UNIVERSITY FOR DEVELOPMENT STUDIES, TAMALE

DETERMINANTS AND EFFECTS OF CLIMATE CHANGE ADAPTATION STRATEGIES ON THE PERFORMANCE AND WELFARE OF ARTISANAL FISHERS IN THE BRONG AHAFO REGION

AWAL FUSEINI

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BY

AWAL FUSEINI

(MPHIL AGRICULTURAL ECONOMICS)

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AUGUST, 2020

DECLARATION

I, Awal Fuseini hereby declare that this thesis is the result of my own original work and that no part of it has been presented for another degree in this University or elsewhere.

Awal Fuseini	……………………	…………………………
(Name of Student)	Signature	Date

I hereby declare that the preparation and presentation of the thesis was supervised in accordance with the guidelines on supervision of thesis laid down by the University for Development Studies.

Dr. Franklin N. Mabe	………………………	…………………………...
(Supervisor)	Signature	Date

Dr. Hamdiyah Alhassan	………………………	…………………………...
(Head of Department)	Signature	Date

ABSTRACT

It is evident that climate change is one of the greatest threats to several and diverse areas in contemporary literature. Its impact on fisheries is especially devastating when mentions are made about artisanal fishers whose survival depends on their primary activities of fishing. In fact, empirical evidence has been able to establish the rising temperatures and declining rainfall patterns across the different ecological zones in Ghana and further espoused the falling trends in terms of the average fish catch per annum. Since climate change is inevitable, it is imperative that these fishers employed various strategies to adapt to its glaring impact. Some of these adaptation strategies include changing fishing time, increased fishing time, investing in alternative livelihoods, moratorium and migrating to different fishing area. The major objective this research seeks to address is to determine the impact of climate change adaptation strategies on the performance as well as welfare of artisanal fishers along the Volta basin in the Brong Ahafo region. The specific objectives include examining the factors that determine artisanal fishers' adaptation strategies to the impact of climate change; determining the effects of the adaptation strategies on performance of artisanal fishers and measuring the effects of the performance on household welfare of artisanal fishers. The research was justified on the basis of its contribution to policy, academic literature and methodology. Data for this research was cross-sectional in nature, collected from different fishing communities and specifically from 332 artisanal fishing households in two districts (Pru East and Sene West) using the systematic random sampling techniques. The research was primarily underpinned by the utility maximization theory and data was analyzed using the Multivariate probit analysis and the recursive models as in Conditional Mixed Process (CMP). Whiles the results revealed education, credit access, fisher experience monthly non-fish income, access to electricity, perception index among others as the factors that determine adaptation strategies, profits were found to be significant in determining welfare. Further, adapting to all the three adaptation strategies do not necessary yield more profits. The reasons been that, some of the adaptation strategies are non-complementary and as such using them together rather makes fishers worst-off. The research then recommended that, artisanal fishers be given the requisite education, training and assistance in a well-crafted package by the government through collaborative efforts by the department of fisheries under the Ministry of Food and Agriculture (MoFA) and other ministries and agencies among other stakeholders.

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I cannot also forget the support of some of my family members and friends including my lovely wife, Ibrahim Najahatu, and my brothers Mutala Fusheini and Alhassan Inusah. I wish God's favor and blessings on you all.

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DEDICATION

I dedicate this work entirely to my family and especially my late father, Mr. Alhassan Fuseini and to my lovely daughter, Aqeelah Simdeeya.

LIST OF ACRONYMS

ANN	Artificial Neural Network
CCC	Climate Change Cell
CMP	Conditional Mixed Process
EPA	Environmental Protection Agency
FAO	Food and Agricultural Organization
GoB	Government of Bangladesh
JHS	Junior High School
IFAD	International Fund for Agricultural Development
IPCC	International Panel on Climate Change
MASLOC	Microfinance and Small Loans Center
MNER	Ministry of Natural Resources and Environment
MoE	Ministry of Education
MoFA	Ministry of Food and Agriculture
MoFAD	Ministry of Fisheries and Aquaculture Development
NGO	Non-Governmental Organization
SDGs	Sustainable Development Goals
SHS	Senior High School
SSFM	Small-scale Fishermen in Malaysia

U K	United Kingdom
UN	United Nations
UNDP	United Nations Development Program
UNFCCC	United Nations Framework Convention on Climate change
U S	United States
WTO	World Trade Organization
WWF	World Wildlife Fund

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CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Fish is an essential commodity that is consumed worldwide. It provides food to majority of people at the household level and to others an indispensable source of income. As an essential food commodity, fish is traded both in the local and international markets, drawing huge sums of revenue to firms and governments. In 2016, about 35% of fish produced in the entire globe entered international trade in several forms both for human consumption and for non-edible purposes according to the Food and Agricultural Organization [FAO] (2018). This clearly shows the potential of the commodity in terms of earning foreign exchange for many countries.

In fact, it is further averred that the potential economic value of captured fisheries globally is US $80–85 billion annually with an estimated amount between $225 and $240 billion per year envisaged from the sector when processing and other ancillary activities are considered (Christophe et al., 2016). This shows the economic significance of the fishing sector to various economies and justifies the need for more attention. Of course it further espouses the potential incomes that could be earned within the value chain as a result of the jobs that people are provided. More fascinatingly, fish provides natural source of nutrition and serves as an important source of protein for many people. According to the FAO as cited in the World Wild Life (WWF) report (2016), fish provides more than 3.1 billion people with at least 20% of their animal protein and also serves as an essential source of fatty acids and micronutrients. The implication of fish and fish products on people's diet and health therefore cannot be underrated especially when the number of those using the commodity at different levels throughout the world is proportionately large.

The fisheries sector has also created employment for many people along its value chain from fishermen to fish processors and fish traders. Indeed, it hoards the capacity to eradicate poverty and hunger either through direct or indirect effect by generating incomes for those involved in the fish value chain and thus ends up facilitating the attainment of some milestones envisaged in the sustainable development goals (SDGs). It is accordingly estimated that, the primary fishing sector of captured fisheries and aquaculture had employed about 59.6 million fishers in the world in the year 2016. Specifically, 19.3 million people are engaged in aquaculture whiles the remaining 40.3 million people are engaged in captured fisheries (FAO, 2018). This indicates that, deliberate policies from governments and international organizations could protect the jobs of several millions of people across the globe.

In Africa, fish plays an important role in terms of food security and accounts significantly for the improvement in animal source of protein among the people. It is estimated that, approximately 200 million people from the African continent obtains high-quality and low cost protein from fish (Obiero et al., 2019). Further as a result of the decline in performance of agricultural and other natural resources, fish is estimated to contribute 50% of animal protein for most West African countries (Lam et al., 2012). This suggests the significant impact the fisheries sectors have had in terms of contributing to the provision of protein which is a requirement for balance diet and healthy living.

According to the FAO, (2018) the estimated number of people engaged in both captured fisheries and aquaculture in Africa was approximately 5.7 million of which captured fisheries alone accounted for approximately 5.3 million. However, the total number increases to 12.3 million if processing and other ancillaries including post-harvest activities and marketing are taking into consideration. This shows the extent to which employment is created for the vast number of people within the continent and further projects the fisheries sector as a viable source of livelihood. Additionally, the sector has also been significant in contributing to the Gross Domestic Products (GDP) of African countries. For instance, the fisheries sector based on the Gross Value Added (GVA) approach contributed an amount of US$24 billion in 2018 to the GDP of the African continent. This signifies that, a strategic investment into the sector is worth yielding huge returns for the countries in Africa.

Fish is recognized in Ghana as one of the essential sources of animal protein expected to provide 60% of animal protein needs (Ministry of Food and Agriculture [MoFA], 2015). Undeniably, it forms an essential portion of diet for many people and results in significant amount of fish consumed in the country. In 2015 for instance, the average fish consumption was higher relative to the world's average. As the world's average peaked 13 kg per capita, that of Ghana's was estimated at around 23 kg per capita indicating an excess of 10 kg per capita (MoFA, 2015). This indicates that, the consumption of fish in Ghana was much higher which provides the basis to protect the fishing industry in order to enable them deliver the right qualities and quantities of fish appropriately to households and the national economy in general.

Furthermore, as many as 2.6 million people in Ghana are dependent on the fisheries sector for their livelihoods. From that, approximately 135,000 of them are in the marine capture fisheries sector and 124,000 are artisanal fishers based in rural areas that have thus far remained at the margin of the country's economic growth (FAO, 2016). It is further estimated that, 300,000 people are directly dependent on the Volta Lake alone, from which 80,000 are fishers and the rest are fish traders, processors, marketers among others (FAO, 2016). In terms of foreign exchange, the fishing sector contributed an amount of US$1billion to the Ghanaian economy according to the Ministry of Fisheries and Aquaculture Development [MoFAD], (2011). However, the sector's recent contribution to GDP in 2018 was GH₵ 572 million (Ghana Statistical Service [GSS], 2018). This implies that, the fisheries sector is capable of drawing huge revenues to support the government's budget which could consequently improve the livelihoods of fishers' significantly.

Irrespective of the significant successes chalked over the years in the fishing industries, impediments to the sector's further growth and expansion are pervasive. Internally, issues of overexploitation, discrimination against access to resources, post-harvest losses and poor management are evidenced across many countries including Ghana. As reported by the FAO, an estimated 30% of stocks are currently overexploited (International Fund for Agricultural Development [IFAD], 2014). Sadly, the above impediments to the sector's growth are further exacerbated by the impact of climate change to the extent that, the livelihoods of the millions of people which depends on the sector are under serious threats.

In fact, the rise in global temperatures, unpredictable rainfalls and increases in sea levels which are the results of climate change are consequential to the demise of a rather vibrant sector. Although fisheries basically survive and produce within ecosystems, these systems are unfortunately threatened by the impact of the change in climate and ultimately result in low fish production. For instance, the average fish production or catches in Ghana declined significantly by 66% from 252,112 metric tons to 84,980 metric tons (Thomas et al., 2014). This finding was further corroborated by the report of MoFA (2015) that, as the total fish requirement in Ghana surged to 880,000 metric tons that of production declined to 434,121 metric tons. This suddenly created a deficit of 445,879 metric tons which was imported. This suggests that, huge sums of foreign exchange which could have remained in the country were rather spent on imports thereby creating wealth for those countries.

As a result, artisanal fishers whose livelihoods depend on fishing need to employ strategies to effectively get adapted to the impact of climate change. These adaptation strategies could either be planned by a development actor such as the government and other stakeholders or be autonomously employed. According to Sereenonchai & Arunrat (2019), some of the climate change adaptation strategies used by small-scale fishers include, fishing for longer hours, shifting fishing time, changing the locations of fishing, migration to different fishing areas and the adoption of climate-smart options which include the development of alternative livelihoods. Indeed, these adaptation strategies could yield significant results for artisanal fishers especially with regards to their performance and welfare which is quite imperative if the livelihoods of millions of people ought to be sustained.

1.2 Problem Statement

The change in the world's climate is clearly evident in the fluctuating pattern of rainfalls and incessant increasing temperatures among others. In fact, there are enormous findings in the literature, results quite substantial to conclude the prevalence of climate change not only in the world as such but also in Africa and Ghana to be specific. For instance, whiles Serdeczny et al. (2016) and Brown et al. (2019) have been able to adduce evidence to the effect that the climate was changing in Africa, findings from Daniel & Emmanuel (2011), Felix & Franklin (2015), Issahaku et al. (2016) and Abdul Rahman et al. (2016) among others have all demonstrated using time series data that spanned over an average of 10 years to conclude that, the average rainfall declined whiles that of temperatures increased across all the agro-ecological zones in Ghana. This situation doubtlessly depicts evidence of climate change which gravely impacts on the fishers in general and further making the artisanal ones worst-off.

In terms of the effects of the changing climate on fisheries, several findings have indicated among other consequences the increase in water acidity and salinity, increased sea temperature and current flows which results in the reduction in fish stock through mortality, invasive species, reduction in the size of the fish, changes in the distribution of fish species, adverse impact on fish recruitment and reduced dissolved oxygen. In other works, the impact of climate change on the fishing sector has been classified as either physical in a form of temperature rise, increase in salinity, sea level rise and ocean acidification or biological in a form of changes in fish stock and production and changes in fish distribution. All these factors adversely affects the ecosystem and results in a decline in fish catch.

Ordinarily, artisanal fishers observed the changes in the trends of the climatic variables around their environments and equally noticed that, such changes are often dovetailed by empirical decline in fish catch. According to the FAO (2016), there has been a decline in fish catch or production in Ghana from the marine sector which encapsulates artisanal fisheries since 1999 from 420,000 metric tons to 202,000 metric tons in 2014. Aside this fact, some of the fishers have had discussions with peers, extension officers or monitored programs in the media where issues of climate change are made topical. All these factors sharpened their understanding regarding climate change and direct them towards the employment of smart and sustainable adaptation strategies that are capable of minimizing climate change effects on their livelihoods. The bubbling question that necessitated this research therefore remains that, are these adaptation strategies the artisanal fishers are using effective in improving their profits and welfare?

Following the problem statement, these research questions below are imperative,

1. What are the factors influencing the adaptation strategies fishers use to mitigate the effects of climate change on fishing?
2. What are the effects of the adaptation strategies on the performance of artisanal fishers?
3. What effects does performance of artisanal fishing have on household welfare?

1.3 Research Objectives

The main objective of the study is to assess the implications of using climate change adaptation strategies on the performance and welfare of artisanal fishers. The specific objectives of the study are to:

1. Identify the factors that determine adaptation strategies fishers used to mitigate the effects of climate change on fishing.
2. Estimate the effects of adaptation strategies on the performance of artisanal fishers.
3. Measure the effects of performance of artisanal fishing on household welfare.

1.4 Justification of the Study

It is doubtless that climate change is a reality and indeed its impact on fisheries scientifically established. The confidence reposed in the thermometer justified the increases in mean temperatures across various regions of the globe. The results of climate change in a form of increase in water salinity and acidity is injurious to the several aquatic species which includes the fish. This by implications means that, the millions of artisanal fishers whose very survival and livelihood are tied to fisheries are equally threatened. Therefore, the need to research into the adaptation strategies adopted by the artisanal fishers to mitigate the effects of climate change and the extent of their performance and welfare is imperative.

Also, the study means a lot to policy in terms of international and national dimensions. The international response to the impact of climate change necessitated the formation of the Intergovernmental Panel on Climate Change (IPCC) of the UN in 1988. Several other countries have enacted their own climate change codes to govern their local peculiarities. Ghana's fisheries sector for instant is climate dependent and highly vulnerable. Therefore, in finding measures to address climate change impact, the National Climate Change Strategy was prepared in 2008 (MoFA, 2015). This research is therefore targeted to inform policy in the fisheries sub-sector in Ghana and many other sub-Saharan African countries with respect to factors influencing artisanal fishers' adaptation and the effects of adaptation on performance and welfare.

Furthermore, the contribution of this study to knowledge and academic literature cannot be understated. It is worth mentioning that, several studies have been conducted with respect to climate change impact on fisheries and climate change adaptation strategies; however this study switches the rhythm to examine the effect of climate change adaptation strategies on artisanal fishers' performance in terms of profit and welfare since that is deficient in literature. Additionally, the artisanal fishers could be better informed in terms of the factors that influence their adaptation strategies to climate change, their profits and welfare through carefully thought through policies and interventions by state actors and other development agencies interested in climate change and resource management.

Finally, the contribution of the study particularly to methodology is appreciable. The Multivariate Probit (MVP) was employed to examine the determinants of the adaptation strategies and the recursive model was applied to examine the effects of the adaptation strategies on profit and consequently on household consumption expenditure through the Conditional Mixed Process (CMP). The superiority of these methodological models compared with similar ones under the circumstance is grounded not only in their resilience in estimating equations as systems, but also their abilities to deal with the problems of endogeneity and selectivity biases which are obvious in studies of this nature. In all, the relevance of this study cannot be overemphasized because artisanal fishers are the least contributors to the cause of climate change, however the most vulnerable to the impact of climate change not only in sub-Saharan African countries but the world at large (FAO, 2018).

1.5 Organization of the Study

The report of this research is organized into five chapters. The first chapter is the introduction which laid the background to the study and unearths the problem that the research is intended to address. It also includes the specific research questions that translate to the study objectives. The relevance of the study in terms of its contribution to policy and literature has also been included. The second chapter is the review of relevant literature that is related to the study objectives. Indeed, the theoretical/conceptual frameworks as well as the empirical studies have been reviewed.

Chapter three espoused the research methodology intended to be used to achieve the stated objectives. It particularly described the nature and environment of the study area and the design of the research. The targeted population and the sample size have also been determined. The methods of data collection, sources of data, and instruments of data collection have among other things been thoroughly discussed. Finally, Results from the data analyzed have been presented and discussed in the fourth chapter and thereafter, the summary of findings, conclusion and recommendations made in the fifth chapter.

CHAPTER TWO

LITERATURE REVIEW

2.1 Chapter outline

This chapter focuses on the theoretical/conceptual and as well as the empirical literature on climate change adaptation strategies. It also looks at some essential concepts within the study and in the end certain relationships are established and points of convergence and divergences including gaps are analyzed.

2.2 Definition of concepts

2.2.1 Climate change

The Inter-governmental Panel on Climate Change (IPCC), 2012 referred to climate change as a change in the manner of the climate that can be identified statistically by the changes in mean or variability of climate properties and that stays for a period of ten years or more. Usually, the change in the climate overtime could either emanate from natural variability or through the activities of human beings. On the other hand, the United Nations Framework Convention on Climate Change (UNFCCC) (2011) defined climate change as any form of change in the climate that is attributable directly or otherwise to the activities of human beings and natural phenomenon which changes the composition of the global atmosphere over a period of time. It can therefore be inferred from these definitions that, the climate is naturally bound to change even without human activities. However, the activities of humans in a form of burning fossils, agricultural and industrial emissions among others contribute speedily to the occurrence of climate change. In fact, both cases espoused the strong connection of human activities to the changes in the atmospheric conditions but also acknowledged the natural aspect of climate change. Aside these definitions, other efforts are made to conceptualize climate change. Accordingly, climate change is seen as the changes in the long-term statistical distribution of the patterns of weather as in precipitation, temperature etc. spanning several decades to millions of years (Rahman, 2013). This means climate change is a time dependent event which occurrence usually takes a long period spanning many years.

Additionally, and in accordance with the literature and scientific studies, changes in climate are caused by several factors including the burning of fossil fuels, emission of carbon dioxide and other greenhouse gases such as methane, chlorine, nitrogen oxides and bromine into the atmosphere. These gases warm up the earth and leads to global warming which eventually results in climate change. Accordingly, the greenhouse gases once built-up, alters the radiative equilibrium in the atmosphere and eventually warms up the earth through the absorption of the out-going radiation and re-radiate them back to the earth surface. In fact, the net warming of the atmosphere as at the end of the 20^{th} century from 1850 was equivalent to 2.5W/m2 with carbon dioxide being the lead causative agent contributing about 60%, whiles that of methane, nitrous oxide and halocarbons contributed 25% and 15% respectively (Shahzad, 2015). This explains the fact that; a reduction in the discharge of these gases especially carbon dioxide into the earth surface could moderate the rate at which climate change occurs.

2.2.2 Climate change adaptation strategies

The Intergovernmental Panel on Climate Change (IPCC) as reported by Smith et al. (2001) referred to adaptation as adjustments in economic, social and ecological systems in reaction to actual or expected climatic stimuli and their effects. It also encapsulates the adjustments to minimal harm from, or to benefit from, recent climate variability and the expected climate change (UNDP, 2019). Similarly, adaptation to climate change is also seen as the adjustment of a system to regulate the impacts of climate change, to harness the advantages in terms of new opportunities or to manage with the consequences (Adger et al., 2013). Further, adaptation is perceived as an active set of strategies and actions employed by people either in reaction to, or in anticipation of a change in order to facilitate or maintain their state of well-being. This means that, adaptation can encapsulate both building the adaptive capacity to strengthen the ability of individuals, groups or organizations to predict and adapt to changes, as well as implementing adaptation decisions such as transforming that capacity into action. Therefore, adaptation is a continuous stream of activities, actions, and attitudes that informs decisions about several aspects of life and that mirrors existing social norms and processes (Daw et al., 2009). Based on the definitions above, adaptation simply refers to all actions put together to manage or decrease the negative effects of climate change.

Adaptation to climate change has further been referred as any behavioral or capital changes of any economic units such as the household, firm or governments that minimizes the harm or increase the benefits resulting from climate change(Malik & Smith, 2012). Perry et al. (2007) as in the works of Brown et al. (2019) also made an effort to conceptualized adaptation in the context of climate change as, something that takes place through adjustments to minimize vulnerability or enhance resilience to either observe or anticipated changes in climate, and takes into account changes in processes, practices, functions and perceptions. Following from the above, adaptation could either mean the reduction of the negative effects to decrease ones vulnerability or increasing the benefits that come with climate change.

In another scenario, adaptation is understood as the removal and prevention of maladaptive practices (UNFCCC, 2012). Maladaptation in this sense refers to measures to adaptation that do not encourage the reduction in vulnerabilities but increase them rather. Some of the measures that prevent maladaptation among others include: taking better care of systems of irrigation and expunging laws that can subtly increase vulnerability such as destruction of mangroves and laxation in regulations regarding building on flood plains and coastal areas (UNFCCC, 2012). Indeed, the prevention of maladaptive practices could best be dealt with at the macro level instead of being left to fishers at the household level. Usually, it takes a deliberate policy initiative either from the government and other stakeholders to remove maladaptive impediments to enhance fishers' adaptation to climate change.

Climate change adaptation strategies are dichotomized into two according to Malik & Smith (2012). These include autonomous adaptation and that of planned adaptation. The autonomous adaptation happens when the farmers or fishers in their own abilities and understanding put up measures to counter the negative effect of the climate change without any informed external intervention. Planned adaptation on the other hand occurs when government or its agencies, or other informed organizations map a coherent and tractable strategy to deal with the effect of climate change. Further, planned adaptation is that type of adaptation undertaken by a state agency or government and need to have a characteristic of public good whiles, autonomous adaptation is undertaken by households, firms, or both of these, and likely not to have a public good characteristics. Mendelsohn (2012) also divides adaptation into two broad categories thus, private and public adaptation. Whiles private adaptation only gives gains to the agent undertaking it; public adaptation has a public good trait and gives benefits to several agents and not just the agent implementing the adaptation. Even though, private and public adaptations are closely associated to what we describe as autonomous and planned adaptations respectively, the two are not identical.

Adaptation can also be both reactive and anticipatory to changes in climate. For reactive responses, they are taken up as a measure to an already observed impact of climate whiles that of anticipatory adaptation are measures that are targeted at reducing the exposure to risks in the future posed by change in climate. Some of the reactive adaptation measures in the agricultural and food security sector which happens to be one of the most vulnerable sectors are erosion control, dam construction for irrigation, changes in fertilizer use and application, introduction of new crops, soil fertility management, changes in times of planting and harvesting, switching to different cultivars, educational and outreach programs on conservation and management of soil and water etc. Examples of anticipatory adaptation measures include development of crops resistant to drought, salt, and pests' research, soil-water management, diversification and intensification of food and plantation crops policy measures, subsidies, and the development of early warning systems (UNFCC, 2012). The IPCC (2014) also posited that, adaptation can be reactionary or anticipatory depending on the timing (Malik & Smith, 2012). The anticipatory type of adaptation also called proactive adaptation occurs usually before climate change impacts are observed whiles that of the reactive adaptation refers to measures taken after climate change impact. Anticipatory adaptation requires a better understanding of change in the climate and also knowledge on the adaptation strategies. The planned adaptation can therefore be classified as either been reactive or anticipatory and the autonomous adaptation is mainly reactionary in nature. Adaptation can further be classified or grouped into localized and widespread (Malik & Smith, 2012). Localized adaptation refers to measures and strategies uniquely undertaken by a group of people within a defined area or community and specific to their environment milieu whereas widespread adaptation involves the use of adaptation strategies that are universally pervasive.

2.2.3 Artisanal fishing

The term artisanal fishing has different connotations depending on the context within which it is used. However, in the context of this research, the term is not different from small-scale fishing where fishers employ less sophisticated technologies and equally depends on their harvest for subsistence. Tim & Paul (2014) defined artisanal fishing as any mall-scale fishing that is not sport-fishing and encapsulates both subsistence and small-scale commercial fishing. In other words, it is primarily meant to put food on the table of the people involved in it. In Ghana, the artisanal fishing primarily involves the use of canoes or dug-out wooden boats with either inboard or outboard engines affix to them. The kinds of fishing gears used are also diverse, including set nets, beach seine nets, purse seine nets, drift gillnets, and hook and line. The major fish species landed include, sardinellas, mackerels, tuna, burrito and Atlantic bumpers among others with the minor ones being red fish, flat fish and white groupers (Kwamena & Chu, 2019).

The United States (U.S) department of fisheries defined artisanal fisheries as small-scale fisheries that employ labor-intensive methods of catching, processing and distribution technologies to exploit marine and inland fisheries (Schorr, 2015). Usually, fisheries from this source typically targets local rather than export markets. In furtherance to the difficulty in given a precise definition to the term, the World Trade Organization (WTO) rather proposed some definitional elements broadly categorized into four: physical attributes, pattern of fishing, social structure and economic conditions (UNEP, 2005). With respect to the physical attributes, there is the need to analyze the vessel type which is often a canoe or dory, the size of the vessel which must be small and whether it is motorized or not. The pattern of fishing has the type of fishing gear which is often small nets and the type of fish targeted ought to be multi-species. Whiles the social structure of artisanal fisheries is concerned with the community, the economic condition is about the market orientation which is often meant for direct consumption and income levels at subsistence.

2.3 Climate Change around the Globe

According to Mote (2003), the northwestern part of the United States (U.S.) has experienced increased in temperature between $0.7°C$ and $0.9°C$ during the 20th century. Starting from 1950, the mean annual air temperatures at many meteorological stations in the region have risen by approximately $0.25°C$ per decade which could be dangerous to fish species such as salmon during the spawning, incubation, and rearing stages of their life cycle (Battin et al., 2007). This further implies that, warmer temperature induces earlier snowmelt and to a low proportion of the precipitation falling as snow. In Malaysia, climate change is said to have serious implications for several areas of their economic life for which the fisheries sector is not an exception. Shaffril et al. as cited in Samah et al. (2019) has it that, Small Scale Fishermen in Malaysia (SSFM) has been facing climate change such as increased temperatures, sea-level rises, unstable monsoon patterns and extremes of waves and winds.

Another glaring evidence of the effect of climate change is the level of sea rise across many areas in different regions. Sea levels all around the world are rising and the speed of the rise is expected to increase in future. Approximately, mean sea levels have risen by 12cm to 22 cm since the 1890s and further predicted that, global average sea levels will surge from 18cm to 59cm by 2100 on the grounds that, melting of the Greenland and Antarctic ice sheets does not accelerate (IPCC, 2013). This is a clear indication of danger especially for communities living around the coastal areas. Their fishing activities could also be severely impacted as a result if urgent steps are not taken to address this issue.

The meteorological department of the United Kingdom (Metoffice), (2019) reported that, the average number of warm days as well as warm nights all over the world have increased since 1950. This according to them is as a result of human activities. In the UK for instance, several studies have shown increases in heat waves. The country is particularly experiencing high maximum temperatures and longer warm spells which are the crystal evidence of climate change. Temperature projections have pointed upwards and by the middle of the 21st century, the record breaking heat waves recorded in 2018 appeared as though normal. According to the Climate Change Cell (CCC) as cited in the works of Paul & Rashid (2016), Bangladesh regimes of the temperature, regional flow patterns and monsoon greatly influenced the country. The mean annual temperature of the country from the year 1948-2007 had increased significantly at the rate of 2.34°F per 100 years and more intense at the rate of 3.85°F per 100 years over the period 1980 to 2007 (Serdeczny et al., 2016). As a result, the dry seasons would impact on yields of crop, land use suitability, potable water, and livestock, cropping cycle, biodiversity and small-scale fisheries in Bangladesh.

Indeed, several research works in Malaysia confirmed that the country is getting warmer. In the year 2015, the Malaysian Ministry of Natural Resources and

Environment (MNRE) worked on rising temperature and indicated that the country had a rise of $0.25°C$, $0.20°C$ and $0.14°C$ per decade respectively for Peninsular, Sabah, and Sarawak. In a related work however, Shahid et al. (2017) revealed that, Peninsular Malaysia had a temperature upsurge between $1.1°C$ and $3.6°C$ as a result the country could be hit with extreme and unpredictable weathers such as drought and flood.

2.4 Climate Change in Africa

According to the IPCC (2014) the African continent has been identified as one of the most vulnerable to the impacts of climate change with the average temperature expected to rise across the region even though the warming is relatively less strong than that of the global land area. In fact, temperature range is classified as either high-emission or low-emission cases depending on the intensity. It is described as low-emission case when it reaches $2°C$ and high-emission when it peaks $4°C$. In terms of geography, this warming is rather uniformly distributed. However, in subtropical southern Africa, the differences in warming between the low-emission and high-emission cases are large (Serdeczny et al., 2016). These incessant increases in the mean temperature across the continent have dire consequences for the fisheries sector.

The prevailing problems with respect to water in Africa are most likely to exacerbate owing to climate change. In fact, Brown et al. (2019) averred that, more volumes of rainfall will multiply the incidence of flooding in many areas; minimizing the quality and quantity of water available for domestic and industrial use and production of hydropower. They further emphasized that, getting to the end of the 21st century projected rise in the sea-level will impact on low-lying coastal areas with huge populations such as Senegal, northern Egypt, the Gambia, and the gulf of Guinea.

The World Bank as cited by Deb & Haque (2017) further asserted that, from the total of 2.85 million hectares of coastal and offshore areas, approximately 1.2 million hectares of arable land are impacted already by varying degrees of salinization in Africa. However, the mean rainfall indicated an increase by 4.4 percent from the period 1990 to 2012. In some selected countries in sub-Saharan Africa, sea-level rise for selected locations like Abidjan, Lome, Lagos and Maputo are projected to surge upwards from the year 2081 to 2100, with the rise estimated at between 0.4 m and 1.15 m in high-emission zones and 0.2m to 0.7m in low-emission zones (Serdeczny et al., 2016).

The increasing trend of temperature across different regions and countries in Africa is also inarguable noticeable especially in the works of Hassan & Deressa (2009) as mentioned in the works of Skambraks (2014) that, the climate of Ethiopia will change in the near future. The findings further postulate that, Ethiopia will experience an upsurge in its mean annual temperature by the year 2050 with the predicted values ranging from $1.7°C$ to $3.82°C$ in time. However, at the same level of investigations, the models are in dissonance with the changes in precipitations. Whiles some predicts a decrease in the mean annual precipitation, others predict a slight increase in the average precipitation by the year 2050. This indicates how precipitation has been likely to be fluctuating and the repercussions of such fluctuating might be devastating.

Scientifically, by the year 2050 sub-Saharan Africa is predicted to have up to 10 percent decline in mean annual rainfall within its interior (Brown et al., 2019). This then implies that, there would be particularly serious impacts of climate change on agriculture in sub-Saharan Africa where 75 percent of agriculture is rain-fed. Sadly, the places most suitable for agriculture, the extent of growing seasons and yields of crop are all anticipated to decline, with serious implications for food security. In support of these findings, Bewket & Conway (2007) argued that, the increased variability in terms of rainfall and increasing temperatures will most likely impact on the agriculture of Ethiopia and also expected to further worsen the existing conditions such as soil erosion, land degradation, deforestation, desertification, and loss of biodiversity. The damage however will not be the same in all the ecological zones because some will gain from a slight increase in temperature whereas others will experience devastating changes (Skambraks, 2014).

Africa is the continent most vulnerable to the impact of climate change and climate variability, a situation compounded by the interaction of several stressors happening at various levels and low adaptive capacity (IPCC, 2017). The African continent is likely to be warm this century, with the drier sub-tropical regions warming more than the moist tropics. Rainfall trends will alter as the hydrological cycle becomes more intense. Annual rainfall is likely to decline throughout most of the continent, except the eastern Africa, where it is estimated to rise (Brown et al., 2019).

2.5 Climate Change in Ghana

The climate of Ghana has indeed being changing over the last decades based on scientific findings and research conducted at different levels and different period of time. The findings regarding averages in the mean temperature and rainfall values in major regions of the country and the mean values of the country in general has been striking. According to Logoh et al. (2013) on the analysis of rainfall variability in Ghana, they concluded that there was a general decline in the mean annual rainfall over the past 30 years from 1981 to 2010. In fact, the work further revealed that; mean annual rainfall totals less than 1000 mm which was hitherto localized in the extremes of the north-east in the Upper East region had spread to the central part of the Northern region and a little across the extreme north west in the Upper West region.

Agyeman-Bonsu & Kemp-Benedict (2008) reported that, whiles there is enough evidence in Ghana indicating that, temperatures in all the ecological zones are increasing, that of rainfall levels and patterns have been generally decreasing and gradually becoming erratic. Climate change has damning consequences on the national economy largely due to the fact that, the national economy depends on climate sensitive areas such as forestry, agriculture, energy among others. It is also forecasted based on a 20-year baseline climate observation that, maize and other cereals productivity will decline by 7% by the year 2050 (UNDP, 2019). The implications for food and nutritional security would be devastating and plans and programs can therefore be earlier initiated to target this prediction in order to minimize its full effects.

It is further mentioned that, in the business of aquaculture, change in the climate is thought to have a negative impact on the quality of product and reputation of business which finally affects the profitability (Ingrid et al., 2014). Ultimately, businesses with low margins of profit have a weak ability to diversify their operations or to venture in other areas of income generation. Such businesses are not also in a better position to take up opportunities as a result of either slow or sudden upsurge in the cost of operations, thereby putting them at a higher risk and more vulnerable to the impact of climate change.

Further research on rainfall analysis revealed that, parts of the Northern and the Upper West regions have rather benefited in terms of the amount of rainfall which are currently within the range of 1,000 mm to 1400 mm (Logah et al., 2013). However, this cannot be a similar scenario along the coast in the southern part of the country that equally received rainfall values below 1000 mm. In the south, places with rainfall amounts below 1000 mm have rather diminished further whiles others have between 1000 mm to 1400 mm (Felix & Franklin, 2015). Their findings further indicates that, areas that initially received mean annual rainfall values between 1400 mm to 1900 mm experienced a significant drop to between 1000 mm to 1400 mm from 1981 to 2010. The sudden decline in rainfall values means a lot to the artisanal fishers and farmers whose activities are mostly rain dependent.

In terms of the ecological zones, Owusu & Waylen as captured in Felix & Franklin (2015) asserted that, there would be about 20% reduction in rainfall in the forest zone which is greater than the 10% predicted within the savannah in the north and the transition zone. In the coastal zone, the major problems anticipated are salt water intrusion and coastal erosion. Further, the effects of other anthropogenic activities cannot be discounted in terms of its consequences on climate change. It is revealed that, anthropogenic activities such as overgrazing, farming, urbanization, deforestation and industrialization among result in global warming and have a negative impact on the variability of rainfall in the country (Logah et al., 2013). Therefore, minimizing these anthropogenic activities could produce the results anticipated with respect to the fluctuating rainfall.

Additionally, Issahaku et al. (2016) also analyzed data on rainfall and temperature of the Upper East region of Ghana as a proxy for climatic factors and revealed that, whiles rainfall in the region was trending downwards, that of the average temperature respectively for night and day soared. These findings are also consistent with the findings of the Ghana Environmental Protection Agency (EPA) as cited in the work of Abdul-Rahman et al. (2016), that, there is a projected decrease in the rainfall values at an average of about 2.8% to 10.9% by the year 2050 within the savannah agro-ecological zone in the next decade. However, it contradicts the findings of Jung and Kunsman who observed that a moderate upsurge in rainfall was expected in the next decades within the northern regions of Ghana.

Ghana has experienced increasing temperature and falling values of mean annual rainfall which has become erratic and have dire consequences on many sectors of the economy including the fisheries (Johnson et al., 2018). In furtherance to this finding, the stock of fish and their habitats are affected due to the fact that, warmer temperatures induce the stock of fish, the mortality rate of the wild fish stock, the pattern of migration and also determine the kinds of species to be farmed in some regions. Additionally, the effects of the climate on fish have some implications both social and economic on the livelihood of the fish dependent communities and people. In another study conducted by World fish (2010) to examine the vulnerability of economies to the potential impact of climate change on captured fisheries, the findings showed that, Ghana was placed at the 25th position among 33 countries ranked as highly vulnerable (Felix & Franklin, 2015).

The extremes of weather such as flooding, high temperatures and drought are the major challenges in all the ecological zones in Ghana. The stoppage of rainfall in its earliest are some of the expected patterns to be observed in the transitional zone with the probability of changing bi-modal rainfall periods to uni-modal ones (Daniel &

Emmanuel, 2011). The consequences are greatly felt within the fisheries and agricultural sector especially rain-fed agriculture. Consequently, Dontwi et al. found that, there was a close relationship between fish stock production and climatological factors. This further revealed a coincidentally lower catch rate of round sardine fish with years of higher sea surface temperature (Felix & Franklin, 2015).

The change in Ghana's climate is manifested through increasing temperatures, falling total values of rainfall and increased variability, sea level rise and finally increased cases of disasters and weather extremes. In effect, the mean annual temperature has surged by $1°C$ in the last 3 decades (Abdul-Rahman et al., 2016). In order to research into the cases of a likely evidence of global warming and climate change in Ghana for that matter, Daniel & Emmanuel (2011) attempted profiling the changes in temperature and rainfall patterns for the period 1931 to 2007. Indeed, the records on the mean monthly rainfall and temperature were taken including the mean monthly minimum and maximum values for three stations in Ghana namely Accra, Kumasi and Navrongo. The three locations were selected taking cognizance of the differences in the ecological zones. Accra is located within the coastal savannah zone, Kumasi in the deciduous forest zone and Navrongo in the Sudan savannah zone.

In the process the researchers methodologically classified the various years into three groups: 1931-1960, 1961-1990 and 1991-2007 and tests conducted to determine whether there were significant differences in means among the groups in terms of both the temperature and rainfall. In their findings it was revealed that, there was rising temperatures and erratic rainfalls in the country which could be explained to have resulted from climate change. Their findings further indicated that, the average monthly maximum temperatures of Navrongo, Kumasi and Accra had strikingly reached all-time record high in the period 1991-2007 compared with the base year in 1931-1960, whiles the average rainfall of two locations: Navrongo and Accra declined. In furtherance to these investigations, it was also indicated that mean annual rainfall in all the six ecological zones in Ghana decreased whiles that of the temperature increased progressively based on a historical data from the year 1961 to 2000. It was further forecasted that, the mean temperatures per year for all agro-ecological zones are estimated to rise in the year 2020 and 2080 between 0.8°C and 5.4°C respectively and mean rainfall per year anticipated to decline by 1.1%, and 20.5% respectively (Felix & Franklin, 2015). These findings in effect conclude that, climate change has occurred in Ghana and policies to mitigate and facilitate adaptation especially with respect to artisanal fishers very imperative.

2.6 Climate Change Adaptation Strategies in the Fishery Sector

There are several adaptation strategies which artisanal fishers used in order to reduce the impact of climate change on their livelihoods. According to Magawata et al. (2014) who studied the mitigation and adaptation strategies employed by fishers in Nigeria reported that, the control of fishing efforts, integrating fishing with agriculture, training opportunities and financial assistance and the adoption of appropriate post-harvest technologies were some of the adaptation strategies. In fact, the adaptation strategies to climate change will vary from changing the location of fishing to shifting the timing and targeting of fish species (CGIAR, 2012). This implies therefore that, the application of shifting fishing time, changing the locations of fishing, and diversifying as in alternative livelihood used in this study are accurate.

According to the FAO (2016), changing the timing of fishing, changing the location of fishing and moving to a new area of fishing (migration) are some of the adaptation strategies fishers can use to reduce the effects of the climate change on their livelihoods. Also, in the quest to examine fisher's decision to adopt climate change adaptation strategies in Thailand, Sereenonchai & Arunrat (2019) identified that, 58.06% of the fishers ventured into alternative livelihoods whiles, 10.42%, 1.88%, and 18.21% used both changing fishing time and locations, fishing for longer time and fishing farther away respectively. Their findings further asserted that, 8.27% stopped fishing activities during the ban (moratorium) whiles 2.03% adapted none of the adaptation strategies. This study therefore adopted the changing of fishing time, changing the location of fishing, moratorium, migrating to different fishing area and alternative livelihoods as the adaptation strategies to be used.

Shelton (2014) mentioned that, there are some specific climate change adaptation strategies that are supposed to be applied by artisanal fishers and farmers who practice aquaculture relative to the specific impacts that the change in climate have on their activities. Whiles these specific impacts listed among other things include, increased yield, increased yield variability, reduced profitability, increased risk etc. that of the specific adaptation strategies include access to higher value markets, increased fishing efforts, selective breeding for increased resilience in aquaculture, migrating to a different area as the distribution of the fish changes, researching and investing into the prediction of the movement of fish species, diversifying livelihood portfolios, diversifying markets and products, adjustment in insurance markets among others.

In furtherance, Daw et al. (2009) observed as part of the response to dealing with reduced yield among artisanal fishers as a result of climate change to include, the intensification of fishing by investing additional resources into the fishery which is termed as increasing fishing efforts, spending more time at the fishing site, increasing fishing capacity through the adoption of technology and fishing farther or deeper into the sea than previously done which all have a negative long-term implications especially when issues of overexploitation is a major concern. In addition, Musinguzi et al. (2015) in analyzing fishers' perceptions about climate change and the impact on their livelihoods and adaptation strategies in Uganda identified in order of importance, fisher diversification into non-fishery livelihood as their most prioritized adaptation strategy. This strategy was closely trailed by increasing the time of fishing at site, changing the fishing site and the practice of species targeting. Another adaptation strategies used among fishers in Fuji to mitigate the effects of climate change include the development of alternative livelihood, diversifying into aquaculture, financing literacy, post-harvest improvement in the quality of fish products and reducing waste and natural resources management (Dey et al., 2016).

Invariably, as a result of the knowledge fishermen acquired about the interactions between the environment and resources as well as their mode of behavior which have been the base of their adaptive capacity, artisan fishers in Rio de la Plata developed three main adaptation strategies to cope with the increased climate variability which include, seasonal migration, changing the fishing sites and cautious fishing behavior and acceptance of loss (Nagy et al., 2006). In conclusion, the adaptation strategies artisanal fishers employ to minimize the effect of climate change on their livelihoods are diverse. It particularly takes into account several factors including the type and manner of the fishing environment, the location of the artisanal fisher, the timing or period of adaptation and the extent of severity of climate change among others.

2.7 Impact of Climate Change and Adaptation Strategies on Household Welfare

It is irrefutably clear that climate change exerts some kind of impact on the welfare of households engaged in different livelihood activities. Indeed, the literature equally provides some evidence to the effect that, the adaptation strategies which are used to mitigate the effects of the climate change also have bearings on the welfare of the households. In determining the influence of adaptation to climate change on household welfare in Ghana, Issahaku & Abdulai (2017) used farm productivity, net farm-income and dietary diversity score as proxies for household welfare. The conclusion from the findings was that, there was 23.5% increase in farm productivity which yielded GH₵410.70 as a result. In fact, the results further posited that, adaptation to climate change increased net farm-income and household dietary diversity score by 16.6% and 65% respectively. The effect of the climate has also proven to be significant in influencing the household welfare in Mexico. Skoufias (2012) determined the impact of weather shocks as a result of climate change on both total household per capita expenditure and household per capita food expenditure used as proxies for welfare in rural Java in Mexico. The results revealed that, whiles a delay of monsoon onset shock was associated with a 13% fall in the per capita food expenditure, a decrease in rainfall shock accounted for a maximum of 14% drop in the per capita total expenditure of the households.

2.8 Measurement of Household Welfare

The concept of welfare has been ambiguous and means differently depending on individual perspectives. In fact, it encapsulates several aspects of the human being that sums up not only to give a particular level of satisfaction but also to ensure ones wellbeing. Welfare could be perceived in terms of social, economic, psychological, physiological, health among others. However in the context of this study, it would depend on the consumption of goods and services at the household level and subject to a budget constraint and the relative prices of the goods and services.

According to the World Bank (1983), one of the approaches to the determination of welfare is the construction of an index of total household consumption expenditure which is a function of goods consumed and deflated by an appropriate index of prices. In some instances the computation takes into consideration the household size and composition which is referred as equivalent scales or consumption per capita where the total household consumption expenditure is divided by the household size. Donkoh et al. (2014) employed the food portion of the total household consumption expenditure to study the pattern of food expenditure and welfare in Ghana. However, Khaufelo et al. (2016) and Skoufias (2012) particularly used the consumption expenditure per capita approach to analyze the determinants of household welfare and poverty in Botswana and how weather shocks affect household welfare and poverty in rural Mexico respectively. In fact, even within the household consumption expenditure, the share of non-food items in total expenditure can be applied as a measure of household welfare according to Deaton (1981). This therefore signifies that, different approaches to the measurement of welfare can be adopted based on the interest of the study.

Another measure of household welfare is the use of the full income concept where all monetary incomes from all productive sources for all the household members are summed. This also includes incomes in kind, value to some services derived from endowment and assets such as housing, durables and time owned by the household (Grootaert, 1983). This measure of welfare is generally difficult taking cognizance of the time component. Indeed, accounting for the number of hours household members spent in the different activities within a day or week is cumbersome. Therefore the choice of household consumption expenditure as a measure of welfare was borne out of the fact that, many people are not comfortable disclosing their incomes especially to people they consider strange. Hence, either an understatement or overstatement of household incomes seems possible with the income approach which may result in bias estimates. But the consumption expenditure is straight forward and requires less time and efforts.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

This chapter outlines the research methods employed in the study. It explains the conceptual as well as the theoretical frameworks that underpinned the study. The empirical models that are used to analyze the various objectives including the multivariate probit and recursive models are thoroughly examined. Again, it describes the study area, the sampling procedure, sample size and the methods of data collection.

3.2 Conceptual Framework

A conceptual framework explains the logic and construct behind the matter under investigation. Camp (2001) defined conceptual framework as a structure that the researcher is convinced can be used appropriately to explain the natural progression of the phenomenon to be investigated. Grant and Osanloo (2014) as cited in Adom et al. (2018) opined that conceptual framework assists the researcher in constructing his/her worldview regarding the matter under investigation. Figure 1 shows the conceptual framework that explains the essential variables which influence adaptation strategies and how the adaptation strategies in turn affect the performance and welfare of artisanal fishers. From Figure 1, climate change adaptation strategies used by artisanal fishers are influenced by institutional/policy variables, artisanal fishers' individual as well as household characteristics and the infrastructural variables. Institutional/policy variables such as access to extension agents and access to credit are hypothesized to have an impact on adaptation strategies.

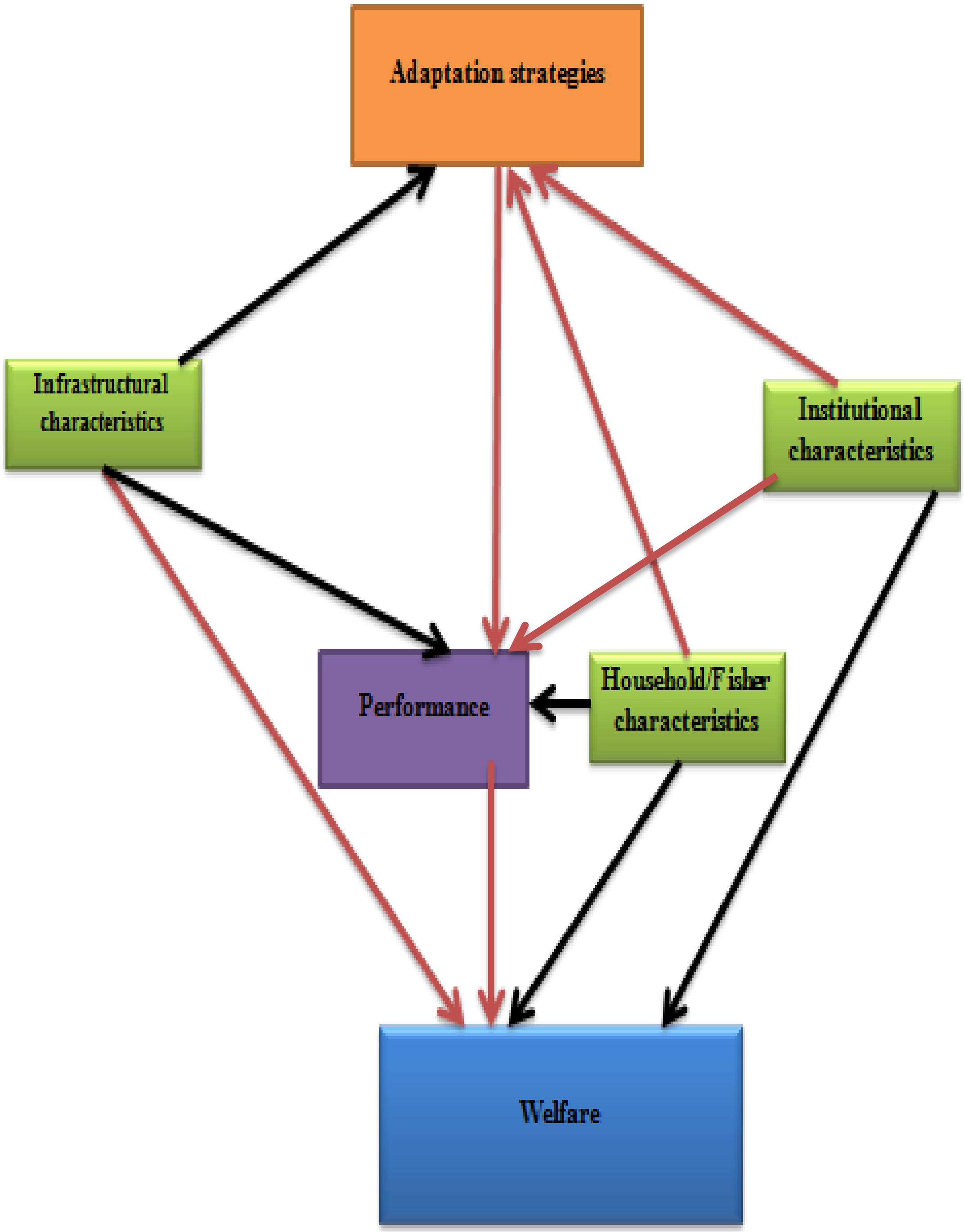

Figure 1: Conceptual Framework

Source: Author's conception

The individual and household characteristics of the fishers that can also influence the type of climate change adaptation strategies include the level of education of the fisher, the income, experience and the household size. In line with this construct, Samah et al. (2019) revealed that, whiles the age of artisanal fishers and their level of fishing experience negatively and significantly influenced adaptation to the impact of climate change in Malaysia, income influenced adaptation positively with no significant relationship defined between household size and adaptation practice. Also, Musinguzi et al. (2015) similarly identified age of the artisanal fisher and their level of education as negatively related to adaptation, whereas the use of technology and fishing days influenced adaptation positively among fishers in Uganda. Indeed, these factors aside influencing adaptations also determines artisanal fishers' decisions to engage in fishing activities in general. In fact, the level of education, average daily catch and access to credit was found to have positively and significantly influenced artisanal fishers' decision to engage in fishing activities in Ghana (Saagulo et al., 2019). With respect to the infrastructural variables, access to mobile network and electricity, good road networks, access to credit among others. All these factors mentioned above come together to influence the decision of fishers to adapt to climate change or not. Further, the adaptation strategies in a form of alternative livelihoods, increased time of fishing, migrating to different fishing area, changing fishing time and moratorium on fishing can impact in combine effect on the yield and value of sales and consequently impact on the profit of artisanal fishers. The adaptation to climate change impacted on fish production and profit in the Fiji, Timor-Leste, Solomon Islands and Vanuatu regions (Dey et al., 2016). Advancing from there, performance (profit) can have a significant impact on the expenditure per capita used as a proxy to measure welfare of artisanal fishers. Therefore, the effect of climate change adaptation strategies on profit performance and that of profit performance on welfare influenced the choice of a recursive model.

Furthermore, the household characteristics, fishing variables as well as the institutional and infrastructural variables can again impact on performance directly and determine welfare as well. The adaptation strategies can also on their own influence the welfare of artisanal fishers without necessarily through performance as in the findings of Muringai et al. (2019), Asmare et al. (2019), and Issahaku & Abdulai (2017) climate change adaptations affects the welfare of artisanal fishers measured in terms of income in Sanyathi fishing basin in Zimbabwe, Ethiopia and Ghana respectively.

3.3 Theoretical Framework

According to literature, several theories have been proposed to explain the decision to use or not to use a new technology, an innovation or a particular event of substantial benefits. However, the most convincing and suitable for this study was proposed by Abdulai & Becerril (2010). Accordingly, the welfare (Y_i) of artisanal fishers measured in this study as household consumption expenditure depends linearly on a vector of explanatory variables (X_i) and a dummy variable for usage (R_i). In terms of linear regression this can be expressed as:

$$Y_i = X_i^{'}\beta + \delta R_i + \mu_i \qquad (1)$$

Where; Y_i denotes the average household consumption expenditure, μ_i denotes a random error term and R_i represents a dummy variable for the usage of climate change adaptation strategies with $R_i = 1$ if employed and $R_i = 0$ if otherwise. The variable X_i indicates fisher specific or household level characteristics, institutional or policy and infrastructural variables. The decision of a fisher to use a particular climate change adaptation strategies or otherwise depends on his/her individual and household characteristics and the level of fishing activities at the time.

Based on the random utility approach, the decision to employ a climate change adaptation strategy is based on a latent variable which is express as:

$$R_i^* = X_i^{'}\gamma + \varepsilon_i \text{..}(2)$$

Where R_i^* represent the difference between the utility of employing (U_{iA}) and the utility for not using a particular adaptation strategy (U_{iN}). The artisanal fisher uses a climate change adaptation strategy only if the utility and latent variable for that matter is positive, thus

$$R_i^* = U_{iA} - U_{iN} > 0 \text{..}(3)$$

This implies that, the difference in the utility ($U_{iA} - U_{iN}$) is captured in the $X_i^{'}\gamma$ term.

Interestingly, one can argue that a household that is better in terms of welfare as in household consumption expenditure in this study could be better positioned to use climate change adaptation strategies than their counterparts. On the other hand, the usage of climate change adaptation strategies could also improve the welfare of artisanal fisher households. Therefore, there is some relationship of interdependence between the error terms of the outcome equation (μ_i) and the usage equation (ε_i) and this could result in selectivity bias if the two equations are influenced by unobservable factors. Also, fishers who used a particular climate change adaptation strategies might be based on certain common characteristics or access to certain information and hence the issue of self-selection might arise. This therefore suggest that, the use of the

Ordinary Least Squares (OLS) to estimate the impact of climate change adaptation strategies on the performance/welfare of fishers could produce bias and inconsistent parameter estimates (Abdulai & Becerril, 2010). Furthermore, the assumption that the covariates/regressors are not correlated with the error term could be violated as a result of the nature of the study. According to Greene (2012), several reasons could account for such situations and include measuring the regressors with errors, omission of significant variables from the regressors, simultaneous equation bias, and sample election bias among others. These consequently result in an econometric problem described as endogeneity which cannot be appropriately addressed with the application of OLS.

3.4 Empirical Model

Multivariate probit (MVP): Determinants of climate change adaptation strategies

The multivariate probit model was used to examine the factors that influenced fishers' decision to use certain climate change adaptation strategies. The choice of the multivariate probit is informed by the nature and behavior of adaptation strategies which are the regressand in the model. Adaptation strategies are made up of alternative livelihoods, increased time of fishing, migrating to different fishing area, moratorium and alternating fishing time. Therefore, if a fisher uses a particular strategy that was coded one (1) and if such strategy is not used that was coded zero (0) making the process a binary situation. The multivariate probit model in principle is an extension of the bivariate probit model with the ability to deal with more than two outcomes variables with the addition of more equations. It is theoretically expressed as,

$$y_{ij}^{*} = X_{ij}^{'}\beta + \varepsilon_{ij} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

$$y_{ij} = 1, if, X_{ij}^{'}\ \beta + \varepsilon_{ij} > 0, \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Otherwise

$$y_{ij} = 0, if, X_{ij}^{'}\beta + \varepsilon_{ij} \leq 0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

$$where,\ i = 1,\ldots\ldots, n;\ j = 1,\ldots, J$$

The empirical specification can therefore be expressed as:

$$\begin{aligned} y_i(1,2,3,4,5) &= \beta_0 + \beta_1 HHSize_i + \beta_2 Experience_i + \beta_3 EducYrs_i + \beta_5 TabooMonth_i \\ &+ \beta_6 Bankaccount_i + \beta_7 Roadmotor_i + \beta_8 MrkDist_i + \beta_9 FishIncNon_i + \\ &\beta_{10} Totalinputcost_i + \beta_{11} CreditAccess_i + \beta_{12} Weathrep_i + \beta_{13} ElectAccess_i + \\ &\beta_{14} PerceptIndex_i + \beta_{15} Networkstatus_i + \varepsilon_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (7) \end{aligned}$$

Where β_0 is the intercept or the constant term, $\beta_1, \beta_2, \ldots \beta_n$ represent the parameters to be estimated, and ε_i is the error term for each of the observations. The model encapsulates essential variables in addition to the socio-economic ones that helped to explain the fishers' choice of a particular adaptation strategy. Table 1 shows the variables to be used in the model including their respective definitions, measurements and *apriori* expectations. Fishers' perception on climate change was also computed as an index to feature in the multivariate probit model. The import for this was to analyze whether at all perceptions on climate change have an effect on fishers' choice of adaptation strategies. The index was computed using variables such as the rainfall pattern of fishers' perceptions on temperature, sunshine intensity, flooding and drought as a proxy to climate change.

Table 1: Definitions, Measurements and *Apriori* expectation

Variables	Definitions	Measurement	Apriori Ex
HH size	The size of the household	Number	+
Experience	Number of years of fishing	Years	+/-
Education	Educational level of the fisher	Number of years	+
Credit access	Access to credit by the fisher	Dummy, 1if yes, 0 otherwise	+
Electric access	Fisher access to electricity	Dummy, 1 if yes, 0 otherwise	+
Network status	The state of network in community	Dummy, 1 if good, 0 otherwise	+
Market dist.	Distance to the market	Kilometer (Km)	-
Fish Inc.-Non	Monthly non fish income	Amount GH₵	+/-
Weather report	Fisher monitoring of weather reports	Dummy, 1 if yes, 0 otherwise	+
Taboo Month	Number of days in a month observed as taboo	Number of days	+/-
Bank account	Fisher access to bank account	Dummy, 1 if yes, 0 otherwise	+/-
Road motor.	Motorability of road linking community to the district capital.	Dummy, 1 if motorable, 0 otherwise	+/-
Tot. Input cost	Total cost incurred on inputs	Amount GH₵	-
Rainpercept	Fishers perception on rainfall	Dummy, 1 if yes, 0 otherwise	+/-
Tempercept	Fishers perception on temperature	Dummy, 1 if yes, 0 otherwise	+/-
Sunpercept	Fishers perception on sunshine intensity	Dummy, 1 if yes, 0 otherwise	+/-
Floodpercept	Fishers perception on sunshine intensity	Dummy, 1 if yes, 0 otherwise	+/-
Percept. Index	Perceptions of the artisanal fisher about climate change	Dummy, 1 if higher and 0 if lower	+/-

The range of the index was between zero (0) and one (1) where zero means the artisanal fisher has no perception on the particular climate change variable and one means otherwise. The index was further categorized into two thus, lower perception index (from 0 to 0.49) and higher perceptions index (from 0.5 to 1) transposing the perception index into a dummy variable and featured in the model.

Model 2

The conditional recursive model was employed to analyze the effects of the adaptation strategies on the performance of artisanal fishers as well as the effects of performance on welfare. The logic that underpinned the choice of the recursive model is that, a fisher's choice of using a particular adaptation strategy will have an influence on their performance (profit). Also, performance from fishing determines the welfare (household consumption expenditure) of the household. According to Robert (2002), a system of equations is said to be recursive if the endogenous variables can be determined sequentially instead of jointly. Usually, the first endogenous variable is determined explicitly by only exogenous variables, the second is determined by only the first endogenous variable and other exogenous variables and the third by only the first two endogenous variables and other exogenous variables. Special importance is however attached to the fact that, feedbacks from endogenous variables higher in the causal chain need not exist. The theoretical specification of the recursive model is written as:

$$Y_{1j} = \alpha_{11}X_{1j} + \varepsilon_1 \quad (8)$$

$$Y_{2j} = \alpha_{21}X_{1j} + \beta_{21}Y_{1j} + \varepsilon_2 \quad (9)$$

$$Y_{3j} = \alpha_{31}X_{1j} + \beta_{31}Y_{1j} + \beta_{32}Y_{2j} + \varepsilon_3 \quad (10)$$

Empirically, the model can be specified as,

$$NumAdaptation_{1j} = \beta_1 HHsize_i + \beta_2 Educ_i + \beta_3 Experience_i + \beta_4 FishIncNon_i$$
$$+ \beta_5 Electricaccess_i + \beta_6 DistMarket_i + \beta_7 Networkstatus_i + \beta_8 CreditAccess_i$$
$$+ \beta_9 Weatherreport_i + \beta_{10} PerceptIndex_i + \beta_{11} Extensionaccess_i +$$
$$\beta_{12} PerceptionIndex_i + \beta_{13} TotalinputCost_i + \beta_{14} Roadmotor_i + \beta_{15} Mainmarket_i$$
$$+ \beta_{16} TabooMonth_i + \varepsilon_{1i}$$

$$\Pr ofits_{2j} = \alpha_{21} NumberAdaptation_i + \beta_{17} Education_i + \beta_{18} HHsize_i +$$
$$\beta_{19} Experience_i + \beta_{20} FishIncNon_i + \beta_{21} Creditaccess_i + \beta_{22} Electricaccess_i +$$
$$\beta_{23} Networkstatus_i + \beta_{24} TabooMonth_i + \beta_{25} Mainmarket_i + \beta_{26} Roadmotor_i +$$
$$\beta_{27} Extensionaccess_i + \beta_{28} FishHarvest_i + \beta_{29} Marketdis\tan ce + \varepsilon_{2i}$$

$$Consuptionexp enditure_{3j} = \alpha_{31} profit_i + \beta_{30} NumAdapt_i + \beta_{31} HHSize_i$$
$$+ \beta_{32} Education_i + \beta_{33} Experience_i + \beta_{34} FishIncNon_i + \beta_{35} Creditaccess_i$$
$$+ \beta_{36} Electricaccess_i + \beta_{37} Networkstatus_i + \beta_{38} TabooMonth_i + \beta_{39} Bankaccount_i$$
$$+ \beta_{40} Mainmarket_i + \beta_{41} Roadmotor_i + \beta_{42} Extensionaccess_i + \beta_{43} Marketdis\tan ce$$
$$+ \varepsilon_{3i}$$

In order to avoid the feedbacks from endogenous variables higher in the causal chain, profits from fishing are delinked from the exogenous variables of the first equation just as much as consumption expenditure are disassociated from the explanatory variables in second equation.

Table 2: Description, Measurements and *Apriori* expectation

Variables	Definitions	Measurement	*A priori Expectation*		
			Adaptation strategies	**Performance (profit)**	**Household Welfare**
HH size	The size of the household	Number	+/-	+	+
Experience	Number of years of fishing	Years	+	+	+
Education	Educational level of the fisher	Number of years	+/-	+	+
Credit access	Access to credit by the fisher	Dummy, 1if yes, 0 otherwise	+	+	+
Electric access	Fisher access to electricity	Dummy, 1 if yes, 0 otherwise	+	+	+
Network status	The state of network in community	Dummy, 1 if good, 0 otherwise	+/-	+	+
Market dist.	Distance to the market	Kilometer (Km)	+	+/-	+/-
Fish Inc.-Non	Monthly non fish	Amount GH₵	+	+	+

	income				
Weather report	Fisher monitoring of weather reports	Dummy, 1 if yes, 0 otherwise	+	+/-	N/A
Taboo Month	Number of days in a month observed as taboo	Number of days	+	+/-	+/-
Bank account	Fisher access to bank account	Dummy, 1 if yes, 0 otherwise	+	N/A	+
Road motor.	Motorability of road linking the district capital.	Dummy, 1 if motorable, 0 otherwise	+	+	+/-
Total Input cost	Total cost incurred on inputs	Amount GH₵	+/-	N/A	N/A
Percept. Index	Perceptions of the artisanal fisher about climate change	Dummy, 1 if higher and 0 if lower	+	N/A	N/A
Num. Adapt	Number of adaptation strategies	Number	N/A	+	+
Profit	Annual Profit made	GH₵	N/A	N/A	+

*N/A means not available

3.5 The Study Area

The study was conducted in the Brong-Ahafo region of Ghana. The region has a total population of 2,310,983 according to 2010 population census and covers a total land area of 39,557 km square. It is boarded to the north by the Northern region, to the east by the Volta region, to the south by the Ashanti region and to the west by Ivory Coast. The vegetation and climatic conditions in the area are suitable for agricultural production. In fact, the region has two agro-ecological zones of forest savannah on the upper part and the semi-deciduous rain forest on the lower part and hence often described as the transition belt. Politically, Sunyani is the regional capital in addition to 18 other administrative districts. Aside the cultivation of staple crops such as maize, yam, cassava groundnut, rice etc. the region is also noted for the production of cash crops such as cocoa.

The Volta basin covers an estimated area of 400, 000 square kilometers and it is the ninth largest lake in sub-Saharan Africa. It extends from latitude 50, 30’ N in Ghana to 140, 30 N in Mali. Though the basin is made up of the Red Volta, the White Volta and the Black Volta, its dominant feature in Ghana is the Volta Lake that has the

Akosombo hydro-plant and also produces more than 90 percent of fresh water inland fisheries in Ghana (Bene, 2007). Indeed, the Volta basin cuts across several regions in the country including the Brong-Ahafo region that was marked for the study. Even though some of the fishers who lived along the Volta basin are immigrants from the Volta, Greater Accra and the Northern regions, natives of the region are equally engaged in the fishing activities.

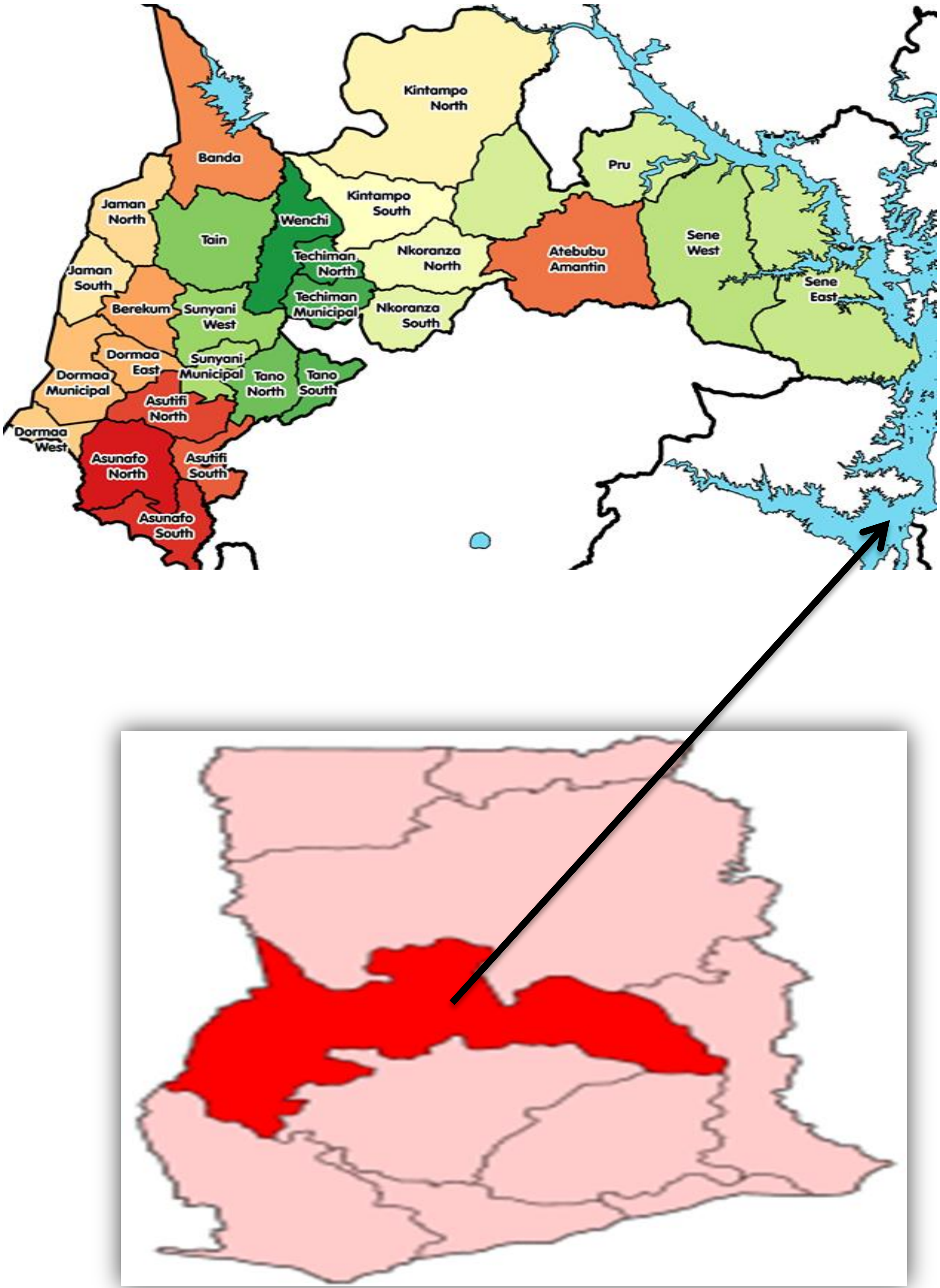

Figure 2: Map of Brong Ahafo region showing the districts along the Volta Lake

Source: Ghana maps (2019)

3.6 Sampling Procedure

3.6.1 Sample size

In order that the research findings are made possible for inferences and generalization, the sample size determination formula was adopted from the works of Charan & Biswas (2013) and computed to arrive at a total sample size of 310. Below is the formula and the computation process,

$$\text{Sample size (n)} = \frac{(Z_{1-\alpha/2})^2 p(1-p)}{d^2} \text{..}10$$

$Z_{1-\alpha/2}$ is the Z-critical which is determined from the confidence level and corresponds to 1.96 from the reading in the Z-table at 95% level of confidence. The variable p represents the expected proportion in the population based on pilot or previous studies. This work used a value of 0.28 based on similar works within the social science framework. Finally, d denotes the margin of error the researcher prefers to allow for the study which has been purged at 0.05 in this study. Therefore, the sample size is determined as,

$$\text{Sample size (n)} = \frac{1.96^2 \times 0.28(1-0.28)}{0.05^2} \text{..}11$$

$= 309.7866$

3.6.2 Sampling technique

The multi-stage sampling technique was used to select the respondents for the study. In the Brong-Ahafo region, out of five districts sharing boundaries with the Volta river, two were selected using stratified random sampling. A list of fishing communities along the Volta basin was obtained from the district assemblies. Five communities each were selected from each district using simple random sampling technique and twenty-two artisan fisher households from each community were selected using systematic sampling technique.

3.7 Data Collection

3.7.1 Sources of data

Data was sourced primarily from the artisanal fishers in the various fishing communities who conduct their daily fishing activities along the Volta lake. The data was cross-sectional in nature since the fishers were visited just once and in case a respondent was unavailable at the time, a subsequent call back was made before any replacement attempt. Artisanal fishers in the context of this study refer to fishers whose primary livelihood in a form of food, income and employment depends on fishing. These fishers often use less sophisticated fishing materials and employs relatively small number of labor. Data collection processes was particularly simplified for the respondents by interviewing them in either Akan or English languages. However, in the unlikely event a respondent could not communicate in either of the two, the services of an interpreter was sought to aid the process.

3.7.2 Data materials and methods

A semi-structured questionnaire with both open-ended and closed-ended questions was used to conduct face-to-face interviews with the artisanal fishers. The questionnaire was divided into various sections along the lines of the research objectives to make it easier for the respondents to comprehend. It included the demographic characteristics of fishers, the adaptation strategies of climate change, performance with respect to their fishing activities and issues of welfare. It is important to note that, a questionnaire could not capture all the salient variables needed for the analysis. It can only capture the verbal responses in terms of the demographic characteristics of respondents, the adaptation strategies, perceptions and socio-economic variables. However, personal observations was also employed especially in soliciting information regarding the type of fishing gear used and to corroborate other essential information that could help explain the behavior of certain variables.

3.8 Data Analysis

Data collected was entered into STATA version 14 and analyzed using tables and charts for the demographic characteristics. The objectives on the other hand were analyzed using the Multivariate probit and the recursive models within the general framework of the Conditional Mixed Process (CMP).

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Chapter Outline

This chapter presents the results and discussions of the socio-economic and demographic characteristics of artisanal fisher households. It further discusses the factors that determine the adaptation strategies fishers employed using the multivariate probit analyses and the recursive effects of the adaptation strategies on performance and welfare using the recursive methods expressed within the framework of Conditional Mixed Process (CMP).

4.2 Summary Statistics of Variables

The summary statistics of key variables are presented and discussed in the subsections below. These variables are used in the multivariate probit and recursive Conditional Mixed Process (CMP) models, which in one way or the other affects fishers' choice of adaptation strategies, their performance as well as welfare.

4.2.1 Summary statistics of household characteristics of fishers

From the results shown in Table 3, about 328 artisanal fisher households out of 332 were headed by males representing 99% of the total sample. This implies that, majority of the decisions made at the household level regarding the location of fishing sites, the timing of fishing and the type of fishing gear to be employed are to a large extent influenced by males. Likewise, the results of Samah et al. (2019) indicated that, about 98.2% of artisanal fishers in Malaysia are males with an average age of 48 years. Also in Zimbabwe, about 89% of small-scale fishers from Kariba region are males taking major decisions with regards to fishing (Muringai et al., 2019). This finding further exalts the argument that, significant proportions of those engaged in small-scale fishing are males especially in Africa. In furtherance to these findings, Kwamena & Chu (2019) reported that, though women are essential actors in the small-scale fisheries subsector in the developing world, their participation rate in both pre and post-harvesting activities is about 48 % on the average and 40% specifically in Ghana.

With respect to the age of the artisanal household heads, the data revealed an average age of 41.5 years. This indicates that, household heads were within the active labor force brackets and could by themselves engage in fishing and not merely provide technical and managerial guidance. This result is in conformity with the findings of Twumasi et al. (2020) which showed that, artisanal fishing in Ghana is dominated by the youth endowed with the adequate energy to deal with the challenges of fish production though with low level of education. The data also revealed that, respondents were very experienced in fishing. On the average, an artisanal fisher had 20.1 years of fishing experience. This finding was in close consonance with the findings of Kwamena & Chu (2019) which revealed that, on the average an artisanal fisher in Ghana has 19 years of fishing experience. Furthermore, Setsoafia et al. (2017), conducted a research on artisanal fishing in the Pru East district of the Brong-Ahafo region, and found that on the average an artisanal fisher had an experience of 16.5 years. In contrast, the findings from Malaysia which is similar to the Ghanaian scenario revealed that, on the average a small-scale fisher had 20 years of fishing experience (Samah et al., 2019). This suggests that, artisanal fishing in Ghana and many other parts of the world especially in developing countries are mainly undertaken by fishers with several years of fishing experience. In actual fact, experience improves knowledge and skill of labor and therefore anticipated to translate into yield and consequently welfare of households. Regarding household composition, the average household size measured in terms of the average number of people within the household was 8 with a standard deviation of 5 persons. Also, the number of adult members within the household showed an average of 4, with dependents which was measured in terms of those above the ages of 60 and below 18 years within the household averaged at 0.98. Further, the average man-hours labor spent on the activities of fishing: carrying, processing and selling at the household level were determined at 1,084hrs.

Table 3 Summary Statistics of Household Characteristics of Fishers

Variable name	Measurement	Mean	St. Dev	Min	Max
HH Heads sex	1=Male, 0 = Female	0.9880*	0.1093	0.0	1.0
HH Heads age	Years	41.521	11.820	25	58
HH size	Number	7.9458	5.2480	1.0	24
HH Adults	Number	4.1837	2.2000	1.0	18
Experience	Years	20.057	11.252	1.0	50
Labor	Man days	1084	1593	30	2177
Dependents	Number	1.2035	0.2800	1.0	6.0
Marriage	1=Married,0=Single	0.9036*	0.2956	0.0	1.0
Education	Completed years	4.5512	5.0532	0.0	23
Percept Index	1=high, 0=low	0.594	0.492	0.0	1.0
Consump. Exp.	GH₵	355	165	32	1105

* are proportions

Source: Field survey (2018)

Regarding the marital status of the respondents, the survey revealed that about 90% of the total respondents were married. However in a similar research, about 47% of the total sampled artisanal fishers in Ghana are reported to be married (Twumasi et al., 2020). The results also showed educational status of respondents based on the number of completed years. In fact, the average educational level attained was 4.5 which implied that on the average fishers who attended school obtained basic education alone. These findings primarily exposed the inertia on the part of artisanal fishers along the Volta basin to seek formal education in Ghana. In fact, similar findings from the Pru East district of the Brong-Ahafo region indicated that, 50% of the artisanal fishers had no formal education (Saagulo et al., 2019) and another in the same study area similarly showed that, the combination of all artisanal fishers who had no formal education and those with primary education alone accounted for about 86.5% of the total sample used for the study (Setsoafia et al., 2017). Likewise in Uganda, about 73.3% of sampled artisanal fishers on the Wamala Lake either had no formal education or attempted primary education but never completed (Musinguzi et al., 2015). On the contrary, Mungarai et al. (2019) indicated in their findings that, about 70% of small-scale fishers had attended and completed secondary schools in Kariba in Zimbabwe. Education is a significant parameter in this study, not only due to its influence but also the guide it provide fishers regarding climate change adaptation through access to information. In fact, education makes access to information and the usage of such information simple and that justifies its implication on the choice of adaptation strategies.

The monthly incomes earned by artisanal fishers were either through fishing and other fishing related activities which was referred as fish income or through other economic activities aside fishing referred as non-fish income. It is important to report that aside fishing, some other economic ventures were undertaken which include farming, petty trading, artisanship, animal husbandry etc. Whereas data were collected on fish income from all respondents, non-fish income which was complementary in nature was collected from a section of the respondents.

4.2.2 Summary Statistics of Fishing Variables

Table 4 shows the **summary statistics of fishing variables.** Fish catch was in pans and baskets but the need for consistency and standardization called for the conversion of the pans into kilograms which stood at 44kg per pan. Initially, the choice of the pans was informed not just by the fact that it was widely used, but baskets could have been easily converted to pans. From the results, mean quantity of fish catch was 22 pans (968kg) per month with a minimum and maximum quantities of 1.4 pans (61.6kg) and 287 pans (12, 628kg) respectively.

Furthermore, artisanal fishers who used boats required premix fuel as an input for their operations. Unfortunately, access and quantity needed was a challenge to the fishers because of the strict regulation regime. In some of the fishing communities, premix fuel was discharged into a tank and served a specific number of gallons at a fix fee of GH₵7.00 per gallon. However, any additional quantity needed was to be sought from the black market at a fee of about GH₵14.00. The average number of gallons used per month was 40 with average fish revenues earned amounting to GH₵3208.00 per month. In fact, the premix fuel regime in Ghana has been an issue of a major concern to artisanal fishers and policy makers both in terms of the level of government subsidy and the level of diversion of the commodity into the black market for some period of time in the past and in recent times. Indeed, since the introduction of the subsidy program on the commodity in 1995, a number of challenges emanated from the program which includes the diversion of fuel into the black market (Thomas et al., 2014). This reason accounted for the two different pricing regimes of the product in the fishing communities and makes it even more burdensome in terms of cost to the artisanal fishers to acquire in the black market

The average per annum differences between the mean annual revenues that accrued to artisanal fishers from their fishing activities solely and the average variable cost of fishing expenditure per annum was determined to either be positive for some fishers indicating profits or negative for others indicating losses. In fact, the results showed that, on the average, the annual profits and losses earned by the artisanal fishers were GH₵30360.00 and GH₵1834.00 respectively. Though some of the artisanal fishers made annual operational losses, the number was marginal and relatively infinitesimal compared to those who earned profits. Evidence from the results indicates only 7.49% of the respondents earned losses juxtaposed with the remaining 92.5% fishers who earned profits and depicts a high sense of operational efficiency on the part of the artisanal fishers. In a related work to estimate the profit efficiency of artisanal fishers in the Pru East district of the Brong-Ahafo region in Ghana, Setsoafia et al. (2017) determined that, the average profit efficiency of artisanal fishers were about 81.66% implying that, about 18% of profits were lost to inefficiencies. This finding was a clear indication of the application of appropriate methods of fishing which ended up yielding significant results. In terms of the expenditure on consumption, special emphasis was placed on consumer non-durables which are very significant in the computation of the annual consumption expenditure used as a proxy for welfare. Indeed, the mean amount artisanal fisher spent per month on consumption expenditure was GH₵355.00. Additionally, the average annual cost on all variable fishing inputs was GH₵4093.00 which clearly depicts the level of resource fishers committed to their operations. The annual cost of variable input was used for the computation of the annual profits.

The average monthly fish income was GHS 2,888.90 ($577.78) and that of the non-fish income was GHS 264.75 ($52.95). By implication, artisanal fishers generated much income from fishing and its subsidiary activities compared to non-fishing activities. In fact, the results showed that, about 28.14% of the respondents earned non-fishing income contrary to the findings of Twumasi et al. (2020) that, about 66% of artisanal fishers in Ghana earn non-fishing income from engaging in other economic activities. Much especially, a chunk of the income earned was as a result of the sale of smoked fish. Indeed, smoked fish was the most usual form sold because of the perceived value added to them. Most often fishes were smoked using the furnace constructed in households and sold at relatively higher prices. From the results, 50% of the total fish sold was smoked, whiles the fresh and dried/salted fish constituted 12% and 38% respectively.

Regarding the inputs used in fishing, artisanal fishers applied both fixed as well as variable inputs. Some of the fixed inputs used include, canoes, boats, paddles, knives, nets, hooks, pans among others whiles the variable inputs include, baits, engine oil, premix fuel, spare parts etc. Fixed inputs were depreciated using the straight line method to cater for the loss in value and to ascertain the true cost of asset. Following that, the overall amounts expended on inputs were then computed. The average annual depreciation cost of canoe and boat was GHS 1,600 and GHS 2,500 respectively. In terms of the fishing gears, stationary as well as non-stationary ones were applied by the artisanal fishers. These included stationary nets, hook and line, traps, surrounding nets and dredge nets etc.

Table 4: Summary Statistics of Fishing Variables

Variable name	Measurement	Mean	St. Dev	Min	Max
Fisher Category	1=FT,0= Casual	0.9488*	0.2208	0.00	1.00
Fish Catch per month	Pans	22.000	28	1.4	287
Premix Fuel per month	Gallons	40.000	29	30.0	168
Fish Revenue per month	GH₵	3208	3902	80	50000
Non-fish Income per month	GH₵	120.47	440.06	0.00	4200
Annual depreciated cost of canoe	GH₵	1600	1574	1400	2400
Annual depreciated cost of boat	GH₵	2500	1516	2000	10000
Main Gear	1=Station, 0=Non	0.9157*	0.2783	0.00	1.00
Monthly Fishing days	Number of days	22.061	4.105	0.0	28.0
Net size	Yards	991.90	100.70	100	6000
Mesh size	Inches	50.36	54.766	0.00	1000
Total cost of variable input per annum	GH₵	4092	3434.1	422.2	23741
Profit per annum	GH₵	30360	4465	-1834	58487

* are proportions

Source: Field survey (2018)

From the Table 5, the mean number of hook and lines applied in fishing was 976.3 with a huge standard variation of 1891.6. The fishers also employed traps which were locally woven to harvest fish even though the number applied was not quite substantial due to the difficulty in setting them up relative to the number of fishes harvested. On the average 1267.5 traps were used with some artisanal fishers applying as much as 2000 pieces. In contrast, stationary nets were widely used as the most efficient fishing gear among the fishers though other ones such as the dredge and surrounding nets were also applied. The mesh sizes that were used on the average was 50.36 mm which is absolutely within the constitutional provisions though others used relatively smaller mesh in eminent deviance of the law. Though the fisheries Act of 2002 (625) requires artisanal fishers to use the appropriate and standard mesh sizes of 25 mm and to avoid any below the standard, only 5% of them act in compliance to this provision (Akpalu, Eriksen & Vondolia, 2018). In contrast, artisan fishers constituting 51.9% and 48.1% on the Wamala Lake in Uganda however used more of gill nets and hooks respectively as opposed to the other forms of fishing gears with the dominant mesh size been 101.6 mm (Musinguzi et al., 2015)

Table 5: Types of Fishing Gear used by Artisanal Fishers

Gear type	Mean	Sta. Dev.	Min	Max
Hook and line	976.29	1891.64	0	8000
Traps	1267.47	2640.29	0	2000
Stationary nets	10.682	9.190	0	60
Dredge nets	4.532	2.71	0	10
Surrounding nets	2.523	2.332	0	4
Others	0.935	0.123	0	2

Source: Field survey (2018)

4.2.3 Summary Statistics of Institutional and Infrastructural Variables

Policy, infrastructural and institutional variables can also be significant in determining adaptation to changes in the climate. The summary statistics of these Policy, infrastructural and institutional variables are shown in Table 6. First and foremost, the effect of artisanal fishers' access to credit on adaptation and welfare cannot be underrated. Just as much as credit access is supposed to enable artisanal fishers to use efficient climate change and post-harvest loss technologies to improve the value of the fish along its value chain, the findings of Musinguzi et al. (2015) which corroborated this fact revealed that, the inadequate access to credit facilities debilitates against effective and efficient adaption of the climate change adaptation strategies among artisan fishers operating on Lake Wamala in Uganda. The results in table 6 indicated that, on the average 39.7% of the respondents had access to credit services. This implied that, there is relatively high access to the credit market. Specifically, credit was taken from sources such as banks, microfinance institutions, fish off-takers (buyers) and family and friends.

It was also observed that access to electricity and mobile communication network were averaged at 13.3% and 97.0% respectively. Though artisanal fishers had a wide access to network for communication purposes, access to electricity on the contrary was a challenge for several of the fishing communities. With respect to the access to extension services, the respondents berated the unavailability of extension officers to guide them. The results indicated that, 32 fishers representing 10% had access to extension services. Also, the average distance to the district capital where artisanal fishers sell their fish was 128.62 kilometers which suggests that, huge cost was expended on transportation.

The state of roads motorability to the district capitals was thought to have a significant and direct effect on artisanal fishers' adaption to the adaptation strategies. In actual fact, it was measured as a dummy and specified as to whether roads were motorable or otherwise. From Table 6 above, the average road motorabilty in terms of proportion was 0.491 which implied that, about 49% of the fishers had motorable roads to plough to their district capitals. In conjunction, fishers monitoring of weather reports was also measured as a dummy with respect to either monitoring or otherwise. Again, from the Table 6, the average proportion of fishers who monitor weather was 0.810 indicating that, about 81% of the artisanal fishers gave attention to weather reports.

Table 6: Summary Statistics of Institutional and Infrastructural Variables

Variable name	Measurement	Mean	St. Dev	Min	Max
Credit Access	1=Yes, 0=No	0.3976*	0.4901	0.00	1.00
Electric Access	1=Yes, 0=No	0.1325*	0.3396	0.0	1.0
Network Acces	1=Yes, 0=No	0.9698*	0.1714	0.0	1.0
Extens. Access	1=Yes, 0=No	0.0964*	0.2956	0.0	1.0
Road motorable	1=Yes, 0=No	0.491*	0.501	0.0	1.0
Bank Account	1=Access, 0=No	0.250*	0.434	0.0	1.0
Credit amount	GH₵	447	964	0.0	7500
Extension times	Number	0.1355	0.4496	0.0	3.0
District Dist.	Kilometers	128.62	1908.7	5.0	2400
Weather report	1=Yes, 0=No	0.810*	0.393	0.0	1.0

* are proportions

Source: Field survey (2018)

4.3 Climate Change Adaptation Strategies

Though climate change adaptation strategies are varied and multifarious, it depends to a large extent the nature and interest of the investigation. In this study for instance, five distinct adaptation strategies were presented to the respondents after having discussed thoroughly their perceptions regarding rainfall, sunshine and temperature. Indeed, fishers were asked to answer yes or no for all the specific adaptation strategies to indicate their agreement or otherwise that such strategies were employed. These adaptation strategies included increased time of fishing (MoreHrs), engagement in alternative livelihood (Alternlives), migrating to a different fishing location (MigrateArea), self-restraint from fishing for a defined period (Moratorium) and changing the time of fishing (Changetime). This section presents the frequency distribution and correlation between the climate change adaptation strategies used by artisanal fishers.

4.3.1 Frequency distribution of climate change adaptation strategies

Figure 3 gives a pictorial view and further throws more light on the different adaptation strategies employed. The figure is a cluster bar graph which depicts the adaptation strategies used in the analyses and the trend of fishers' adaption to these strategies. Each of the bars constitutes a distinct adaptation strategy comprising lower and upper divisions which denotes fishers' adaption and non-adaption respectively. In fact, the height of the lower divisions illustrates the magnitude and degree to which a particular adaptation strategy is used. At the apex of the graph the bars are leveled indicating that, the sum of both lower and upper divisions of each of the bars yields an equal number and corresponds with the 332 sample used. The graph portrayed changing time of fishing as the widely employed and predominantly used strategy among all the adaptation strategies in sharp contrast to moratorium which was the least adaptation strategy employed. This is contrary to the findings that, alternative livelihood in a form of agriculture, particularly the cultivation of rubber, oil palm and orchards was the highly adapted among the strategies in Malaysia which accounted for about 32.28% as compared to 18.21%, 10.42%, 6.33%, 3.07% and 1.88% respectively for fishing further or deeper in the sea, shifting fishing times and location, labor in fisheries, labor in agriculture and fishing for a longer time (Sereenonchai & Arunrat, 2017). This underscores the differences in the level of usage of the adaptation strategies which to some degree depends on the environment surrounding the artisanal fishers.

In this study, more hours of fishing refer to increasing the time of fishing. Usually, artisanal fishers have an average number of hours they spend routinely on fishing. But as a result of climate change they adapted a new strategy of staying for longer hours in the lake than before. From the data about 216 fishers said they are adapting this strategy which represents 65% of the total sample. Furthermore, alternative livelihood as an adaptation strategy refers to fishers' engagement in other economic activities or livelihoods that generate income and improve their welfare aside fishing. These activities include farming, trading, artisanship, aquaculture, animal husbandry among other services. Small-scale fishers are highly vulnerable and in a state of livelihood insecurity which underscores the need to enhance their livelihood diversification (Jeyarajah, 2016). Musinguzi et al. (2015) also revealed that, the adaptation strategies that artisanal fishers employed in Uganda and which are ranked in order of importance are, diversification into non-fishery activities, increasing time of fishing, changing time and location of fishing, and targeting of fish species. The findings further indicated that, crop agriculture (45.5%), livestock agriculture (36.4%) and retail trading (11.1%) were the areas fishers diverted into. From the results in Figure 3, 153 artisanal fishers adapted this strategy which represents 46.2% of the total number of respondents.

Additionally, some artisanal fishers migrated from their original fishing areas to entirely new locations either within or outside the region. Sievanen (2014) identified temporal migration as one of the adaptation strategies artisans fishers employed to mitigate the impact of climate change in addition to fishing for longer hours and alternative livelihoods. Some of the factors that account for artisanal fishers' migration particularly in West Africa include the possibility of earning more income, the search for better fishing sites, a general passion to improve one's life and migration as a culture or tradition (Wanyonyi et al., 2015). In this particular study for instance, some fishers were found to have migrated from the central region to the Brong Ahafo region purposely for fishing and as a strategy to adapt to climate change. The results indicated that, about 205 fishers representing 61.8% of the sample adapted this strategy. Also, 29.2% and 80.1% of artisanal fishers adapted the moratorium and changing time strategies respectively. In this context, moratorium refers to a situation where fishers voluntarily decided to restrain from fishing for a given period and changing time of fishing compares the particular time in a day fishers used on the lake and their current strategic time of fishing.

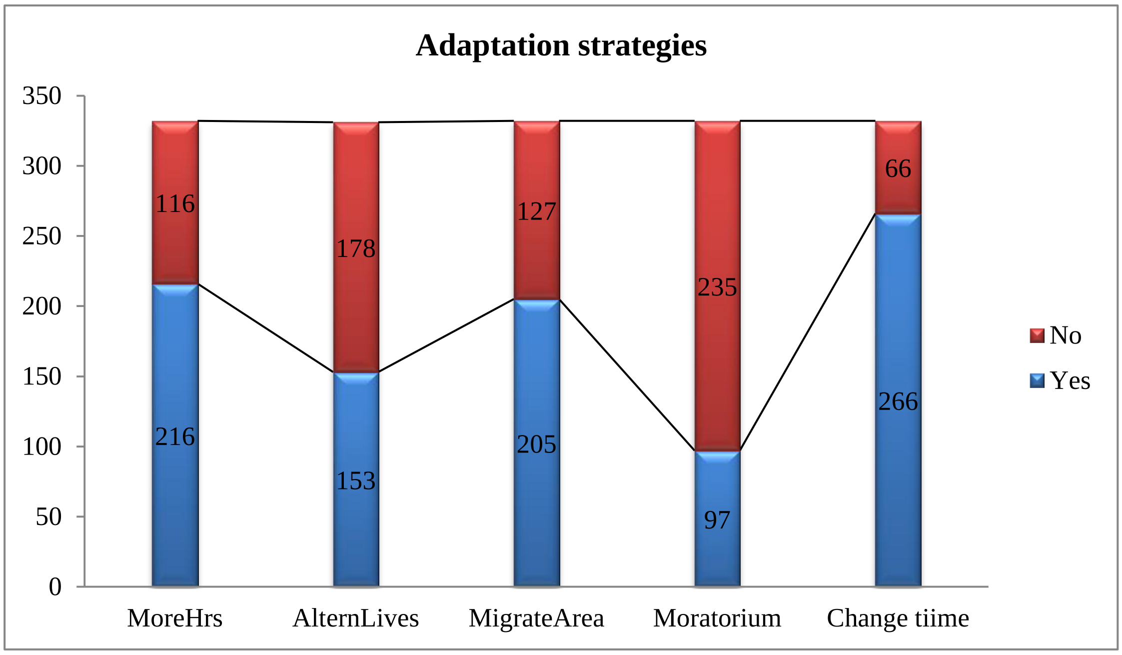

Figure 3: Climate Change Adaptation Strategies

Source: Field survey (2018)

4.3.2 Correlation between climate change adaptation strategies

Pairwise correlation matrix was computed to examine the relationships that exist between the adaptation strategies. From Table 7, the highest positive correlation coefficient was 22.1% between moratorium and increased time of fishing. Other adaptation strategies with positive correlation coefficients include increased fishing time and changing fishing time, changing fishing time and moratorium, alternative livelihood and moratorium, and changing fishing time and migrating to a different fishing area. However, it is important to state that, all the positive correlation coefficients are weak. Usually, a positive correlation coefficient depicts that, an increase in the use of one adaptation strategy also increases the use of the other without contradiction or difficulty. This then follows that, the two adaptation strategies are complementary (Donkoh et al., 2019 & Mabe et al. 2018) and can be employed together to yield results on performance and welfare. Invariably, there has also been a negative correlation matrix between other adaptation strategies. Indeed, migrating to different fishing area and alternative livelihood had a negative correlation coefficient of 30.3% while's alternative livelihood and increased time had the lowest negative correlation of 1.8%. Whiles the relationship between increased time of fishing and alternative livelihood, changing fishing time and alternative livelihood exhibited weak correlation coefficients, that of increased fishing time and migrating to a different fishing area, alternative livelihood and migrating to a different fishing area and moratorium and migrating to a different fishing area exhibited intermediate negative correlation coefficients. Indeed a negative correlation matrix indicates that, increases in the usage of one adaptation strategy decrease the usage of the other strategy. This further implies that, the two adaptation strategies are non-complementary and hence, employing them together would rather reduce the performance and welfare of artisanal fishers which ends up making them worst –off.

Table 7: Pairwise correlation matrix of climate change adaptation strategies

	Increased fishing time	**Changing fishing time**	**Alternative Livelihood**	**Moratorium**	**Migrate Area**
Increased fishing time	1				
Changing fishing time	0.1099	1			
Alternative Livelihood	-0.0175	-0.0985	1		
Moratorium	0.2208	0.0711	0.1953	1	
Migrate Area	-0.2908	0.0428	-0.3028	-0.271	1

$r = -1$ indicates a perfect negative correlation

$-0.75 \leq r < -1$ indicates a strong negative correlation

$-0.25 \leq r < -0.75$ indicates an intermediate negative correlation

$0 < r < -0.25$ indicates a weak negative correlation

$0 =$ indicates no correlation

$0 < r < 0.25$ indicates a weak positive correlation

$0.25 \leq r < 0.75$ indicates an intermediate positive

$0.75 \leq r < 1$ indicates a strong positive correlation

$r = 1$ indicates perfect positive correlation

Source: Field survey (2018)

4.4 Determinants of Climate Change Adaptation Strategies

Table 8 presents the results of the multivariate probit model used to identify factors influencing climate change adaptation strategies of artisanal fishers. The coefficient of the rho (ρ) measures the correlation between the adaptation strategies which ought to be significant in order to justify the theoretical need for the multivariate probit models. Indeed, the significance of the correlation coefficients between the adaptation strategies further indicates that, estimating the equations as a system using **MVP** is better than estimating them as binary probit models individually (Mulwa et al., 2017).

Table 8: MVP: Determinants of climate change adaptation strategies

Variable	Increased fishing time	Alternative Livelihoods	Migrate to different Area	Moratorium	Changing time of fishing
HH size	-0.011	0.001	0.016	0.024	0.015
	(0.017)	(0.016)	(0.025)	(0.017)	(0.025)
Education	-0.030*	0.050***	-0.005	0.039**	-0.000
	(0.016)	(0.017)	(0.019)	(0.017)	(0.019)
Non-fish	-5.820	0.0001 ***	7.120	-6.720	-0.000
Inc.	(8.550)	(0.00003)	(9.480)	(8.760)	(8.470)
Experience	-0.003	0.015 **	0.012	-0.010	-0.025***
	(0.007)	(0.007)	(0.009)	(0.008)	(0.008)
Credit	0.609***	0.071	-0.260	0.817***	-0.177
Access	(0.172)	(0.153)	(0.179)	(0.165)	(0.192)
Elect.	1.083***	-0.150	-0.359	-0.158	1.224**
Access	(0.309)	(0.264)	(0.310)	(0.303)	(0.543)
Network	0.374**	0.072	-0.081	0.400**	0.630***
sta.	(0.164)	(0.155)	(0.188)	(0.170)	(0.201)
Weather rep.	0.968***	-0.185	-0.419*	0.337	0.979***
	(0.207)	(0.196)	(0.242)	(0.229)	(0.214)
Taboo	0.070	0.077*	-0.039	0.269***	0 .024
Month	(0.048)	(0.046)	(0.057)	(0.059)	(0.060)
Bank Acc.	0.198	-0.083	-0.295	-0.056	-0.063
	(0.202)	(0.187)	(0.223)	(0.200)	(0.238)
Market Dist.	0.140**	0.057	-0.059	0.0729	-0.019
	(0.063)	(0.059)	(0.073)	(0.062)	(0.081)
Road motor.	-0.45***	0.220	-0.045	-0.242	-0.709***
	(0.171)	(0.157)	(0.194)	(0.173)	(0.208)
Total input	0.000**	-0.000	-0.00006*	0.000	-0.000
cost	(0.000)	(0.000)	(0.00003)	(0.000)	(0.000)
Percept.	-0.64***	0.458***	2.266***	-0.295**	0.526***
Index	(0.175)	(0.156)	(0.194)	(0.170)	(0.190)
Cross equation correlation	ρ_{21} 0.524	ρ_{31} 0.001	ρ_{41} 0.046	ρ_{32} 0.000	ρ_{42} 0.002
Wald χ^2 test	360.90				
Chi2(Prob)	0.0000				
Observations	329				

***1% level of significance
**5% level of significance
*10% level of significance

The Wald χ^2 which measures the joint significance of the explanatory variables on the dependent variables was 360.90 and highly significant at 1% indicating that, at least one of the independent variables was significant in explaining adaptation strategies artisanal fishers use to minimize the impact of climate change on fishing. It also implies that, the hypothesis of independence or no correlation of the error terms of the different adaptation strategies is highly rejected (Kassie et al., 2014). Interestingly, the experience in fishing, level of education of the artisanal fisher, level of income earned from non-fish sources, access to credit and electricity were some of the significant variables which influenced artisanal fishers' adaptation decisions. In addition, the status of mobile communication networks, monitoring reports of weather, number of taboo days in a month, distance and state of road motorabilty to markets, total cost of inputs and the index of perception with respect to prominent climate variables were also significant. Similarly, the findings of Shaffril et al. (2015) on the Malaysian coastal communities indicated that, educational status, access to credit and income are significant determinants of small-scale fishers' choice of adaptation practices (Samah et al., 2019).

Firstly, education was measured in terms of the number of years of schooling and found to be significant in determining three of the adaptation strategies i.e. increased time of fishing, alternative livelihood and moratorium strategies. Although the variable had a positive effects on both alternative livelihood and moratorium strategies, that of increased time of fishing strategy was negative. From the results revealed in Table 8, an additional year of schooling obtained by an artisanal fisher increased the likelihood of adapting to both alternative livelihood and moratorium strategies significantly at 1% and 5% respectively but decreased the likelihood of adapting increased time spent on fishing strategy significant at 10%. In similitude to this finding, Issahaku & Abdulai (2017) discovered that, education was a significant factor that influenced the adaption of climate change adaptation strategies. Essentially, education is an important parameter that is worth the consideration in climate change discourse and its effects on fishers' choice of adaptation strategies cannot be underestimated. In fact, with education fishers are able to learn to acquire new skills and knowledge, learn to diversify in order to expand their streams of income, communicate with extension agents and monitor reports of weather without serious challenges. Therefore fishers who were more educated easily appreciated the need for diversification and investment into other areas where additional income could be generated. In furtherance, educated artisanal fishers easily felt the need to at a point in defined time voluntarily restrain themselves from fishing along the basin. Pre-emptively, such voluntary restraint would not be effective because of the lack of external enforcement to that effect. However, the impact of such move on increased fish stock and growth cannot equally be discounted. The study further revealed that, alternative livelihood strategy and then increased time spent on fishing strategy are not complementary. This implies that, spending more time and resource engaging in alternative livelihoods was to the detriment of the time spent on fishing. This accounted and explained the negative effects of the education variable on the increased time spent on fishing as a strategy.

Non-fishing income which is primarily income from other economic activities aside fishing such as farming, trading, aquaculture and other services also accrued to some artisanal fishers. This type of income was complementary in nature and had a positive effect on only the alternative livelihood strategy. From the results, an increase by GH₵ 1 in the monthly non-fishing income increased the probability of artisanal fishers adapting to the alternative livelihood strategy which was significant at 1%. This result is consistent with the empirical studies and findings of Sereenonchai & Arunrat (2019) that, non-fishing income increases the likelihood of artisanal fishers adapting climate change adaptation strategies but decreases the expectations of their children to pursue that same profession. Really, holding all other factors constant, a relative increase in the non-fish income has a proportionate effect on the marginal propensity to save component of the total income. The implication therefore was that, artisanal fishers accumulated some savings from these other sources and reinvested into either same businesses for the purposes of expansion or into different businesses distinct from fishing.

Additionally, the experience of the artisanal fisher has a significant effect on the adaptation strategies. The variable was measured in terms of the total number of years an artisanal fisher had spent specifically on fishing. Appropriately, it had both positive and negative effects on alternative livelihoods strategies and changing time of fishing strategies respectively. In fact, an additional year of experience gained increased the probability of fishers adapting the alternative livelihood strategy and decreased the probability of adapting the changing time of fishing strategy both significant at 5% and 1% respectively. Indeed, the experience of small-scale fishers was supported to have negatively influenced climate change adaptation strategies in Malaysia according to Samah et al. (2019). This finding was however contrary to that from Shaffril et al. (2013), and Islam et al. (2014). This shows therefore that, experience could influence fishers' adaptation to climate change both positively and negatively. In fact, as a result of the long years of fish harvest and trade, artisanal fishers have understood the dynamics of their activities: the trend of fish production, the pattern of the weather especially with regards to rainfall and temperature, revenues from the sale of fishes among others and concluded on diversification as an indispensable alternative. Indeed, experienced fishers tend to decrease the rate of changing their time spent on fishing presumably to give more time to their alternative businesses which served as avenues for extra income aside fishing.

Interestingly, fishers' access to credit was also a significant determinant of the likelihood to adapt to strategies of climate change according to Di Falco et al. (2011). The variable was distinctively categorized into those with access and those without access and the results however showed conclusively that, credit access had a positive effect on increased time spent on fishing strategy and that of moratorium strategy. This further implied that artisanal fishers with access to credit had an increased likelihood of adapting to the increased time spent on fishing strategy and moratorium strategy both significant at 1% compared with their counterparts without access to credit. From the field, it was noted that, those with access to credit were capable of acquiring more equipment, inputs and materials to expand and recapitalized their operations by purchasing and repairing damaged fleet. Artisanal fishers who had for instance one fishing net earlier but for credit access could now double or even more than double the size of their nets and as a result ends up spending more time than their counterparts. Also, those with access to credit could voluntarily restrain themselves for some period from fishing because; credit was often given with a consumption component. This then implied that, even if they restrain themselves from fishing, they could get food from the consumption share of the credit to cater for their households needs.

Again, electricity was an important infrastructural determinant which significantly influenced the adaptive capacity of artisanal fishers. Similarly, artisanal fishers either had access to electricity or otherwise due to the fact that, the variable was measured as a dummy. The results indicated that, electricity had a significant positive effect on both increased time spent on fishing strategy and changing time of fishing strategy. In fact, artisanal fishers with access to electricity were more likely to adapt to increased time spent on fishing strategy and changing time of fishing strategy both significant at 1% and 5% respectively. The findings interestingly indicated that, fishers with access to electricity monitored weather reports and other insightful programs about climate change on both television and radio. As a result, they acquired knowledge about climate change and adaptation strategies which consequently influenced them to alternate the time of fishing. More to the point fishers with access to electricity continued to work after returning from their daily fishing activities. They often engaged in net patching even in the night which their counterparts without electricity cannot. As a result, more nets could be available to increase the amount of effort applied and consequently result in increased time spent.

The existence and status of mobile communication network was also essential in further explaining the adaptation strategies of artisanal fishers. Network status was measured as either good or poor and it influenced the adaptation to increased time spent on fishing strategy, moratorium strategy and changing the time of fishing strategy positively and significantly. From the results it can be interpreted that, fishers with good network had an increased probability of adapting to both increased time spent on fishing and moratorium strategies significant at 5% and that of changing time of fishing strategies significant at 1%. Undoubtedly, a good network facilitates effective communication not only between fishers in different communities but also between fishers and extension officers. It also made it easier for those who subscribed to the agricultural e-platforms received prompt messages as well as those who used the internet where possible, checked for weather information. Through that, fishers acquired some knowledge about these adaptation strategies relative to those with poor network and their adaptation was greatly influenced.

Report about the state of weather also contributed to artisanal fishers' adaptation options. It particularly influenced both increased time of fishing and changing the time of fishing strategies positively whiles migrating to a different area as a strategy was negatively influenced. From the results, artisanal fishers who monitored the reports of weather had an increased likelihood of adapting both increased time spent on fishing strategy and changing time of fishing strategy both significant at 1% and a decreased likelihood of adapting migration to a different fishing area strategy significant at 10%. Ordinarily, report of the weather provided a guide to the fisher as to time and the extent to go about their fishing expedition. It was observed that, those who monitored weather reports were relatively informed and that reduced the uncertainty that engulfed their activities. As a result of been exposed to the requisite information, fishers adapted positively to both the more time spent fishing strategy and changing time of fishing strategy. On the contrary, fishers who particularly paid no attention to monitor weather reports were bereft of information and as a result resort to migrating to different fishing areas in order that they adapt to the change in climate.

Another significant determinant of the adaptation strategies was the number of days in a month set aside to restrain fishers from fishing termed as taboo days. The results indicated that, alternative livelihood and moratorium strategies are directly and significantly influenced at 10% and 1% respectively. In fact, a one more day added to the number of taboo days within a month, increased fishers' probability of adapting both alternative livelihood and moratorium strategies. From the field, tabooing fishing does not imply a complete halt on all economic activities. Therefore fishers were more comfortable engaging in other economic activities such as farming and artisanship during such days rather than idling. This further meant that, artisanal fishers were able to also self-restrain themselves for some period from fishing whiles there were different kinds of economic activities to engage them.

As expected, market distance also accounted significantly for fishers' choice of climate change adaptation strategies. Although only the increased time spent on fishing strategy was significant, the coefficient was positive indicating that, a unit increase in market distance by one kilometer increased the likelihood of adapting increased time spent strategy which was significant at 5%. This result was in line with the apriori expectation because fishers who had to sell their fish commodity in markets that were relatively farther in distance committed to gathering and processing huge quantities of fish to reduce the average cost paid for transporting the commodity which forthwith influenced their decision to increased their daily average hours spent on fishing.

In a related term, the motorabilty or otherwise of the road linking the fishing communities to their respective district capitals had a negative effect on both increased time of fishing strategy and changing time of fishing strategy. This finding was however not in consonance with the apriori expectation that, motorable roads increased the probability of fishers' adaptation. From the results, artisanal fishers were less likely to adapt to increased time of fishing strategy and changing time of fishing strategy both significant at 1% when roads were motorable. The underlying explanation was the fact that, fishers often smoked their fishes after returning from the fishing sites and transported them easily to the district markets as a result of the motorable roads where relatively higher revenues were earned. The fishers therefore discounted the idea of spending longer hours at the fishing sites and changing the time of their fishing since the opportunity cost for that according to them was huge.

The total cost incurred on inputs was a reflection of the apriori expectation and significant in determining both the increased time spent and migration to different fishing area strategies, though positive and negative respectively. The results indicated that, a unit increase in the total cost of inputs by GH₵1 increased and decreased the likelihood of fishers adapting to increased time spent strategy and migrating to a different fishing area strategy significant at 5% and 10% respectively. The cost of inputs included the sum of both the depreciable value of fixed cost like canoes, boats, engine etc. and variable cost such as premix fuel for boats, fishing baits, fuel wood etc. Artisanal fishers adapted spending more time to fishing in order to compensate for their rising expenditure and make profit from their expedition. However, migration and new settlement was accompanied with a different set of cost on its own and for that matter, fishers with rising cost of inputs tend to be very critical about migration as a strategy to adapt to climate change.

The perception of artisanal fishers regarding climate change variables was especially paramount to this research. Indeed, rather than been uniform, artisanal fishers have different levels of perceptions regarding precipitation and temperature which empirically has some bearings with scientific data. According to Sereenonchai & Arunrat (2019), perceptions of fishers regarding temperature and rainfall were consistent with scientific fact of a likely increase in both variables by 0.02℃ and 4.15mm per year respectively. The index of perceptions was computed and added to the covariates to understand its role in fishers' choice of adaptation strategies. Strikingly, perception index significantly determined all the adaptation strategies both positively and negatively. From the results, high perception levels influenced the adaptation to alternative livelihood, migration to different fishing area and changing time of fishing strategies all significant at 1%, whiles more time spent fishing and moratorium strategies were influenced negatively at 1% and 5% respectively. Likewise, the perceptions about climate change by small-scale fishers in Karabi influenced their adaptation decisions. In fact, whereas 80% of artisanal fishers indicated their catch was decreasing, 68% mentioned climate change as the reason for their declining catch (Muringai et al., 2019). This signifies that, the perceptions of artisanal fishers' can play significant role in influencing their adaptation decisions.

4.5 Effects of Adaptation Strategies on Performance and Welfare

Table 9 presents the results of the Conditional Mixed Process (CMP) of three equations that are recursive in nature. It is believed that, fishers' choice of climate change adaptation strategies have an effect on performance which subsequently impacts on their welfare. Therefore, the first equation is made up of an ordered probit model that shows fishers choice and adaptation of either one or a combination of many strategies. The second and third are the performance and welfare equations respectively where profit and consumption expenditure are used as a proxies for performance and welfare respectively.

Table 9: CMP: Effects of adaptation strategies on performance and welfare

VARIABLE	CMP ESTIMATES	
Number of adaptation	**Coefficients**	**S.E**
Household size	-0.017	0.012
Education	-0.024**	0.012
Experience	0.014***	0.005
Non-fish Income	2.330	6.150
Credit Access	-0.397***	0.119
Electric Access	-0.424**	0.192
Network Status	-0.107	0.118
Weather report	-0.356***	0.135
Road motorable	0.433***	0.133
Total input cost	-0.000***	0.000
Extension Access	-0.122	0.200
Market Distance	-0.003***	0.001
Perception index	-0.557***	0.122
Fishing days	0.098	0.061
Performance		
Num_adapt	24821.96***	9677.402
Household size	1960.25***	645.539
Education	1875.58***	747.283
Experience	527.66	331.345
Non-fish Income	0.263	0.338
Credit Access	11875.88**	6925.463
Electric Access	9162.83	11763.07
Fishing days	4595.986	3682.938
Road Motorable	998.55**	8638.883
Extension Access	-7094.801	7136.998
Market Distance	-35.032	27.945
Bank Account	9564.676	7368.48
Consumption Exp.		
Performance	3324.08***	0.075
Household size	-124.876	175.159
Education	-183.466	144.019
Experience	-124.197	87.644
Non-fish Income	-0.091	0.068
Electric Access	2867**	1914.969
Network status	65.792	930.308
Fishing days	-761.68	882.098
Bank Account	484.124	1613.85
Road motorable	336.221	1557.73
Market Dist_Km	13.993**	6.052
Household Adults	521.597**	241.510
Cut_1_1	-2.909***	0.529
Cut_1_2	-2.290***	0.506
Cut_1_3	-1.032**	0.493

Cut_1_4	-0.004	0.492
Insig_2		
atanhrho_12	-0.364***	0.173
atanhrho_13	-0.133***	0.180
atanhrho_23	-0.798	0.110
Sig_2		
rho_12	-0.349***	0.136
rho_13	-0.132***	0.136
rho_23	-0.663	0.108
CMP Model	LRChi2=186.76	Prob>Chi2=0.000

The rho (ρ) which measures the correlation between the equations was highly significant at 1% and justified the estimation of the equations as a system and which in essence helps in addressing the problem of endogeneity. Furthermore, the antanrho specifically are measures of the existence of endogeneity in the model. In fact, a negative antanrho value means there are unobserved factors that negatively had an impact on adaptation strategies and the outcome equation. Moreover, it indicates the presence of selectivity bias in the equations. For instance, the antanrho of -0.364 was significant and suggests that unobserved variables which negatively affects consumption expenditure and the adaptation strategies. Furthermore, the likelihood χ^2 value of 186.76 rejects the null hypothesis of no endogeneity which was highly significant at 1%. The thresholds of the classes indicated in the table as cuts are significant for all and implied that, there are significant differences between them.

From the results presented in Table 9, education is a significant factor that negatively influenced artisanal fishers' choice of adaptation strategy. Even though the apriori expectation was for artisanal fishers with more years of education to adapt many strategies, the results appeared rather alternate. It indicated that, an increased in education by a year, decreased the likelihood of using more adaptation strategies and increased the likelihood of adapting a single adaptation strategies significant at 5%. On the contrary, education was found to positively and significantly determine the climate change adaptation strategies among the people of Umuahia south area in the Abia state in Nigeria (Anyoha et al., 2013). These discrepancies however could be the result of the differences in environmental and ecological factors within the study areas. The results further implied that, as fishers gained more education, they tend to decrease the number of adaptation strategies. The irony of this finding was explicably justified in the sense that, whiles some of the adaptation strategies could be complementary others were non-complementary. As such combining non-complementary adaptation strategies which was a result of lack of proper education or misinformation made artisanal fishers worst-off. For instance an attempt to combine the strategy of increased time of fishing and that of alternative livelihood strategy such as farming would result in conflict of activities which consequently have dire welfare implications. Additionally, fishers' educational level significantly influenced their performance at 1% even though its effects on welfare was insignificant contrary to the findings of Skoufias (2012), which revealed a strong positive correlation between education and household per capita consumption . The results indicated that, an additional year of education an artisanal fisher attained increased their profits by GH₵1875.88 per annum.

The apriori anticipation of experience was positive which resultantly corroborated the finding in the recursive model. Indeed, fishers with several years of fishing were expected to rather than a single strategy adapted multiple strategies for the attainment of higher levels of welfare. From the results, experience increased with increased likelihood of adapting all adaptation strategies but increased with a decreased likelihood of adapting a single adaptation strategy significantly at 1%. This simply suggests that, fishers with more experience adapted multiple strategies as opposed to a single strategy. In similitude, findings from Obeng et al. (2014) indicate that, experience of artisanal fishers significantly determined their adaption to the climate change adaptation strategies in the Cape Coast municipality of Ghana. Accordingly, the adaptation of multiple strategies in the sum effect was thought to have had a high positive impact on the welfare of fishers as compared to a single strategy. As a result, experienced fishers ensured that, the best maximum combinations of the adaptation strategies that were worth effective and plausible were undertaken.

Artisanal fishers' participation and access to credit from both the formal and informal financial institutions and markets within the study area was generally very low. In fact, the factors that accounted for the low participation and access are not entirely different from what is known in the literature. Especially among artisanal fishers in Ghana, the results of an Instrumental Variable (IV) probit model employed by Twumasi et al. (2020) to examine the determinants of credit constraints revealed that, procedure in loan application, boat ownership, the disbursement time lag of loan application and access to off-fish income were some of the factors that significantly debilitated against fishermen access to credit. The results as revealed in table 9 indicates access to credit contradicted the apriori expectation. The anticipation which the results clearly opposed was that, fishers with access to credit would be advantaged to adapt multiple adaptation strategies as against their counterparts without access to credit. But, the CMP estimates indicated that, artisanal fishers with access to credit had a decreased probability of adapting multiple adaptation strategies but an increased probability of adapting a single adaptation strategy significantly at 1%. This also meant that, fishers with credit access were less likely to employ all the adaption strategies. Similarly, the conclusions from the research of Amevenku et al. (2019) indicated that, fisher's access to credit decreases their likelihood of participation in adaptation strategies. However, a contrary finding has indicated that, rather than been negative; access to credit had a positive influence on the adaption of climate change adaptation strategies. For instance, in determining the impact of climate change adaptation strategies on food security in Ethiopia, Di Falco et al. (2011) indicated that, farmers with access to credit were more likely to employ the adaptation strategies compared with their counterparts without access to credit. In fact, the reasons underlying this finding were that, fishers with access to credit could not have applied the credit specifically and directly to all the adaptation strategies. For instance credit could have been applied directly to alternative livelihoods such as trading and also influence the decision to restrain from fishing for a particular period (moratorium) but could not directly influence the decision of changing the time of fishing. Additionally, the finding was also borne out of their understanding that, adapting all the adaptation strategies does not necessarily impact on their welfare since some of the adaptation strategies were non-complementary and could have reduced the net welfare impact as a result of uninformed combination. The results further adduced in the model that, credit access also impacted negatively on fishers' performance. For that matter, fishers without access to credit on the average made GH₵ 11,875.88 more profit annually than those who had access to credit which was highly significant at 1%. Unsurprised with this fact, artisanal fishers lacked proper education, training and skills on credit application and management. In fact, this in some circumstances resulted in either credit misapplication and or credit diversion which explained its negative impact on their performance.

The CMP model again had access to electricity affecting both the number of adaptation strategies fishers employed in the ordered probit model and consumption expenditure. Rather than been positive, access to electricity contradicted the apriori expectation and reflected a negative relationship to the number of adaptation strategies in the ordered probit model. From the results, fishers with access to electricity had a decreased probability of adapting all the adaptation strategies and an increased probability of adapting a single adaptation strategy significantly at 5%. Ordinarily, the implication of this result was that, fishers with access to electricity adapted less adaptation strategies. The results further revealed that, access to electricity showed a positive impact on fishers' welfare which is in consonance with the findings of Skoufia (2012) that, having electricity indicates wealth and has a positive effect on welfare. In fact, the findings showed an amount of GH₵2867 as the welfare difference between fishers with access and those without access to electricity. In simple terms, fishers with access to electricity are GH₵ 2867 better-off in terms of welfare as compared to those without access to electricity which was significant at 10%.

The monitoring of weather reports was an important variable employed as an instrument in the ordered probit model and as such was not featured in any of the other two equations. In the end the variable proved very useful since it is indicated to have a significantly positive effect. From the results, artisanal fishers who monitored the reports of the weather either through the radio or television had an increased likelihood of adapting a single strategy and a decreased likelihood of adapting all the adaptation strategies significantly at 1%. In fact, access to radio or television sets is an indispensable part of the whole fishing process especially when the issues of weather reports are at stake. The results of a probit model also revealed that, radio and for that matter mass media in general has a significant influence in determining the adaptation strategies artisanal fishers employed in the Cape Coast municipality of Ghana (Obeng et al., 2014).

The motorabilty or otherwise of the road to the district capital had an effect on both the adaptation strategies and performance equations within the CMP model. In fact, the apriori expectation of both equations were met and the results did indicated that, fishers with motorable roads to the district capital had an increased likelihood of adapting all the adaptation strategies and a decreased likelihood of adapting a single adaptation strategy significantly at 1%. Furthermore, the results depicted the variable to have equally and significantly influenced the performance of artisanal fishers. Evidently, artisanal fishers with access to motorable roads had performed better than their counterparts without and the difference on average was a sum of GH₵998.55 which was highly significant at 5%.

The total cost incurred on fishing inputs was also found to significantly determine adaptation strategies artisanal fishers employed. The results indicated that, an increase in the total cost of fishing inputs decreased the likelihood of adapting to all the adaptation strategies but increased the artisanal fishers' probability of adapting to a single strategy significantly at 1%. This finding was consistent with the apriori expectation that depicted a negative relationship between the total cost of fishing inputs and adaptation strategies. Indeed, increasing cost of fishing inputs directly affects the cost of production of the artisanal fishers in a significant magnitude. This further implies that, their performance in terms of levels of profits equally dwindles with the rising cost of inputs. Under the circumstance therefore, artisanal fishers cannot adapt to some of the adaptation strategies which usually and most certainly come with cost implications.

Also, the distance in kilometers to the main market was found to be a significant determinant of both the adaptation strategies and welfare. From the results, an increased in the market distance by one kilometer decreased the probability of adapting all adaptation strategies and increased fishers' chances of adapting a single strategy. Indeed, increased distance to market centers is a disincentive to artisanal fishers not just because they incur extra transport cost that reduced their profit margin, but also because they needed to add value to their commodities by adopting efficient technologies that also comes with cost. This resulted in artisanal fishers adapting relatively fewer adaptation strategies. Consequently, market distance positively increased the welfare of artisanal fishers which was in direct consonance with the apriori expectation. The results further averred that, a one kilometer increased in market distance increased welfare by GH₵13.993 significant at 5%.

The size of the artisanal fishers' households and the number of adults within the households respectively and significantly influenced the fishing performance and welfare of households. Whilst the effects of household size on fishing performance is 1% significant, that of the effects of adult number in the household is significant at 5%. The results from the estimates showed that, an increase in the household size by one person, increased profits on the average by GH₵1960.25 per annum, welfare was not affected. However, Asmare et al. (2019) indicated in their findings that, the size of the household negatively and significantly affected net income of the household which was used as a proxy for welfare. Fairly, the activities that artisanal fishers are engaged in which include, fishing, carrying, processing, selling among others are enormous and labor demanding. Therefore, artisanal fishers with bigger household sizes have the greatest propensity to accomplish more of the activities within a relatively shorter period of time, harvest significant quantity of fish and also earn relatively more profits. On the other hand, a unit increase in the number of adults within the household increased the consumption expenditure on the average by GH₵521.597 per annum. This finding was in consonance with the apriori expectation that established a positive relationship between the number of adults per household and consumption expenditure which assumed a proxy status for welfare. Indeed, the overwhelming significance in the explication of this result lies bare in the fact that, adult members of the artisanal fishers' households have the relative experience of fishing couple with the level of energy exertion required at some stages of the fishing processes. These factors give them the edge in terms of guidance and directives and for that matter adult artisanal fishers become pivotal to the quantum of harvested fish, revenues as well as profits earned from fishing. Therefore, if all other factors remained constant, an increase in the number of adults within the household of an artisanal fisher come with a commensurate increase in the number of family labor, the quantum of fish harvested which ultimately translates in increased welfare for the time being.

The perception index of fishers exhibited a negative relationship in the ordered probit model within the CMP. This implied that, artisanal fishers with high perception indexes had a decreased probability of adapting all the adaptation strategies and an increased probability of adapting a single adaptation strategy significantly at 1%. In simple terms, higher perceptions influenced the adaption of lesser strategies rather than more strategies. This result was completely in sharp contradiction to the apriori expectation that higher perceptions informed the adaption of all the adaptation strategies. Even though perceptions do not necessarily represent the reality, it is a quality that sometimes guides critical decisions among humans. Indeed, not only does the perception of artisanal fishers regarding the climate variables such as temperature and rainfall influence the adaptation strategies, but in reality, findings from researches indicate that, it equally has an impact on household net income. Findings from Ethiopia indicates that, a unit increase in temperature and rainfall increases the net income of both adopters and non-adopters of climate change adaptation strategies respectively significant at 5% and 10% even though among adapters were quite larger than that of the non-adapters (Asmare et al., 2019).

The CMP framework simplifies the application of recursive models by allowing the featuring of lower order equations into higher ones. As a result, adaptation strategies which were ordered in nature featured in the performance equation just as much as performance equally featured in the welfare equation and both exhibited high level of significance. The results revealed that, adaptation strategies positively related to profit and accounted for about GH₵24821.96 on the average per annum. This also meant that, as almost all adaptation strategies are employed, artisanal fishers on the average per annum made profits to the tune of GH₵24821.96 significantly at 5%. This striking revelation is an indication that, the combination of relatively lesser adaptation strategies yielded relatively lesser results in terms of both performance and welfare than the combination of all the adaptation strategies under review. Also, profit earned from fishing was found to have significantly influenced the welfare of artisanal fishers positively as anticipated. The results suggested that, profits increased welfare by GH₵3342.08 on the average per annum which was highly significant at 1%

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Chapter outline

This chapter presents the summary of the key findings of this research and the conclusions that are drawn from the analyses and discussions of results in the previous chapter. Relevant recommendations are also proffered in the area of policy for the interest of government and other important stakeholders in fishery sector. Recommendations for further research are also proffered for those in the academia.

5.2 Summary

Climate change remains one of the greatest threats to many economic sectors of the world. Indeed, the devastating impact of climate change on agriculture and fisheries has been scientifically established, putting the livelihoods of millions of people in Africa at risk and threatening the fight against poverty, inequality and malnutrition as contained in the Sustainable Development Goals (SDGs). Ghana has a chunk of the population having their livelihood and sustenance in one way or the other tied to the fisheries sector. In particular, the artisanal fishers are the category of fishers who are especially affected greatly by climate change since their livelihood and survival depends on fish and as a result, adapting to the climate change adaptation strategies for those people was inevitable. It is therefore against this background that this research sought to empirically analyze the factors influencing the adaptation strategies artisanal fishers employed to mitigate the effect of climate change. It also assessed the contribution of climate change adaptation strategies to performance and welfare.

Methodologically, the research was conducted in the Brong Ahafo region of Ghana where two districts were chosen. These districts are Pru East and Sene West with their capitals at Yeji and Kwame Danso respectively. In all about 48 fishing communities were visited and a total number of 332 respondents were sampled and interviewed. The multi-stage sampling technique was used and the data were collected through interviews and the use of semi-structured questionnaires. The multivariate probit (MVP) analysis was used to identify the factors that determined the adaptation strategies whiles the recursive model (CMP) on the other hand was used to examine the effects of adaptation strategies on performance and welfare.

Some of the key findings are that, the artisanal fishing sector was predominantly male who constituted 99% of the sample. The study further revealed that, many artisanal fishers were uneducated with only 27% of them completing both the basic and senior high schools whilst the remaining 73% were either drop-outs or never attempted formal education. Additionally, Incomes earned from fishing sources were significantly sufficient to yield profits. On the average, whiles monthly fish income for a household on the average was GH₵2888.90 that of annual profit was GH₵30360. Also, there was low access to credit with barely 2.74% of the artisanal fishers accessing an average of GH₵447 largely through fish off-takers who appeared more reliable than the formal sector.

Pertinent findings as revealed by both the Multivariate Probit (MVP) model and the recursive model in the CMP indicated that, education significantly influenced the adoption of adaptation strategies. In particular, education determined artisanal fishers' decision to adapting positively to both alternative livelihood and moratorium strategies and negatively to increased time of fishing strategies. This finding was further corroborated by the ordered model within the CMP that, education influences the adaption of some strategies but not necessarily all the adaptation strategies.

Furthermore, the experience of fishers also contributed significantly in explaining their adaptive decisions. The results revealed that, experienced fishers were more likely to adapt multiple adaptation strategies and less likely to adapt a single strategy. It was however not significant in accounting for changes in performance and welfare.

In addition, non-fish income was also found to significantly influenced fishers' adaption of adaptation strategies. The study revealed that, artisanal fishers who had other sources of income aside the fish income were more likely to adapt alternative livelihood strategy. Clearly, the results revealed further that, access to electricity decreased fishers' likelihood of adapting all the adaptation strategies. It further proved to be useful in the improvement of artisanal fishers' welfare. In fact, fishers with access to electricity were better-off than their counterparts in terms of welfare with a difference of GH₵ 2866.96 annually. Closely linked to electricity was the status or condition of mobile communication network within the fishing communities. The findings indicated that, good network positively and significantly determined the adaption to increased time spent, moratorium and changing time of fishing strategies.

The report of weather was another variable that had an essential influence on the adaptive decisions and of course a great impact on the adaptation strategies. The study revealed that, fishers who monitored reports of weather had an increased probability of adapting increased time of fishing and changing time of fishing strategies and a decreased probability of adapting migration to a different fishing area strategy. Moreover, the motorability of roads to the district capital was also significant to the extent that, it increased the fishers' likelihood of adapting multiple strategies and decreased their likelihood of adapting a single strategy. In fact, fishers with access to motorable roads performed better than their counterparts. The results indicated that, on the average fishers with access to motorable roads earned profits of about GH₵9475.30 per annum more than those without motorable roads.

The perceptions of fishers regarding climate change were particularly exceptional in influencing their adaptive decisions. This finding did not only reflected the adaptation strategies that could be influenced, but it also revealed the degree to which perceptions can shape fishers choice. The results showed that, perception index generally decreased fishers likelihood to adapting all the adaptation strategies. In support of this fact, high perception index particularly decreased the probability of fishers adapting moratorium and increased time of fishing strategies.

More fascinating in the findings was the behavior of the adaptation strategies in the performance function and that of performance in the welfare function, both been significant to invigorate the recursive nature of the model. Indeed, the adaptation strategies exhibited a positive influence on performance indicating that, the adaptation of all strategies yielded a profit of GH₵24821.96 per annum on the average. On the other hand, profits were found to have a significant and positive effect on welfare. From the results, profits increased the welfare of artisanal fishers by an amount of GH₵3342.08 on the average per annum.

5.3 Conclusions

This study has made significant findings that have implications for policy formulation by the government and other developmental partners regarding the welfare of artisanal fishers and for the purposes of further research. The findings have shown that, artisanal fishers employed either some specific adaptation strategies or a combination of multiple adaptation strategies. These adaptation strategies include increased time of fishing, investing in alternative livelihoods, migrating to a different fishing area, self-restraint from fishing (moratorium), and changing the time of fishing. In the end the results indicated that, the adaptation of all the five strategies does not necessarily improved performance but instead the adaption of specific informed combination of adaptation strategies. It is also worth noting that, all the adaptation strategies were autonomous rather than been a deliberate policy initiative.

Additionally, the policy on adaptation to climate change strategies could be made with reference to the educational level, access to credit, income from non-fishing sources and experience of the artisanal fishers at the household level. Similarly, other infrastructural determinants such as the access to electricity and motorable roads, strong mobile network availability in fishing communities and the reports of weather also accounted for the adaption of the adaptation strategies. Furthermore, artisanal fishers had formed perceptions which were deeply hinged on weather variables such as rainfall, temperature, sunshine etc. These perceptions were either high or low depending on the index. Interestingly, the findings indicate perceptions to have influenced the adaptation strategies of fishers.

Finally, the employment of all the adaptation strategies had a negative effect on fishers' performance. Therefore fishers who employed the combination of all strategies were worst-off compared to those who employed other strategic combinations. Resultantly, performance, access to electricity, market distance and access to bank account proved to be highly significant in terms of its effect on welfare of artisanal fishers. The study also concluded that, governmental support to the artisanal fishers in a form of increased access to electricity, enforcing education in the fishing communities and broadening and facilitating the ease of access and participation to credit and educating fishers on proper credit application could go a long way to improve the welfare of the artisanal fishers.

5.4 Policy recommendations

Based on the findings made in this research, some recommendations key to policy formulation and imperative in addressing the identified challenges confronting artisanal fishers are proposed as follow,

Firstly, education is one of the fundamental finding that needs urgent attention even though it was significant in determining the adaptation strategies. The results revealed that, about 27% of the fishers have had secondary education which is unsatisfactorily low and needs urgent attention. The government through the education ministry in collaboration with department of fisheries under the ministry of agriculture could launch a special campaign in the fishing communities to get them sensitized and further motivated with a package to arouse their interest in education. Even though the Free Compulsory Universal Basic Education (FCUBE) is in full force coupled with the current Free SHS policy, fishers' response to education had generally been a lax and demands a deliberate intervention. Similarly, other development partners and Non-Governmental Organizations (NGOs) with priority in education could support fishing communities with scholarship packages and other learning materials to spice up the passion for education.

Secondly, the government and other stakeholders should support artisanal fishers in a form of giving them technical and skills training and also financial assistance to engage in other economic activities or livelihoods to support themselves. Indeed, such an intervention would not only influence fishers to adapting effective and responsive combination of adaptation strategies, but it would also encourage them to reinvest their proceeds to expand such businesses. In addition, enabling infrastructure should be provided in the fishing communities. For instance, the government needs to ensure that, roads are both accessible and motorable from the fishing communities to the district capitals. This would minimize the average travelling time, reduced cost of transport and ultimately improve performance and welfare.

Furthermore, the extension of electricity to fishing communities should be encouraged. In fact, government through its agency such as the department of fisheries could liaise with the Volta River Authority to extend electricity to unconnected fishing communities through the rural electrification project. It is obvious from the findings that, electricity would not only increase fishers' likelihood of adapting the adaptation strategies but it would also improve the welfare of fishers in the household. Subsequently, the fisheries department can also collaborate with the ministry of communication to facilitate the improvement in communication networks across the fishing communities. This would enable artisanal fishers to communicate effectively with extension officers and also help in prompt access and reception of vital weather, fishing and agricultural as well as marketing information through electronic platforms such as Essoko, E-agriculture etc.

Thirdly, access to credit among artisanal fishers was a significant determinant of climate change adaptation strategies even though its impact on profit was rather negative. The reasons which accounted for this result was that, over 90% of the artisanal fishers accessed credit through fish off takers and families. These credits instead of been invested into their fishing was rather diverted into other household needs. Therefore, stakeholders such as microfinance institution should take deliberate steps to offer fishers credit and ensure its applied directly to their fishing activities. Fishers can regularly be monitored to ensure strict compliance. The government also through a collaborative effort between the department of fisheries and the Microfinance and Small Loans Centre (MASLOC) can design a special loan offer for artisanal fishers at affordable interest rates. In that regard fishers could be encouraged to adopt the Village Savings and Loans Association (VSLA) modules that could be used for their household support whiles the loans are restricted to their fishing activities.

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APPENDICES

Appendix 1: Questionnaire

RESEARCH TOPIC: CLIMATE CHANGE AND ARTISANAL FISHING: IMPACTS AND ADAPTATION STRATEGIES ALONG VOLTA BASIN IN GHANA

Serial number of questionnaire ………………………..

Please introduce yourself and the research objective to the respondents:

Hello! My **name** is ……………………………, a research assistant from the **University for Development Studies**. I am conducting a research in this community and I will very much appreciate your time if you could be part of this exercise. The research is concerned with how artisanal fishers adapt to the impact of climate change and how their adaptations affect their performance in terms of catch and profit. I will also find out how your fishing activities impact on your well-being. The interview will take approximately 25 to 30 minutes. I would like to assure you that your responses will strictly be treated confidential and hence your **anonymity is guaranteed**. You may opt out at any point during this interview.

SECTION A: REFERENCE INFORMATION

A1. Date of interview:	**A4. Enumerator's ID**:
A2. Name of District:	**A5. Name of Community**:
A3. Name of Household head:	**A6. Respondent Telephone:**

SECTION B: SOCIO-DEMOGRAPHIC CHARACTERISTICS

B1	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**B8**	**B9**	**B10**
Relationship of the respondent to the **HH**	Sex of HH	Age of HH	Marital Status	Level of education	Years of education	Main occupation	Years of fishing (experience**)**	Household size	Number of household members with JHS education

Codes [1] Head [2] Child [3] Parent [4] Grandchild [5] Son/daughter in-law [6] Other relative [7] Non relative	**Codes** [0] = F [1] =M		**Codes:** (1) Single (2) Married (3) Widow/widower (4) Divorced	(1) No education (2) Non-formal/only Islamic (3) Primary school (4) Middle school/JSS/JHS (5) Voc/Sec. Tech/SSS/SHS (6) Teacher/Nursing Colleges (7) Polytechnic/University		**Codes** [1] Fishing [2] Farming [3] Non-farm (e.g. shops, trade) [4] livestock rearing [5] civil servant [6] Artisan [7] Others (Specify)			

B11	B12	B13	B14	B15	B16	B17	B18
Category of fisher?	Monthly income (fishing only)	Annual income (fishing only)	Monthly income (non-fishing activities)	Annual income (non-fishing activities)	Distance of community to district capital (Km)	How many days of the week do you go fishing?	How many taboo days do you observe in a week?
Codes [0] Casual [1] Full-time							

SECTION C: FISHING ACTIVITIES/TECHNOLOGIES AND POLICY VARIABLES

C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**
Ownership of canoe	Canoe size	Ownership of boat (motorized)	Boat size	What type of fishing gear do you use? (multiple response**)**	What is the main type of fishing gear used?	Net size (mm)	Mesh size (inches)	Fishing in Volta Lake	Fishing in deep water
[0] No [1] Yes	(1) Small size (2) Medium size (3) Big size	[0] No [1] Yes	(1) Small size (2) Medium size (3) Big size	**Codes** [1] hook n line [2] traps [3] nets [4]others (specify)	**Codes** [1] non-stationary gear [1] stationary gear			[0] No [1] Yes	[0] No [1] Yes

C11	**C12**	**C13**	C14	**C15**	**C16**	**C17**	**C18**	**B19**	**B20**
Do you belong to any fishers based org. (FBO)	If you belong to FBO, how many times did you meet in a month?	Do you have insurance cover?	Do you have bank account?	Have you taken credit for fishing in 2018?	Sources of credit and amount (multiple response	Access to electricity	Availability of mobile network in the community	Do you have access to extension services? **No, >>C1**	If yes to **B19,** how many times in a year?

[0] No [1] Yes		[0] No [1] Yes	[0] No [1] Yes	[0] No [1] Yes	[1] Family and friends: Gh¢ ………. [2] Government: Gh¢ ………. [3] NGOs: Gh¢ ………. [4] Micro finance: Gh¢ ………. [5] Banks: Gh¢ ………. [6] Fish offtakers: Gh¢ ……….	[0] No [1] Yes	[0] No [1] Yes	[0] No [1] Yes	

C21	**C22**	**C23**	**C24**	**C25**	**C26**	**C27**
Did you ever had training of climate change adaptation strategies?	Do you monitor weather reports?	Sources of weather information **(multiple response)**	Choose one main source of weather information	Main selling point of fish	Distance to main market selling point (Km)	Motorability of road to market
[0] No [1] Yes	**Codes** [0] No [1] Yes	**Codes** [1] TV [2] Radio [3] Graphics [4] Extension officer [5] Smart phone [6] Others	**Codes** [1] TV [2] Radio [3] Graphics [4] Extension officer [5] Smart phone [6] Others	[1] River bank [2] In the house [3] Within community [4] Local market centers [5] District market centers [6] Regional market		**Codes** [1] Non-motorable [2] Motorable

C28	C29	C30	C31
Main form of fish sold	Proportion of fresh fish sold (%)	Proportion of smoked fish sold (%)	Average distance you normally cover in fishing(km)
Codes [1] Fresh [2] Smoked			

SECTION D: FIXED INPUTS

Name of fixed inputs	Net	Traps	Hook and lines	Knifes	Canoe	Boat	Engine	Paddle	Furnace for smoking
Useful life (*a*)									
Quantity (*b*)									
Unit price (*c*) (Gh¢)									
Total cost $(b \times c)/a$	D1	D2	D3	D4	D5	D6	D7	D8	D9

SECTION E: NON-LABOUR VARIABLE INPUTS USE PER MONTH

Name of variable inputs	Premix fuel	Fuel	Bait	Fuelwood	Lubricant	Transportation of fish	Others (specify)		
							……….	……….	……….
Unit									
Quantity (a)									
Unit price (b) (Gh¢)									
Total cost (a) X (b)	E1	E2	E3	E4	E5	E6	E7	E8	E9

SECTION F: LABOUR VARIABLE INPUTS USE PER WEEK

Adult family labour								
Activities	No. of adult family labourers worked per week		Number of days worked per week		Average number of hours worked per day		Wage per person per day	
	Males	Females	Males	Females	Males	Females	Males	Females
Fishing								
Carrying of fish								
Processing (scaling and smoking)								
Selling								
Total								

Children family labour								
Activities	No. of family labourers worked per week		Number of days worked per week		Average number of hours worked per day		Wage per person per day	
	Males	Females	Males	Females	Males	Females	Males	Females
Fishing								
Carrying of fish								
Processing (scaling and smoking)								
Selling								
Total								

Adult hired labour								
Activities	No. of adult hired labourers worked per week		Number of days worked per week		Average number of hours worked per day		Wage per person per day	
	Males	Females	Males	Females	Males	Females	Males	Females
Fishing								
Carrying of fish								
Processing (scaling and smoking)								
Selling								
Total								

Children hired labour								
Activities	No. of hired labourers worked per week		Number of days worked per week		Average number of hours worked per day		Wage per person per day	
	Males	Females	Males	Females	Males	Females	Males	Females
Fishing								
Carrying of fish								
Processing (scaling and smoking)								
Selling								
Total								

SECTION G: REVENUE PER MONTH

G1	G2	G3	G4	G5	G6
Fish sold per month (a)	Fish consumed per month (b)	Fish given as gift per month (c)	Total fish harvested per month (d=a+b+c)	Unit price (e)	Total revenue (f= a x e)
Unit. ………...	Unit. ………...	Unit. ………...	Unit. ………...	(Gh¢)	(Gh¢)
……………….	……………….	……………….	……………….	……………….	……………….

SECTION H: IMPACTS OF CLIMATE VARIABILITY ON FISHING

	Impacts of climate variability on fishing	**5= Strongly agree** **4= Agree** **3=No change** **2=Disagree** **1=Strongly disagree**
	Rainfall variability	
H1	Low rainfall reduces reproduction of fish thereby reducing quantity of fish available for fishing	
H2	Low rainfall reduces growth of fish thereby making fishers to catch smaller fishes during fishing	
H3	Low rainfall forces fishes to migrate to cooler areas thereby reducing number of fishes available for fishing	
H4	Increased incidence of drought cause water level to reduce (death of some fishes) thereby reducing quantity of fish catch	
	Temperature variability	
H5	High temperature reduces reproduction of fish thereby reducing quantity of fish available for fishing	
H6	High temperature reduces growth of fish thereby making fishers to catch smaller fishes during fishing	
H7	High temperature makes water hot forcing fishes to migrate to cooler areas thereby reducing number of fishes available for fishing	
	Sunshine	
H8	Excessive sunshine cause fish to hide and hence reduce the quantity of fish catch	
H9	Excessive sunshine reduces the number of hours fishers stay on river thereby reducing quantity of fish catch	

	Wind	
H10	Heavy wind storm forces fishes to swim towards wind direction thereby reducing quantity of catch	
H11	Heavy wind storm destroy fishing net thereby reduction quantity of fish catch	
	Climate change	
H12	Climate change has resulted in a reduction in quantity of fish catch	
H13	Due to climate change, small size fished are caught	
H15	Due to climate change, some species of fish are not available	
H16	Climate change has resulted in migration of fishes	
H17	Climate change has resulted occurrence of invasive species	
H18	Climate change has resulted in non-availability of regular species	
H19	Climate change has resulted in varied catch composition	
H20	Climate change has resulted in narrow fishing season	
H21	Climate change has resulted in loss in craft and gear	
H22	Climate change has shifted spawning season of fishes	
H23	Climate change has increased cost of fishing	
H24	Climate change has increased fishing efforts	

SECTION I: CLIMATE CHANGE ADAPTATION STRATEGIES

I1	I2	I3	I4	I5	I6	I7	I8	I9	I10	I11
Increase fishing time (spend more hours in fishing per day)	Increase fishing efforts (use large nets, larger boats, high capacity boat, small mesh size)	Change fishing time	Increase fishing time	Engage in aquaculture	Migrate to another fishing area	fishing further away	Catching smaller fish to compensate for unavailability of bigger fish	Alternative non-fishing livelihoods	Investing in improved postharvest systems	Taking a moratorium in fishing (stop fishing for a while)
[0] No [1] Yes	[0] No [1] Yes	[0] No [1] Yes	[0] No [1] Yes	[0] No [1] Yes	[0] No [1] Yes	[0] No [1] Yes	[0] No [1] Yes	[0] No [1] Yes	[0] No [1] Yes	[0] No [1] Yes

SECTION J: HOUSEHOLD CONSUMPTION EXPENDITURE AS A MEASURE OF WELFARE

(Household Expenditure on Food Items (Total cost of food consumed in the last 7 days for your household only)

	Cost of own food consumed if had sold (GH¢) (a)	***Cost of food bought and consumed (GH¢)*** *(b)*	***Cost of food received as a gift and consumed if had sold (GH¢)*** *(c)*	***Total consumption expenditure (GH¢)*** *(a + b + c)*
Staple Foods				
Maize				J1
Rice				J2
Cassava				J3
Yam				J4
Groundnut				J5
Beans				J6
Vegetables and minerals				
Tomatoes				J7
Pepper				J8
Salt				J9
Fruits				J10
Oranges				J11
Mangoes				J12

Pawpaw				J13
Banana				J14
Pineapple				J15
Meat				
Animal meat (beef, chevon, mutton, eggs, schicken, game)				J16
Fish				J17
Beverages/Drinks				
Tea				J18
Soft Drink				J19
Fruit juices				J20
Alcoholic drinks				J21
Water				J22
Fats and oils				
Cooking oil				J23
Bread				J24
Pastries				J25
Total consumption expenditure				J26

SECTION K: HOUSEHOLD ASSETS

Assets	[0] No [1] Yes	Number possessed in a household
Mobile phone		
Bicycle		
Motor bike		
Canoe		
Motorized boat		
Sewing machine		
Refrigerator		
Blender		
Electric iron		
TV-set		
Car		
Others (specify)		

THANK YOU FOR THE TIME!

END OF INTERVIEW

Appendix 2: Stata Estimates

```
Multivariate probit (SML, # draws = 5)            Number of obs   =       329
                                                  Wald chi2(70)   =    360.90
Log likelihood = -740.54162                       Prob > chi2     =    0.0000
```

	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
MoreHrs_Fish						
FishingExper	-.0031452	.0073284	-0.43	0.668	-.0175086	.0112181
EducYrs	-.0296683	.0161466	-1.84	0.066	-.0613151	.0019785
HHSize	-.0112036	.0165819	-0.68	0.499	-.0437035	.0212964
AnuaInc_Non	-5.82e-06	8.55e-06	-0.68	0.496	-.0000226	.0000109
AccessCredit	.6090226	.1717377	3.55	0.000	.2724228	.9456223
ElectrAccess	1.083416	.3086038	3.51	0.000	.4785636	1.688268
Network_stat	.3740542	.1635393	2.29	0.022	.053523	.6945854
WeathRep	.9676352	.2066058	4.68	0.000	.5626952	1.372575
TabooMonth	.0697493	.0477594	1.46	0.144	-.0238574	.163356
BankAccount	.1979106	.2016392	0.98	0.326	-.1972951	.5931162
Spoint_main	.1395687	.0631001	2.21	0.027	.0158948	.2632426
Road_motor	-.4541505	.1708871	-2.66	0.008	-.7890831	-.1192179
k_anual2	.0000673	.0000325	2.07	0.038	3.63e-06	.000131
PerIndex	-.642418	.1748955	-3.67	0.000	-.9852068	-.2996291
_cons	-1.030569	.5351881	-1.93	0.054	-2.079519	.0183803
Alternatlive						
FishingExper	.0146317	.0069461	2.11	0.035	.0010176	.0282457
EducYrs	.0494553	.0166564	2.97	0.003	.0168093	.0821012
HHSize	.0007537	.0162377	0.05	0.963	-.0310716	.0325791
AnuaInc_Non	.0000792	.0000273	2.90	0.004	.0000257	.0001327
AccessCredit	.0705583	.1532775	0.46	0.645	-.2298602	.3709768
ElectrAccess	-.1494679	.2642991	-0.57	0.572	-.6674847	.3685488
Network_stat	.0715806	.1545327	0.46	0.643	-.2312979	.374459
WeathRep	-.1845241	.1958379	-0.94	0.346	-.5683594	.1993112
TabooMonth	.0766184	.0460967	1.66	0.096	-.0137294	.1669662
BankAccount	-.0831589	.186954	-0.44	0.656	-.4495819	.2832642
Spoint_main	.0573186	.0585907	0.98	0.328	-.0575171	.1721544
Road_motor	.2196454	.1572729	1.40	0.163	-.0886038	.5278945
k_anual2	-.0000259	.000025	-1.04	0.300	-.0000749	.0000231
PerIndex	-.4580013	.1562327	-2.93	0.003	-.7642119	-.1517908
_cons	-1.094331	.4900752	-2.23	0.026	-2.05486	-.1338007

MigrateArea_01						
FishingExper	.0114789	.0087748	1.31	0.191	-.0057193	.0286771
EducYrs	-.0049206	.0190496	-0.26	0.796	-.0422571	.0324159
HHSize	.0160615	.0245966	0.65	0.514	-.032147	.06427
AnuaInc_Non	7.12e-06	9.48e-06	0.75	0.453	-.0000115	.0000257
AccessCredit	-.2600541	.1791553	-1.45	0.147	-.611192	.0910837
ElectrAccess	-.3585723	.3103301	-1.16	0.248	-.966808	.2496634
Network_stat	-.0806404	.1882766	-0.43	0.668	-.4496558	.288375
WeathRep	-.4187593	.242183	-1.73	0.084	-.8934293	.0559107
TabooMonth	-.0393534	.0566826	-0.69	0.488	-.1504492	.0717424
BankAccount	-.2951238	.2226898	-1.33	0.185	-.7315879	.1413402
Spoint_main	-.0593621	.0730189	-0.81	0.416	-.2024765	.0837523
Road_motor	-.0445349	.1937774	-0.23	0.818	-.4243316	.3352617
k_anual2	-.0000548	.0000299	-1.83	0.067	-.0001135	3.79e-06
PerIndex	2.266127	.1944408	11.65	0.000	1.88503	2.647224
_cons	.1119397	.5895981	0.19	0.849	-1.043651	1.267531
Moratarium						
FishingExper	-.0101961	.0075633	-1.35	0.178	-.0250199	.0046278
EducYrs	.0387361	.0167988	2.31	0.021	.005811	.0716612
HHSize	.0244424	.0170562	1.43	0.152	-.0089871	.0578719
AnuaInc_Non	-6.72e-07	8.76e-06	-0.08	0.939	-.0000178	.0000165
AccessCredit	.8172394	.1652277	4.95	0.000	.493399	1.14108
ElectrAccess	-.1578734	.3031657	-0.52	0.603	-.7520672	.4363204
Network_stat	.4001989	.1697966	2.36	0.018	.0674037	.732994
WeathRep	.3371721	.2294374	1.47	0.142	-.112517	.7868611
TabooMonth	.2688898	.0594344	4.52	0.000	.1524005	.3853791
BankAccount	-.0558566	.1996036	-0.28	0.780	-.4470725	.3353593
Spoint_main	.0728994	.0622742	1.17	0.242	-.0491558	.1949547
Road_motor	-.242199	.1725443	-1.40	0.160	-.5803796	.0959816
k_anual2	.0000409	.0000263	1.56	0.119	-.0000106	.0000924
PerIndex	-.2946802	.1702199	-1.73	0.083	-.628305	.0389446
_cons	-2.790789	.5652118	-4.94	0.000	-3.898584	-1.682994

Changetime						
FishingExper	-.0249142	.0083857	-2.97	0.003	-.0413498	-.0084786
EducYrs	-.0001578	.0189322	-0.01	0.993	-.0372643	.0369488
HHSize	.0152493	.0244897	0.62	0.533	-.0327498	.0632483
AnuaInc_Non	-.0000128	8.47e-06	-1.51	0.131	-.0000294	3.81e-06
AccessCredit	-.1767524	.1921637	-0.92	0.358	-.5533863	.1998815
ElectrAccess	1.2244	.5428935	2.26	0.024	.1603479	2.288451
Network_stat	.6303096	.2012713	3.13	0.002	.2358251	1.024794
WeathRep	.9785579	.2143662	4.56	0.000	.5584079	1.398708
TabooMonth	.0241183	.0598801	0.40	0.687	-.0932444	.1414811
BankAccount	-.0628512	.2374975	-0.26	0.791	-.5283378	.4026354
Spoint_main	-.0193806	.0804675	-0.24	0.810	-.177094	.1383329
Road_motor	-.7086932	.2080497	-3.41	0.001	-1.116463	-.3009233
k_anual2	-.0000211	.0000304	-0.69	0.487	-.0000806	.0000384
PerIndex	.5256558	.1897835	2.77	0.006	.153687	.8976246
_cons	.5696191	.5986196	0.95	0.341	-.6036538	1.742892
/atrho21	.0609498	.095873	0.64	0.525	-.1269579	.2488575
/atrho31	-.3933552	.1277972	-3.08	0.002	-.6438331	-.1428774
/atrho41	.2233627	.1155279	1.93	0.053	-.0030679	.4497932
/atrho51	-.0019026	.1131428	-0.02	0.987	-.2236584	.2198532
/atrho32	-.5880969	.1257643	-4.68	0.000	-.8345905	-.3416033
/atrho42	.3096433	.1077499	2.87	0.004	.0984574	.5208292
/atrho52	-.0281787	.1147768	-0.25	0.806	-.253137	.1967796
/atrho43	-.4701961	.1096522	-4.29	0.000	-.6851103	-.2552818
/atrho53	-.0883413	.1170683	-0.75	0.450	-.3177909	.1411083
/atrho54	.0906501	.1187506	0.76	0.445	-.1420967	.3233969

.

rho21	.0608744	.0955178	0.64	0.524	-.1262802	.2438444
rho31	-.3742491	.1098976	-3.41	0.001	-.5675038	-.141913
rho41	.2197208	.1099505	2.00	0.046	-.0030679	.421729
rho51	-.0019026	.1131424	-0.02	0.987	-.2200022	.2163781
rho32	-.5285255	.0906334	-5.83	0.000	-.6829332	-.328908
rho42	.3001126	.0980451	3.06	0.002	.0981405	.4783397
rho52	-.0281713	.1146857	-0.25	0.806	-.2478652	.1942784
rho43	-.4383577	.0885817	-4.95	0.000	-.5948316	-.2498771
rho53	-.0881122	.1161594	-0.76	0.448	-.3075081	.1401791
rho54	.0904026	.11778	0.77	0.443	-.141148	.3125752

```
Likelihood ratio test of  rho21 = rho31 = rho41 = rho51 = rho32 = rho42 = rho52 = rho43 = rho53 = rho54 = 0:
             chi2(10) =   58.2353    Prob > chi2 = 0.0000
```

.

```
Iteration 77:   log likelihood = -7982.0239
Iteration 78:   log likelihood =  -7981.558
Iteration 79:   log likelihood = -7981.5134
Iteration 80:   log likelihood = -7981.5057
Iteration 81:   log likelihood = -7981.5057

Mixed-process regression                        Number of obs     =        332
                                                LR chi2(37)       =     186.76
Log likelihood = -7981.5057                     Prob > chi2       =     0.0000
```

	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
num_adapt_2						
FishingExper	.0138464	.0053064	2.61	0.009	.003446	.0242468
EducYrs	-.0248529	.0122299	-2.03	0.042	-.0488232	-.0008827
HHSize	-.0165219	.0114333	-1.45	0.148	-.0389308	.005887
AnuaInc_Non	2.33e-06	6.14e-06	0.38	0.704	-9.69e-06	.0000144
AccessCredit	-.3971527	.119108	-3.33	0.001	-.6306	-.1637054
ElectrAccess	-.424049	.1917129	-2.21	0.027	-.7997994	-.0482986
Network_stat	-.1072998	.117783	-0.91	0.362	-.3381503	.1235506
WeathRep	-.3559809	.1354349	-2.63	0.009	-.6214285	-.0905334
FishingDays	.098165	.061217	1.60	0.109	-.0218182	.2181481
Road_motor	.4327976	.1330666	3.25	0.001	.1719919	.6936033
k_anual2	-.0000526	.0000162	-3.25	0.001	-.0000843	-.0000209
Extens_Acces	-.1218976	.2002655	-0.61	0.543	-.5144107	.2706155
DistMarket	-.0025365	.0006121	-4.14	0.000	-.0037362	-.0013367
PerIndex2	-.5566691	.1224427	-4.55	0.000	-.7966525	-.3166857
annual_profit						
num_adapt_2	24821.96	9677.402	2.56	0.010	5854.598	43789.32
FishingExper	527.6649	331.3451	1.59	0.111	-121.7594	1177.089
EducYrs	1875.581	747.2834	2.51	0.012	410.9324	3340.229
HHSize	1960.251	645.5385	3.04	0.002	695.019	3225.483
AnuaInc_Non	.2634429	.3383337	0.78	0.436	-.399679	.9265649
AccessCredit	11875.88	6925.463	1.71	0.086	-1697.779	25449.54
ElectrAccess	9162.83	11763.07	0.78	0.436	-13892.35	32218.01
BankAccount	9564.676	7368.48	1.30	0.194	-4877.28	24006.63
DistMarket	46.68856	39.7896	1.17	0.241	-31.29762	124.6747
Road_motor	-998.549	8638.883	-0.12	0.908	-17930.45	15933.35
FishingDays	4595.986	3682.938	1.25	0.212	-2622.439	11814.41
_cons	-164135.3	45744.15	-3.59	0.000	-253792.2	-74478.46

annual_con_exp						
annual_profit	.2011427	.074576	2.70	0.007	.0549763	.347309
FishingExper	-124.1968	87.64374	-1.42	0.156	-295.9754	47.58177
EducYrs	-183.4656	144.0192	-1.27	0.203	-465.738	98.80675
HHSize	-124.8759	175.1588	-0.71	0.476	-468.1809	218.429
AnuaInc_Non	-.0905558	.0676806	-1.34	0.181	-.2232072	.0420957
ElectrAccess	-135.1321	1914.969	-0.07	0.944	-3888.403	3618.139
Road_motor	336.2212	1557.73	0.22	0.829	-2716.874	3389.317
Network_stat	65.79232	930.3086	0.07	0.944	-1757.579	1889.164
BankAccount	484.1237	1613.852	0.30	0.764	-2678.967	3647.215
DistMarket	13.99337	6.051997	2.31	0.021	2.13167	25.85506
HHAdults	521.597	241.5103	2.16	0.031	48.24542	994.9485
FishingDays	-761.6811	882.0981	-0.86	0.388	-2490.562	967.1994
_cons	15345.95	6091.209	2.52	0.012	3407.401	27284.5
/cut_1_1	-2.90856	.5292223	-5.50	0.000	-3.945816	-1.871303
/cut_1_2	-2.189956	.5058077	-4.33	0.000	-3.181321	-1.198591
/cut_1_3	-1.031823	.4933947	-2.09	0.037	-1.998858	-.0647868
/cut_1_4	-.0041621	.4923702	-0.01	0.993	-.96919	.9608658
/cut_1_5	.9036863	.495102	1.83	0.068	-.0666958	1.874068
/cut_1_6	1.867612	.500491	3.73	0.000	.886668	2.848557
/cut_1_7	2.787627	.5792131	4.81	0.000	1.652391	3.922864
/lnsig_2	10.96662	.0704741	155.61	0.000	10.8285	11.10475
/lnsig_3	9.264919	.2974177	31.15	0.000	8.681991	9.847847
/atanhrho_12	-.3644258	.1980517	-1.84	0.066	-.7526	.0237484
/atanhrho_13	-.1325816	.0600104	-2.21	0.027	-.2501999	-.0149634
/atanhrho_23	-.7975957	.3610789	-2.21	0.027	-1.505297	-.089894
sig_2	57908.67	4081.064			50437.77	66486.17
sig_3	10560.95	3141.014			5895.771	18917.58
rho_12	-.3491065	.1739141			-.6366975	.0237439
rho_13	-.1318102	.0589678			-.2451065	-.0149623
rho_23	-.6626905	.202508			-.9061009	-.0896526

	MoreHr~h	Change~e	Altern~e	Morata~m	Migra~01
MoreHrs_Fish	1.0000				
Changetime	0.1099	1.0000			
Alternatlive	-0.0175	-0.0985	1.0000		
Moratarium	0.2208	0.0711	0.1953	1.0000	
MigrateAr~01	-0.2908	0.0428	-0.3028	-0.2711	1.0000

Appendix 3: Matrix for Objectives, Methods, Key Findings, Conclusions and Recommendations

Objectives	**Method**	**Key Findings**	**Conclusions**	**Policy Recommendations**
1. Identify the factors that determine adaptation strategies fishers used to mitigate the effects of climate change on fishing.	Multivariate probit analysis (MVP)	The level of education determined artisanal fishers' decision to adapting positively to both alternative livelihood and moratorium strategies and negatively to increased time of fishing strategies. Fishers who monitored reports of weather had an increased probability of adapting increased time of fishing and changing time of fishing strategies and a decreased probability of adapting migration to a different fishing area strategy. Indeed, high perception levels influenced the adaptation to alternative livelihood,	Policy on adaptation to climate change strategies should be fashioned with reference to the educational level, credit, alternative livelihoods non-fishing sources and experience of the artisanal fishers at the household level.	The government through the education ministry in collaboration with department of fisheries under the ministry of agriculture could launch a special campaign in the fishing communities to get them sensitized and further motivated with a package to arouse their interest in education. The government and other stakeholders should support artisanal fishers in a form of giving them technical and skills training and also financial assistance to engage in other economic activities or livelihoods to support

		migration to different fishing area and changing time of fishing strategies		themselves.
2. Estimate the effects of adaptation strategies on the performance of artisanal fishers.	Conditional Mixed Process (CMP)	The adaptation strategies exhibited a positive influence on performance indicating that, the adaptation of all strategies yielded a profit of GH₵ 24821.96 per annum on the average. The motorability of roads to the district capital was significant to the extent that, it increased the fishers' likelihood of adapting multiple strategies and decreased their likelihood of adapting a single strategy. Perception index generally	Artisanal fishers have formed perceptions which were deeply hinged on weather variables such as rainfall, temperature, sunshine etc. These perceptions were either high or low depending on the index. Interestingly, the findings indicate	The government and other agencies could influence the extension of electricity by liaising with the Volta River Authority to extend electricity to unconnected fishing communities through the rural electrification project. Subsequently, the fisheries department can as matter of fact also collaborate with the ministry of communication to facilitate the improvement in communication networks

		decreased fishers' likelihood to adapting all the adaptation strategies. In support of this fact, high perception index particularly decreased the probability of fishers adapting moratorium and increased time of fishing strategies. Experience increased with increased likelihood of adapting all adaptation strategies but increased with a decreased likelihood of adapting a single adaptation strategy	perceptions to have influenced the adaptation strategies of fishers.	across the fishing communities. This would enable artisanal fishers to communicate effectively with extension officers and also help in prompt access and reception of vital weather, fishing and agricultural as well as marketing information through electronic platforms such as Essoko and E-agriculture. The government also through a collaborative effort between the department of fisheries and the Microfinance and

				Small Loans Centre (MASLOC) can design a special loan offer for artisanal fishers at affordable interest rates. In that regard fishers could be encouraged to adopt the Village Savings and Loans Association (VSLA) modules that could be used for their household support whiles the loans are restricted to their fishing activities.
3. Measure the effects of performance of artisanal fishing on	Conditional Mixed Process	The size of the artisanal fishers' households and the number of adults within the households significantly	Performance of the artisanal fishers, access to electricity,	The government and other essential stakeholders in the fisheries sector such as NGOs should collaborate to ensure

household welfare		influenced both the performance and the welfare e significantly at 1% and 5% respectively.	market distance and access to bank account proved to be highly significant in terms of its effect on welfare of artisanal fishers. The study also concluded that, governmental support to the artisanal fishers in a form of increased access to electricity, enforcing education in the fishing communities and broadening and	that, all impediments that works against artisanal fishers in terms of making profits and for that matter rises their cost of production should be significantly minimized to ensure that the level of their welfare are enhanced.

			facilitating the ease of access and participation to credit and educating fishers on proper credit application could go a long way to improve the welfare of the artisanal fishers.	