishing vessels from 1992 to 2005 (152 to 183) and then to a peak of 339 from 2006 to 2008. In other words, the fleet size in the sector increased by 86% between these years. The situation was different in 2009 to 2017, when it experienced significant fluctuations in fleet size. The highest peak of fleet in the fishery was reached in 2013 with 360 fishing boats. After 2013, the size has significantly declined to a present state of 182 boats in 2018, accounting for about 96% decrease in fleet size as shown in Figure 3. Generally, the number of fishing vessels in the fishery have been increasing over the years.

The trend of annual production by the semi-industrial sector in Ghana increased steadily, with the highest level of production occurring in 1986 (22,000 tonnes). The annual landings since 1986 have experienced a steady decline and fluctuation from 1987 to 2002. The lowest annual production was recorded in 1999 with 5149.4 tonnes, and this can be seen in Figure 4. From 2003 to 2009, semi-industrial annual catch production fluctuated greatly, increasing and decreasing at different times. Another declining trend was noticed for a four-year period (2010 to 2014) after which landings seemed to have stabilized between 11,000 tonnes and 13,000 tonnes, from 2015 to 2017 and later declined in successive years (2018 to 2019) with a percentage of 20% reduction in total annual production.

Earlier in the 1980's, the annual total production was significantly greater (Figure 5) and an increase in catches of about 22,000 tonnes was observed in 1986, before dropping to around 7,400 tonnes during the year 1991. The decline in the catch subsequently precipitated a decrease in the number of boats from 238 to 146 in 1980 and 1991, respectively. The fleet size remained relatively constant until 2006, when the numbers rapidly expanded from 153 to 339 in 2008, with a lower catch of about 6140 tonnes. However, the year 2009 experienced a sudden upsurge in catches of about 12,000 tonnes following some fluctuations in subsequent years. The number of fishing vessels in this sector have declined owing to the fluctuations in targeted stock (Figure 5) from 2009 to 2018. In general, the number of licensed vessels showed an increasing trend within declining annual production.

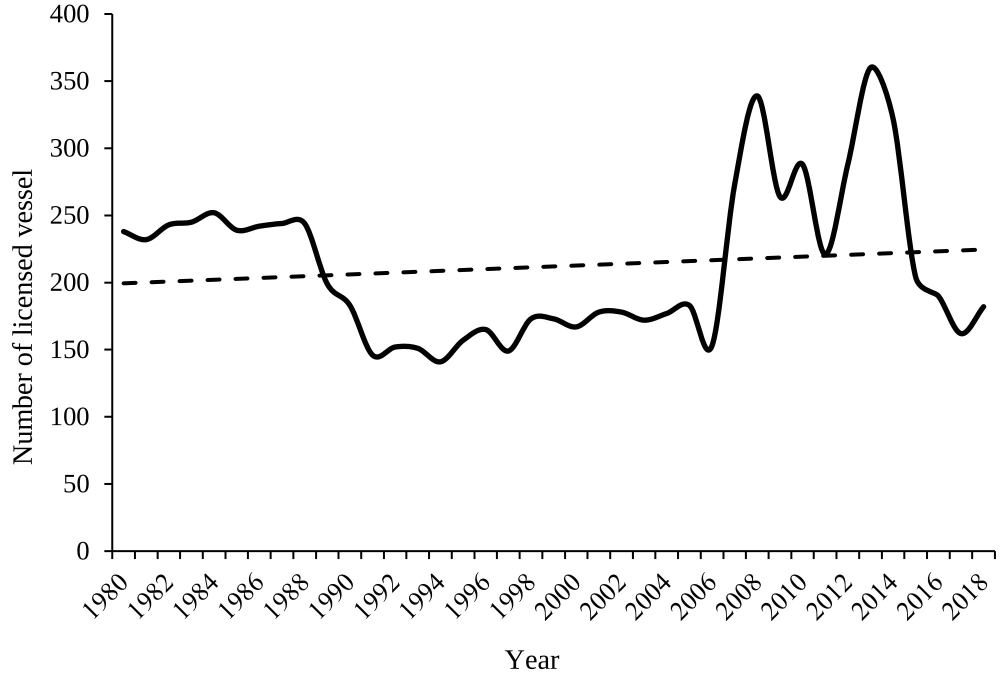


*Figure 3:* Historical trends of licensed fleets of the semi -industrial fishery from 1980 to 2018

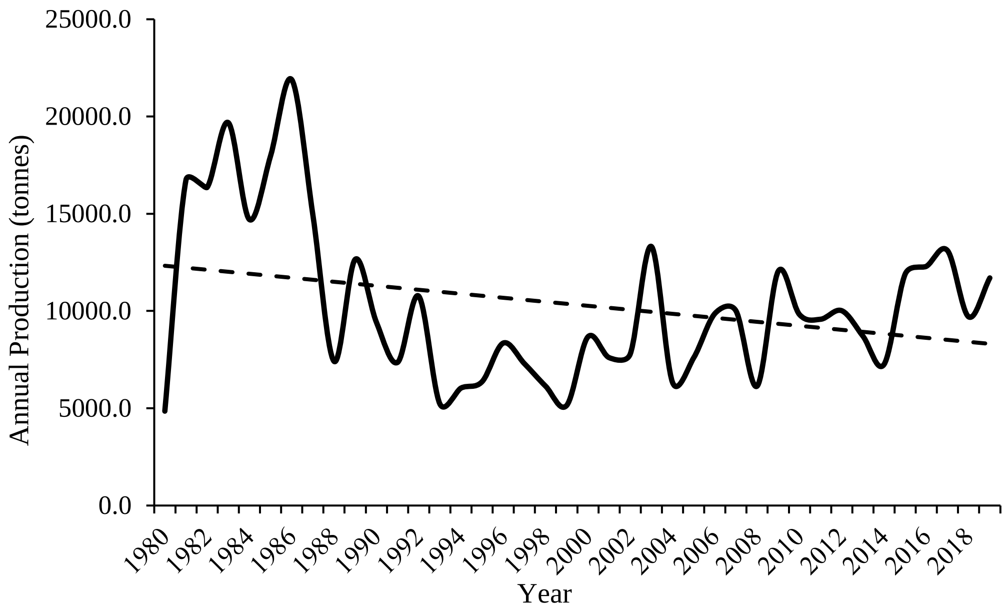


*Figure 4:* Historical catch trends (tonnes) of the semi- industrial fishery during the period 1980 to 2019

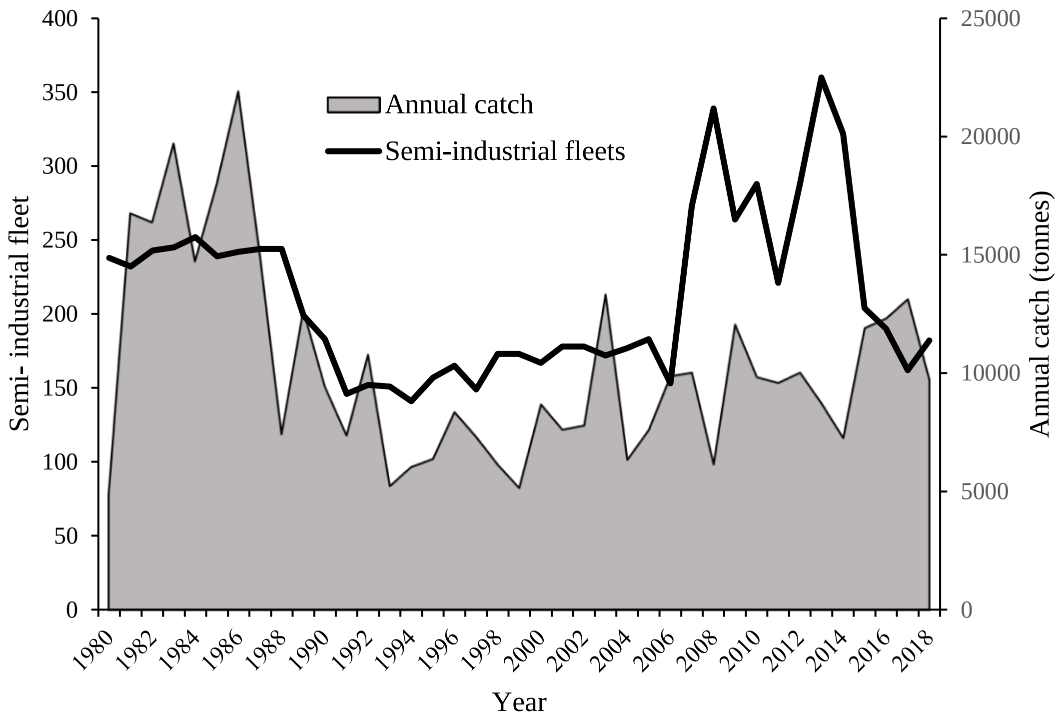


*Figure 5:* Historical trends between annual catch and semi – industrial fleet from 1980 to 2018

### 4.1.2 Total Standard Catch Per Unit Effort Trends

***CPUE for number of licensed vessels***

Figure 6 revealed that the overall catch per unit effort increased from 20.2 to 72.1 between 1980 and 1981, where after it experienced some fluctuations from 1982 to 1984. The highest peak of CPUE (90.5) was attained in 1986. However, this was followed by a decline in CPUE to as low as 30.4 in 1988, as more efforts were put into the fishery. Between 1989 and 2001, the catch per unit effort dropped by 28%. It then increased from 2002 to 2006, reaching a peak of 64.5, accounting for about 48% increase. Between 2006 and 2008 the trend in CPUE exhibited the lowest decline in the fishery of about 73%, thus from 64.5 to 17.2, which is most likely caused by the increase in effort. A four-year fluctuation trend was observed from 2009 to 2013, following which CPUE appeared to have increase sharply from 22.5 to 80.9 in 2014 to 2017. After 2017, the trend gradually declined to 53.3 as shown in Figure 6. In general, the CPUE for number of licensed vessels showed a decreasing trend.

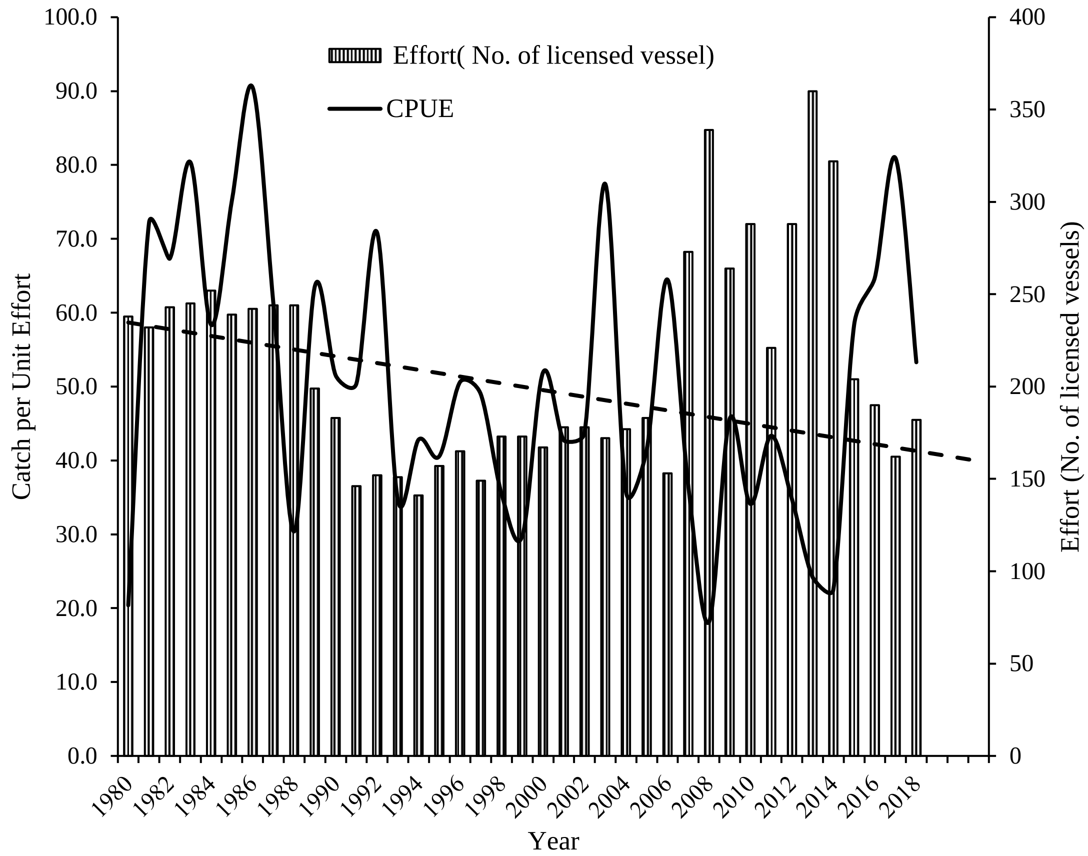


*Figure 6:* Trends between the effort (no. of fishing vessels) and CPUE of semi–industrial fishery during 1980 to 2018

***CPUE for number of days at sea***

The total Catch per Unit Effort tended to increase over the first 7 years (2005-2012) within an index range of 0.04 to 0.12, although there was a slight decline in 2010. The highest CPUE (0.12) was attained in 2012, accounting for an increase in percentage of about 71% from 2009 to 2012. CPUE sharply declined again in a space of a year (2013 to 2014) from 0.12 to 0.08, before gradually increasing again to a peak of 0.12 in 2015. Since then, the catch per unit effort has been fluctuating between 2016 and 2019, as Figure 7 illustrates. Generally, the CPUE trend experienced an increase over time.

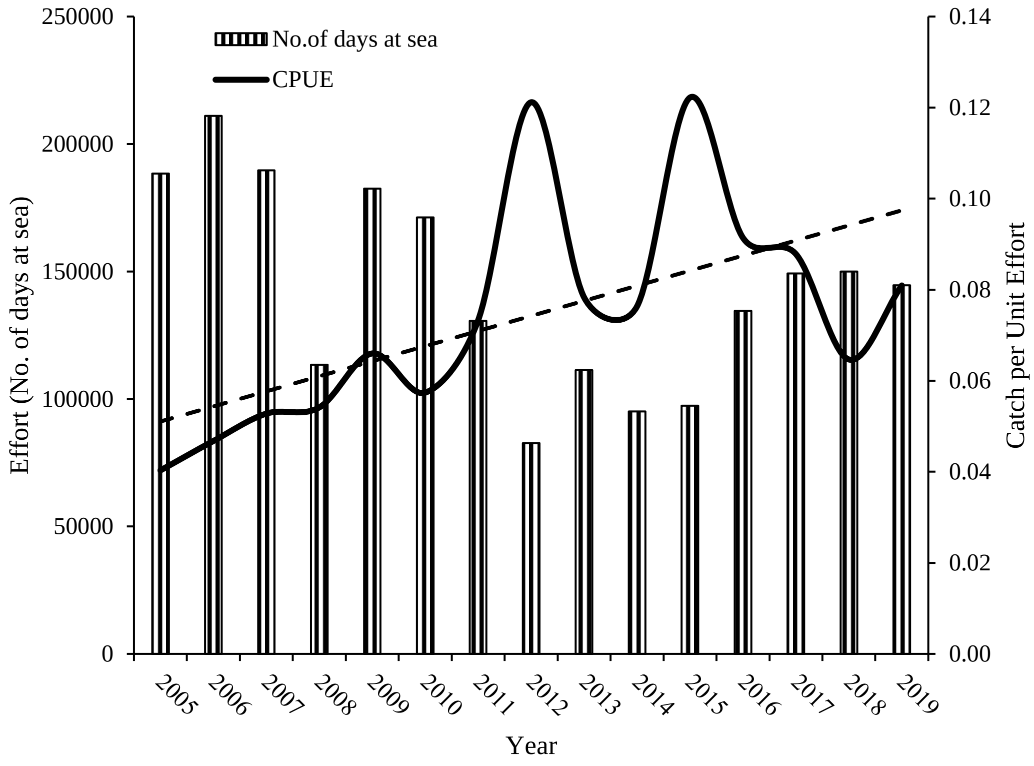


*Figure 7:* Trends between the effort (no. of days at sea) and CPUE of semi-industrial fishery during 2005 to 2019

### 4.1.3 Trends between number of vessels and days spent at sea

Figure 8, presents the trends between the number of licensed vessels and the number of days spent at sea. The trends showed an inverse trend from 2005 to 2011, except in 2010 to 2011 where the trends declined parallelly to each other. A reverse trend was observed between the number of fishing days at sea and the number of licensed fleet from 2016 – 2017 but trends increased parallelly in 2018.

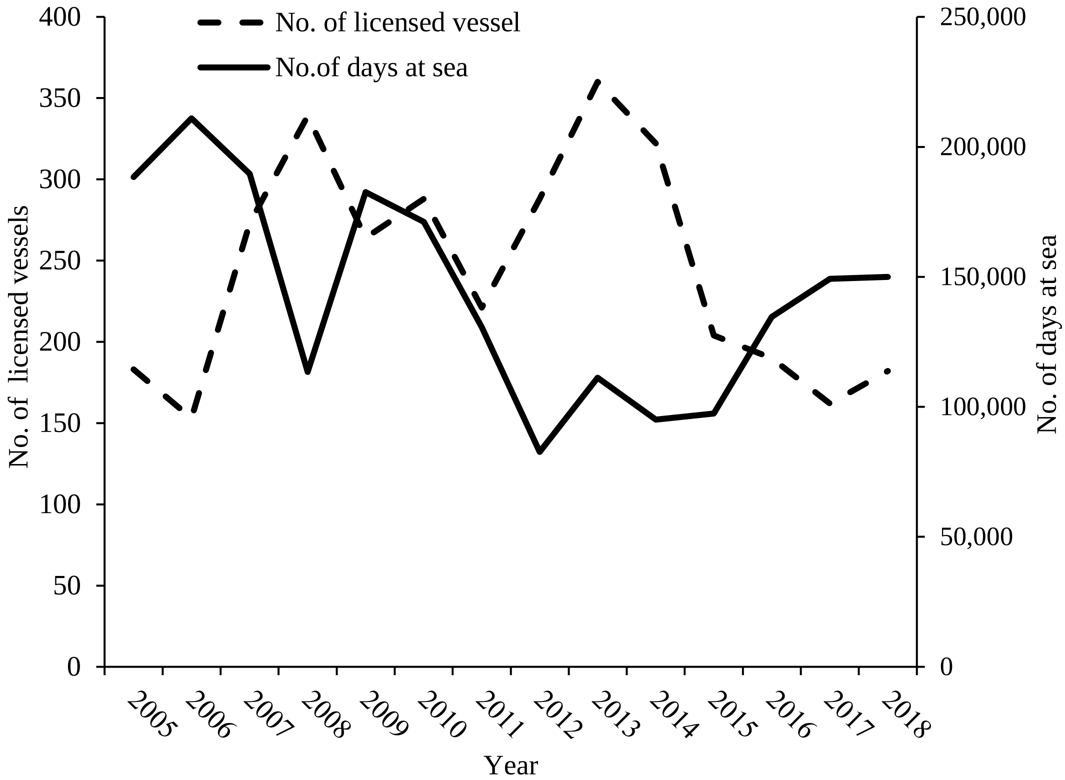


*Figure 8:* Trends between number of days spent at sea and number of fishing vessels from 2005 to 2018

### 4.1.4 Decadal rate of change in CPUE

The decadal rate of change in catch per unit effort, as seen in Figure 9, showed a decline of -0.68 in the first ten (1980–1990) years. The decadal rate of change from 1991 – 2000 recorded the highest index of 0.73, which showed a clear distinction, but there was a significant decline to 0.14, accounting for a percentage of 81% from 2001 to 2010. However, a much more rapid decline was detected from 2001 – 2018 (end of records for this study), which recorded an index of -0.36.

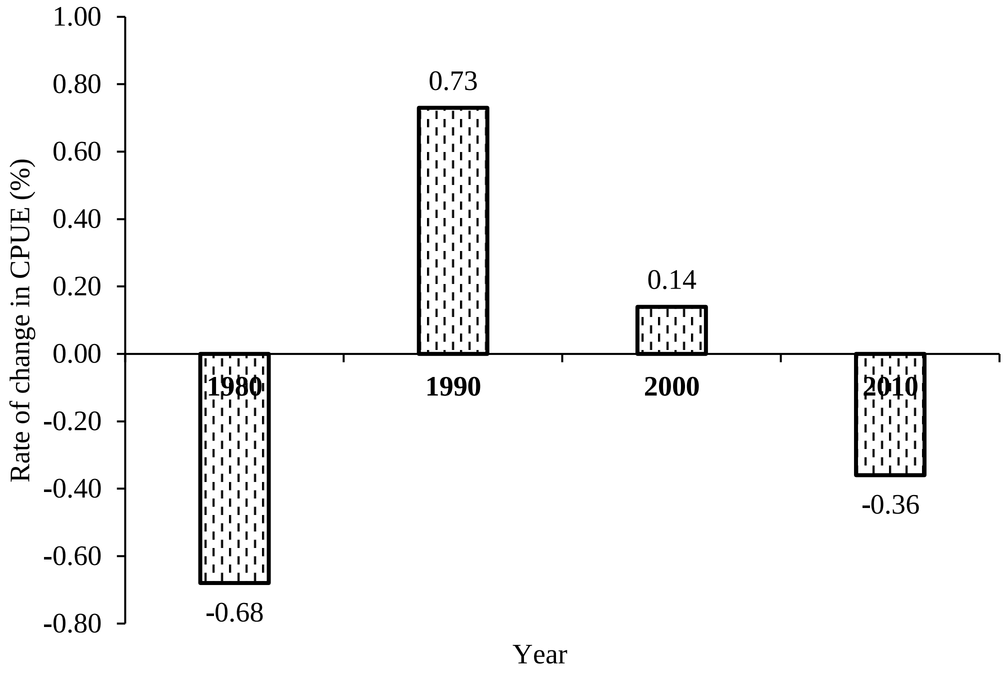


*Figure 9:* Decadal rate of change in CPUE for number of licensed vessels by the semi -industrial fishery from 1980 to 2018

**4.1.5 CPUE of some targeted species by the Semi -industrial fishery**

The available historical catch-effort data described the semi-industrial fishery in Ghana as a multi-species fishery comprising two main fleets (trawlers and purse seiners) targeting demersal and pelagic species at any time. Figure 10, shows the trends of some targeted species of the semi-industrial in Ghanaian waters. The CPUE of round sardinella experienced an increasing trend from 2005 to 2012 (0.122 – 0.429) and from 2013 to 2014, the trend of the CPUE decreased sharply to 0.241, accounting for a decrease of about 44% between these years. Since 2015, the catch per unit effort has experienced a steady decline and fluctuations. The lowest CPUE of round sardinella occurred in 2018 with an index of 0.16. Chub mackerel also recorded a fluctuating and declining trend from 2005 to 2009, with a CPUE range of 0.209 to 0.120. The highest CPUE was recorded in 2011, which increased by 66% from 0.120 in 2010 to 0.358 in 2011. The trend distinctly fluctuated and declined from 2012 to 2018 by 86% where the lowest CPUE was reached, and sharply upsurge to 0.088 in 2019.

Cuttlefish from 2005 to 2019 have experienced a very low CPUE of less than 0.028 in the semi-industrial fishery. The maximum CPUE attained was in 2018, which accounted for an index of 0.032. The CPUE of flat sardines recorded a steadily increasing trend from 2005 to 2011 within a range of 0.018 – 0.166. For three consecutive years, its CPUE fluctuated again, approaching one of its lowest levels (0.007) in 2014. The trend of its CPUE showed yet another significant increase, with a 96% increase from 2014 to 2017 (0.210), the highest CPUE ever recorded. The CPUE dropped sharply by 0.018 in 2018, but it did rise in 2019. (0.108). The CPUE of cassava croaker has also remained continually stable for about a decade and more but have experienced slight fluctuations markedly for the years 2003 and 2015; declining by 27% from 2013 to 2014 and slightly rising to 0.029 in 2015 (Figure 10). Since then, there have been a few spikes, notably in 2016 and 2019.

Generally, the CPUE of shrimps has also remained fairly constant and has experienced slight variations for some years (2005 to 2019). The highest peak of CPUE reached was recorded in the year 2010 with an index of 0.045, and another slight decline for three consecutive years was observed from 2011 to 2013 (0.038- 0.019).

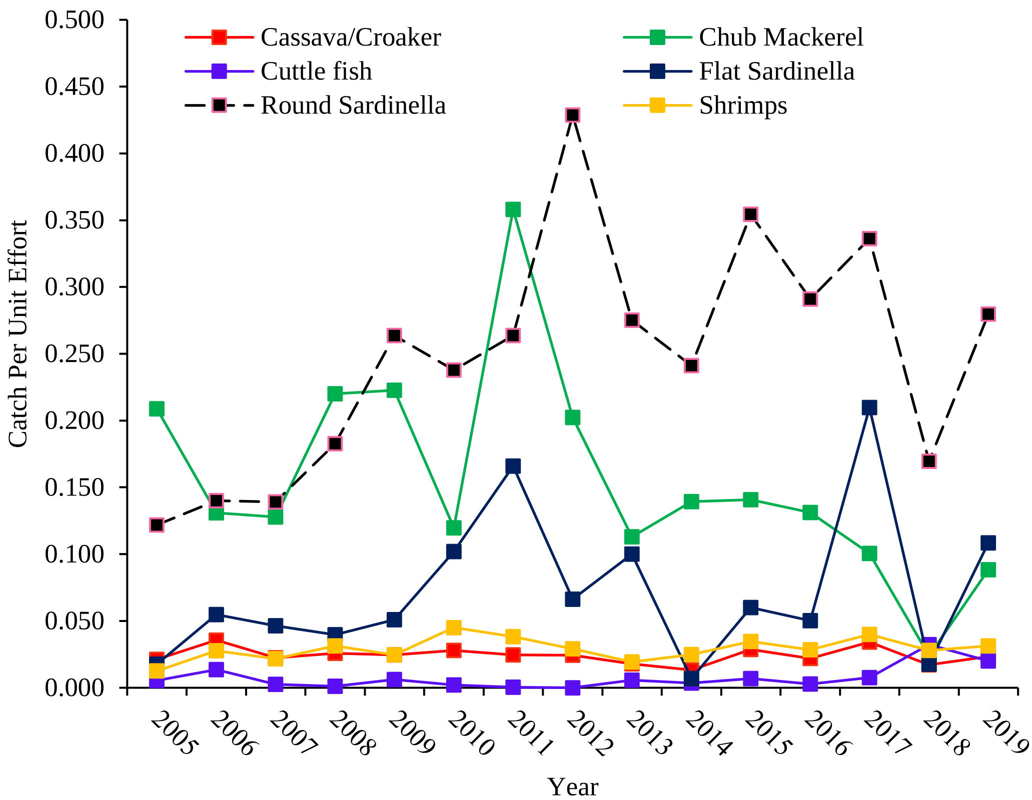


*Figure 10:* CPUE of some targeted species landed by the semi -industrial fishery from 2005 to 2019

### 4.1.6 The value of landing by the semi- industrial fishery

As shown in Figure 11, the trends in the monetary value of fish landings by the semi-industrial fishery over a period of time are shown. The total catch by this sector from 2005-2018 is estimated to be around 150,000 tonnes, which includes both pelagic and demersal stocks. The total value of landings (67,000 GHc – 93,000 GHc) increased rapidly during the first three consecutive years (2005–2007), paralleling an increase in annual production. The highest peak of landing revenue (93, 506 GHc) was attained in 2007, which had an outstanding peak with a total annual production of 10008.96 tonnes. Between 2008 and 2010, the trend in the value of the total landings decline exhibited the lowest landing value in the fishery of about 79%, thus from 76,557 GHc to 15,792 GHc.

Although the annual catch in 2009 was around 12,000 tonnes, which was more than that of 2007 (10008.96 tonnes), it accounted for one of the lowest landing values (16,1684 GHc). However, the condition was quite different from 2011 - 2018, when the annual landing value experienced a notable increasing trend of about 23,065 GHc – 86,187 GHc despite the fluctuating trends in annual production (catch). In other words, the total value of fish landings by this sector of the fishery increased by about 73% between these years.

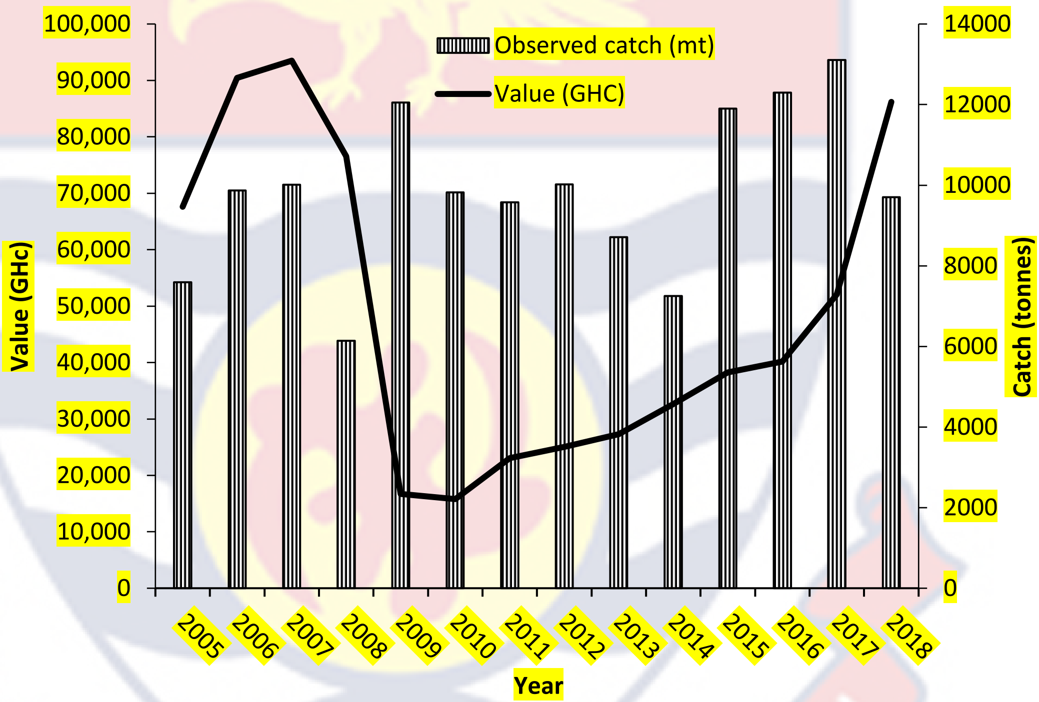


*Figure 11:* Annual catch (tonnes) and the estimated value of the landed catch from the semi – industrial fishery for the period 2005 to 2018 (Source: FSSD, 2021)

## 4.2 Bioeconomic Analysis

### 4.2.1 Yield-effort curve (number of days at sea)

The CPUE-effort regression analysis of the semi-industrial fishery was described by the equation *CPUE* = a – b (f), where *a* = intercept (intrinsic growth rate) and *b* = slope (mortality rate) as shown in Figure 12. The correlation coefficient (*r* = 0.7492) and analysis of variance of the regression analysis ($F$ =16.628, $df$ = 1, $p$ < 0.001) suggested a negative and moderately significant relationship between the CPUE and effort (number of fishing days at sea). The coefficient of determination ($R^2$= 0.5612) of the regression indicated that about 56% of the increase in CPUE could be explained by unit of effort. Again, the correlation between efforts and CPUE showed negative growth in 2005 to *2019; CPUE = 0.141* - $5^{-07}f$, implying that putting more effort will lower the CPUE. The findings revealed that Ghana's semi-industrial fishery is experiencing catchment pressure.

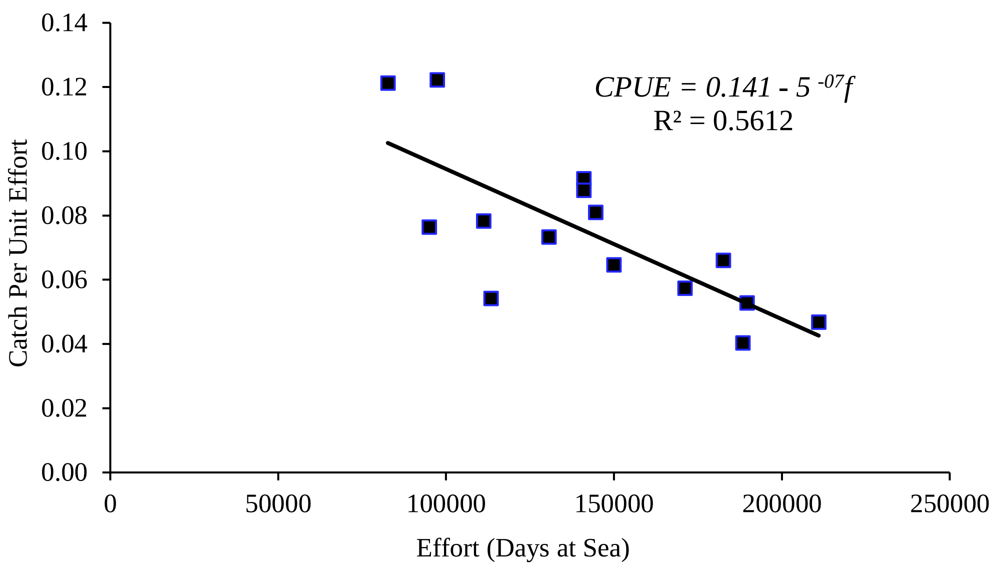


*Figure 12:* Regression Analysis of CPUE on the corresponding Efforts level of the Semi – industrial fishery in Ghana from 2005 to 2019

Figure 13, shows the graph of yield ($Y_t$) versus effort ($E_t$) for the Gordon-Schaefer model fit to the data (using the method of least squares which can be expressed as, Y = a $f$ - b $f^2$). According to the figure, the Maximum Sustainable Yield for Ghana's semi-industrial fishery was 10,740.58 tonnes. The corresponding efforts at MSY was 152,804.14 days at sea. Y= 0.141$f$ - $5^{-07} f^2$

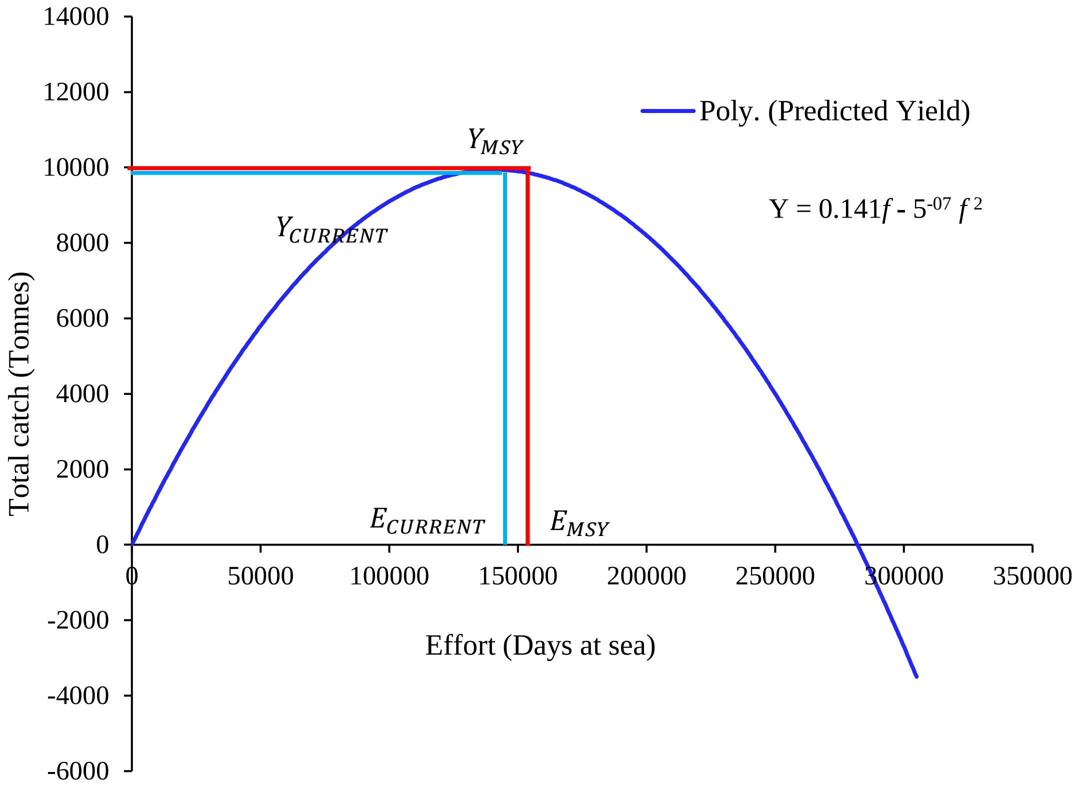


*Figure 13:* Gordon- Schaefer Harvest Curve for the semi-industrial fishery from 2005 to 2019

The values of a and b were estimated as 0.1405798 and -0.000000461 respectively. To derive these values, a regression analysis of CPUE was performed on the corresponding effort level, as shown in Table 1. The lower and upper interval at 95% for *a* was 0.10336 and 0.17779 respectively and that of *b* was 7.1116E-07 and 2.1085E-07. By inserting the estimated values of the *a*, *b* and *q* (4.6101E-07) in equations (17) and (18), the values of *K* (304,936.47) and *r* (0.141), $E_{MSY}$ (152,804), $Y_{MSY}$ (10,740 tonnes) and $F_{MSY}$ (0.1) were computed.

*Table 1:Biological parameters estimated from the Gordon Schaefer (1954) model for the Semi-Industrial Fishery in Ghana from 2005 - 2019*

| **Biological parameter** | **Estimate** | **Lower 95%** | **Upper 95%** | **R square** |
|---|---|---|---|---|
| Alpha (α) | 0.140579808 | 0.10336264 | 0.177796977 | 0.5612 |
| Beta (β) | - 4.61E-07 | 7.11E-07 | 2.11E-07 | |
| K | 304,936.47 | 145,581 | 846,652.27 | |
| $E_{MSY}$ | 152,804.14 | 72,790.59 | 423,326.14 | |
| $Y_{MSY}$ | 10,740.58 | 3,761.91 | 37,633.05 | |
| $F_{MSY}$ | 0.07044 | 0.05168 | 0.08890 | |
| $E_{CURRENT}$ | 144,591.00 | | | |
| $Y_{CURRENT}$ | 11,701.69 | | | |

**4.2.2 Yield – effort curve (number of vessels)**

The CPUE- effort regression of the semi-industrial fishery was described by the equation *CPUE = a – b* (f), where *a* = intercept (intrinsic growth rate) and *b* = slope (mortality rate), as shown in Figure 14. The correlation coefficient ($r$ = 0.3083) and analysis of variance of the regression analysis ($F$ = 3.888, $df$ = 1, $p$ < 0.001) suggested a negative and relatively significant relationship between the CPUE and effort (number of licensed vessels). The coefficient of determination ($R^2$= 0.0951) of the regression indicated that about 10% of the increase in CPUE could be explained by the unit of effort. Again, the relationship between efforts and CPUE showed a negative trend from 1980 - 2018; *CPUE = 71.178 - 0.1 f*, which means that more efforts applied would lower the CPUE. The findings revealed that Ghana's semi-industrial fishery is facing catchment pressures.

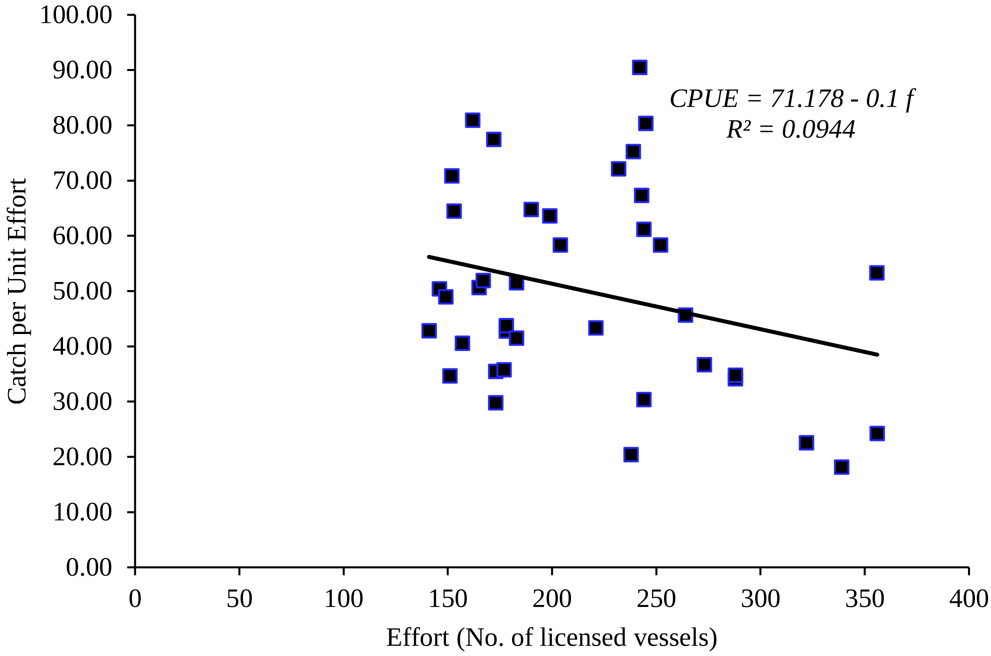


*Figure 14:* Regression Analysis of CPUE on the corresponding Efforts level of the semi – industrial fishery in Ghana from 1980 to 2018

Figure 15, shows the graph of yield ($Y_t$) versus effort ($E_t$) for the Gordon-Schaefer model fit to the data (using the method of least squares). According to the figure, the MSY for Ghana's semi-industrial fishery was 12,661 tonnes. This MSY yield is approximately 2000 tonnes higher than the Maximum Economic Yield (10,493.62 tonnes). Since MEY is generally a more conservative reference point, this result was expected (Seijo et al., 1998). The corresponding efforts at MSY and MEY were 355 and 208 licensed vessels, respectively. The model also estimated the Open Access Equilibrium (OAE) as 12,250 tonnes with a corresponding effort of 417 licensed vessels.

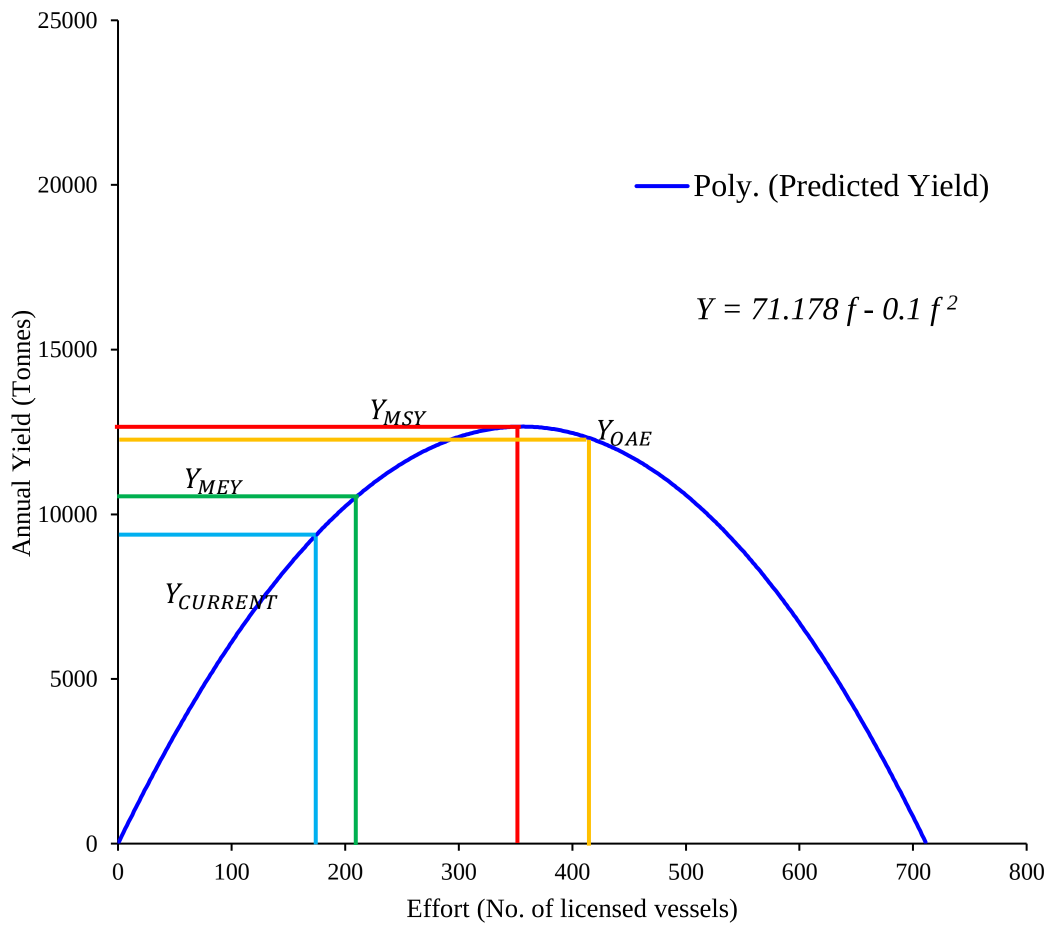


*Figure 15:* Gordon- Schaefer Harvest Curve for the semi-industrial fishery from 1980 to 2018

*Table 2: Bioeconomic parameters estimated from the Gordon Schaefer (1954) model for the Semi-Industrial Fishery in Ghana from 1980 to 2018*

| **Bio-economic parameter** | **Estimate** | **Lower 95%** | **Upper 95%** | **R square** |
|---|---|---|---|---|
| Alpha (α) | 71.17846 | 48.56338 | 93.79354 | 0.0944 |
| Beta (β) | - 0.100034 | | | |
| K | 711.541 | 238.938 | 29,506.51 | |
| $E_{MSY}$ | 355.77 | 119.468 | 14,735.254 | |
| $Y_{MSY}$ | 12,661.63 | 2,900.905 | 691,880.011 | |
| $E_{MEY}$ | 208.62 | | | |
| $Y_{MEY}$ | 10,493.62 | | | |
| $E_{OAE}$ | 417.11 | | | |

### 4.2.3 Estimates of MSY, MEY and Current costs, revenues and economic rents of the fishery

Table 2 shows the costs, revenue, and rents associated with MSY, MEY, and the current status quo. The figures were derived from estimated MSY, MEY, and current catch in tonnes, as well as effort in the number of licensed vessels.

*Table 3: Estimates of MSY and MEY Costs, Revenues and Economic rents*

| Conditions | Total Revenue (GHC) | Total Cost (GHC) | Economic Rent (GHC) |
|---|---|---|---|
| **MSY** | 158,270,375.00 | 130,982,293.24 | 27,288,081.76 |
| **MEY** | 131,170,194.40 | 76,782,649.17 | 54,387,545.23 |
| **Current** | 121,237,500.00 | 67,005,959.93 | 54,231,540.07 |

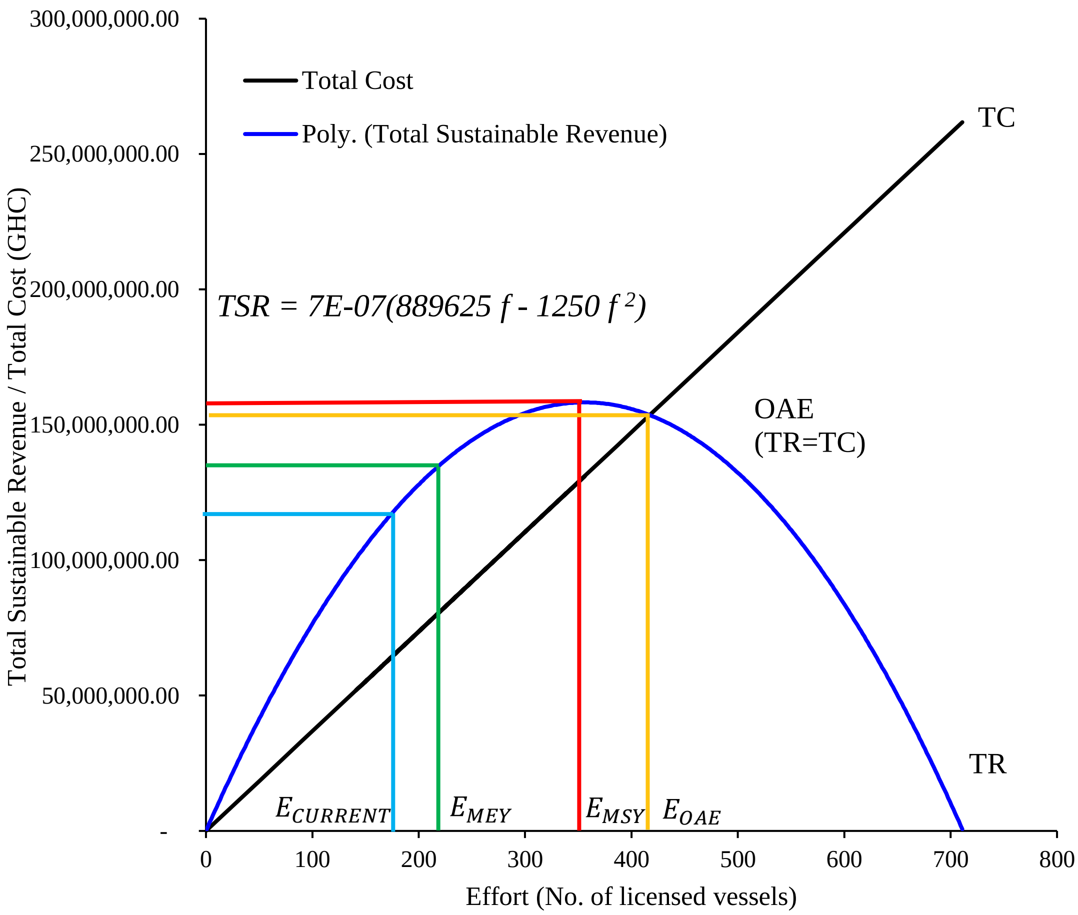


*Figure 16:* MSY, MEY, OAE and Current status for the semi – industrial fishery from 1980 to 2018

From Figure 16, it was estimated that the economic rent at MEY and MSY for semi-industrial fishery was 54,387,545.23 GHC and 27,288,081.76 GHC, respectively. The maximum economic rent of the current fishery status as at 2018 was 54,231,540.07 GHC. The total revenue of the fishery at MEY and MSY was 131,170,194.40 GHC and 158,270,375.00 GHC, respectively, whereas that of the total cost of production at MEY and MSY was estimated to be 76,782,649.17 GHC and 130,982,293.24 GHC, respectively. The total cost and revenue of the current status quo (2018) of the semi-industrial fishery was estimated to be 67,005,959.93 GHC and 121,237,500.00 GHC, respectively.

**4.2.4 Trends of annual fishery economic rent**

The trend analysis of annual fishery economic rents of semi - industrial fishery from 1980 to 2018 is illustrated in Figures 17.

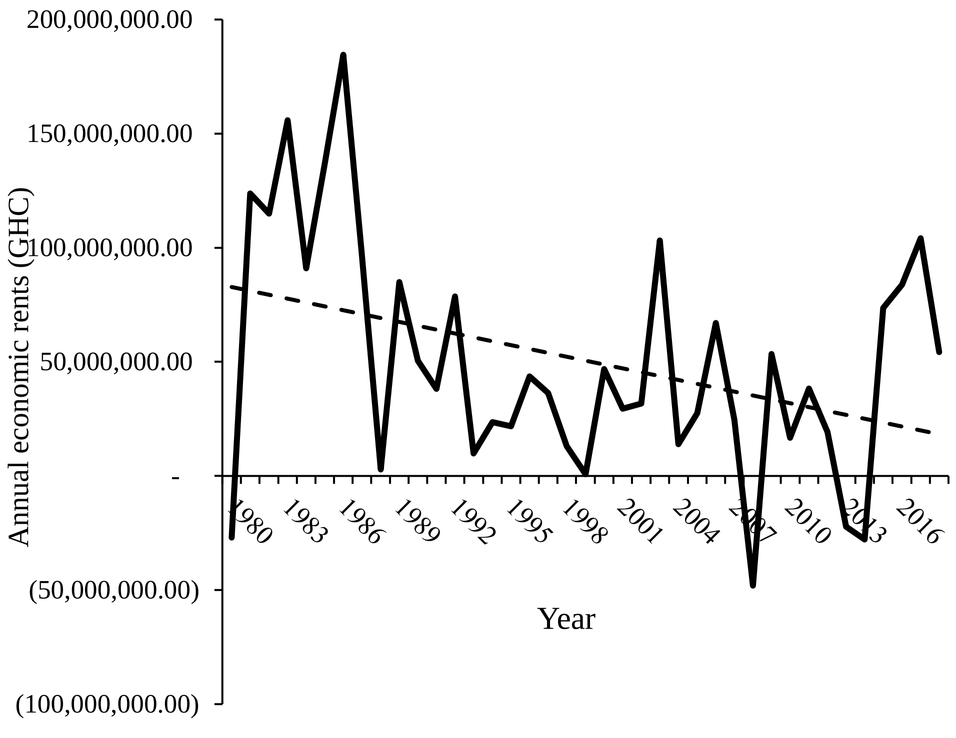


*Figure 17:* Trend of annual economic rents for semi–industrial fishery from 1980 to 2018

Figure 17 demonstrates that the annual rent of semi-industrial fishery has been declining over time. Positive economic rents were observed from 1981 to 1987 with maximum economic rent in 1986. This coincided with the highest peak of CPUE. A decline in economic rent of approximately 3,000,000.00 GHC – 600,000.00GHC was experienced in 1988 and 1999. Since 1988, there has been a fluctuating and declining trend with few increasing peaks in 2003 and 2017. The fishery experienced some levels of negative economic rents in the 2008, 2013 and 2014 and this concurred with the period of overcapacity and overexploitation.

### 4.2.5 Estimates of present value of fishery

The estimates for present value of semi-industrial fishery were projected for the next 13 years covering the period from 2018 to 2030. The current state of fishery economic rents was discounted to estimate present values, which were then compared to the MEY and MSY present values. Figure 18, depicts the results of the present value for semi-industrial fishery.

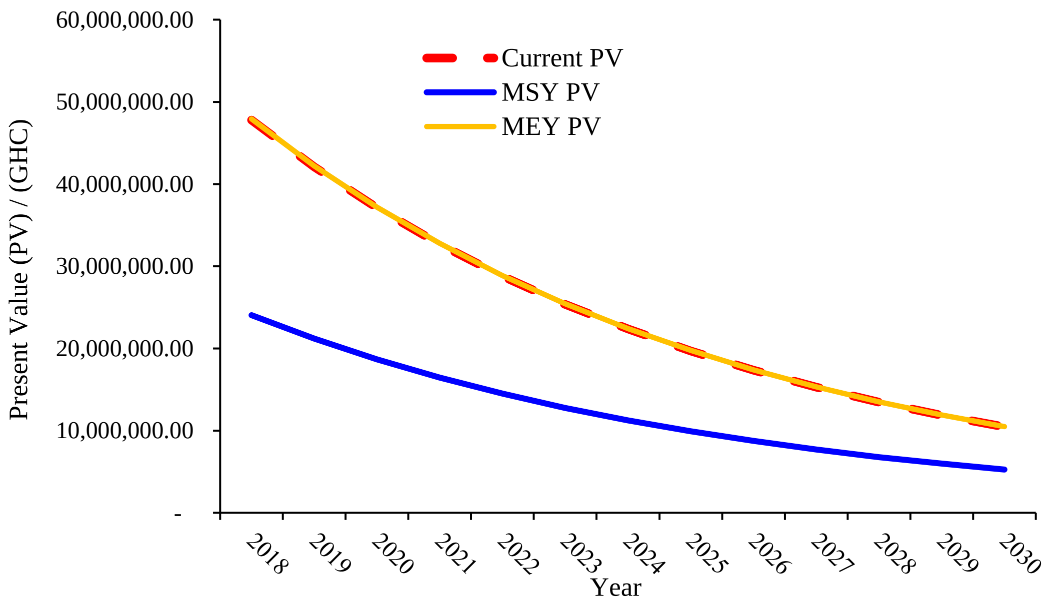


*Figure 18:* Estimates of the present value of semi – industrial fishery from 2018 to 2030

The results reveal that the present values for the semi-industrial fishery economic rents, MEY and MSY from 2018 to 2030 are positive but lowering with time. As a whole, the current MEY values and current fishery status are greater than the current MSY values.

**4.2.6 Estimates of Net Present Value (NPV)**

The Net Present Value was calculated to ascertain the economic profitability of Ghana's semi-industrial fishery. The result of estimated NPV is presented in Figure 19.

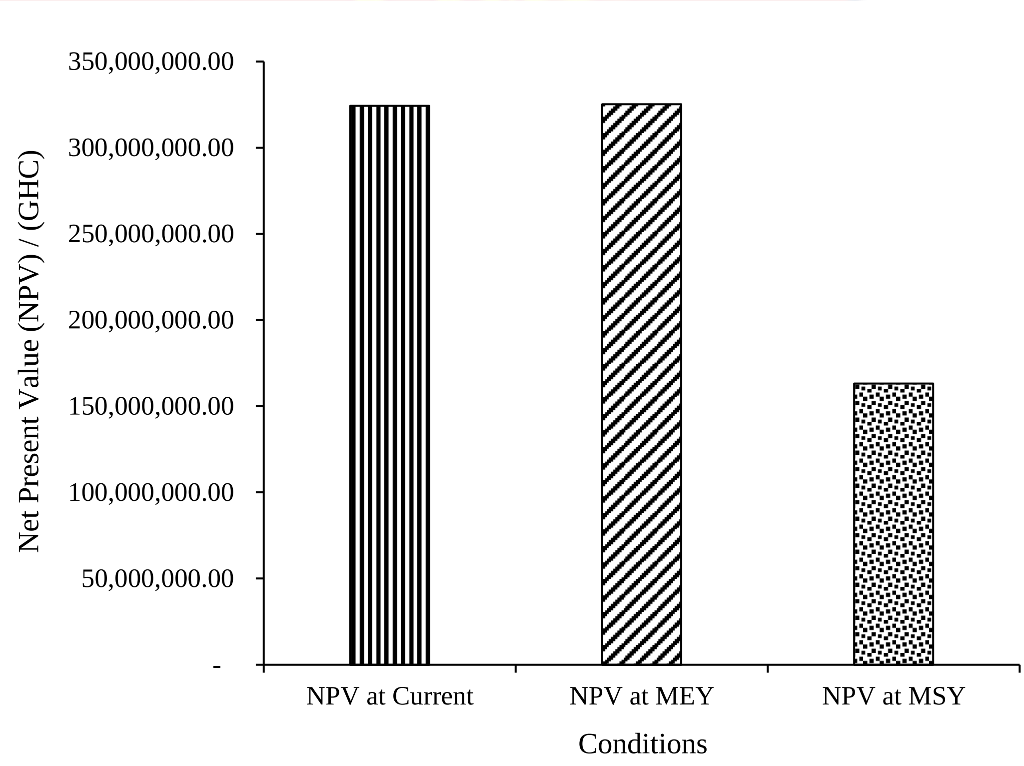


*Figure 19:* Estimated Net Present Value for different conditions of the semi-industrial fishery

As presented in Figure 19, the fishery under each condition is economically viable to be exploited by the semi -industrial fishery.

### 4.2.7 Sensitivity Analysis

**Environmental Scenarios**

Under each regime, the biological parameters have been varied with individual climatic and anthropogenic consequences, as shown in Table 4. These were done to ascertain the possible impact of potential climatic and anthropogenic changes on the fisheries resources.

***Scenario 0 (current status):*** The current status based on the *K* and *r* which were derivatives of the catch-effort data, reveals that the current status quo of the fishery is below the MEY and MSY as well. However, the difference in profit level between the MEY and the current state was 156,024.01 GHC, whereas the profit level of the MSY was found to be 27,287,897.41 GHC and that of the MEY level was 54,387,563.17 GHC.

***Scenario 1* (*K = current status; r = -10%*):** This scenario gives an account of a regime where the carrying capacity (*K*) remains constant while the growth rate (*r*) is reduced by 10%. At MEY and MSY, the differences in economic rent between this scenario and the current situation (scenario 0) varied by about 0.25% and 80% respectively. Furthermore, when compared to the current state, the harvest levels at MEY and MSY have changed by 10% and 19%, respectively.

*Consequences*

According to this scenario, the MSY level has changed by about 19%, which is not a positive indication for the economic growth of the country.

***Scenario 2* (*K = current status; r = -25%*):** This scenario gives an account of a regime where the carrying capacity (*K*) remains constant while the growth rate (*r*) is reduced by 25%. In this scenario, the MSY and MEY levels varied by about 133% and 0.09% in profit and 44% and 25% in harvest, respectively, compared with the current situation.

*Consequences*

In comparison to the current situation, this could result in a change of 36,497,618.12 GHC and 46,919.5 5GHC at MSY and MEY, respectively.

***Scenario 3* (*K = -10%; r = current status*):** This scenario gives an account of a regime where the carrying capacity (*K*) is reduced by 10% while the growth rate (*r*) still remains constant. The current state and the MSY of this scenario recorded the same harvest level, but there was a difference of 1507.04 tonnes at MEY compared to the current state.

*Consequences*

Because both carrying capacity and profit change in the negative direction, the MEY and profit are expected to be lower. In comparison to the reference situation, the profit level has been reduced by 34% at the MEY level.

***Scenario 4* (*K = -10%; r = -10%*):** This scenario gives an account of a regime where the carrying capacity (*K*) is reduced by 10% while the growth rate (*r*) is also reduced by 10%. The model's results based on this scenario vary by 10% in effort at MSY and 17% in effort at MEY and OAE. In comparison to scenario 0, the average change in harvest level was 20% at MSY and MEY levels.

*Consequences*

In comparison to the reference scenario, the profit contribution is estimated to be around 62% and 31% lower at MSY and MEY levels, respectively.

*Table 4: Yield, corresponding Effort and Rent at MEY, MSY and OAE level in response to changes in the Biological parameters K and r with potential changing Environmental scenarios*

| K= 711.54 -20% | r = 71.178 - 25% Scenario 8 | | r = 71.178 -10% Scenario 7 | | r = 71.178 Scenario 6 | |
|---|---|---|---|---|---|---|
| | E_MSY | 266.83 | E_MSY | 320.19 | E_MSY | 355.77 |
| | E_MEY | 119.61 | E_MEY | 172.98 | E_MEY | 208.56 |
| | E_OAY | 239.23 | E_OAY | 345.96 | E_OAY | 417.11 |
| | Y_MSY | 7122.15 | Y_MSY | 10255.90 | Y_MSY | 12661.61 |
| | Y_MEY | 4954.17 | Y_MEY | 5945.00 | Y_MEY | 6605.55 |
| | Π_MSY | -9,209,720.71 | Π_MSY | 10,314,798.66 | Π_MSY | 27,287,897.41 |
| | Π_MEY | 17,889,974.56 | Π_MEY | 10,628,058.98 | Π_MEY | 5,786,781.93 |
| **K = 711.54 -10%** | **Scenario 5** | | **Scenario 4** | | **Scenario 3** | |
| | E_MSY | 266.83 | E_MSY | 320.19 | E_MSY | 355.77 |
| | E_MEY | 119.61 | E_MEY | 172.98 | E_MEY | 208.56 |
| | E_OAY | 239.23 | E_OAY | 345.96 | E_OAY | 417.11 |
| | Y_MSY | 7122.15 | Y_MSY | 10255.90 | Y_MSY | 12661.61 |
| | Y_MEY | 6739.93 | Y_MEY | 8087.91 | Y_MEY | 8986.58 |
| | Π_MSY | -9,209,720.71 | Π_MSY | 10,314,798.66 | Π_MSY | 27,287,897.41 |
| | Π_MEY | 40,212,071.46 | Π_MEY | 37,414,466.50 | Π_MEY | 35,549,577.79 |
| **K = 711.54** | **Scenario 2** | | **Scenario 1** | | **Scenario 0** | |
| | E_MSY | 266.83 | E_MSY | 320.19 | E_MSY | 355.77 |
| | E_MEY | 119.61 | E_MEY | 172.98 | E_MEY | 208.56 |
| | E_OAY | 239.23 | E_OAY | 345.96 | E_OAY | 417.11 |
| | Y_MSY | 7122.15 | Y_MSY | 10255.90 | Y_MSY | 12661.61 |
| | Y_MEY | 7870.22 | Y_MEY | 9444.25 | Y_MEY | 10493.62 |
| | Π_MSY | -9,209,720.71 | Π_MSY | 10,314,798.66 | Π_MSY | 27,287,897.41 |
| | Π_MEY | 54,340,643.62 | Π_MEY | 54,368,745.02 | Π_MEY | 54,387,563.17 |
| | | | | | Π_Current | 54,231,539.16 |

***Scenario 5* (*K = -10%; r = -25%*):** This scenario gives an account of a regime where the carrying capacity (*K*) is reduced by 10% while the growth rate (*r*) is also reduced by 25%. Roughly, about 43% and 35% of the harvest levels at MEY and MSY were accounted lower in this scenario than in the current situation.

*Consequences*

MEY's profit margins were approximately 89% lower than they are presently.

***Scenario 6 (K = -20%; r = current status)*:** This scenario gives an account of a regime where the carrying capacity (*K*) is reduced by 20% while the growth rate (*r*) still remains constant. There was no difference in the effort levels compared to the reference situation. In contrast, there was a difference in harvest level at MEY which were estimated to be 3888.0 tonnes compared to the present scenario.

*Consequences*

In terms of the current situation, the profit level has been impacted by 89 % on MEY level.

***Scenario 7 (K = -20%; r = -10%):*** This scenario gives an account of a regime where the carrying capacity (*K*) is reduced by 20% while the growth rate (*r*) is also reduced by 10%. In comparison to the reference scenario, this scenario has a higher difference in harvest and profit levels.

*Consequences*

In relation to the current situation, the difference in profit level was 43,759,504 GHC at MEY level.

***Scenario 8 (K = -20%; r = -25%)*:** This scenario gives an account of a regime where the carrying capacity (*K*) is reduced by 20% while the growth rate (*r*) is also reduced by 25%. In comparison to the current situation, harvest level variations were found to be 5,539.45 tonnes at both MEY and MSY levels. Because of the substantial changes in carrying capacity and growth rate of the semi-industrial fishery in this scenario, these significant variations were expected.

*Consequences*

This sort of extreme change in growth and carrying capacity has an impact on profit by 67% at MEY level compared to the present situation.

**Economic Scenarios**

Sensitivity analysis shows how a project is capable of absorbing "shocks" due to increase in costs, decrease in benefits or both. It is used to measure the riskiness of the investment due to uncertainties. either one or both It is used to assess the investment's riskiness in the face of unknowns. The analysis was undertaken and the findings were focused primarily on variations in the total cost and revenue of the reference situation (2018). As shown in Table 5, all the scenarios were compared to the market dynamics in order to quantify the potential impact on fisheries resources.

Generally, the yield at MSY with its corresponding effort level remained unaffected throughout all the scenarios despite the variations in total cost and revenue.

***Scenario 0 (current status)*:** This scenario gives an account of a regime where the current total cost of operations remains constant while the current price of harvest also remains constant. The difference in profit level between the MEY and current state was 156,201.01 GHC, whereas the profit level of the MSY was found to be 27,287,897.41 GHC and that of MEY level was 54,387,563.17

GHC. The yield at MEY and the current state varied by 7.5%, whereas that of the MSY and the current status varied with a percentage of 23.4%. The corresponding effort as OAE, MSY, MEY and Current status were recorded as 417, 355, 208 and 182 respectively.

***Scenario 1 (C = current status; P = 10%)*:** This scenario gives an account of a regime where the current total cost of operations remains constant while the current price of harvest is increased by 10%. Based on this scenario, the results of the model showed a profit variation of about 102,057,026.24GHC, 75,258,333.24GHC and 48,181,613.85GHC at MSY, MEY and the current status respectively. The change in effort level was 38.5% at MEY compared to scenario 0.

*Consequences*

The effort impact is estimated to be around 39% at MEY level which is greater than the reference situation (scenario 0). The effort at MEY level at this scenario would take an increase of 4.6% to reach MSY of the current situation, which economically might be undesirable.

***Scenario 2* (*C = current status; P = 20%*):** This scenario gives an account of a regime where the current total cost of operations remains constant while the current price of harvest is increased by 20%. In this scenario, the change in yield at MEY level was estimated to be about 6%, and the effort level at MEY was estimated to be about 10% higher than the current situation.

*Consequences*

This could lead to changes in the profit level at MSY and MEY of an estimated increase of about 54% and 33% respectively compared with current scenario.

***Scenario 3 (C = -10%; P = 20%)*:** This scenario gives an account of a regime where the total cost of operations was reduced by 10% while the current price of harvest is increased by 20%. About 8% increase in harvest was accounted for MEY under this scenario compared to present situation whereas roughly 15% increase in effort level of both OA and MSY level occurred in this scenario.

*Consequences*

The level of profit at MSY, MEY current status under this scenario was approximately 62%, 40% and 36% respectively from the present situation.

***Scenario 4* (*C = -10%; P = 10%*):** This scenario gives an account of a regime where the total cost of operations was reduced by 10% while the current price of harvest is increased by 10%. There were no differences of harvest level at MSY and MEY, respectively, compared to the current situation. Compared to the current situation, the average change in profitability level was 10% lower.

*Consequences*

The MSY, MEY, and current status, as well as their corresponding profits, are all lower than expected. In comparison to the current situation, the profit level has decreased by about 10%.

***Scenario 5 (C = -10%; P = current status)*:** This scenario gives an account of a regime where the total cost of operations was reduced by 10% while the current price of harvest still remains constant. The results of the model predicated on this scenario differ by about 6.6% in effort level at OAE and by an average of 1.2% in OAE, MEY, and MSY harvest levels when compared to scenario 0.

*Consequences*

The profit contribution on MSY is approximately 32% when compared to the reference situation.

***Scenario 6 (C = -20%; P = 20%)*****:** This scenario gives an account of a regime where the total cost of operations was reduced by 20% while the current price of harvest is increased by 20%. The drastic changes observed in this scenario contributed approximately 10.3% to an increase in harvest level at MEY when compared to the current situation, while almost 68% and approximately 33% changes in profit were observed at the MSY and MEY levels, respectively.

*Consequences*

At MEY, the effort was roughly 10.5% higher than the present situation.

***Scenario 7 (C= -20%; P= 10%)*****:** This scenario gives an account of a regime where the total cost of operations was reduced by 20% while the current price of harvest is increased by 10%. Comparatively, this scenario showed a higher variation in profit levels at MSY, MEY and current status as compared to the reference scenario with corresponding effort at MEY increasing by 6%.

*Consequences*

There has been a difference between the profitability at MSY, MEY and current status level of about 60%, 41% and 32% respectively as compared to the current situation.

***Scenario 8 (C = -20%; P = current status)*****:** This scenario gives an account of a regime where the total cost of operations was reduced by 20% while the current price of harvest is still constant. The increase in profit across the MSY, MEY, and current status under this regime was triggered by the difference in effort and yield from the current status (scenario 0). In comparison to the current situation, the difference in harvest level at MEY was found to be 1204 tonnes, and the corresponding effort was 19% higher. The effort at OAE also experienced an increase of about 19% compared to the current situation.

*Table 5: Yield, corresponding Effort and Rent at MEY, MSY, OAE and Current level in response to changes in the Economic parameters c and p with potential changing Economic scenarios*

| **C = 368,164.62 GHC -20%** | **P = 12,500 GHC +20%** | | **P =12,500 GHC +10%** | | **P = 12,500 GHC** | |
|---|---|---|---|---|---|---|
| | **Scenario 6** | | **Scenario 7** | | **Scenario 8** | |
| | E_Curr | 182.00 | E_Curr | 182.00 | E_Curr | 182.00 |
| | E_MSY | 355.77 | E_MSY | 355.77 | E_MSY | 355.77 |
| | E_MEY | 233.09 | E_MEY | 221.94 | E_MEY | 257.63 |
| | E_OAY | 466.18 | E_OAY | 443.88 | E_OAY | 515.25 |
| | Y_Curr | 9,699.00 | Y_Curr | 9,699.00 | Y_Curr | 9,699.00 |
| | Y_MSY | 12,661.63 | Y_MSY | 12,661.63 | Y_MSY | 12,661.63 |
| | Y_MEY | 11,698.05 | Y_MEY | 11,514.90 | Y_MEY | 11,698.05 |
| | Π_MSY | 85,138,613.98 | Π_MSY | 69,311,576.48 | Π_MSY | 85,138,613.98 |
| | Π_MEY | 106,818,036.11 | Π_MEY | 92,961,929.11 | Π_MEY | 99,591,429.02 |
| | Π_Current | 91,880,231.33 | Π_Current | 79,756,481.33 | Π_Current | 91,880,231.33 |
| **C = 368,164.62 GHC - 10%** | **Scenario 3** | | **Scenario 4** | | **Scenario 5** | |
| | E_Curr | 182.00 | E_Curr | 182.00 | E_Curr | 182.00 |
| | E_MSY | 355.77 | E_MSY | 355.77 | E_MSY | 355.77 |
| | E_MEY | 245.4 | E_MEY | 208.56 | E_MEY | 223.28 |
| | E_OAY | 490.7 | E_OAY | 417.11 | E_OAY | 446.55 |
| | Y_Curr | 9,699.00 | Y_Curr | 9,699.00 | Y_Curr | 9,699.00 |
| | Y_MSY | 12,661.63 | Y_MSY | 12,661.63 | Y_MSY | 12,661.63 |
| | Y_MEY | 11,442.11 | Y_MEY | 10,493.62 | Y_MEY | 10,905.53 |
| | Π_MSY | 72,040,384.48 | Π_MSY | 24,559,271.98 | Π_MSY | 40,386,309.48 |
| | Π_MEY | 90,332,341.08 | Π_MEY | 48,948,789.77 | Π_MEY | 62,336,810.51 |
| | Π_Current | 85,179,635.24 | Π_Current | 48,808,385.24 | Π_Current | 60,932,135.24 |

| C = 368,164.62 GHC | P = 12,500 GHC +20% Scenario 2 | | P =12,500 GHC +10% Scenario 1 | | P = 12,500 GHC Scenario 0 | |
|---|---|---|---|---|---|---|
| | E_Curr | 182 | E_Curr | 182 | E_Curr | 182 |
| | E_MSY | 355.77 | E_MSY | 355.77 | E_MSY | 355.77 |
| | E_MEY | 233.09 | E_MEY | 339.41 | E_MEY | 208.6 |
| | E_OAY | 466.18 | E_OAY | 678.83 | E_OAY | 417.11 |
| | Y_Curr | 9,699.00 | Y_Curr | 9,699.00 | Y_Curr | 9,699.00 |
| | Y_MSY | 12,661.63 | Y_MSY | 12,661.63 | Y_MSY | 12,661.63 |
| | Y_MEY | 11,156.05 | Y_MEY | 12,634.83 | Y_MEY | 10,493.62 |
| | Π_MSY | 58,942,156.76 | Π_MSY | 129,345,108.00 | Π_MSY | 27,288,081.76 |
| | Π_MEY | 81,524,916.93 | Π_MEY | 129,645,878.47 | Π_MEY | 54,387,545.23 |
| | Π_Current | 78,479,040.07 | Π_Current | 102,413,153.92 | Π_Current | 54,231,540.07 |

*Consequences*

The reduction of cost by 20% had an influence in increasing profitability at MSY, MEY and current status by 68%, 45% and 41% respectively

**4.3 Value Chain Analysis of the Semi - industrial fishery**

The analysis of the actors in the value chain in the semi- industrial sector of Ghana begins with a some descriptive of the demographic and socioeconomic characteristics (Table 6). These criteria are crucial in determining the variations in socioeconomic level between the actors of the value chain.

*Table 6: Study Population and Location (N = 250)*

| | **Value Chain Actors** | | | |
|---|---|---|---|---|
| Fishing Communities | Fishermen | Fish Processors | Fish Traders | Total |
| Tema fishing harbor | 27 | 12 | 14 | 53 |
| Elmina landing quay | 29 | 12 | 60 | 101 |
| Sekondi fishing harbor | 44 | 26 | 26 | 96 |
| **Total** | **100** | **50** | **100** | **250** |

Source: Field survey 2020 to 2021

**4.3.1 Socioeconomic Characteristics of the Value Chain Actors**

The socio-demographic characteristics of the 250 respondents in the value chain of the semi – industrial fishery in Ghana are presented in Table 7 below. Along the value chain 100% of the men dominated as boatowners/fishermen with 4% and 10% as fish processors and fish traders respectively. Women were not represented as boatowners but dominated the fish processing and trading with a percentage of 96% and 90% respectively. Majority of the respondents had over 20 years of working experience in their occupation with a percentage of 47%, 50% and 55% respectively for fishermen, fish processor and fish traders. A few percentage of fishermen, fish processors and fish traders (15.2%, 10% and 10% respectively) had less than 5 years of working experience. Results from the study discovered that 84.8% of the fishermen, 86% of the fish processors and 86% of the fish traders, had fishing activities as their only sources of income. These findings revealed that the majority of the actors rely on fishing as a daily means of income. Although the results showed majority of the actors' livelihood depends on fishing activities, 8.4% of the total respondents were involved in trading, whereas 11% of the fishermen were electricians and mechanics as an alternate source of livelihood.

From the results presented in Appendix I, the major source of funding for the fishing operation of most boat owners were from their family and friends. This constituted about 70% of the respondent whereas 20% of the funding for operation were derived from fish processors or mammies. 4% of the respondent revealed that, they acquired their source of funding from credit union and susu collectors. Just 1% of the respondent revealed their source of funding was derived from the bank.

In the survey, the most common season of abundant fish catch was from June to August (61.6%) whereas 17% of the respondents couldn't associate abundant fish catch to any season of the year. However, 6% of the fishermen could ascribe the season of abundant fish catch from April- May while and 15% of them attributed it to September to December. Nonetheless, the results from the semi-industrial fishery showed that 52.5% of the respondents always except Tuesday go for fishing while 36% of the respondent only go for fishing every day except the lunar cycle (full moon). However, 11% of the respondent do not go fishing in the rainy season.

*Table 7: Socioeconomic characteristics of the Value Chain Actors (N =250)*

| Variables | Fishermen/Boat Owners | | Fish Processors | | Fish Traders | |
|---|---|---|---|---|---|---|
| | Freq | % F | Freq | % F | Freq | % F |
| **Gender** | | | | | | |
| Male | 100 | 100 | 2 | 4 | 10 | 10 |
| Female | 0 | 0 | 48 | 96 | 90 | 90 |
| **Total** | **100** | **100** | **50** | **100** | **100** | **100** |
| **Years of experience** | | | | | | |
| Less than 5yrs | 15 | 15.2 | 5 | 10 | 10 | 10 |
| 6-10yrs | 17 | 17.2 | 6 | 12 | 21 | 21 |
| 11 - 20yrs | 21 | 21.2 | 14 | 28 | 24 | 34 |
| Above 20yrs | 48 | 47.5 | 25 | 50 | 45 | 55 |
| **Total** | **100** | **100** | **50** | **100** | **100** | **100** |
| **Fishing as the only means of income** | | | | | | |
| Yes | 84 | 84.8 | 43 | 86 | 86 | 86 |
| No | 16 | 15.2 | 7 | 14 | 14 | 14 |
| **Total** | **100** | **100** | **50** | **100** | **100** | **100** |
| **Other source of income** | | | | | | |
| Trading | 4 | 4 | 7 | 14 | 10 | 10 |
| Electrician/ Mechanic | 11 | 11.1 | 0 | 0 | 0 | 0 |
| No other source | 85 | 84.8 | 43 | 86 | 90 | 90 |
| **Total** | **100** | **100** | **50** | **100** | **100** | **100** |

### 4.3.2 Variations in fish prices

The study specified certain factors that influenced the pricing of fishes as shown in Figure 20. A larger percentage of fishermen, fish processors and fish traders (50%, 58% and 51% respectively) associated the variations of fish pricing to the availability and abundance of fishes. A total of 16.4%, 13.3% and 10.8% of the respondent interviewed also liaised the variations of fish pricing to increase in fuel pricing and other fishing inputs, quality and size range and seasonality respectively. 7.6 % of the respondent represented the percentage of people who suggested there are no variations in fish pricing throughout the year.

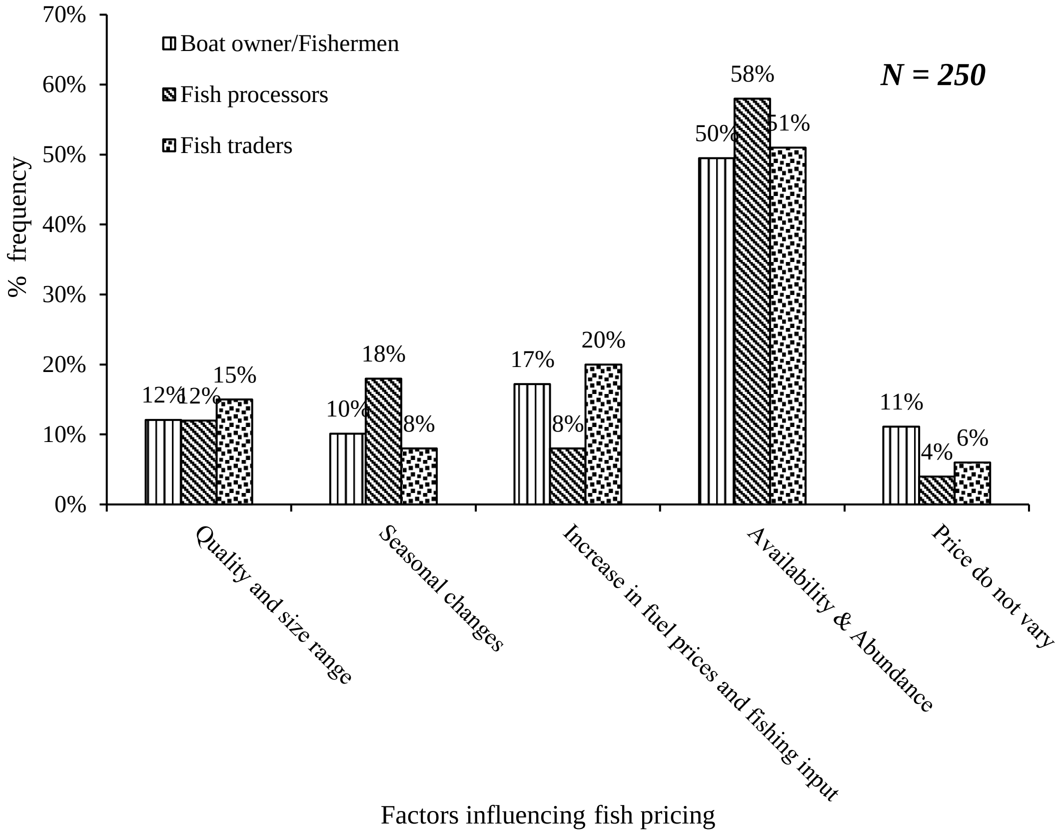


*Figure 20:* Factors influencing the variations of fish prices in the fishery industry

### 4.3.3 Major constraints that impedes marketing of fish products

Fish processors and traders from the results revealed the major constraint that impeded the marketing of their fish products. The results presented in Figure 21 shows that, about 28% of total respondent indicated lack of storage facilities as one of the major challenges in marketing. However, 17.3% of processors and traders also revealed low profitability and losses and health issues as a major source of constraint impeding marketing. 14.0% and 13.3% of the total respondent also attributed insufficient capital and credit-based purchasing from their customers respectively as a major constraint whiles 10.0% of them ascribed unstable fish prices as part of the constraints inhibiting marketing.

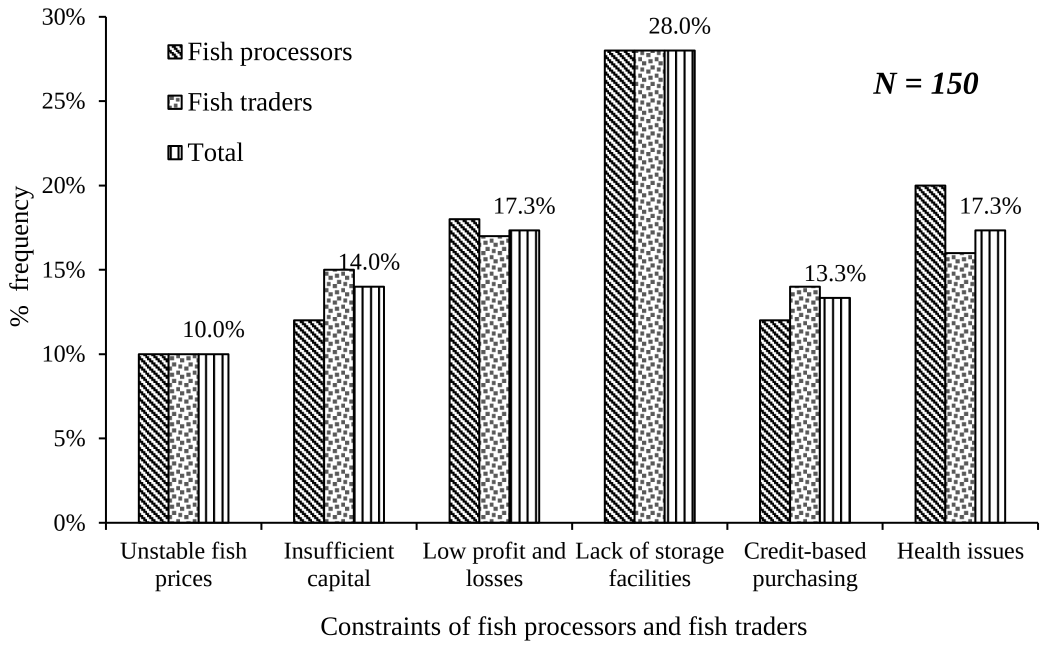


*Figure 21:* Constraints and challenges impeding marketing among the value chain actors

### 4.3.4 Impact of Artisanal fishery on the operations of semi-industrial

About 62.6% of fishermen interviewed, reported that the artisanal fishery had no impact on their operations, with only 37.4% indicating the impact of artisanal fishery on their operations as shown in Appendix I. Out of the 37.4% respondent, 20% attributed the destructive fishing as a major impact while 17.1% also associated the use of noxious substance and unauthorized mesh gears as the major impact of which the activities of artisanal have on their operations.

### 4.3.5 Impact of Industrial fishery on the operations of semi-industrial

Figure 22 depicts, the impact of the industrial fishery on the semi- industrial fishery. A greater percentage of the respondent (76%) reported the impact of industrial vessel on their operations while 23.2% also revealed that the industrial fishery had no impact on their operations. Out of the 76% respondent, 28% ascribed the trawling in inshore waters by the industrial as the major impact on their operation. 15% of these respondents also attributed the use of unauthorized gears and mesh sizes as an impact on their operation. Dumping of unwanted by-catches and targeting of pelagic fishes instead of demersals also scored 13% and 11% respectively.

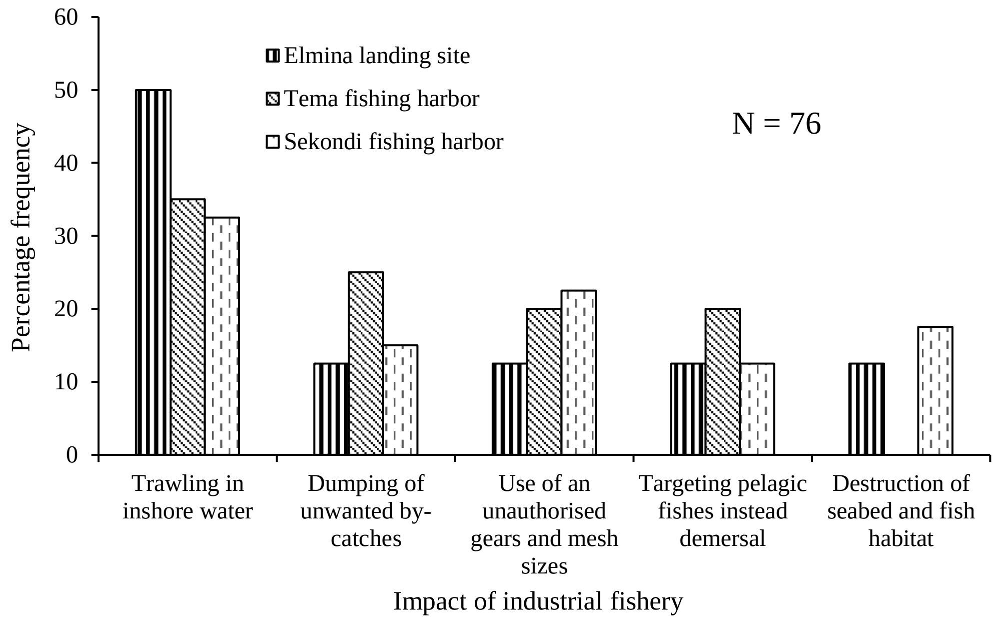


*Figure 22:* Impact of industrial fishery on the operations of semi-industrial fishery at various study areas

#### 4.3.6 Major causes of fluctuation of fleets in the sector

As revealed by the boatowners in Figure 23, 25% of them indicated the main cause of fluctuations of fleets to the high pricing of fuel and other fishing input and also "Saiko" fishing and high influx of industrial trawlers. 22.2% and 15.2% of the respondent confirmed that low catch and lack of boatyards or dry dock respectively had precipitated the fluctuation of vessels in the sector. This survey also revealed that only 12% of the respondent reported the lack of marine engines as a major case of the fluctuation in fleets by the sector.

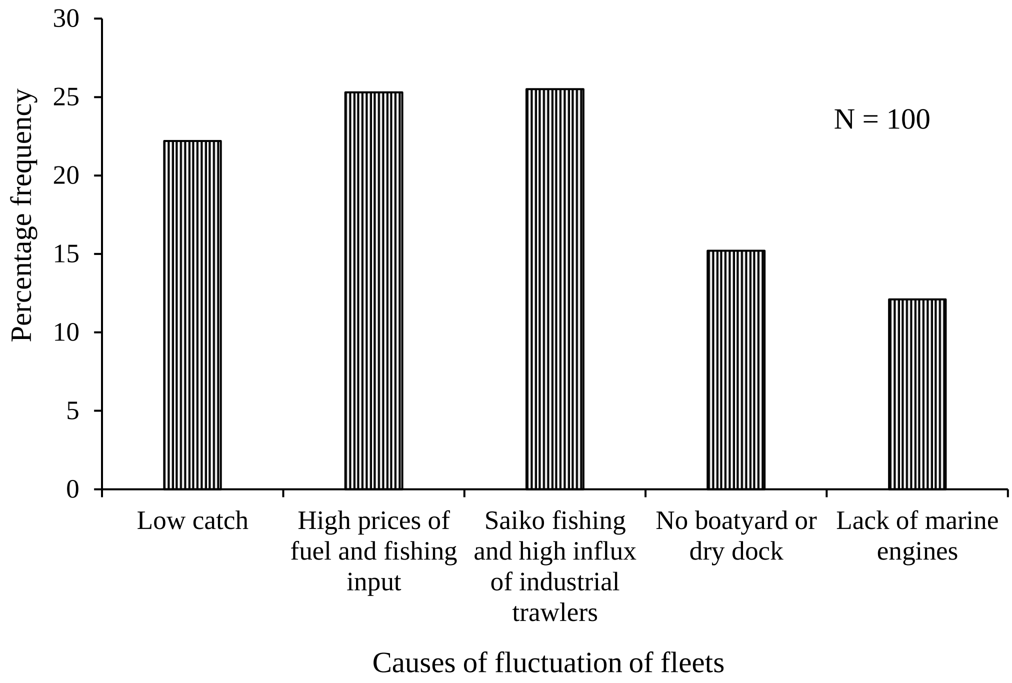


*Figure 23:* Major causes of the fluctuations in the semi-industrial fishery

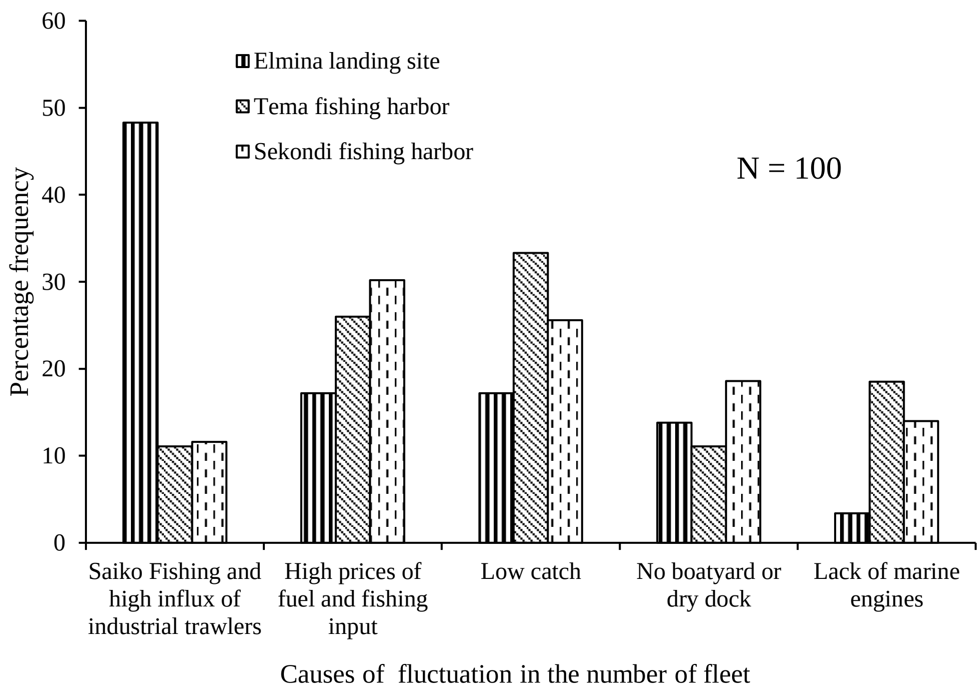


*Figure 24:* Major causes of the fluctuations in the semi-industrial fishery at the three selected study sites

### 4.3.7 Proposed government intervention to improve the fishery

Presented in table 8 are some proposed government interventions to improve the semi-industrial fishery. About 30.3% of the respondent confirmed that, the government should ban "Saiko" fishing activities and regulate the industrial trawlers effectively, while 20% suggested the provision of subsidies on fuel prices. Saiko fishing is an indigenous name ascribed to illegal trans-shipments, where industrial trawlers transfer frozen fish to specially adapted canoes offshore in exchange for cash and/or other items. However, 17% of the respondent reported that the fisheries laws must be strictly enforced to prosecute culprits, whereas 11% indicated easy access to credit facilities as a proposed tool for improvement of the sector. Nonetheless, provision of marine engines and other fishing technology were also suggested by 9% of the respondent and 8% of the respondent also revealed that the construction of boatyards and dry docks could also help improve the semi-industrial fishing activities. Of the total respondents, only 4% indicated that measure should be put in place to curb the risk of oil spillage.

*Table 8: Government Interventions to improve the Sector*

| **Changes to improve the sector** | **Freq** | **% Freq** |
|---|---|---|
| Ban and/ or regulation industrial trawlers and Saiko fishing activities | 30 | 30.3 |
| Easy access to credit facilities | 11 | 11.1 |
| Enforcement of the laws | 17 | 17.2 |
| Provision of subsidies on fuel prices | 20 | 20.2 |
| Provision of marine engines and other fishing technology | 9 | 9.1 |
| Construction of boatyards or dry dock | 8 | 8.1 |
| Measures to reduce the risk of oil spillage | 5 | 4 |
| **Total** | **100** | **100** |

### 4.3.8 Characteristics of Semi – Industrial Fishing Fleet

The study's findings, as presented in Appendix II, revealed that the fleet in this sector are multipurposed (i.e. have dual purpose). The fleet size comprised of trawlers (56.6%) and purse seiners (43.4%). Majority (43.4%) of the fleets an overall length between the ranges of 36ft – 50ft while 17.2% of the total sampled fleets had an overall length between 61ft – 69ft. However, about 15.2% of the fleets recorded ranged between the length of 51ft – 60ft, whereas 13.1% represented 70ft and above LOA. Appendix II presented the range of horse power engines used by the fleets in this sector. The inboard engines ranged from 90 hp – 450 hp, with majority (28.3%) of the sampled vessels having 90 - 140 hp and vessels with inboard engines of 391 hp- 440 hp and 241 hp - 290 hp having the least percentage of 5.1%.

The average number of crews/ fishers in each sampled fleet is presented in Appendix II indicating majority (48.5%) of the vessels had 6 -10 crews on board for their fishing operation, whiles 5.1% vessels had a crew number of 26 – 30. Majority of the vessels (60.6%) go for fishing 18 days in a month, while 39.4% also go for fishing 15 days in a month. The highest number of days spent at sea was 3-4 days which recorded a percentage of 23.2, whereas the least number of days spent at sea is 1 day represented 32.2%. Majority (44.4%) of the sampled boats spent 1-2 days at sea as shown in Appendix II.

### 4.3.9 Profitability Analysis of the fishery

The value chain's cost and return of the semi-industrial fishery are shown in Table 9. The various players in the value chain incurred both fixed and variable costs. Along the study areas, the average variable cost of a boatowner/fisherman was 94.55% of total production costs, while that for fish processors and marketers were 97.81% and 98.73%, respectively. The fixed cost along the value chain constituted 5.45%, 2.19% and 1.27% for the boatowners/fishermen, fish processors and fish traders respectively. The majority (56.33%) of the total cost of operation for the boatowners was based on fuel and lubricant (oil) whereas the amount of fish purchased accounted for 88.6% and 90.95% of total cost of production for fish processors and fish traders, respectively. Crew wages and ice also formed 23.65% and 9.6% of the total production cost by the boatowners, respectively. The cost of firewood accounted for 4.16% and 2.48% of the total cost of operation by the fish processor and fish trader respectively, whereas packaging materials also accounted for 1.97% and 2.65% of the total cost of both the fish processor and fish trader respectively.

Net farm income analysis used to assess the profitability of the value chain revealed that an average boatowner/ fisherman earned a margin of about GH₵ 76,983.00 per annum which was on the average approximately GH₵ 422.99 ($73.00) per daily fishing trip, whereas an average fish processor earned an average per annum margin of GH₵ 81,366.50, which was approximately daily GH₵ 447.07 ($77.21) and an average fish trader earned an average per annum margin of GH₵ 83,043.00 implying a daily earning of GH₵ 456.28 ($78.80) daily. As of August 8, 2021, the dollar exchange rates were $1 to GH₵ 5.7974, according to the Bank of Ghana (BoG). The Net Return on Investment (NROI) of 0.20 for boatowners/fishermen, 0.25 for fish processors, and 0.27 for fish traders meant that for every Ghana cedi invested into the fishing activities, boatowners, fish processors, and fish traders received 0.20, 0.25, and 0.27 GHC, respectively.

Gross margins were computed for fishermen, processors and fish-marketers. The findings revealed that the average boat owner/fisherman earned a margin of about GH₵ 97,597.50 per annum which represented 21.45% of the total revenue, whereas fish processors and fish traders acquired GH₵ 88,433.50 (21.85%) of the total revenue and GH₵ 86,952.00 (22%) of the total revenue respectively. The expense structure ratio of 0.05, 0.02 and 0.01 for the three main actors in the value chain implied that about 5.4%, 2.2% and 1.27% of the total cost of production was made up of the fixed cost; while 0.17, 0.20 and 0.21 values for the net profit margin implied that profit margins of 17%, 20% and 21% respectively for the fishermen, processors and fish traders respectively per annum. The Benefit Cost Ratio of 1.20 (fishermen/ boatowners), 1.25 (fish processors) and 1.27 (fish traders) revealed that value chain of the semi-industrial fishery is economically viable despite the challenges impeding its expansion.

*Table 9: Average Cost and Return Analysis of Value Chain Actor per Annum*

| Items | Boat Owners/ Fishermen (49ft) | | Fish Processors | | Fish Traders | |
|---|---|---|---|---|---|---|
| | Amount (GHC) | % of Total cost | Amount (GHC) | % of Total cost | Amount (GHC) | % of Total cost |
| **Fixed Cost** | | | | | | |
| Vessel depreciation | 14,608.00 | 3.86 | - | - | - | - |
| Boat registration & license | 506.00 | 0.13 | - | - | - | - |
| Boat & gear maintenance | 5,500.00 | 1.45 | - | - | - | - |
| Wire Gauze | - | - | 1,365.00 | 0.42 | | |
| Oven / Freezer | - | - | 5,460.00 | 1.69 | 3,640.00 | 1.18 |
| Dep. Knife / Scissors | - | - | 36.00 | 0.01 | 27.00 | 0.01 |
| Dep. Pan or Basket | - | - | 160.00 | 0.05 | 160.00 | 0.05 |
| Dep. Table | - | - | 56.00 | 0.02 | 25.00 | 0.01 |
| Dep. Flat wooden tray | - | - | - | - | 57.00 | 0.02 |
| **Total Fixed Cost (TFC)** | **20,614.00** | **5.45** | **7,077.00** | **2.19** | **3,909.00** | **1.27** |
| **Variable cost** | | | | | | |
| Fuel & Lubricants (oil) | 212,940.00 | 56.33 | - | - | - | - |
| Ice for fish conservation | 36,400.00 | 9.63 | - | - | - | - |
| Food | 15,470.00 | 4.09 | - | - | - | - |
| Fresh water | 3,185.00 | 0.84 | 546.00 | 0.17 | 455.00 | 0.15 |
| Crew wages | 89,407.50 | 23.65 | - | - | - | - |
| Packaging material | - | - | 6,370.00 | 1.97 | 8,190.00 | 2.65 |
| Labor | - | - | 5,460.00 | 1.69 | 3,640.00 | 1.18 |
| Firewood | - | - | 13,468.00 | 4.16 | 7,644.00 | 2.48 |
| Transportation | - | - | 3,458.00 | 1.07 | 3,640.00 | 1.18 |
| Toll (tax) | - | - | 455.00 | 0.14 | 455.00 | 0.15 |
| Fish | - | - | 286,650.00 | 88.61 | 280,644.00 | 90.95 |

| Items | Boat Owners/ Fishermen (49ft) | | Fish Processors | | Fish Traders | |
|---|---|---|---|---|---|---|
| | Amount (GHC) | % of Total cost | Amount (GHC) | % of Total cost | Amount (GHC) | % of Total cost |
| **Total Variable Cost (TVC)** | **357,402.50** | **94.55** | **316,407.00** | **97.81** | **304,668.00** | **98.73** |
| **Total cost (TC)** | **378,016.50** | | **323,484.00** | | **308,577.00** | |
| **Total Revenue (TR)** | **455,000.00** | | **404,850.50** | | **391,620.00** | |
| **Gross Margin (GM)** | **97,597.50** | | **88,443.50** | | **86,952.00** | |
| **Net Farm Income (NFI)** | **76,983.50** | | **81,366.50** | | **83,043.00** | |
| **Net Returns on Investment (NROI)** | **0.20** | | **0.25** | | **0.27** | |
| **Net Profit Margin (NPM)** | **0.17** | | **0.20** | | **0.21** | |
| **Expense Structure Ratio (ESR)** | **0.05** | | **0.02** | | **0.01** | |
| **Benefit Cost Ratio (BCR)** | **1.20** | | **1.25** | | **1.27** | |

# CHAPTER FIVE

# DISCUSSION

The current findings are interpreted in this chapter, with references to relevant previous literature. It looks at trends in catch and catch per unit effort, as well as a bioeconomic analysis of the fishery and the industry's profitability along Ghana's coast.

## 5.1 Trends in Catch and Catch per Unit Effort

Stock levels fluctuate due to a variety of factors, including changes in the marine environment, fishing intensity (effort), market demand and prices, target species, and capture technology (catchability coefficient) (Caddy and Gulland, 1983; de Mutsert et al., 2008). As shown in Figure 4, the trend of annual production (catch) has experienced some fluctuations and declined steadily over time, with an increasing trend in effort in the fishery as demonstrated in Figure 3. This suggests that the fishery stock is dwindling at a faster rate than the catches (FAO, 2006). Currently, the Ghanaian fishery, as reported by MOFAD (2015), has experienced excessive fishing capacity, exploiting the current stock level, especially in the trawl sector. As shown in Figure 5, it could be observed that over time, as fishing efforts increased, the annual catch also decreased and vice versa, which is an indication of the effect of increasing effort on stock levels.

When no detailed effort data is available, total catch trends, as important as they are, may not provide a complete picture of the state of the fishery. However, catch per unit effort (CPUE) can be used to determine the relative abundance of a fishery when the general trend of the corresponding fishing efforts is available. This is due to the fact that the same quantity of fish could be harvested within different time frames, but the level of effort employed in the exploitation might differ. CPUE has widely been reported as a developmental indicator for sustainable fisheries utilization (Garcia & Staples, 2000). It is often assumed to be proportional to fish abundance and extensively used as a yardstick in measuring relative stock abundance in fisheries science (Richards & Schnute, 1986). The increasing trends in CPUE depict that exploitation of resources can still progress, whereas a declining CPUE indicate overfishing as a result of overexploitation. A fairly constant trend in CPUE indicates that impact on the fish stock on the fishery is very minimal (Hoggarth et al., 2006). As shown in Figure 6 the declining trend in CPUE indicates the presence of overexploitation of the fishery resources targeted by the semi-industrial fishery. Considering the increasing effort trends with decreasing annual catch trend as shown in Figure 6, the catch per fishing vessel has also declined. The results indicate a significant decline in catch per unit effort (CPUE) for the semi-industrial fleets, which agrees with Finegold et al., (2010). This trend, when continued over time, can result in a typified Malthusian overfishing (Pauly, 1994; McClanahan et al., 2008) and in worse cases, depletion of stocks (Hannesson, 1996).

The declining trend of CPUE recorded for this present study is similar to that of the trends in other subsectors of the Ghanaian fishery (Attah Mills et al., 2004; MOFAD, 2015) and in most West African fisheries (Silva et al., 2017; Coulibaly et al., 2018). According to the MFRD, as cited by Sackey-Mensah et al., (2012), the high proportion of artisanal fishing fleet in Ghana has resulted in overcapacity and overexploitation of fish stocks. The current declining catch per unit effort (CPUE) in this sector is supported by this report, which shows how overcapacity has led to overexploitation and, as a result, a decline in profitability. As shown in this study, the average CPUE has decreased by one-third in the last ten years (World Bank, 2011). In spite of the fact that fleet composition provides a measure of effort which is widely used in most instances (FAO 2004; Hanchet et al., 2005; Soldo et al., 2019), it does not on its own provides the magnitude of fishing pressure exerted on the stock. Evolution in the number of trips, days/hours spent at sea, employment of advance and innovative technologies (gears, engines, inboard storage facilities, GPS and fish finding devices) and increasing the number of crew is likely to expand and have a dramatic impact on the fishing pressure on the resources. Finegold et al., (2010) reported how relatively important it is to know how long vessels spend fishing as fishing pressure goes beyond vessel numbers. If the number of vessels increases but the number of days each vessel spends fishing decreases, vessel numbers alone may overestimate the change in fishing effort. Figure 7 reveals that the CPUE in terms of the number of days generally increased. This might be due to the fact that, the number of days spent at sea kept on increasing despite the fluctuation and declining trend of the fishing fleets and fish stocks. From figure 8, it could be inferred that there was an inverse relation between the number of days spent at sea and the size of the fleet in the fishery over time, which was mirrored in the results of the various CPUE trends.

The decadal rate of change in catch per unit effort as shown in Figure 9 reveals a decline of -0.68 in the first decade (1980 to 1990) which tends to increase from 1991 to 2000 and recorded the highest index of 0.73 showing a clear distinction. This increasing trend is unlikely to be the result of stock rebuilding or large stock sizes in Ghanaian waters. This is due to the fact that the decadal rate significantly declined to 0.14 from 2001 to 2010 and has negatively declined to an index of -0.36 currently. The decline could indicate that the fishery has reached its maximum level of overexploitation, and as such, the decline in decadal catch rates signifies overfishing. According to Hoof and Salz (2001), a decrease in CPUE correlates with a decrease in stock size.

Unlike the temperate regions where most of the fisheries are single species (Alverson, 1987; Carlson et al., 2018), the fisheries in the tropics show a distinct variation in multi-species (Mees, 1995; MRAG, 1996; Pinaya et al., 2016) and the case of Ghana cannot be exempted. This implies that fishing vessels, although they have targeted species, cannot exclude some level of by-catch in their operations. The semi-industrial fleets in Ghana are specially designed for trawling and purse seining purposes. According to the available historical catch data, the fishery depicts a perfect multi-species fishery, which targets both demersal and pelagic species. In order to derive the number of efforts per species, an assumption was made which directly related the quantity of harvest of individuals species to the level of effort that was applied. The total fishing days per vessel which landed a particular species was used as the fishing effort of an individual species. As a result, the CPUE per year for each species is equal to the ratio of each species' annual total landings to the total effort (days at sea) applied that year. The pelagic species (Chub mackerel, Round sardines and Flat sardine) had higher CPUE indices as compared to the demersal species (Cassava croaker, Shrimps, Cuttle fish) as revealed in Figure 10. Although from the survey, all these species abundance depends seasonality and mostly upwelling (Tall & Failler, 2012; Nunoo et al., 2015), the efforts exerted in harvesting them differ.

The semi-industrial, as reported by (Samey et al., 2015), operates as purse seiners during the upwelling seasons, targeting small pelagics, which are abundant in the Gulf of Guinea (GoG) during this season, while in the lean season they operate as trawlers targeting demersals. From the survey, it could be inferred that the size of purse seine boats is often larger (45ft – over 70ft LOA) in sizes with larger gear lengths as compared to trawlers. Again, the number of crew sizes ranges from 16 to 30 people on board in the purse seine boats, whereas the size of the crew ranges from 5 to 12 people at most in the trawl boats. All these characteristics of these boats can be said to contribute greatly to the fishing effort, which directly impacts the annual production, thereby driving an increasing effort.

Figure 10, illustrates an increasing trend in the CPUE of the three small pelagics except for Chub mackerel, which exhibited a declining trend in the CPUE, signifying a declining trend in stocks. According to USAID (2015), the total annual catches of chub mackerel have declined and are reported to be less than 10,000 mt from 2012 to date. Generally, the current fishing pressure exerted on the small pelagics by the semi-industrial fishery has exceeded the acceptable level of fishing pressure 0.40, a situation caused by excess fishing effort (USAID, 2015). The small pelagic fishery in Ghana is currently said to be overexploited; with a current decline in three of the four main species (USAID, 2015; Lazar et al., 2017; Lazar et al., 2018). The total annual catches of all three demersal species fluctuated considerably, with a general declining trend. According to Gulland et al., 1973, the CPUE of demersal stocks has generally shown a declining trend over a period of time.

The fishery sector of Ghana contributes significantly to the national economy, generating over US $1 billion in revenue each year, accounting for 1.2% of fisheries' Gross Domestic Product (GDP) (Quagrainie, 2019). Figure 11 shows the trends of the estimated revenue the semi-industrial fishery contributes to the fisheries GDP from 2005 - 2018. The revenue of the fishery is derived from total amount of income generated by the sales of the total annual production, corporate taxes, licensing fees, and other levies and investments. It could be observed that year-2007 recorded the highest revenue of about 93,500.00 GHC with a total annual production of 10,000 tonnes, whereas 2009, which recorded an annual catch of about 12,000 tonnes recorded the lowest revenue of 16,684.00 GHC. Several factors account for the pricing of fish landed. From the survey, availability and abundance is one of the key components that affect the prices of fishes. The trends observed in figure 10 could be a primary factor contributing to the fluctuations in the revenue of the fishery. Sizes and quality of fishes as well competition from other fishery also affect the market value of the fishery as revealed from the survey. In general, the revenue of the semi-industrial fishery has declined over the years, and according to Koranteng (1998), the decline of the semi-industrial sector has had a significant impact on the economy, reducing investment in fishing, GDP contribution, and employment.

**5.2 Bioeconomics and Fisheries Management**

Managing multispecies fisheries is a challenging task; as a result, efforts have been made over the years to develop new models to manage complex fisheries systems. Such models include: the Gordon-Schaefer model (Gordon & Schaefer, 1954), the Fox model (Fox, 1975), the Walters-Hiborn model

(Walters & Hilborn, 1976), the Schnute model (Schnute, 1977), the CYP model (Clarke et al., 1992). This study employed a static model approach based on Gordon-Schaefer specifications to provide an estimate for the optimal utilization policy of the semi- industrial fishery in Ghana.

To determine the ecological sustainability of current fish harvesting practices, the estimated MSY and associated effort levels were compared to actual or observed catch and effort levels. According to the findings of this study (Figure 14), the semi-industrial fishery is characterized by an increasing fishing effort and a decreasing CPUE. The yield-effort curve is derived from the current model results, as shown in Figure 15, with the catch and effort levels corresponding to the MSY (i.e., red vertical line), MEY (i.e., green vertical line) based on the cost of fishing (i.e., upward sloping black line), OAY (i.e., yellow line), and current level of effort (i.e., the blue line).

The current status quo of effort in the fishery deviated from the usual pattern of many fisheries in Africa (Gumulira et al., 2019) and the world at large (Kar & Chakraborty, 2010), where the current condition always exceeded the MEY and/or MSY. The observed current condition portrays that the fishing effort has been reduced drastically below the MSY and even the MEY level. In the past years (2007 to 2012), the effort levels of the semi-industrial fishery exceeded the current MEY level (208 licensed vessels) and in 2013 the level of effort went beyond the MSY level (356 licensed vessels), which clearly indicated overcapacity, overexploitation, and subsequent decline in economic benefit. These findings also depict that a lot of livelihoods revolve around the fishery. According to Grafton et al. (2007) overexploitation results in economic losses. This is based on an increasing fishing effort, according to FAO (2018).

This is also true of the semi-industrial fishery's number of days at sea, as the effort required at MSY (152,804 days at sea) with an annual harvest of 10740 tonnes/annum surpassed the calculated effort at MSY in previous years (2005, 2006, 2007 and 2009).

Fishermen are hunters and would always respond by moving to locations where the rate of economic opportunity is higher (Hillborn, 2007). They tend to maximize their profit by increasing their catch. However, stocks may encounter extinction if the total catch per unit vessel is not regulated properly (Clark, 1973), which in the long-term afflict the fishery with economic losses. The current condition was due to high cost incurred in fishing operations, and low revenue generated, which were not able to offset the cost of operations, let alone talk about making substantial profit in previous years (2007 to 2013). This economic condition forced most of the fishers and stakeholders to move out of the fishery and dock their boats, as reported by ex-vessel owners. This situation is comparable to that discussed by Atta-Mills et al., (2004). MOFAD reported that, the semi – industrial fishery produces the lowest landings amongst the three major fisheries subsectors of Ghana, although its efforts have doubled over the last decade (MOFAD, 2015). Again, the activities of the Saiko fishers have hampered the total revenue of these local fishers. The Saiko fishers tend to sell their landings at a relatively cheaper price as compared to that of the semi-industrial fishers. Hence, the local fishers (semi-industrial) are also compelled to reduce their fish prices so as to compete with them at the landing site.

Using the estimated parameter values, the maximum sustainable production (MSY) of the semi-industrial fishery in Ghana was calculated to be 12,661.63 tonnes/annum with a corresponding effort of 356 licensed vessels.

This indicates that sustaining the fishery biologically without destructing the biomass requires not more than 356 licensed vessels in the fishery. The Open Access Yield gave the highest effort level of about 417 licensed vessels with an estimated catch of 12,250 tonnes/year. The results from the OAY reveal that, the yield at MSY level (12,661 tonnes) is very close to that of the OAY, which indicates that fishing at the MSY level will need effective monitoring and management so as to prevent the fishery from reaching the condition of the OAY. At this level, poorly managing or regulating the fishery for short-term economic maximization will tend to overexploitation, but will avoid the complete dissipation of economic rent (Lleonart & Merino, 2010). Because of the economic phenomenon of the open-access regime mechanism, if effort is not controlled in the future, fishing costs will increase and revenue will fall (Hardin, 1968). To avoid this situation, current effort levels could be maintained or increased by 12.5% over the next ten years to reach MEY, and more attention should be focused on increasing total economic revenue and lowering total costs through proper policy implementation.

The economic equilibrium was determined by calculating the Maximum Economic Yield (MEY) from the estimated biological and economic parameters. This is the point at which there is the greatest disparity between total revenue and the total cost of fishing (Clark, 1985). According to the study, the harvest and cost of harvest are lower at the MEY level than at the MSY and OAY levels, but the economic rents are higher. The maximum profit at MSY was estimated to be GH₵27,288,081.76, whereas at MEY the profitability was maximized to an estimated value of GH₵54,387,545.23. Since the total revenue at open access equilibrium is equal to that of the total cost of operation, zero profit was made at this point. According to Kompas (2005), the effort level at MEY is the most socially desirable level of effort because it generates the highest net returns and makes efficient use of fishing resources.

Furthermore, the MEY point had a relatively larger range, with the maximum production at MSY of 12,661 tonnes/annum and the effort of 356 licensed vessels, due to higher operational costs and low revenue. Clark (1990) as cited by Sumaila and Hannesson (2010), explains that perhaps MSY and MEY are equal when the fishing cost is zero. However, the relatively greater difference between MSY and MEY levels may result in a win-win situation for both the fishers operating at MEY (added profitability) and the environment (larger fish stocks and lower impacts on the rest of the ecosystem) (Kompass et al., 2010). A given amount of production and effort would produce zero profit at bionomic equilibrium (Clarke, 1976). At the condition when the effort level exceeds the open access equilibrium, then total cost will be bigger than the total revenue (TC > TR). Thus, the economic rent will be negative. At this point the fishermen and boatowners will tend to suffer from loss and tend to leave the business. This is because the benefits of the fishery in terms of natural productivity are offset by competitive forces that result in overexploitation, lowering the return on fishing effort (Kompass et al., 2010). The result of the model suggests that, the current actual average production is 9,699 tonnes per annum which is lower than the optimum utilization at MSY and MEY level. It means that semi-industrial fishery utilization in Ghana has not optimum yet. This study therefore conforms with the findings of Habib et al. (2014), which reported that the fishery of Bay of Bengal had also not been biologically overexploited.

However, this necessitates effective regulations to maintain the current status quo of the fishery and even if there would be an increment in effort, it must not exceed the level of Maximum Economic Yield. Weak and ineffective management of semi-industrial fisheries has been hindered by increased fishing effort, industrial trawler impact, and insufficient institutional and legal frameworks. Thus, the current study recommends policy intervention to save the stock from depletion and subsequent collapse.

The historical fishery profitability results are as predicted. Fisheries operated near and beyond the MSY. From 1980 to 2018, the fishery's economic rent fluctuated immensely. The fluctuations in the economic rent were mainly due to excessive fishing effort, which precipitated the low catch per vessel and therefore resulted in lower revenue despite the high cost of fishing operation. The negative rents recorded in 2008, 2013 and 2014 reveal that the efforts of the fishery were very close to the MSY and sometimes even beyond. The current status quo suggest that should effort be maintained; the fishery would generate a net benefit of GH₵ 54,231,540.07 per annum. This current state would require management to regulate the fishery effectively.

The net present value (NPV) of projected cash flows is an important economic measure used to assess the profitability of a project or investment where decision making is based on the investment with the highest positive NPV (Sumaila et al., 2012). The change in NPV for different fisheries management conditions was used to represent the economic benefits of fishing (Current status quo, MSY, and MEY). The fishery business is an industry where cash flow is uncertain due to climate change and changes in stock size. This implies that actors and stakeholders in this industry would want to get the highest present value on the amount spent on acquiring the capital goods.

With the current status quo, the net present value was estimated to be GH₵ 324,273,930.29 after inflation adjustment, which means that the total benefits were approximately 19% lower than the total cost. Under the MSY condition, the NPV was estimated to GH₵163,167,291.78 which is about twice (GH₵ 161,106,638.51) less than the current status at the same discount rate. It is vital to note that, the total discount rates are the same for all the conditions. Even so, we can see that the total estimated cost plays an important role as the outcomes with the same discount rates differ from one another. The net present value with a MEY level was also calculated and the result show a positive value of GH₵ 325,206,752.90 which is approximately GH₵ 932,000.00 higher than the NPV at MSY, accounting for a 49.82% difference. The net present value (NPV) for the current state and MEY level of the semi-industrial fishery reveals that the fishery is economically viable and sustainable for exploitation at the effort levels of these conditions. Although exploitation would be economically viable at MSY in short terms since it has a positive NPV, the rate of returns would be low and would be advisable if fishing exploitation should operate at the current status or the MEY level. As a result, immediate intervention is necessary to reevaluate current management measures for the sustainable management of semi-industrial fisheries.

**Environmental and economic scenarios**

The United States Sustainable Fisheries Act (Office of Coastal Management, 2019) and the United Nations Convention on the Law of the Sea (United Nations, 1982) both emphasize the importance of considering economic, environmental, and social implications when managing any fishery. The model must be inclusive by taking into account the three dimensions: the biology of the fish, the economics of harvesting, and the environment. However, the current study did take into account some of these potential scenarios. With nine different scenarios, the fishery's sensitivity to potential climatic change and economic conditions was examined in terms of carrying capacity, growth rate, and economic performance. Scenarios 3, 5, 6, and 8 showed a distinct percentage change in harvest level (MEY and MSY), corresponding effort, and profit level. In comparison to the current situation, these four scenarios showed profit levels of GH₵ 19 million (35%), GH₵ 14 million (26%), GH₵ 49 million (89%), and GH₵ 36 million (67%) at MEY level respectively.

The occurrence of such scenarios is not expected in the case of semi-industrial fishery. However, current human-induced activities, climatic variations, and existing fishery management measures can easily lead to the situation predicted in Scenarios 1, 4, and 7. However, in light of the potential consequences of climate change, the fishery manager should make every effort to maintain existing MEY, which will help to sustain the semi-industrial fishery. The impact of climate change on the of fish stocks could be categorized into two, which includes; the physical changes (e.g. changes in salinity, ocean acidification and rise in sea surface temperature) and the biological changes (e.g. growth, recruitment, primary production, and spatial fish stock distribution), (Eide & Heen, 2002; Mohammed & Uraguchi, 2013).

According to Hare et al. (2010), the success of stock recruitment may be influenced by changes in climatic conditions, which tend to impact the productivity of the population. Biological parameters such as growth, mortality, and recruitment are extremely related to a specific range of environmental conditions both spatially and temporally (Orensaz, 1986; Kifani et al., 2018). Hence, changes in climatic conditions may interrupt with projections and assessments of the future fishery if not duly considered in predictive models.

From the model employed in this study, it could be deduced that, climate induced changes in the fishery can significantly impact the profitability of the fishery. According to some assessments reported by (IPCC, 2007; Westlund et al., 2007; FAO, 2018), the fishery resources in the West African coasts are gradually becoming scarcer, which is likely to affect profitability of the small-scale fishing operations because of the increase in time spent per fishing operation, cost of operation (fuel expenditure) and irregular catches. According to collective studies based on global models, the Guinea Current subregion's marine catch potential will be significantly reduced by 2050. (Cheung et al., 2010). This situation might be the same or worse in the Ghanaian marine fishery as it often suffers from anthropogenic stressors. The changes in climatic conditions also impacted the effort level and yield at various scenarios. In the current scenario, the effort at MSY, MEY, and OAY were consistent with that of scenario 3 and 6.

The sensitivity analysis also revealed that in the current situation, the model is extremely sensitive to changes in revenue and operating costs, resulting in changes in profit levels. The sensitivity analysis revealed that, even if biological parameter estimates and price and cost information significantly change, the semi-industrial fishery has the ability to increase economic rents ranging from GH₵ 49 million to GH₵ 130 million at MEY, and GH₵ 24 million to GH₵ 129 million at MSY from the model at different scenarios. At the current level the fishery is likely to generate an economic rent between GH₵ 49 million to GH₵ 102 million. In addition, should cost decrease by 10%, keeping the current fish price constant, the revenue acquired from the fishery could increase by 13% (GH₵ 7 million) with an increase in the effort of 7% (15 licensed vessels) at MEY. The bioeconomic model developed in this study shows that the semi-industrial fishery is generally profitable. But in the phase of unaddressed constraints the prospective outcomes of implementing the optimum reference points derived from the model for the fishery would be inhibited.

**5.3 Profitability of the semi – industrial fishery**

Gender roles plays an essential component of the Ghanaian fishery, according to Odotei (1995). The present study focuses on the profitability of the semi-industrial fishery in Ghana which was assessed through value chain analysis. The study identified three major nodes in the value chain, including; fishermen, fish processors and fish traders. Along this chain 100% of the men dominated as fishermen with 4% and 10% as fish processors and fish traders respectively. Women as well were not represented as fishers but dominated the fish processing and trading with a percentage of 96% and 90% respectively. These results may be attributed to the energetic and multi-tasking nature of commercial marine fishing activities, which the male gender may be able to handle effectively compared to the female gender, whereas the activities associated with getting fish landed at the beach to the consumer, as described by Over (1992), are best handled by women.

Women tend to dominate the processing and distribution chains (Sackey, 2007; Pomeroy & Andrew, 2011; Harper et al., 2013). The few men encountered in the processing (4%) and trading (10%) sections of the value chain revealed that they were engaged in it as part time and that it was only done to support their wives when demands were high or catches were in excess to prevent post-harvest losses. The above findings suggest that the value chain is gender sensitive, with males dominating as fishermen and females dominating as fish processors and traders. These findings were in agreement with the results of Olubanjo et al., (2007); Olawumi et al., (2010); and Odebiyi et al., (2013) that the fishing industry was gender sensitive.

The years of working experience was empirically evidential that a greater percentage of the actors in the value chain had more than 20 years of experience in the business with a percentage of 47%, 50% and 55% fishermen, fish processor and fish traders respectively. The fish traders had a higher percentage of respondents due to the fact that, labor turnover for traders are lower than that of the fisherman and processors. According to Akpalu (2002) fishing and fish related business is one of the most important forms of both direct and indirect employment-generating activity in Ghana's coastal area. According to the study, the majority of actors were entirely reliant on fishing-related activities for their income and livelihood. This finding also conforms with that of Ameyaw et al. (2020) which found out that the sector employs and sustains the livelihoods of a significant number of the active labor force, including women who play key roles in the on-shore post-harvest activities, undertaking fish processing and storage and trade activities along the coast of Ghana. The few percentage (8.4%) of respondents who had an alternate source of income and livelihood operated predominantly during the lean or closed season.

Due to the current decline and fluctuations in the fishery as cited by Atta-Mills et al. (2004) and World Bank (2019), fish mammies and processors who played a vital role in financing fishing trips (Britwum, 2009, Chikondi et al., 2017, Ameyaw et al., 2020) constituted 20% with family and friends constituting 70% of the respondent as shown in Appendix I. This might be due to some consistent losses incurred for sometimes on the premises of low catches by the fishing fleets they fund. Furthermore, owing to the requirements for a formal bank loan including the provision of collateral and a regular income both of which might be lacking by the fisher folks, and the high rate of interest charged on loans (McKernan, 2002), boatowners/ fishermen tend to resort to their family and friends for their source of funding which comes with some sort of flexible conditions as revealed by some respondents. From the study only 1% of the respondents disclosed that their source of funding was derived from the bank.

In Ghana, marine fisheries have been confirmed to be largely influenced by seasonal upwelling (Perry & Sumaila, 2007; Neokye et al., 2021); major season (July-September) and minor season (December-January/February) that occur in its coastal waters, which tends to increase its biological production and abundance. In the current study, the most common season of abundant fish catch was from June to August (61.6%) and September to December (15%), as reported by the respondents. This conforms with that of Taller and Failer (2012). Meanwhile, 17% of the respondents could not associate abundant fish catch to any season of the year. It is evidential from the results that a greater proportion (50%, 58% and 51%) of the fishermen, fish processor and traders associated the variations of fish prices to availability and abundance. This result was anticipated since it appeared to be consistent with the scarcity principle in economic theory. According to the principle, the price of a scarce good would rise until an equilibrium is reached between demand and supply. Therefore, the prices of fish landed are not fixed as a result of the mismatch between the desired supply and demand equilibrium.

The increase in fuel prices and other fishing input also had a great influence in fish pricing which scored 16.4% out of the total respondent. In economics, the cost of production influence prices because they directly affect supply. The increase in prices of gasoline over the years have been a key driver in the variations in fish prices experienced. Ochiewo, 2004 reported that, seasonality is one of the major factors which influences fish prices. From the study, it could be inferred that, during the upwelling periods, the prices of fishes reduce because of increase in productivity as compared to that of the lean season when productivity is relatively low. The few respondent (7.6%) who recorded that prices do not vary argued that fish prices are relatively stable throughout the year and that no factors influence the price of the fishes.

This study revealed certain constraints encountered by the women in the value chain which impeded the marketing of their fish product. A total of six (6) major constraints were identified from the results. Majority (28%) of the respondent indicated that the lack of storage facilities is one of the key challenges in the fish value chain development. A larger group among fish processors preserve fresh fish mainly through smoking (Odebiyi, 2013). This is done to increase the shelf life of the fish and also for value addition purposes before reaching consumers. During the peak seasons, there is a significant rate of fish decay as a result of poor storage facilities making large quantity of fish go bad thereby contributing to huge economic losses. Due to this constraint, prices of fishes are reduced and sold at relatively cheaper prices to prevent zero economic losses.

In addition, the technology (chorkor smoker) employed by most fish processors in smoking their fish tends to have implication on their health. Health issues as cited by Ameyaw et al. (2019) are focused around lung problems and irritations of the eyes caused by continuous ingestion and inhalation of fumes and exposure to heat during the fish processing activities. This was evidential in the percentage (17.3%) of respondents who indicated health issues as a major constraint affecting their livelihood. However low profit, insufficient capital, credit- based purchasing and unstable fish prices were other constraints which hampered the sustainability of the livelihood of these women to a great extent. These limitations were no different from that which are been experienced by women in other parts of Sub Saharan Africa (Matsue et al., 2014; FAO, 2019). In Malawi, as reported by Manyungwa-Pasani et al., (2017), some traders do return back home when they are unable to sell their fishes because of low prices offered by traders and retailers, tied with the fact that the landing sites and markets do not have proper storage facilities for preservation of fishes until prices are conducive for sale. Further studies conducted in Lake Victoria, Tanzania also revealed that low financial capacities for women in fisheries, especially fish processors were those who had failed to generate products with acceptable quality for regional markets. This was based on the fact that, the terms and condition set by financial institutions for loan accessibility are almost impossible for women to fulfil (EMEDO, 2007).

**Effect of industrial on semi industrial operations**

The number in fleet size of industrial trawlers in Ghanaian waters has in recent years expanded (EJF, 2020) and has shifted focus from their authorized species to those licensed for the inshore sector. The current study indicates that, about 76% of the respondents reported the impact of industrial vessels on their operations. A greater proportion (28%) of the 76% of the respondents emphasized that, trawling in inshore waters by industrial trawlers has had a significant impact on their output. This is due to the fact that these vessels are well-sophisticated, which tends to destruct the seabed and fish habitat during their operations in inshore waters. This causes some fish species to migrate upstream in search of conducive habitats. Under the fisheries law, Act 625, towing gears are prohibited to operate in shallow waters with a depth of less than 30 meters, but due to lax monitoring and surveillance, these vessels continue to operate, causing substantial economic losses to the inshore fishery.

Unauthorized mesh sizes and gears have now been employed by industrial trawlers according to 15% of the respondent interviewed. EJF (2020) confirmed that some industrial trawlers line their trawl nets with a small unauthorized mesh size at the codend, resulting in the capture of juvenile fishes. In addition, some bottom trawl gears have been adjusted to serve as mid-water trawls to target pelagics within the water column. Due to these illegal practices, semi-industrial fishers have to triple their effort at sea to recoup the cost of operations. Some key informants in this sector reported that most fishers are not even able to break even on their cost of operation, let alone make a profit. This validates the report by MOFAD (2015) that the profitability in this subsector is the lowest amongst the three subsectors in Ghana. Recently, research conducted by EJF and Hen Mpoano proved that several tonnes of unwanted bycatches are dumped into the sea by these industrial trawlers.

Under the fisheries regulation Act 625, gears of industrial trawlers are prohibited to land more than 10% bycatch of their total landings. Owing to this, they are forced to select the desirable sizes of the commercially important species and dump the remains at sea. When this occurs, the dumped fishes (organic matter) tend to decompose, utilizing oxygen in the process and producing methane (foul smell) which causes an anoxic environment, compelling the fishes to migrate from their breeding and feeding grounds in search of a favorable environment. Unfortunately, most of these illegal practices (dumping) are undertaken within the fishing grounds of the inshore fishery, which have a great impact on their operations, as reported by 13% of the respondents.

One of the most talked about IUU practices precipitating the collapse of the semi-industrial fishery and the Ghanaian fishery at large, is the act of transshipment, popularly known as the "Saiko fishing" in Ghana. This activity has become very deliberate in exploiting juvenile fish and non-targeted species, such as the small pelagics for transshipment at sea to specially adapted canoes (EJF & Hen Mpoano, 2018). In 2017, as reported by (Aheto et al., 2020: EJF & Hen Mpoano, 2019), an estimated catch of about 100,000 tonnes of fishes were landed by industrial trawlers through Saiko fishing activities, which were predominantly made up of small pelagics. Economically, this illegal fishing business poses a severe threat to the inshore fishery since it creates some kind of competition between them and these Chinese vessels (SFMP, 2018). The number of specialized adapted canoes involved in these transshipment activities is on the increase in the central and western parts of Ghana (Dovlo et al., 2016).

In recent years, there has been a significant overcapacity of industrial fleets in the waters of Ghana. Industrial trawlers have increased by a rate of 49% from 52 vessels in 2009 to 103 vessels in 2014. As of 2016, the industrial fishery constituted a total of 98 vessels, and currently (2018), there are 76 registered industrial vessels (FSSD). According to MoFAD (2015) report, the current status of the industrial fleet (effort) in Ghanaian waters exceeds the corresponding Maximum Sustainable Yield (MSY) reference point, which is an indication of overcapacity and overfishing in Ghanaian waters. Under the Management Plan of MoFAD (2015), one of the five key issues it purposed to address was the reduction of fishing effort by 50% and overcapacity of the industrial trawlers, which has seemingly become impossible to initiate due to political interference. These vessels, instead of operating beyond the Inshore Exclusion Zone (IEZ), are now seen competing in the same waters as the semi-industrial fleets. Due to low capacity, most of the semi-industrial boats are unable to operate beyond the IEZ which are reserved for them, but this is vice versa for the industrial vessels. Eriksen et al., (2018) indicated that the industry is likely to lose an accumulated sum of over USD 200 million to these trawlers. Globally, ineffective fisheries management results in revenue losses of more than USD 80 billion per year, which could be recovered if global fisheries were significantly reformed, including a 44% reduction in fishing intensity (World Bank, 2017).

Prices of petroleum products have constantly increased over the last decade in the Ghanaian market, increasing the cost of operations in goods and services. Per Bennet & Mallick (2002), the prevailing economic conditions have had a number of effects, even in the context of fisheries. The rise in petroleum prices has increased the cost of fishing operations and input prices. As the operational cost rises, so do the fish prices also rise to compensate it (GoG, 2000). Actors involved in subsequent nodes of the value chain also experience a rise in their cost of operations. The knock-on effect is widely spread. Maintenance and repair of boats are one of the core sections of the industry that could generate substantial revenue for the development of the semi-industrial fishery in Ghana. In general, a well-maintained boat would increase its effective performance, thereby increasing its life span and maximizing revenue generated. Two main Boatyard Corporation were established by the Government of Ghana in Sekondi (1952) and Tema (1962) for semi-industrial fishery but due to lack of proper management and maintenance, these facilities have lost it main purpose. These boatyards have now been converted into slum settlements by fisherfolk and other infrastructural development in recent times. Proper maintenance and mending of fishing boats has really become a burden for boatowners due to the lack of drydocks along the coast of Ghana.

As reported in Sekondi fishing harbor by some key informants, the only functional boatyard operating has been made specially for industrial vessels. This facility is private-owned and hence their services are relatively expensive, which comes in foreign currency (dollars), which these boat owners are not able to afford. About 15.2% of the boatowners revealed that, a lot of faulty boats have been docked at the harbor for years and are in very poor condition. In the long run, the alternative method of maintaining and repairing boats along the coast worsens their conditions and shortens their lifespan, causing economic insecurity for the owners.

**Government interventions to improve the sector**

The fisherfolks in this subsector were then asked about the policies and strategies the government implement to improve the sector and the industry at large as far as their livelihood were concerned. In all, seven (7) different forms of suggestions were mentioned by respondents across the three coastal regions. Majority (30.3%) of the respondents were of the view that the ban on Saiko fishing activities and effective regulation of the industrial trawlers is the number one prerequisite of revamping the sector. Most boatowners and fisherfolks hinted that apart from these industrial trawlers pursuing the same species of semi-industrial f, fleet, their involvement in Saiko fishing activities create a competitive market for them and tends defaces their total revenue at the long round. Good fishing revenues from landings help compensate for cost of fishing operations and improves livelihood of fisherfolks. Provision of subsidies on petroleum products (diesel) was one pertinent interventions policy suggested by 20% of the respondents. Higher cost of fishing inputs especially fuel have indirectly reduced the number of hours spent per trawl and days spent at sea.

Although from an effort reduction perspective, it may look positive, this trend is negative from an economic point of view because, among the small-scale fishers, semi-industrial vessels are the only subsector that pays licensing fees and other levies each year before they are permitted to operate. Meanwhile they operate in the same waters (IEZ) and targets the same species with the artisanal whose fuel cost and other fishing input such as outboard motors and gears are been subsidized. However, another prominent request of the fisherfolks was found to be easy access to credit facilities. The nature of their work is capital-intensive and requires money to invest due to the cost of fishing trips as well as logistics for operations. Without a doubt, in the small-scale fisheries sector, access to fishing inputs, loans, and other financial support is critical to one's ability to thrive (World bank, 2009). Also 17% of the respondent highlighted enforcement of the law as a key driver in improving the sector. Sanctioning and fining violators of the fisheries laws could deter others from committing that same crime, but most often what is been observed is the weakness in the system for prosecution of offenders.

Cases of trawlers charged with violating regulations, according to Eriksen et al. (2018), may be taken to court or transferred to an arbitration arrangement known as Alternative Dispute Resolution (ADR), where settlements are reached and violators fined. However, because the penalties are too low, these agreements do not dissuade perpetrators. Political power and influence are a major roadblock to enacting effective legislation and regulations. Following up from this, the provision of marine engines and other fishing technologies and the construction of boatyards or drydocks were some interventions schemes revealed by the respondents. Currently, most of the inboard engines used by the semi – industrial fleets are altered heavy-duty diesel engines, which turns to consume a lot of fuel because of the high rate of combustion. Owing to the high cost of marine inboard engines, only a small percentage of fleet owners in this industry have them.

Fisherfolk suggested that the government could import marine inboard engines and subsidize them, so they pay them in installments to improve their livelihood. They further added that the altered heavy-duty diesel engine increases their cost of operation (fuel and maintenance), thereby reducing their rents. The few (4%) respondents who suggested measures to reduce the risk of oil spillage interventions were based in Sekondi fishing harbor. This could be due to their proximity and interactions with the Jubilee Oil Field and its unforeseen consequences.

**Profitability of the fishery**

The net return on investment (NROI), net profit margin (NPM), and net farm income (NFI) were calculated (Table 9) for each actor along the value chain. The total revenue derived from the fishery activities by the boatowner, fish processor, and fish trader was GH₵ 455,000.00, GH₵ 404,850.50, and GH₵ 391,620.00, respectively. The total costs incurred by the boatowner, fish processor, and fish trader were GH₵ 378,016.50, GH₵ 323,484.00, and GH₵ 308,57700 per annum, respectively. In outright terms, the boatowner, fish processor and fish trader acquired, GH₵ 97,597.50, GH₵ 88,433.50, and GH₵ 86,952.00 worth of profit from the fishery activities per annum respectively. Similar values were recorded by Asmah (2008).

Fishing operations by all actors in the study areas are profitable, from the net margin analysis. From the analysis of profitability indicators, the NROI for the fishermen, processors, and traders was 0.20, 0.25, and 0.27, respectively as shown in (Table 9). This shows that for every Ghana cedi invested in the business, a return of the GHC 0.20, GHC 0.25 and GHC 0.27 respectively was obtained by fishermen, processors, and traders, which further showed that there is relatively high profit across the value chain. In terms of economics, the fish trader would earn a higher return on investment than the other actors in the chain for every unit of capital invested. This is in contrast with the findings of

Adewuyi et al. (2010) in their studies on profitability of fish farming and economic analysis of coastal fisheries value chain. Moreover, the BCR as shown in (Table 9) for all the actors in the value chain was greater than 1, as revealed in the table which implied that the fish value chain was profitable irrespective of the stage in the value.

# CHAPTER SIX

# SUMMARY, CONCLUSION AND RECOMMENDATIONS

## 6.1 Summary

The overarching aim of this study was to empirically examine the biological and economic factors that affect or influence the semi-industrial fishery in order to determine the most efficient management options for optimizing outputs from the fishery. The trends in annual catch, effort, and catch per unit effort per unit of the fishery are presented in this study. The study also employed a bioeconomic model for the semi-industrial fishery from 1980-2018, which highlighted the various fishery reference point (maximum sustainable yield, maximum economic yield, open access yield, and current status) as well as the efforts required to achieve them. The economic rents achieved at each reference points were also estimated. Data from the Fishery Scientific Survey Division was used to assess information on the value of the fishery from 1980 to 2018. (FSSD).

To ascertain the profitability of the fishery at each reference points, the net present value (NPV) at each reference point was determined. Sensitivity analyses (SA) were run to determine the impact of potential climatic and economic variations that might possibly influence the biological and economic parameters of the fishery in the future. For the socioeconomics of the semi-industrial fishery, information on the demography of various actors along the value chain and profitability of the fishery are presented.

## 6.2 Conclusions

Generally, the CPUE for the semi-industrial fishery in Ghanaian waters showed a steady declining trend over the years. Such trends in a fishery may be symptomatic of overfishing and fishermen might suffer high costs if no fisheries subsidies are given (Willmann et al., 2010). The observed trends were in conformity with the findings of Dovlo (2020) where there was a decline in CPUE of the artisanal fishery in Ghanaian waters as well as Habib et al., 2014, where the commercial fishery in the Bay of Bengal experienced a decline in CPUE. Small fish, which do not contribute much in terms of total weight in yield, are subjected to increased effort pressure, which reflects the declining trend. CPUE has traditionally been used as a stock abundance index, including assessments of pelagic and demersal resources (Koranteng, 1998; Hoyle et al., 2014).

In terms of species wise, pelagic species tend to have a higher CPUE than demersals. This could be as a result of size of the vessels, crews, horse power of inboard engines, gears and technologies employed in purse seine operations, which are more efficient as compared to that of the trawlers. Though both the CPUE's and the annual catch of purse seine boats were higher than that of trawlers, the cost of operations by the trawlers are relatively lesser than that of purse seine boats. The value of CPUE of semi-industrial fishery in Ghanaian waters over a period of 39 years (1980-2018) shows a fluctuating and declining trend. The average CPUE value is 50 tonnes per vessel, whereas the highest CPUE value occurred in 1986 which was 90.5 tonnes per vessel and the lowest CPUE value occurred in 2008, which was 18.1 tonnes per vessel.

Factors such as the amount of fuel, fishermen's experience, size of boats, horse power of engines and the number of days spent at sea simultaneously (concurrently) had a significant effect on the fishing production of semi-industrial. The amount of fuel is the dominant factor or has a strong influence in the fishing production in the fishery since it reflects the number of days spent at sea per vessel, which generally showed an increasing trend in CPUE from 2005-2019. The major factors associated with semi-industrial fishery recording the lowest annual production over the past decades in Ghana could also be a result of overcapacity of fishing fleet, leading to overexploitation of the fishery resources and the subsequent decline of stocks. Illegal activities on the part of industrial trawlers, such as Saiko fishing, trawling in the inshore zone and destruction of fishing grounds by the use of sophisticated gears can be said to be a contributing factor to the decline in the annual production of the fishery.

This study then employed a surplus production model to determine the most appropriate management strategy for Ghana's semi-industrial fishery. Economic models and other population growth models can be used in the management and regulation of such fisheries. The Gordon-Schaefer model was chosen over other models because it is a comprehensive model that can be used to understand the fate of fisheries under natural open-access and can describe their economic efficiency (Valatin, 2000; McGoodwin, 2020). Despite this strength, the Gordon Schaefer (G-S) model has some flaws due to unrealistic assumptions. Again, the biological process and spatial distribution are ignored. The reasons for fluctuations in fishing or natural processes are unclear (Seijo et al., 1998).

The findings of the current status of this study are in contrast with the general perception that the fishery is experiencing an overcapacity of fishing efforts, which eventually leads to overfishing. Despite the overall findings of the status of the fishery currently, the fishery had exceeded the level of maximum economic yield and even, to an extent, gone beyond the sustainable production level some years ago, which necessitated an effective management regime to prevent it from negatively overtaking the bionomic equilibrium. The years 1980 to 1988 and 2007 to 2014 show a clear instance where effort at both MEY and MSY exceeded the current reference points of the fishery. The highest profit was made at a production level of 10,490 tonnes/annum with an effort level of 208 vessels/year, whereas the best biological utilization of semi-industrial fishery occurred at a production level of 12,661 tonnes/annum with an effort level of 356 vessel/year. At an effort level of 417 vessels, the profit will gradually decrease to zero after passing through the MSY level (which is equal to the effort at open access equilibrium).

Currently, the actual average production is 9,699 tonnes per annum with an effort level of 182 vessels per year which is below the optimum utilisation at MSY and MEY levels. This depicts that the semi-industrial fishery utilisation in Ghana has not reached its optimum level yet. Utilization of the biological resources at MSY and MEY had a relatively narrow range, but the profitability at MEY was twice that of MSY from estimations derived in this study. These results show that it is more profitable to operate at the current status quo and MEY for the fishery at MSY. It is therefore prudent that the fishery should be managed intensively by the fishery managers and all interested stakeholders with strong emphasis in enforcement of the existing regulations and also maintaining the fishery effort at the current status quo or if any expansion should not exceed the MEY. Further expansion in fishing effort beyond the MEY and close to the MSY will produce a relatively smaller profit and subsequently yield zero economic benefit at effort beyond the MSY level. When this occurs, there would be an unnecessary wastage of fishing inputs such as money, labor, and fuel in the fishery, and this would disturb its biological and economic equilibrium. For conservation, restoration, and sustainability of the fishery, it is necessary to develop regulations and enforce laws with respect to the reference points. In this respect, it should be noted that this study provides an estimated value of fishing effort to achieve MEY, which is a globally accepted fishery management tool to manage the resource sustainably.

Despite the fact that the number of vessels has reduced over time and is currently below the MEY level, the study also reveals that if there is no effective management and conservation policy, semi-industrial fisheries may experience overexploitation, owing to an increase in corresponding effort (number of days spent at sea). The effort (number of days at sea; 144,591) had almost reached the optimum effort level (MSY; 152,804) with its corresponding yield (11,701 tonnes) exceeding the maximum production level (10,740 tonnes per annum), indicating overfishing. Since the corresponding effort levels (number of days spent at sea) of the semi-industrial fishery has already achieved MEY and are very close to MSY, there is a pressing need to monitor the dynamics of this fishery resource in order to ensure its long-term viability. The expansion of effort in terms of the number of days spent at sea may threaten the fishery and lead to the gradual collapse of the fishery economically. Thus, not only increase in the number of vessels should be regulated but also the number of fishing days spent at sea should be monitored. The semi-industrial fishery shows that MEY and MSY have a positive present value and are decreasing over time. The current MEY levels are, on average, higher than the current MSY levels. Using the discounted rents from MEY and MSY for the fishery, the net present value of GH₵ 325,206,752.90 and GH₵ 163,167,291.78 would be achieved, respectively. In view of this, it can be concluded that exploitation of semi-industrial stocks will be more economically viable even till the year 2030 if the fisheries are exploited at MEY and the current status quo.

In spite of the estimated profitability of this subsector of the Ghanaian fishery at various conditions, the study also highlighted some major constraints that impeded the development of the semi-industrial fishery. Saiko fishing activities and the high influx of trawling vessels, high prices of fuel and other fishing inputs lack of boatyards or dry docks, and lack of marine engines were the major constraints that accounted for the major fluctuations of the semi-industrial fleets in Ghanaian waters. Management strategies are unlikely to produce optimum results in the existence of these constraints impeding the development of the fishery. Therefore, regulations and policies to curb these constraints must be addressed to enhance the implementation of any management regime yielding tangible results.

To evaluate the profitability of the fishery, the value chain analysis approach was employed. Three main actors were identified in the fish value chains of the semi-industrial fishery in Ghana. They are the fishermen (solely men), the fish processors (dominated by women), and the fish traders (dominated by women). The actors in the distribution of fish to the final consumers performed different functions such as buying and selling, processing, packaging, transportation, and storage which could be classified into physical, exchange, and facilitating functions (Amador et al., 2006). The landings and marketing from the semi-industrial fishery are locally consumed and some demersals are occasionally exported. Most often fish processors along the chain handled their fishes through smoking (chorkor smokers).

All value chain actors lived above the World Bank's international poverty line of $1.90 per day, according to the net margin analysis. The high Expense Structure Ratio of the fishery can be attributed to the fishermen's earnings, which are just above the poverty line. Despite the fact that the net margin analysis revealed that the fish traders were the most profitable actors in the value chain, the results revealed that they had a higher benefit cost ratio (BCR). All of the value chain activities had BCRs greater than 1.0, indicating that they all provided high returns to the actors. Each actor's investment yielded a profit. The semi-industrial value chain can thus be used as a tool for poverty alleviation in the coastal areas and also promote food security in Ghana.

The Net Farm Income (NFI) and Net Return on Investment (NROI) for the various actors along the semi-industrial value chain are significantly inequitably distributed and hence very competitive. Although the value chain was found to be profitable at each node, the problems of lack of storage facilities, low profit and losses, health issues, insufficient capital, credit-based purchasing, and unstable fish prices were the major constraints inhibiting the development of the main actors in the value chain and this is a cause for concern.

### 6.3 Recommendations

The following are recommendations derived from the study's findings that are thought to be beneficial to the long-term sustainability of Ghana's semi-industrial fishery. To maximize the economic rent of the local fishery (semi - industrial fishery), illegal activities by the foreign vessels (industrial trawlers) such as Saiko fishing, trawling in inshore waters and the destruction of the sea bed should be monitored and regulated effectively by the government of Ghana, Fisheries commission and Ghana Maritime Authority. The government should restrict the number based on the health of available stock and intensify monitoring and enforcement on their operations. Fish stocks and marine biodiversity would be able to rebuild if the heavy industrial fishing pressure are reduced, which leads to a decreased negative impact on the ecosystem.

The local fishers involved in illegal fishing practices should be sensitized and educated to desist from it, due to the long-term mayhem (decline and subsequent depletion of stocks) these illegalities have on the nation's food security (decline of annual fish production) and its socio-economic implications on the livelihood of coastal inhabitants at large. In addition, the current number of semi-industrial vessels (182) operating in Ghanaian waters are not based on any particular limits set by the authorities but as results of high debt incurred. For biological and economic sustainability, semi-industrial fishery resource utilization should be done at MEY level using at least a maximum effort of 208 vessel/annum from now to 2030.The government could collaborate with interested stakeholders in the development and construction of boatyards or dry docks along the coast of Ghana to aid reduce the high cost of fishing operation and sustain the lifespan of the fishing fleets which in a long-term generate income for the fishery.

The Fisheries Scientific Survey Division and other institutions tasked with collecting fisheries data should consider collecting consistent and reliable economic data for the fishery and making it more easily accessible. This would help enhance research by students, research scientist and others which would inform decisions and improve policy making in the fishery sector. Again, although the fishery value chain is lucrative, the government and other financial institutions can improve the livelihood of the actors through easy accessibility to credit facilities; for the purchase or leasing of fishing inputs and processing equipment. This could help reduce the high unemployment among youth in the coastal areas and gradually alleviate poverty. Since the semi-industrial and artisanal operate in the same waters, subsidies on outboard engines and premix fuel provided by the government through MOFAD to the artisanal fishery should be redirected to the post-harvest sector through the construction and development of cold room facilities, landing beaches and market facilities and fish processing facilities to enhance value addition. This would help reduce overexploitation and increase the shelf life of the fishes.

To further contribute to the biological and economic sustainability of the semi-industrial fishery, the following recommendations for future studies are made:

I. Comparative bioeconomic analysis of semi-industrial fishery in Ghanaian waters.

II. Ecological impact assessment of some selected fishing grounds in the inshore economic zone (IEZ) of Ghanaian waters.

III. Economic performance of unauthorized fishing practices. A case study of gears and light fishing in the semi-industrial fishery of Ghana.

# REFERENCES

Adewuyi, S. A., Phillip, B. B., Ayinde, I. A., & Akerele, D. (2010). Analysis of profitability of fish farming in Ogun State, Nigeria. *Journal of Human Ecology*, *31*(3), 179-184.

Adjetey, J. N. N. (1973). Ghana's experience in distant-water fisheries. *Journal of the Fisheries Board of Canada*, *30*(12), 2463-2467.

Afoakwah, R., Osei, M. B. D., & Effah, E. (2018). A guide on illegal fishing activities in Ghana. *USAID/Ghana Sustainable Fisheries Management Project. Narragansett, RI: Coastal Resources Center, Graduate School of Oceanography, University of Rhode Island. Prepared by the University of Cape Coast, Ghana. GH2014_SCI048_UCC*, *64*.

Africa, U. N. D. P. (2017). *Strengthening Strategic Alignment for Africa's Development Lessons from the UN 2030 Agenda for Sustainable Development, the African Union Agenda 2063 and the African Development Bank High Fives* (No. 2063-2018-589)

Agbodeka, F. (1992). E*conomic history of Ghana from the earliest times*. Ghana Universities Press. *Agriculture*, Accra-Ghana. 24p.

Aheto, D. W., Asare, N. K., Quaynor, B., Tenkorang, E. Y., Asare, C., & Okyere, I. (2012). Profitability of small-scale fisheries in Elmina, Ghana. *Sustainability*, *4*(11), 2785-2794.

Aheto, D. W., Okyere, I., Asare, N. K., Eshilley, J., & Odoi, J. O. (2020). Fish species transshipped at sea (Saiko fish) in Ghana with a note on implications for marine conservation.

Ahiable, g. (2015). *Assessment of the Maximum Sustainable Yield (MSY) of the tuna* (doctoral dissertation, department of marine and fisheries sciences, University of Ghana, Legon).

Akpalu, W. (2002). Compliance to mesh size regulations in artisanal marine fishery in Ghana.

Allison, E. H., Perry, A. L., Badjeck, M. C., Neil Adger, W., Brown, K., Conway, D., ... & Dulvy, N. K. (2009). Vulnerability of national economies to the impacts of climate change on fisheries. *Fish and fisheries*, *10*(2), 173-196.

Alverson, D. L., Freeberg, M. H., Murawski, S. A., & Pope, J. G. (1994). *A global assessment of fisheries bycatch and discards* (Vol. 339). Food & Agriculture Org.

Amador, K., Bannerman, P., Quartey, R., & Ashong, R. (2006). Ghana canoe frame survey 2004. *Marine Fisheries Research Division, Accra, Technical Paper (34), 43*.

Ameyaw, A. B., Breckwoldt, A., Reuter, H., & Aheto, D. W. (2020). From fish to cash: Analyzing the role of women in fisheries in the western region of Ghana. *Marine policy, 113*, 103790.

Amponsah, S. K., Ofori-Danson, P. K., & Nunoo, F. K. (2017). Population dynamics of Engraulis encrasicolus (Linnaeus, 1758) within Ghana's coastal waters.

Anderson, L. G., & Seijo, J. C. (2010). *Bioeconomics of fisheries management*. John Wiley & Sons.

Anderson, L. G., A. Ben-Israel, G. Custis. & C. C. Sarabun. (1979). "Modeling and simulation of interdependent fisheries and optimal effort allocation using mathematical programming." *NATO Symposium on Applied Operations Research in Fishing*, 14 Aug. Trondheim (Norway), 1:501-525.

Andrew, N. L., Béné, C., Hall, S. J., Allison, E. H., Heck, S., & Ratner, B. D. (2007). Diagnosis and management of small‐scale fisheries in developing countries. *Fish and Fisheries*, *8*(3), 227-240.

Anna, Z., Suryana, A. A. H., Maulina, I., Rizal, A., & Hindayani, P. (2017). Biological parameters of fish stock estimation in Cirata Reservoir (West Java, Indonesia): A comparative analysis of bio-economic models. *Biodiversitas Journal of Biological Diversity*, *18*(4), 1468-1474

Antwi-Asare, T. O., & Abbey, E. N. (2011). Fishery value chain analysis—Ghana. *Food and Agriculture Organization, Fisheries*.

Aps, R., Kell, L.T., Lassen, H. & Liiv, I. (2007) Negotiation Framework for Baltic Fisheries Management: Striking the Balance of Interest. *ICES Journal of Marine Science* 7(12): 858– 861.

Ashitey, E. (2019). Ghana: Fish and seafood report. USDA Foreign Agricultural Service. *Global Agricultural Information Network*. https://gain.fas.usda.gov/Recent GAIN Publications/Fish and Seafood Report_Accra_Ghana_3-8-2019.pdf

Asmah, R. (2008). Development potential and financial viability of fish farming in Ghana.

Aswanthy, N., Shanmugam, T. R., Ashok, K. R., & Sathiadhas, R. (2009). A bioeconomic analysis of sustainability of marine fish production in Kerala. *Journal of the Indian Fisheries Association*, *36*, 1-8.

Atta-Kesson R. and Atuguba R.A. (2007). Of fish, fishing, fisherfolk, the law, and fishing institutions. A Paper Prepared for the Corporate Social Responsibility Movement (CSRM).

Atta-Mills, J., Alder, J., & Rashid Sumaila, U. (2004, February). The decline of a regional fishing nation: the case of Ghana and West Africa. In *Natural Resources Forum* (Vol. 28, No. 1, pp. 13-21). Oxford, UK: Blackwell Publishing Ltd.

Ayivi, S. S. (2012). Seasonal trend and abundance of Sparids in Ghanaian coastal waters: An assessment of the artisanal fisheries sector. *United Nations University Fisheries Training Programme, Iceland [final project]*.

Bailey, M., Quaatey, S., Armah, A. K., Jacquet, J., Khan, A., Alder, J., & Sumaila, U. R. (2011). Meeting socioeconomic objectives in Ghana's sardinella fishery. *Natural resources in Ghana: management, policy and economics*, 293-308.

Bank of Ghana (2008). The Fishing Sub-sector and Ghana's Economy. *Research Department, Bank of Ghana, Accra*, pp: 34.

Bannerman, P. O., & Cowx, I. G. (2002). Stock assessment of the big-eye grunt (Brachydeuterus auritus, Val.) fishery in Ghanaian coastal waters. *Fisheries research*, *59*(1-2), 197-207

Bajaj, S. O. N. I. A. (2017). Effect of environmental factors on fish growth. *Indian J. Sci. Res*, *12*(2), 087-091.

Bennett, E., Jolley, T., Lewins, R., & Cattermoul, B. (2002). The Management of Conflict in Tropical Fisheries-Field Work Report (Ghana).

Beran, K. (2018). *Value Chain Improvements in Small-scale Fisheries: Case Studies from West Africa*. University of Rhode Island.

Bortier-Verstraaten, M. B. (2002). *A bioeconomic analysis of the Ghanaian tuna fishery (1980-2000)* (Master's thesis, Universitetet i Tromsø).

Britwum, A. O. (2009). The gendered dynamics of production relations in Ghanaian coastal fishing.

Caddy, J. F., & Agnew, D. J. (2004). An overview of recent global experience with recovery plans for depleted marine resources and suggested guidelines for recovery planning. *Reviews in Fish Biology and Fisheries*, *14*(1), 43.

Caddy, J. F., & Gulland, J. A. (1983). Historical patterns of fish stocks. *Marine policy*, *7*(4), 267-278.

Carlson, A. K., Taylor, W. W., Liu, J., & Orlic, I. (2018). Peruvian anchoveta as a telecoupled fisheries system. *Ecology and Society*, *23*(1).

CEMARE. (2009) *The Application of Bio-economic and Compliance Theory to Three Case Studies.* (Research Report No. 022717). Portsmouth, United Kingdom: The Centre for the Economics and Management of Aquatic Resources (CEMARE), Department of Economics, University of Portsmouth.

Chan, C. Y., Tran, N., Pethiyagoda, S., Crissman, C. C., Sulser, T. B., & Phillips, M. J. (2019). Prospects and challenges of fish for food security in Africa. *Global food security*, *20*, 17-25.

Chaudhuri, K. S., & RAY, S. S. (1996). On the combined harvesting of a prey-predator system. *Journal of Biological Systems*, *4*(03), 373-389.

Chaudhuri, K., & Johnson, T. (1990). Bioeconomic dynamics of a fishery modeled as an S-system. *Mathematical biosciences*, *99*(2), 231-249.

Cheung, W. W., Lam, V. W., Sarmiento, J. L., Kearney, K., Watson, R. E. G., Zeller, D., & Pauly, D. (2010). Large-scale redistribution of maximum fisheries catch potential in the global ocean under climate change. *Global Change Biology*, *16*(1), 24-35.

Christensen, V. (2010). Mey = msy. *Fish and Fisheries*, *11*(1), 105-110.

Clark, C. W. (1973). The economics of overexploitation. *Science*, *181*(4100), 630-634.

Clark, C. W. (1976). *Mathematical bioeconomics: the optimal management resources*. John Wiley & Sons.

Clark, C. W. (1985). Bioeconomic modelling and fisheries management.

Clark, C. W. (2006a). Fisheries bioeconomics: why is it so widely misunderstood? *Population Ecology*, *48*(2), 95-98.

Clark, C. W. (2006b). *The worldwide crisis in fisheries: economic models and human behavior*. Cambridge University Press.

Clarke, R. P., Yoshimoto, S. S., & Pooley, S. G. (1992). A bioeconomic analysis of the Northwestern Hawaiian Islands lobster fishery. *Marine Resource Economics*, *7*(3), 115-140.

Cochrane, K. L. (Ed.). (2002). *A fishery manager's guidebook: management measures and their application* (No. 424). Food & Agriculture Org.

Conrad, J. M., & Clark, C. W. (1987). *Natural resource economics: notes and problems*. Cambridge University Press.

Conrad, J. M., & Clark, C. W. (1994). *Natural resource economics: notes and problems*. (First printed 1987). Cambridge University Press.

Coulibaly, B., Tah, L., Aboua, B. D. R., Joanny, T. G. T., Koné, T., & Kouamélan, E. P. (2018). Assessment of fishing effort, catch per unit effort and fish production of the tropical coastal lagoon of grand-lahou (Côte-d'ivoire, West Africa). *International Journal of Fisheries and Aquatic Studies*, *6*(1), 206-212.

da Silva, C., Parker, D., Winker, H., West, W., & Kerwath, S. E. (2017). *Standardization of the catch per unit effort for swordfish (Xiphias gladius) for the South African longline fishery*. IOTC-2017-WPB15-37.

de Mutsert, K., Cowan, J. H., Essington, T. E., & Hilborn, R. (2008). Reanalyses of Gulf of Mexico fisheries data: landings can be misleading in assessments of fisheries and fisheries ecosystems. *Proceedings of the National Academy of Sciences*, *105*(7), 2740-2744.

Defeo, O. & Seijo, J.C. (1999). Yield-mortality models: a precautionary bioeconomic approach. *Fish. Res*., 40: 7 -16

Directorate of Fisheries (2004). Information on Fisheries in Ghana. *Ministry of Food and Agriculture.*

DoF, 2003. Ghana: Post-Harvest Fisheries Overview, Directorate of Fisheries, Ministry of Food and Agriculture, Ghana. FAO (2006) Yearbook. Fishery and Aquaculture Statistics 2006. *FAO Fisheries and Aquaculture Information and Statistics Service*, p. 57p. Rome, FAO. 2008.

Doortmont, M. R. (2003). *The Elmina 2015 Strategy*: 'Building on the Past to Create a Better Future'; Part III: Elmina Profile and Summary Profile.

Dovlo E. K. (2020). “Catch Trends of Artisanal Fisheries in Ghana, West Africa". *Acta Scientific Agriculture* 4.3: 01-04.

Dovlo. E., Amador. K., & Nkrumah. B. (2016). R*eport on the 2016 Ghana Marine Canoe Frame Survey.* Ministry of Fisheries and Aquaculture Development. Fisheries Commission. Fisheries Scientific Survey Division. Information report no 36.

Eide, A., & Heen, K. (2002). Economic impacts of global warming: a study of the fishing industry in North Norway. *Fisheries Research*, *56*(3), 261-274.

EJF (2020). The “people’s” Fishery on the Brink of Collapse. Small Pelagics in Landings of Ghana’s Industrial Trawl Fleet. *Environmental Justice Foundation*, 1 Amwell Street, London, EC1R 1UL, United Kingdom.

Entee, S. (2015). Post-harvest processing value chain literature review report. *The USAID/Ghana sustainable fisheries management project (SFMP). Narragansett, RI: Coastal Resources Center, Graduate School of Oceanography, University of Rhode Island and SNV Netherlands Development Organization*.

Environmental Management and Economic Development Organization (EMEDO), (2017). Women’s Role, Struggles and Strategies Across the Fisheries Value Chain the Case of Lake Victoria – Tanzania. *International Collective in Support of Fish workers.*

Eriksen, S. S., Akpalu, W., & Vondolia, G. K. (2018). *The Fisheries Sector in Ghana*: A Political Economy Analysis.

European Commission (2021). *STORY OF THE MONTH: Semi–industrial fishing boats in Mauritius.*

Évora, A. F. O., & Kristófersson, D. M. (2016). Bioeconomic analysis: a case study of the industrial pelagic fisheries in Cape Verde. *United Nations University Fisheries Training Programme, Iceland (final project)*.

FAO (1995). *Code of conduct for responsible fisheries*. Rome, FAO.

FAO (2007). *Ghana Fishery country profile.* The Republic of Ghana (available at: www.fao.org/fi/website/FISearch.do?dom=country)

FAO (2016). Fishery and Aquaculture Country Profiles. The Republic of Ghana (available at: http://www.fao.org/fishery/facp/GHA/en).

FAO (2017). *The 2030 agenda and the sustainable development goal: The challenge for aquaculture development and management, by John Hambrey*. FAO Fisheries and Aquaculture Circular No. 1141, Rome, Italy.

FAO (2018a). *The state of world fisheries and aquaculture 2018 - Meeting the sustainable development goals*. Rome. License: CC BY-NC-SA 3.0 IGO.

FAO (2020a). *The State of World Fisheries and Aquaculture 2020. Sustainability in action*. Rome.https://doi.org/10.4060/ca9229en

FAO (2020b). *Legislating for Sustainable Small-Scale Fisheries – A guide and considerations for implementing aspects of the Voluntary Guidelines for Securing Sustainable Small-Scale Fisheries in the Context of Food Security and Poverty Eradication in national legislation*. Rome. https://doi.org/10.4060/cb0885en

FAO/CECAF (2012). *Fisheries Committee for the Eastern Central Atlantic.* Twentieth session. Main Outcomes of the Sixth Session of the Scientific Subcommittee. Rabat Morocco 14-16 March 2012. FAO 16p.

Finegold, C., Gordon, A., Mills, D., Curtis, L., & Pulis, A. (2010). Western region fisheries sector review. *World Fish Center. USAID Integrated Coastal and Fisheries Governance Initiative for the Western Region, Ghana*.

Finegold, C., Gordon, A., Mills, D., Curtis, L., & Pulis, A. (2010). Western region fisheries sector review. *World Fish Center. USAID Integrated Coastal and Fisheries Governance Initiative for the Western Region, Ghana*.

Fisheries, F. A. O. (2016). Aquaculture. Fishery and aquaculture country profiles—the republic of Ghana.

Food and Agriculture Organization (1998); 'Country Profile: Ghana. FID/CP/GHA Rev.3. *Food and Agriculture Organization of the United Nations* (FAO), Rome. Document available at http://www.fao.orf/fi /dcp/FICP_GDA_E.asp.

Fox, W. W. (1975). Fitting the generalized stock production model by least-squares and equilibrium approximation. *Fish. Bull*, *73*(1), 23-37.

Garcia, S. (1981). *Life cycles, dynamics, exploitation and management of coastal penaeid shrimp stocks* (No. 639.05 F3/203).

Garcia, S. M., & Staples, D. J. (2000). Sustainability reference systems and indicators for responsible marine capture fisheries: a review of concepts and elements for a set of guidelines. *Marine and Freshwater Research*, *51*(5), 385-426.

Gates, J.M. (2009). *Investing in Our Future*: *The Economic Case for Rebuilding Mid-Atlantic Fish Populations*. Washington D.C.: Pew Environmental Group.

GEPC (2008). Comparison of export performance of non-traditional products for the period January-December 2007 (Mimeo). *Ghana Export Promotion Council*. 12 pp.

Ghana Fisheries Act 625 (2002). *Fisheries Act of the Government of Ghana*.

Gooch, M. (2005). *Drivers, benefits and critical success factors of developing closely-aligned agri-food value chains* (No. 861-2019-2012).

Gordon, A., Pulis, A., & Owusu-Adjei, E. (2011). "Smoked marine fish from Western Region, Ghana: a value chain assessment", *WorldFish Center*. USAID Integrated Coastal and Fisheries Governance Initiative for the Western Region, Ghana.

Gordon, H. S. (1954). The economic theory of a common-property resource: the fishery. In *Classic papers in natural resource economics* (pp. 178-203). Palgrave Macmillan, London.

Grafton, R. Q., Kompas, T., & Hilborn, R. W. (2007). Economics of overexploitation revisited. *Science*, *318*(5856), 1601-1601.

Graham, M. (1935). Modern theory of exploiting a fishery and application to North Sea trawling. *ICES J Mar Sci* 10, 264-274

GTZ. (2007). ValueLinks manual: The methodology of value chain promotion.

Gumulira, I., Forrester, G., & Lazar, N. (2019). Bioeconomic analysis of Engraulicypris sardella (USIPA) in South east arm of Lake Malawi. *International Journal of Fisheries and Aquaculture*, *11*(4), 86-96.

Habib, A., Ullah, M., & Duy, N. N. (2014). Bioeconomics of commercial marine fisheries of Bay of Bengal: Status and direction. *Economics Research International*, *2014*

Hanchet, S. M., Blackwell, R. G., & Dunn, A. (2005). Development and evaluation of catch per unit effort indices for southern blue whiting (Micromesistius australis) on the Campbell Island Rise, New Zealand. *ICES Journal of Marine Science*, *62*(6), 1131-1138.

Hannesson, R. (1983) Bioeconomic production function in fisheries. Theoretical and empirical analysis. *Canadian Journal of Fisheries and Aquatic Sciences*, 40: 968-982.

Hannesson, R. (1996). *Fisheries mismanagement: the case of the North Atlantic cod*. Fishing News Books Ltd.

Hardin, G. (1968). The tragedy of the commons: the population problem has no technical solution; it requires a fundamental extension in morality. *science*, *162*(3859), 1243-1248.

Hardin, G. (1998). Extensions of "The tragedy of the commons". *Science*, *280*(5364), 682-683.

Hare, J. A., Alexander, M. A., Fogarty, M. J., Williams, E. H., & Scott, J. D. (2010). Forecasting the dynamics of a coastal fishery species using a coupled climate–population model. *Ecological Applications*, *20*(2), 452-464.

Harper, S., Zeller, D., Hauzer, M., Pauly, D., & Sumaila, U. R. (2013). Women and fisheries: Contribution to food security and local economies. *Marine Policy*, *39*, 56-63.

Hasan, M. M., Hossain, B. S., Alam, M. J., Chowdhury, K. A., Al Karim, A., & Chowdhury, N. M. K. (2018). The prospects of blue economy to promote Bangladesh into a middle-income country. *Open Journal of Marine Science*, *8*(03), 355.

Heinbuch, U. (1994). Animal protein sources for rural and urban populations in Ghana. *Programme Integr Dev Artis Fish West Afr*, *25*.

Hellin, J., & Meijer, M. (2006). Guidelines for value chain analysis. *Food and Agriculture Organization of the United Nations (FAO), Rome, Italy*.

Hempel, E. (2010). Value chain analysis in the fisheries sector in Africa. *Report for INFOSA and the NEPAD Trade Working Group*.

Hilborn, R. (2002). The Dark Side of Reference Points. *Bulletin of Marine Science*, 70: 403-408.

Hilborn, R. (2007). Moving to sustainability by learning from successful fisheries. *Ambio*, 296-303.

Hilborn, R., Orensanz, J.M. & Parma, A.M. (2005) Institutions, Incentives and the Future of Fisheries. Philosophical Transactions. *Biological Sciences*, 360(1453): 47-57.

Hoggarth, D. D. (2006). *Stock assessment for fishery management: a framework guide to the stock assessment tools of the fisheries management and science programme* (No. 487). Food & Agriculture Org.

Homans, F.R., & Wilen, J.E. (2005) Markets and Rent Dissipation in Regulated Open Access Fisheries. *Journal of Environmental Economics and Management*, 49(2): 381-404.

Hoyle, S. D., Langley, A. D., & Campbell, R. A. (2014). Recommended approaches for standardizing CPUE data from pelagic fisheries. *Western and Central Pacific Fisheries Commission*, 1-21.

https://www.crc.uri.edu/download/GH2014_POL005_FC_FisheriesMgtPlan2016.pdf

Intergovernmental Oceanographic Commission. (1997). IOC Regional Workshop for Member States of Western Africa: GODAR-VI (Global Oceanographic Data Archeology and Rescue Project): report.

IPCC (2007) Climate Change 2007: Impacts, Adaptation and Vulnerability Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), Parry M.L., O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, (Eds) *Cambridge University Press*, Cambridge, UK, 1000pp.

Jacob, O. O., & Christianah, O. O. (2013). Impact of Microfinance Bank Loan on Aquaculture Development in Ogun State, Nigeria. *Pertanika Journal of Social Sciences & Humanities*, *21*(3).

Kaplinsky, R., & Morris, M. (2000). *A handbook for value chain research* (Vol. 113). Brighton: University of Sussex, Institute of Development Studies.

Kar, T., & Chakraborty, K. (2010). Bioeconomic modelling of a prey predator system using differential algebraic equations. *International Journal of Engineering, Science and Technology*, *2*(1), 13-34.

Karani, P., & Failler, P. (2020). Comparative coastal and marine tourism, climate change, and the blue economy in African Large Marine Ecosystems. *Environmental Development*, *36*, 100572.

Kassah, J. E. (2020). *Aspects of the biology and length-based assessment of the chub mackerel scomber colias (scombridae) stock off the coast of Ghana* (Doctoral dissertation, University of Cape Coast).

Keen, M. R., Schwarz, A. M., & Wini-Simeon, L. (2018). Towards defining the Blue Economy: Practical lessons from Pacific Ocean governance. *Marine Policy*, *88*, 333-341

Khwaja, S. & Cox, A. (2009) Rebuilding Fisheries: An Overview of Issues and Policy Approaches in the OECD. In: *The Economics of Rebuilding Fisheries: Workshop proceedings*. Paris, France: OECD. pp 5-26. DOI: 10.1787/9789264075429-4-en

Kifani, S., Quansah, E., Masski, H., Houssa, R., & Hilmi, K. (2019). Climate change impacts, vulnerabilities and adaptations: Eastern Central Atlantic marine fisheries. *Impacts of climate change on fisheries and aquaculture*, 159.

King, M. (2013). *Fisheries biology, assessment and management* (2nd ed.). Oxford: Blackwell Scientific Publications.

Kompas, T., & Che, T. N. (2004). A bioeconomic model of the Australian Northern Prawn Fishery: management options under uncertainty. *ABARE e-Reports. ABARE. Canberra, ABARE*.

Kompas, T. (2005). Fisheries Management: Economic Efficiency and the Concept of Maximum Economic Yield'. *Australian Commodities: Forecasts and Issues*, *12*(1), 152-160.

Kompas, T., Grafton, R. Q., Che, N., & Gooday, P. (2009). *Development of Methods and Information to Support the Assessment of Economic Performance in Commonwealth Fisheries. ABARE report for the Fisheries Research and Development Corporation*. Research Report 09.5, Canberra, Australia.

Kompas, T., Dichmont, C. M., Punt, A. E., Deng, A., Che, T. N., Bishop, J., ... & Zhou, S. (2010). Maximizing profits and conserving stocks in the Australian Northern Prawn Fishery. *Australian Journal of Agricultural and Resource Economics*, *54*(3), 281-299.

Koranteng, K. A. (1993). Size at first maturity of the anchovy (Engraulis encrasicolus) in Ghanaian waters and suggestions for appropriate mesh size in its fishery. *Naga, the ICLARM Quarterly*, *16*(1), 29-30.

Koranteng, K. A. (1998). *The impacts of environmental forcing on the dynamics of demersal fishery resources of Ghana* (Doctoral dissertation, University of Warwick).

Koranteng, K. A. (2001). Structure and dynamics of demersal assemblages on the continental shelf and upper slope off Ghana, West Africa. *Marine Ecology Progress Series, 220*, 1-12.

Kwarteng, E., Nsiah A.A.H., A., Samey, B., Boateng, L., & Aziebor, E. (2016b). *Livelihood Options Synthesis Report*. The USAID/Ghana Sustainable Fisheries Management Project (SFMP). Narragansett, RI: Coastal Resources Center, Graduate School of Oceanography, University of Rhode Island. GH2014_ACT072_SNV.

Larkin, S. & Sylvia, G. (1999). Intrinsic Fish Characteristics and Intraseason Production Efficiency: A Management-level Bioeconomic Analysis of a Commercial Fishery. *American Journal of Agricultural Economics*, 81(1): 29-43.

Larkin, S.L., Sylvia, G., Harte, M. & Quigley, K. (2006) Optimal Rebuilding of Fish Stocks in Different Nations: Bioeconomic Lessons for Regulators. *Marine Resource Economics*, 21: 395-413.

Lazar, N., Yankson, K., Blay, J., Ofori-Danson, P., Markwei, P., Agbogah, K., ... & Bilisini, W. B. (2017). Status of the small pelagic stocks in Ghana (2015). *Scientific and Technical Working Group of USAID/Ghana Sustainable Fisheries Management Project (SFMP). Coastal Resources*

*Center, Graduate School of Oceanography, University of Rhode Island. GH2014_ACT093_CRC.*

Lazar, N., Yankson, K., Blay, J., Ofori-Danson, P., Markwei, P., Agbogah, K., ... & Bilisini, W. B. (2018). Status of the small pelagic stocks in Ghana and recommendations to achieve sustainable fishing 2017. *Scientific and Technical Working Group. USAID/Ghana Sustainable Fisheries Management Project (SFMP). Coastal Resources Center, Graduate School of Oceanography, University of Rhode Island. GH2014_SCI04 2_CRC.*

Lleonart, J., & Merino, G. (2010). Immediate maximum economic yield; a realistic fisheries economic reference point. *ICES Journal of Marine Science*, *67*(3), 577-582.

M4P. (2008). *Making value chains work better for the poor: A toolbook for practitioners of value chain analysis, Version 3*. Making Markets Work Better for the Poor (M4P) Project, UK Department for International Development (DFID). Agricultural Development International. Phnom Penh, Cambodia.

Mallick, B., Sultana, Z., & Bennett, C. M. (2020). How do sustainable livelihoods influence environmental (non-) migration aspirations? *Applied Geography*, *124*, 102328.

Manyungwa-Pasani, C. L., Hara, M., & Chimatiro, S. K. (2017). Women's participation in fish value chains and value chain governance in Malawi: A case of Msaka (Lake Malawi) and Kachulu (Lake Chilwa).

Marquette, K.M., Koranteng, K.A., Overa, R., and Aryeetey, G. (2002). Small-scale fisheries, population dynamics, and resource use in Africa: The case of More, Ghana. *Ambio*, *31*(4): 324-336.

Matsue, N., Daw, T., & Garrett, L. (2014). Women fish traders on the Kenyan coast: livelihoods, bargaining power, and participation in management. *Coastal Management*, *42*(6), 531-554.

Maunder, M. N., Sibert, J. R., Fonteneau, A., Hampton, J., Kleiber, P., & Harley, S. J. (2006). Interpreting catch per unit effort data to assess the status of individual stocks and communities. *Ices Journal of marine science*, *63*(8), 1373-1385.

McClanahan, T. R., Hicks, C. C., & Darling, E. S. (2008). Malthusian overfishing and efforts to overcome it on Kenyan coral reefs. *Ecological applications*, *18*(6), 1516-1529

McGoodwin, J. R. (2020). *Crisis in the World's Fisheries*. Stanford University Press.

McKernan, S. M. (2002). The impact of microcredit programs on self-employment profits: Do noncredit program aspects matter? *Review of economics and statistics*, *84*(1), 93-115.

Mees, C. C., & Rossouw, J. A. (1995, June). OPTIMISATION OF YIELD OFPRISTIPOMOIDES FILAMENTOSUS FROM THE TONGAN SEAMOUNT FISHERY BY CHANGING SIZE AT FIRST CAPTURE. In *Dalzell, P. and TJH Adams (compilers) South Pacific Commission and Forum Fisheries Agency Workshop on the Management of South Pacific Inshore Fisheries (1995: Noumea).*

*Manuscript collection of country statements and background papers* (Vol. 1, pp. 291-306).

MFRD (2008). Summary of marine fish production for Ghana for 2007. *Marine Fisheries Research Division, Ministry of Fisheries*, Tema. 2 pp.

Milon, J. W., Larkin, S. L., & Ehrhardt, N. M. (1999). *Bioeconomic models of the Florida commercial spiny lobster fishery*. Florida Sea Grant College Program, University of Florida.

Ministry of Fisheries and Aquaculture Development (MoFAD) (2013) *Annual Progress Report 2012*. MoFAD, Accra Ghana. 44 pp

Ministry of Fisheries and Aquaculture Development (MOFAD) (2015). *National Fisheries Management Plan.* Government of Ghana.

Ministry of Food and Agriculture (MoFA) (2012). Fisheries Commission: Ghana National Aquaculture Development Plan. March 2012. 79pp.

Mkama, W., Mposo, A., Mselemu, M., Tobey, J., Kajubili, P., Robadue, D., & Daffa, J. (2010). Fisheries Value Chain Analysis Bagamoyo District Tanzania. *Narragansett, Rhode Island: Coastal Resources Center, University of Rhode Island*

MoFAD. (2017). *Agricultural sector progress report 2017*. Ministry of Fisheries and Aquaculture, Republic of Ghana.

Mohammed, E. Y., & Uraguchi, Z. B. (2013). Impacts of climate change on fisheries: implications for food security in Sub-Saharan Africa. *Global Food Security, Nova Science Publishers, Inc*, 114-135.

Mpoano, H. (2013). Integrating Voluntary Compliance with the Effective Enforcement of Fishery Regulations. *Issue Brief, 3*.

Mpoano, H. (2019). Stolen at Sea: How illegal'saiko'fishing is fuelling the collapse of Ghana's fisheries.

MRAG, (1996). The Status of Seychelles Demersal Fishery Technical Report. ODA Fish Management Programme - The Management of Tropical Multi-Fisheries Project, R5484, 261pp.

MRAG-Marine Resources Assessment Group-., & University of British Columbia. (2008). *The global extent of illegal fishing*. MRAG.

Munday, P. L., Jones, G. P., Pratchett, M. S., & Williams, A. J. (2008). Climate change and the future for coral reef fishes. *Fish and Fisheries*, *9*(3), 261-285.

Munro, G. (2010) Getting the Economics and the Incentives Right: Instrument Choices in Rebuilding Fisheries. In: *The Economics of Rebuilding Fisheries: Workshop Proceedings*. Paris, France: OECD. pp 27-47.

Munro, G. R. (1982). Fisheries, extended jurisdiction and the economics of common property resources. *Canadian Journal of Economics*, 405-425.

Muringai, R. T., Mafongoya, P. L., & Lottering, R. (2021). Climate change and variability impacts on sub-Saharan African fisheries: A Review. *Reviews in Fisheries Science & Aquaculture*, *29*(4), 706-720.

NAFAG. 2007. *National Fisheries Association of Ghana*, About Us web-page (available at: www.nafagfish.org/aboutus.htm)

Neokye, E. O., Dossou, S., Iniga, M., & Alabi-Doku, B. N. (2021). The role of oceanic environmental conditions on catch of Sardinella spp. in Ghana. *Regional Studies in Marine Science*, *44*, 101768.

NiMble Systems Private Limited. (2005) 'Value Chain Analysis of Fishery in Puri and Ganjam District of Orissa'. *Oxfam India Trust.*

Nunoo, F. K. E., Asiedu, B., Amador, K., Belhabib, D., Lam, V., Sumaila, R., & Pauly, D. (2014). Marine fisheries catch in Ghana: historic reconstruction for 1950 to 2010 and current economic impacts. *Reviews in Fisheries Science & Aquaculture*, *22*(4), 274-283.

Nunoo, F. K. E., Asiedu, B., Olauson, J., & Intsiful, G. (2015). Achieving sustainable fisheries management: A critical look at traditional fisheries management in the marine artisanal fisheries of Ghana, West Africa. *Journal of Energy and Natural Resource Management (JENRM)*, *2*(1).

Nyeko, J. I., & Wiium, V. H. (2004). Co-management and value chains: the role of Nile perch exports in poverty eradication in Lake Victoria fishing communities. *United Nations University Fisheries Training Programme*.

Ochiewo, J. (2004). Changing fisheries practices and their socioeconomic implications in South Coast Kenya. *Ocean & Coastal Management*, *47*(7-8), 389-408.

Odebiyi, O. C., George, F. O. A., Odulate, D. O., Agbonlahor, M. U., & Olaoye, O. J. (2013). Value-chain analysis for coastal fisheries development in Nigeria. *Global Journal of Science Frontier Research Agriculture and Veterinary*, *13*(11), 6-15.

Odotei, I. (1999). Gender and traditional authority in the artisanal marine fishing industry in Ghana. *Institute of African Studies Research Review*, *15*(1), 15-38.

Odotei, I. (2002). The artisanal marine fishing industry in Ghana: a historical overview. *Legon: Institute of African Studies, University of Ghana*.

Office for Coastal Management (2019). Magnusson-Stevens Fishery Conservation Act. From 2010-06-15. *NOAA National centers for Environmental Information*. https://inport.nmfs.noaa.gov/inport/item/48890.

Okpei, P., Aggrey-Fynn, J., & Okyere, I. (2020). Habitat distribution, species composition and size structure of penaeid shrimps (Decapoda: Dendrobranchiata: Penaeidae) in inshore waters of Ghana. *Journal of Fisheries and Coastal Management*, *2*(1), 23-33.

Olawumi, A. T., Dipeolu, A. O., & Bamiro, O. M. (2010). Economic analysis of homestead fish production in Ogun state Nigeria. *Journal of Human Ecology*, *31*(1), 13-17.

Olubanjo, O. O., Akinleye, S. O., & Balogun, A. M. (2006). *Occupational characteristics, technology use and output determinants among fisherfolks in Ogun waterside area, Ogun State* (No. 815-2016-52613)

O'Neill, E. D. (2013). *A value chain analysis of tuna industry in Ghana* (Doctoral dissertation).

Orensanz, J. M. (1986). Size, environment and density: the regulation of a scallop stock and its management implications. In *North Pacific Workshop on Stock Assessment and Management of Invertebrates, 1986*.

Overå, R. (1992). Fish Mammies: The Role of Women in the Artisanal Fishery Sector in Ghana.

Overa, R. (1993). Wives and traders: women's careers in Ghanaian canoe fisheries. *MAST. Maritime anthropological studies*, *6*(1-2), 110-135.

Pauly, D. (1994). *On the sex of fish and the gender of scientists: a collection of essays in fisheries science* (Vol. 14). Springer Science & Business Media.

Pauly, D. 1976. The biology, fishery and potential for aquaculture of *Tilapia melanotheron* in a small West African lagoon. *Aquaculture*, 7:33–49.

Penas, E. (2007) The Fishery Conservation Policy of the European Union after 2002: Towards Long-term Sustainability. *ICES Journal of Marine Science*, 64: 588–595.

Pillay, T. V. R., & Kutty, M. N. (2005). *Aquaculture: principles and practices* (No. Ed. 2). Blackwell publishing.

Pinaya, W. H. D., Lobon-Cervia, F. J., Pita, P., Buss de Souza, R., Freire, J., & Isaac, V. J. (2016). Multispecies fisheries in the lower Amazon River and its relationship with the regional and global climate variability. *PLoS One*, *11*(6), e0157050.

Pitcher, T. J., Kalikoski, D., Short, K., Varkey, D., & Pramod, G. (2009). An evaluation of progress in implementing ecosystem-based management of fisheries in 33 countries. *Marine Policy*, *33*(2), 223-232.

Pittaluga, F., Braimah, L. I., Bortey, A., Wadzah, N., Cromwell, A., Dacosta, M., ... & Salvati, N. (2003). Poverty profile of riverine communities of southern Lake Volta.

Pittaluga, F., Braimah, L. I., Bortey, A., Wadzah, N., Cromwell, A., Dacosta, M., ... & Salvati, N. (2003). *Sustainable fisheries livelihoods programme.*

Pomeroy, R. S., Cinner, J. E., Nielsen, J. R., & Andrew, N. L. (2011). Conditions for successful co-management: Lessons learned in Asia, Africa, the Pacific, and the wider Caribbean. *Small-scale fisheries management: Frameworks and approaches for the developing world*, 115-131.

Pomeroy, R., Nguyen, K. A. T., & Thong, H. X. (2009). Small-scale marine fisheries policy in Vietnam. *Marine Policy*, *33*(2), 419-428.

Porter, M. E. (1986). Changing patterns of international competition. *California management review*, *28*(2), 9-40.

Porter, M. E. (1998). *Clusters and the new economics of competition* (Vol. 76, No. 6, pp. 77-90). Boston: Harvard Business Review.

Quaatey, S. N. K. (1997). Synthesis of recent evaluations undertaken on the major fish stocks in Ghanaian waters. *A working document for the eleventh session of the CECAF working party on Resources Evaluation held in October*.

Quagrainie, K. K., & Chu, J. (2019). Determinants of Catch Sales in Ghanaian Artisanal Fisheries. *Sustainability*, *11*(2), 298.

Quinn, T. J., & Deriso, R. B. (1999). *Quantitative fish dynamics*. oxford university Press.

Richards, L. J., & Schnute, J. T. (1986). An experimental and statistical approach to the question: is CPUE an index of abundance? *Canadian Journal of Fisheries and Aquatic Sciences*, *43*(6), 1214-1227.

Roduner, D. (2004). Analysis of Existing Theories, Methodologies and Discussions of Value Chain Approaches within the Development Cooperation Sector. *A Draft Report*.

Rosales, R. M., Pomeroy, R., Calabio, I. J., Batong, M., Cedo, K., Escara, N., ... & Sobrevega, M. A. (2017). Value chain analysis and small-scale fisheries management. *Marine Policy, 83*, 11-21.

Rosenberg, A.A., Swasey, J.H. & Bowman, M. (2006) Rebuilding US Fisheries: Progress and Problems. *Frontiers in Ecology and the Environment,* 4(6): 303-308.

Russell, D., & Hanoomanjee, S. (2012). Manual on value chain analysis and promotion. *Regional training on value chain analysis*.

Rutherford, J. (2008). Too many boats chasing too few fish: The collapse of the Atlantic groundfish fishery and the avoidance of future collapses through free market environmentalism. *SURG Journal, 2*(1), 11-17.

Sackey-Mensah, K., Knútsson, Ö., & Gestsson, M. H. (2012). Fuel subsidy in Ghana's marine artisanal fisheries sector. *Final Project, United Nations University, Fisheries Training Program*.

Safina, C., Rosenberg, A.A. Myers, R.A. Quinn II, T.J. & Collie, J.S. (2005) United States Ocean Fish Recovery: Staying the Course. *Science*, 309(5735): 707-708.

Samey, B. (2015). *Literature Review on Sardinella Value Chain.* The USAID/Ghana Sustainable Fisheries Management Project (SFMP). Narragansett, RI: Coastal Resources Center, Graduate School of Oceanography, University of Rhode Island and SNV Netherlands Development Organization. GH2014_SCI007_SNV.

Sanon, V. P., Toé, P., Caballer Revenga, J., El Bilali, H., Hundscheid, L. J., Kulakowska, M., ... & Melcher, A. H. (2020). Multiple-line identification of socio-ecological stressors affecting aquatic ecosystems in semi-arid countries: implications for sustainable management of fisheries in sub-saharan Africa. *Water*, *12*(6), 1518.

Sarpong D., Quaatey N. and Harvey S. (2005). The Economic and Social Contribution of Fisheries to Gross Domestic Product and Rural Development in Ghana. *FAO Sustainable Fisheries Livelihoods Programme (SFLP)* GCP/INT/735/UK, Rome. 53p.

Schaefer, M. B. (1954). Some aspects of the dynamics of populations important to the management of the commercial marine fisheries. *Inter-American Tropical Tuna Commission Bulletin*, *1*(2), 23-56.

Schnute, J. (1977). Improved estimates from the Schaefer production model: theoretical considerations. *Journal of the Fisheries Board of Canada*, *34*(5), 583-603.

Science and Technical Working Group. (2015). Rebuilding Depleted Small Pelagic Stocks in Ghana. A Closed Fishing Season Proposal to the Ministry of Fisheries and Aquaculture Development. *The Scientific and Technical Working Group. The USAID/Ghana Sustainable Fisheries Management Project (SFMP). Narragansett, RI: Coastal Resources Center, Graduate School of Oceanography, University of Rhode Island. GH2014_SCI002_CRC. 17 pp*.

Seijo, J. C., Defeo, O., & Salas, S. (1998). Fisheries bioeconomics: theory, modelling and management (No. 368). *Food & Agriculture Org*.

Smith, M.D. & Wilen, J.E. (2003) Economic Impacts of Marine Reserves: The Importance of Spatial Behavior. *Journal of Environmental Economics and Management*, 46(2): 183-206.

Soldo, A., & Bosnić, N. (2019). Characteristics of the Croatian anchovy purse seiner fleet. *Acta Adriatica*, *60*(1). bb

Sparre, P., & Venema, S. G. (1992). Introduction to tropical fish stock assessment part 1. manual FAO FISH. *Tech. Pap*, *306*(1).

Squires, D., Campbell, H., Cunningham, S., Dewees, C., Grafton, R. Q., Herrick Jr, S. F., ... & Vestergaard, N. (1998). Individual transferable quotas in multispecies fisheries. *Marine Policy*, *22*(2), 135-159.

Sumaila, U. R. (2004). Intergenerational cost–benefit analysis and marine ecosystem restoration. *Fish and Fisheries*, *5*(4), 329-343.

Sumaila, U.R. & Suatoni, E. (2005) *Fish Economics: The Benefits of Rebuilding United States Ocean Fish Populations.* Vancouver, Canada: Fisheries Economics Research Unit, University of British Colombia.

Sumaila, U. R., & Hannesson, R. (2010). Maximum economic yield in crisis? *Fish and Fisheries*, *11*(4), 461-465.

Sumaila, U. R., Walsh, M., Hoareau, K., Cox, A., Abdallah, P., Akpalu, W., ... & Sack, K. (2020). Ocean finance: Financing the transition to a sustainable ocean economy. *World Resources Institute*.

Tall, A., & Failler, P. (2012). Fishery and aquaculture industry in Ghana. *Ser. Rep. Rev. Fish. Aquac. Ind*, *22*.

Tetteh, A. S. (2007). *Women's activities in the Ghanaian fishery; The role of social capital* (Master's thesis, Universitetet i Tromsø). http://munin.uit.no/handle/10037/1003

The World Bank (2015). *World Bank Forecasts Global Poverty to Fall Below 10% for First Time; Major Hurdles Remain in Goal to End Poverty by 2030. October 4, 2015, www.worldbank.org.*

Tobey, J., Normanyo, A. K., Osei, P., Beran, K., & Crawford, B. (2016). Subsidies in Ghana's Marine Artisanal Fisheries Sector. *USAID/Ghana Sustainable Fisheries Management Project (SFMP). Narragansett, RI: Coastal Resources Center, Graduate School of Oceanography, University of Rhode Island. GH2014_POL059_CRC.*

Torell, E., Owusu, A., & Okyere Nyako, A. (2015). USAID/Ghana Sustainable Fisheries Management Project (SFMP), Ghana Fisheries Gender Analysis, 2015, Narragansett, RI: Coastal Resources Center, Graduate School of Oceanography, University of Rhode Island. *GEN002. 21p*

Ulrich, C., Le Gallic, B, Dunn, M.R., Gascuel, D. (2002). A multispecies multi-fleet bioeconomic simulation model for the English Channel artisanal fisheries. *Fish Res* 58: 379–401

United Nations (1982). United Nations Convention on the Law of the Sea. Retrieved from http://www.org/Depts/convention_agreement/texts/unclose/unclos_e

USAID. (2015). Ghana's small pelagic fishery in crisis: National food security at risk. Accra, Ghana.

Valatin, G. (2000). Fisheries Management in the Netherlands: An Overview (Draft). In *XIIth Annual Conference of the European Association of Fisheries Economists. Esbjerg, Denmark, 13th-15th April*.

van Hoof, L., Salz, P., & Patijnlaan, B. (2001, April). Applying CPUE as management tool. In *XIII Conference of the EAFE* (pp. 18-20).

Verhulst, P. F. (1838). Notice sur la loi que la population suit dans son accroissement. *Corresp. Math. Phys.*, *10*, 113-126.

Waileruny, W., Wiyono, E. S., Wisudo, S. H., Purbayanto, A., & Nurani, T. W. (2014). Bio-Economics Analysis of Skipjack (Katsuwonus pelamis) Fishery on Banda Sea–Maluku Province. *Simposium Nasional Pengelolaan Perikanan Tuna Berkelanjutan, Bali*, *1011*, 474-483.

Walters, C. J., & Hilborn, R. (1976). Adaptive control of fishing systems. *Journal of the Fisheries Board of Canada*, *33*(1), 145-159.

Ward, J.M. and Kelly, M. (2009). Measuring Management Success: Experience with United States Fisheries. *Marine Policy*, 33(1): 164-171.

Westlund, L., Poulain, F., Bage, H., & Van Anrooy, R. (2007). Disaster response and risk management in the fisheries sector. Rome: FAO.

Whitmarsh, D., James, C., Pickering, H. & Neiland, A. (2000) The Profitability of Marine Commercial Fisheries: A Review of Economic Information Needs with Particular Reference to the UK. *Marine Policy*, 24: 257-263.

Willmann, R. O. L. F., & Kelleher, K. I. E. R. A. N. (2010). Economic trends in global marine fisheries. *Handbook of Marine Fisheries Conservation and Management. Oxford University Press Inc., New York*, 20-42.

World Bank (2009). Revitalizing the Ghanaian Fisheries Sector for Wealth and Sustainability, Scoping Study.

World Bank (2011). Ghana Project under the First Phase of the West Africa Regional Fisheries Programme. *Project Appraisal Document Report* No: 57898-GH. World Bank, Washington, DC. 99 pp.

World bank (2012). Hidden Harvest. The Global Contribution of Capture Fisheries. Report No. 66469-GLB. Washington, DC.

World Bank. (2017). *The sunken billions revisited: Progress and challenges in global marine fisheries*. The World Bank.

Worm, B., Hilborn, R., Baum, J. K., Branch, T. A., Collie, J. S., Costello, C., ... & Zeller, D. (2009). Rebuilding global fisheries. *science*, *325*(5940), 578-585

Yankson, K., & Obodai, E. A. (1999). An update of the number, types and distribution of coastal lagoons in Ghana. *Journal of the Ghana Science Association*, *2*(2), 26-31.

# APPENDICES

*Appendix I:* Socioeconomic characteristics of the semi-industrial fishery

| **Source of funding for operation** | Freq | % Freq |
|---|---|---|
| Bank | 1 | 1 |
| Credit union | 4 | 4 |
| Susu collectors | 4 | 4 |
| Family and friends | 70 | 70.7 |
| Fish Processors and mummies | 20 | 20.2 |
| **Total** | **99** | **100** |
| **Seasons of abundant fish catch** | | |
| June - August | 61 | 61.6 |
| September - December | 6 | 6.1 |
| April - May | 15 | 15.8 |
| I don't know | 17 | 17.2 |
| **Total** | **99** | **100** |
| **Period of No fishing** | | |
| Rainy Season | 11 | 11.1 |
| Every day except full moon | 36 | 36.4 |
| Always except Tuesday | 52 | 52.5 |
| **Total** | **99** | **100** |
| **Impact of artisanal fishers on operation** | | |
| Yes | 37 | 37.4 |
| No | 62 | 62.6 |
| **Total** | **99** | **100** |
| **If Yes, how?** | | |
| Destructive fishing | 20 | 20.2 |
| The use of noxious substances and unauthorized gears | 17 | 17.1 |
| No Impact / I don't Know | 62 | 62.6 |
| **Total** | **99** | **100** |
| **Impact of industrial fishers on operation** | | |
| Yes | 76 | 76.8 |
| No | 23 | 23.2 |
| **Total** | **99** | **100** |
| **If Yes, how?** | | |
| Trawling in inshore waters | 28 | 28.3 |
| Dumping of unwanted by- catches | 13 | 13.1 |
| The use of an unauthorized gears and mesh sizes | 15 | 15.2 |
| Targeting pelagic fishes instead demersal | 11 | 11.1 |
| Destruction of seabed and fish habitat | 9 | 9.1 |
| No Impact / I don't know | 23 | 23.2 |
| **Total** | **99** | **100** |

*Appendix II:* Characteristics of Semi – industrial fishing fleets

| **Fishing Communities** | **Elmina** | | **Tema** | | **Sekondi** | | | |
|---|---|---|---|---|---|---|---|---|
| | Freq | % Freq | Freq | % Freq | Freq | % Freq | **Total Freq** | **Total % F** |
| **Boat purpose** | | | | | | | | |
| Trawling | 29 | 100 | 12 | 44.4 | 15 | 34.9 | 56 | 56.6 |
| Purse seining | 0 | 0 | 15 | 55.6 | 28 | 65.1 | 43 | 43.4 |
| **Total** | **29** | **100** | **27** | **100** | **43** | **100** | **99** | **100** |
| **Boat length (LOA/ ft)** | | | | | | | | |
| 25 – 35 | 6 | 20.7 | 3 | 11.1 | 2 | 4.7 | 11 | 11.1 |
| 36 - 50 | 23 | 79.3 | 7 | 25.9 | 13 | 30.2 | 43 | 43.4 |
| 51- 60 | 0 | 0 | 5 | 18.5 | 10 | 23.3 | 15 | 15.2 |
| 61-69 | 0 | 0 | 4 | 14.8 | 13 | 30.2 | 17 | 17.2 |
| Above 70 | 0 | 0 | 8 | 29.6 | 5 | 11.6 | 13 | 13.1 |
| **Total** | **29** | **100** | **27** | **100** | **43** | **100** | **99** | **100** |
| **HP of inboard engines** | | | | | | | | |
| 90 – 140 | 16 | 55.2 | 10 | 37 | 2 | 4.7 | 28 | 28.3 |
| 141 – 190 | 5 | 17.2 | 3 | 11.1 | 4 | 9.3 | 12 | 12.1 |
| 191 – 240 | 8 | 27.6 | 2 | 7.4 | 8 | 18.6 | 18 | 18.2 |
| 241 – 290 | 0 | 0 | 1 | 3.7 | 4 | 9.3 | 5 | 5.1 |
| 291 – 340 | 0 | 0 | 1 | 3.7 | 6 | 14 | 7 | 7.1 |
| 341 – 390 | 0 | 0 | 7 | 25.9 | 17 | 39.5 | 24 | 24.2 |
| 391 – 440 | 0 | 0 | 3 | 11.1 | 2 | 4.7 | 5 | 5.1 |
| **Total** | **29** | **100** | **27** | **100** | **43** | **100** | **99** | **100** |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Number of fishers / Crew** | | | | | | | | |
| 1 – 5 | 4 | 13.8 | 2 | 7.4 | 5 | 11.6 | 11 | 11.1 |
| 6 – 10 | 25 | 86.2 | 9 | 33.3 | 14 | 32.6 | 48 | 48.5 |
| 11 – 15 | 0 | 0 | 1 | 3.7 | 5 | 11.6 | 6 | 6.1 |
| 16 – 20 | 0 | 0 | 6 | 22.2 | 5 | 11.6 | 11 | 11.1 |
| 21 – 25 | 0 | 0 | 7 | 33.3 | 11 | 25.6 | 18 | 18.2 |
| 26 – 30+ | 0 | 0 | 2 | 7.4 | 3 | 7 | 5 | 5.1 |
| **Total** | **29** | **100** | **27** | **100** | **43** | **100** | **99** | **100** |
| **Av. days of operation/month** | | | | | | | | |
| 15 | 13 | 44.8 | 12 | 44.4 | 14 | 32.6 | 39 | 39.4 |
| 18 | 16 | 55.2 | 15 | 55.6 | 29 | 67.4 | 60 | 60.6 |
| **Total** | **29** | **100** | **27** | **100** | **43** | **100** | **99** | **100** |
| **Days spent at sea** | | | | | | | | |
| 0 – 1 | 18 | 62.1 | 2 | 7.4 | 12 | 27.9 | 32 | 32.3 |
| 1 – 2 | 11 | 37.9 | 12 | 44.4 | 21 | 48.8 | 44 | 44.4 |
| 3 – 4 | 0 | 0 | 13 | 48.1 | 10 | 23.3 | 23 | 23.2 |
| **Total** | **29** | **100** | **27** | **100** | **43** | **100** | **99** | **100** |
| **Type of gears** | | | | | | | | |
| Trawl net | 29 | 96.6 | 12 | 44.4 | 15 | 34.9 | 56 | 56.6 |
| Purse seine net | 0 | 3.4 | 15 | 55.6 | 28 | 65.1 | 43 | 43.4 |
| **Total** | **29** | **100** | **27** | **100** | **43** | **100** | **99** | **100** |

*Appendix III*: Interview Guide for the Socioeconomic Assessment of the Semi - industrial fishery

SURVEY OF FISH PROCESSORS AND FISH TRADERS ALONG THE COAST OF GHANA

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Interview site/ location: ………………… Form no.: …………….

Date: ………………

Hello my name is ………………………………… I am undertaking a research under the World Bank African Center of Excellence in Coastal Resilience project. As part of my research, I am conducting a survey on fish processors and fish traders in this area. I would like to ask you a series of questions which will take about 10-15 minutes. Would you be able to participate?

---

This is an independent survey I am conducting as part of my research. I am going to ask you a series of questions. There are no right or wrong answers. This interview is completely confidential. Your name is not required and, hence, you will not be associated with your answers in any form.

**Demographic information**

1. Gender

☐ Female ☐ Male

2. Are you a fish processor or fish trader?

☐ Fish trader ☐ Fish processor ☐ Both

**Socio- economic information**

1. How many years have you been a fish processor or fish trader?

☐ Less than 5yrs ☐ 5yrs- 10yrs ☐ 10yrs-20yrs

☐ above 20yrs

2. Is fish processing or fish trading your only source of income?

☐ Yes ☐ No

If No, list other sources of income:

………………………………………

3. How often do you get your fish supplies?

☐ Always ☐ Often ☐ Rarely ☐ Very rarely ☐ I don't know

4. Which fishing fleets do you mostly get your fish supplies from?

☐ Artisanal (canoe) ☐ Semi – Industrial (inshore)

5. Do you use ice blocks?

☐ Yes ☐ No

If Yes,

Quantity …………………. Value (GHC)………………...

If No, why not?.........................................................................................

6. List the types and form of fish you mostly purchase (in terms of pans, pieces baskets). List the highest to the lowest priced fish you purchase (1-8).

7.

| VALUE/ PRICE OF DIFFERENT FORMS OF FISH SPECIES PURCHASED PER/DAY BY FISH TRADER AND PROCESSORS | | | | |
|---|---|---|---|---|
| ☐ **FRESH** ☐ **SMOKED** ☐ **DRIED** ☐ **SALTED** | | | | |
| No. | Fish species/ Family | Total number of pans/baskets/pieces | Total weight (pans) | Value / Price (GHC) |
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |
| 4 | | | | |
| 5 | | | | |
| 6 | | | | |
| 7 | | | | |
| 8 | | | | |

8. List the types of fish you sell the most (in terms of kilograms, pans, pieces baskets). List the most type you sell to the least types of fish you sell (1-7). Circle all forms by which fishes are sold that apply to each type of fish.

| Fish Type | Total number of pans/baskets/pieces | Value / Price (GHC) | Forms in which fishes are sold |
|---|---|---|---|
| 1. | | | fresh/ dried/ smoked/ salted/ others: |
| 2. | | | fresh/ dried/ smoked/ salted/ others: |
| 3. | | | fresh/ dried/ smoked/ salted/ others: |
| 4. | | | fresh/ dried/ smoked/ salted/ others: |
| 5. | | | fresh/ dried/ smoked/ salted/ others: |
| 6. | | | fresh/ dried/ smoked/ salted/ others: |
| 7. | | | fresh/ dried/ smoked/ salted/ others: |

9. Do prices vary over the year? ☐ Yes ☐No

If Yes how? …………………………………………………………………

10. Whom do you supply your fishes to?

☐ Fish traders ☐ Fish markets ☐ Restaurants ☐ Hotels ☐ Individuals ☐ Local food vendors ☐Others (specify): …………

11. How far do you live from the landing site?

☐ 0 to 10 minutes ☐ 5 to 20 minutes ☐ 20 to 40 minutes ☐ Beyond 40 minutes

12. By what means do you use to transport your fishes?

☐ Walk ☐ Taxi ☐ Bus ☐ Others ……

13. Cost of transportation for marketing? …………………GHC

14. Any constraints with marketing?

……………………………………………………………………

15. What is the biggest challenge facing you in your job?

| AVERAGE COST OF OPERATION AND RETURN OF FISH TRADER AND FISH PROCESSORS IN THE VALUE CHAIN | | |
|---|---|---|
| **ITEMS** | **FISH PROCESSOR** | **FISH TRADER** |
| | FIXED COST | |
| | Amount/ Value (GHC) | Amount/ Value (GHC) |
| Wire Gauze | | |
| Shop / Store | | |
| Oven / Freezer | | |
| Knife | | |
| Pan or Basket | | |
| Table | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| **TOTAL FIXED COST (TFC)** | | |
| | | |
| | VARIABLE COST | |
| Electricity | | |
| Salt | | |
| Water | | |
| Kerosene | | |
| Packaging material | | |
| Labor | | |
| Firewood | | |
| Transportation | | |
| Basket | | |
| Toll (tax) | | |
| Fish | | |
| | | |
| | | |
| | | |
| | | |
| **TOTAL VARIABLE COST (TVC)** | | |

SURVEY OF BOAT OWNERS AND CREW HEADS OF SEMI-INDUSTRIAL FLEETS ALONG THE COAST OF GHANA

---

Interview site/ location: ………………………… Date: ……………….

Form no.: ……….

Hello my name is …………………………………… I am undertaking a research under the World Bank African Center of Excellence in Coastal Resilience project. As part of my research, I am conducting a survey on boat owners and crew heads of semi-industrial fleets in this area. I would like to ask you a series of questions which will take about 10-15 minutes. Would you be able to participate?

This is an independent survey I am conducting as part of my research. I am going to ask you a series of questions. There are no right or wrong answers. This interview is completely confidential. Your name is not required and, hence, you will not be associated with your answers in any form.

**Demographic information**

1. Gender of boat owner?

☐ Female ☐ Male

2. How many boats do you have?

☐ 1 boat ☐ 2 – 5 boats ☐ 5 – 8 boats ☐ Above 8 boats

3. How many years can your boat last?

☐ 1 – 10yrs ☐ 10 – 15yrs ☐ 15 – 20yrs ☐ Above 20yrs

4. How many years have you being using your boat?
   …………………………
5. How long have you been fishing?

☐ 1 – 10yrs ☐ 10 – 20yrs ☐ 20 – 30yrs ☐ Above 30yrs

**Socioeconomic information**

1. What is/ are your source(s) of funding for your operations?

☐ Bank ☐ Credit Union ☐ Susu collectors ☐ Family & friends ☐ Fish processors

2. Which month (s) are the most abundant fish caught by the semi industrial sector?

☐ June – August ☐ September – December ☐ January – March ☐April -May ☐ I don't know

3. What are the periods of time during the year that you do not fish? ……………………………………………………………………………
4. During this time what do you do for living?
   ……………………………………………………………………………………
6. List the economically valuable group of fishes you mostly catch (in terms of pieces/ pans/ baskets). List the most group of fish catch to the

least group of fish catch (1-6). Tick how often you mostly catch these fishes as applied to each group of fishes.

| Group of fish | Total number of pans/baskets/pieces | Value / Price (GHC) | How often do you get these group of fishes |
|---|---|---|---|
| 1. | | | ☐Always ☐Often ☐Rarely ☐Very rarely ☐ I don't know |
| 2. | | | ☐Always ☐Often ☐Rarely ☐Very rarely ☐ I don't know |
| 3. | | | ☐Always ☐Often ☐Rarely ☐Very rarely ☐ I don't know |
| 4. | | | ☐Always ☐Often ☐Rarely ☐Very rarely ☐ I don't know |
| 5. | | | ☐Always ☐Often ☐Rarely ☐Very rarely ☐ I don't know |
| 6. | | | ☐Always ☐Often ☐Rarely ☐Very rarely ☐ I don't know |

5. Do the operations of the artisanal fishers have any impact of your operation?

☐ Yes ☐ No

If yes, how? ……………………………………………………………………

6. Do the operations of the industrial fishers have any impact of your operation?

☐ Yes ☐ No

If yes, how?

……………………………………………………………………………………

7. When you have a conflict with other fishers, how are they resolved?

……………………………………………………………………………………

8. In your own view what is/are the main cause(s) of the fluctuation in the number of fleets in the inshore fishery?

……………………………………………………………………………………

9. What would you like to see change in this sector of fisheries to improve your life?

……………………………………………………………………………………

10. How are profit shared amongst boat owners, crew head and crew? (specify in percentages, %)

Boat owner: …………% Crew head: …………% Crew: …………%

Any other means? …………………………………………………..

| CATCH AND EFFORT ASSESSMENT SHEET ON SEMI INDUSTRIAL FISHERY, GHANA | | | |
|---|---|---|---|
| | | | **Form No.:** |
| Vessel registration number: | | | Date: |
| Landing site: | | Boat purpose: | Boat length: |
| Type of gear used: | | Total length of gear: | Mesh size: |
| HP of inboard engines: | No. of fishers / Crew: | Time spent in operation: | Days spent at sea: |
| Total weight of catch/kg: | Area fished: | Average days of operations/month: | Twine size: |
| | | | |
| **FIXED COST** | Amount/ value (GHC) | **VARIABLE COST** | Amount/ value (GHC) |
| | | | |
| Vessel depreciation | | Fuel & Lubricants (oil) | |
| Vessel & Gear insurance | | Ice for fish conservation | |
| Boat registration & license | | Foods | |
| Boat & gear maintenance | | Fresh water | |
| | | Crew wages | |
| | | Captain wages | |
| | | Miscellaneous | |
| TOTAL FIXED COST (TFC) | | TOTAL VARIABLE COST (TVC) | |
| | | | |
| | | | |
| | **DAILY AVERAGE INCOME** | | |
| **Daily average catch** | Fish species / family | Weight (no. of pans/ pieces) | Value/ Price (GHC) |
| | 1. | | |
| | 2. | | |
| | 3. | | |
| | 4. | | |
| | 5. | | |
| **Catches given out to friends & relatives, etc.** | | | |